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AUTOMATION AND AUTOMOBILE

Sanjeet Kumar
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BOOKS ARCADE
Regd. Office:
F-10/24, East Krishna Nagar, Near Vijay Chowk, Delhi-110051
Ph. No: +91-11-79669196, +91-9899073222
E-mail: info@booksarcade.co.in, booksarcade.pub@gmail.com
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CHAPTER 1

AUTOMOBILE

Mr. Sanjeet Kumar, Assistant Professor,
Department of Mechanical Engineering, School of Engineering & Technology,
Jaipur National University, Jaipur, India
Email Id- sanjeet.kumar@jnujaipur.ac.in

As the global marketplace demands greater quality items at cheaper prices, factory floor automation has evolved from discrete machines with basic hardware-based controls, if any, to a unified manufacturing organisation with connected and sophisticated control and information systems. For many businesses, the evolution has been gradual, beginning with the incorporation of programmable logic controllers and personal computers into equipment and processes. Others, on the other hand, have seen quick and continuing transformation.In manufacturing, there are two techniques to get high yields. Increasing the number of manufacturing lines is the simplest, but most costly, solution. Another, more preferable option is to enhance the pace of output in the current manufacturing lines. Reduce the cycle time required to create a single component or product to boost production rate. There are additional two methods for reducing cycle time. The first strategy is to enhance the production process. The second strategy is to use reprogrammable and autonomously controlled equipment to automate the production process.

The term "Automation" is derived from the Greek terms "Auto" (self) and "Matos" (machine) (moving). As a result, automation is the mechanism for "self-moving" systems. Aside from the original definition, automated systems attain much greater performance in terms of power, accuracy, and speed of operation than manual systems. A self-propelled, personal, automobile with four or maybe more axles that is designed for use on public roads in any nation or state is referred to as an "automobile." A sedan, station wagon, sports-utility vehicle, or a vehicle of the truck, van, campers, or engine type are all considered automobiles, among other things. Mobile homes and other vehicles used for mass or public transportation are not considered automobiles. Automobile engineering is a subfield that deals with the creation and use of the mechanical components found in autos. It also serves as an introduction to the engineering of vehicles, such as those used in buses, trucks, and cars

Automotive engineering is a subfield of engineering that includes aspects of mechanical, electronics, electronics, software, and engineering applied to the configuration, production, and use of motorcycles, cars, and Lorrie's respective engineering subsystems. It also includes naval architecture and aerospace engineering.Vehicle modifications are also included in this. The manufacture and assembly of full vehicle parts are under the manufacturing domain. The discipline of automobile engineering requires a lot of study and makes use of mathematical equations and formulae directly since the advent of passenger-carrying motor vehicles, automobile engineering has grown in popularity and significance.

Vehicle engineers are in high demand right now as a result of the quick expansion of car component manufacturers and the automobile sectors. One of the most difficult occupations in engineering with a broad range is automobile engineering, often known as automotive design or vehicles engineering. The design, development, manufacture, testing, maintenance, and service of automobiles, including cars, trucks, bikes, scooters, etc., as well as associated sub-engineering systems, are the focus of these fields. Automobile engineering combines the best aspects of different engineering disciplines, including mechanical, electrical, electronic, software, and safety engineering, to create the perfect automobile.

Automation is a technique that uses mechanical, electrical, and computer systems to regulate handling processes and production processes. When work done by labour / labourer was replaced by machine, the use of automation technology began. The technological development process improved continuously until humans began to use robotics, CAD/CAM, flexible production systems, and other technologies to enhance the lives of people and raise industrial productivity.

Introduction of Automobile Engineering

The advent of passenger-carrying motor vehicles, automobile engineering has grown in popularity and significance. Vehicle engineers are in high demand right now as a result of the quick expansion of car component manufacturers and the automobile sectors. One of the most difficult occupations in engineering with a broad range is automobile engineering, often known as automotive engineering or vehicle engineering. Design, development, manufacture, testing, maintenance, and service of vehicles, such as cars, trucks, motorbikes, scooters, etc., as well as associated sub-engineering systems, fall under this discipline of engineering.

Automobile engineering combines the best aspects of different engineering disciplines, including mechanical, electrical, electronic, software, and safety engineering, to create the perfect automobile. Specialized training is required to become a good vehicle engineer, and the occupation demands a lot of labor, devotion, perseverance, and commitment. The design, development, manufacture, and testing of automobiles from the idea stage to the production stage is the primary responsibility of an automobile engineer. This large discipline of engineering encompasses several sub-sections or areas of specialty, including supply chain management, fluid mechanics, thermodynamics, and aerodynamics.

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They must specify automation equipment, design and layout of machinery, machine and line speeds, and production safety protocols. Development engineers are those that link every system in a full-fledged automotive. They are in charge of overseeing the delivery of a engineering components of a finished automotive in accordance with instructions from the automobile manufacturer, legal requirements, and the consumer who purchases the product. The production engineer needs specific information from the development engineers on the spring rate he plans to employ in the vehicle.

Today automotive engineers work in every area of the industry, from the look and mechanism of cars to the safety and security of new forms of transportation. The major function of an automobile engineer is to design, develop, manufacture and test vehicles from the concept stage to the production stage. Automotive engineer is concerned with the development of passenger cars, trucks, buses, motorcycles, or off-road vehicles.

They perform one or more of the following functions:

1. Design new products or modify existing products
2. Troubleshooting and resolving engineering problems
3. Plan and design manufacturing processes
4. Automotive engineers must employ their engineering expertise in a professional setting since the discoveries and fixes must be efficient and successful. His duties in particular include:
5. Vehicle and component research, design, development, and production.
6. Creating design specs and cost estimates.
7. Sketching out plans and diagrams
8. Examining the project's energy, environment, and safety concerns.
9. Employing computer models to predict how a vehicle or component would behave under different circumstances.
10. Creating testing protocols.
11. Investigating faulty products.
12. Condensing technical data into summaries or presentations after analysis and interpretation
13. Manages the technical personnel.
14. Closely collaborated with engineers in the civil, electrical, aeronautical, chemical, and industrial fields.
15. Working with experts in related fields of business, such as sales and law.
16. They have to plan and design the machinery, the machine and line speeds, the automation equipment specifications, and the production.

They must specify automation equipment, design and layout of machinery, machine and line speeds, and production safety protocols. Development engineers are those that link every system in a full-fledged automotive. They are in charge of overseeing the delivery of both the engineering components of a finished automotive in accordance with instructions from the automobile manufacturer, legal requirements, and the consumer who purchases the product. The production engineer needs specific information from the development engineers on the spring rate he plans to employ in the vehicle.

Advantages for Automation

Manufacturing automation and computer integrated manufacturing initiatives are undertaken by businesses for a number of reasons. The following are some of the grounds given to justify automation:

To boost labour productivity. Automating an industrial procedure often boosts output and worker productivity. This translates to more production per hour of worker input.

To cut labour costs. The tendency in the world's industrialised nations has been and continues to be rising labor costs. As a result, increased investment in automation to replace human tasks has become economically acceptable. Machines are increasingly being used to replace human lahar in order to lower unit product cost.

To shift the consequences of labour shortages. Many modern countries have a general labour shortage, which has prompted the invention of automated activities as a replacement for manpower.

To cut down on or eliminate regular manual and administrative chores. It is possible to argue that there is societal benefit in automating tasks that are regular, monotonous, tiring, and potentially irritating. The goal of automating such duties is to improve the overall level of working conditions.

Increase worker safety. The task is made safer by automating a certain activity and moving the worker from active involvement in the process to a supervising function. With the passage of the Occupational Health and Safety Act (OSHA) in 1970, worker safety and physical well-being became a national priority. This has fueled the need for automation.

Enhance product quality. Automation not only leads in better production rates than human processes; it also results in improved uniformity and conformance to quality criteria throughout the manufacturing process. One of the primary advantages of automation is a lower incidence of attraction fault.

To limit the amount of lead lime used in production. Automation shortens the time between a client order & product delivery, giving the manufacturer a competitive edge for future orders. The manufacturer minimises work-in-process inventory by minimising production lead time.

To do tasks that cannot be completed manually. Certain procedures cannot be performed without the assistance of a machine. These procedures have accuracy, miniaturisation, or geometric complexity requirements that cannot be satisfied manually.

Certain integrated circuit manufacturing methods, fast prototyping processes based on computer graphics (CAD) models, and computer numerical control machining of complex, mathematically specified surfaces are examples. Only computer-controlled systems can carry out these procedures.

To avoid the enormous costs associated with not automating. Automating a manufacturing operation provides a considerable competitive advantage. The benefit is difficult to establish on a company's project permission form. The advantages of automation often manifest themselves in unexpected and intangible ways, such as enhanced quality, increased sales, improved employee relations, and a stronger business image. Companies who do not automate are likely to fall behind their competitors in terms of consumers, workers, and the general public.

Disadvantages of Automation

Aside from these benefits, we must also consider the drawbacks of employing and implementing automation in the industrial sector.

Increased startup and operating costs. The substantial capital cost necessary to invest in automation is included in automated equipment. The design, fabrication, and installation of an automated system may cost millions of dollars.

Increased Maintenance Costs. Maintenance is more extensive than with a manually driven equipment. Purchasing electromechanical equipment such as electromechanical valves, sensing devices, and smart gadgets is one of them. Spare components for an automated system may be more expensive than manual operation.

The cost of obsolescence/depreciation. The progressive decrease in the value of physical assets is referred to as obsolescence and depreciation. This effect is common to all physical assets such as machinery and equipment. It was unavoidable as a result of technological advancement. Obsolescence or depreciation is divided into two categories: i. Physical Depreciation - this occurs as a consequence of physical damage to equipment or robotics. It depicts a shape that is readily visible as deterioration, wear, and rust.

Function depreciation - it existed due to changes in demand for services that might be offered.

Depreciation induced by changes in the requirement for an equipment service, the discovery of new equipment, or the incapacity of a robot system to satisfy need joblessness.

Worker displacement is a common problem linked with automation. Because manual employees are being replaced with robots or other automated machines, huge layoffs are occurring. Many individuals are losing their employment, particularly those in the industrial area, such as a car plant.

Small-scale manufacturing is not economically viable.

Types of Automation System

There are three kinds of automated manufacturing systems:

i. Fixed automation
ii. Mobile automation
iii. Immobile automation

Fixed Automation

The sequence of processing (or assembly) processes in a stationary automation system is determined by the equipment setup. Each operation in the sequence is typically basic, comprising either a simple linear or rotational movement or a simple mix of the two; for example, feeding a revolving spindle. The system's complexity stems from the coordination and integration of several similar activities into a single piece of equipment. The following are typical characteristics of fixed automation:

- A significant initial outlay for custom-engineered equipment
- High output rates
- Somewhat rigid in terms of tolerating product variety

Fixed automation has an economic basis in items that are produced in big numbers and at high production rates. The high initial expense of the equipment may be amortised across a large number of units, making the unit cost appealing when compared to other manufacturing processes. Machine transfer lines, automated assembly robots, distillation processes, conveyors, and paint shops are examples of stationary automation.

Programmable Automation

The production equipment in programmable automation is built with the capacity to modify the sequence of activities to meet varied product configurations. A programme, which is a collection of instructions written so that the system can read and comprehend them, controls the operation sequence. New programmes may be created and loaded into the machinery to create new goods. Among the characteristics of programmable automation are:

1. Significant investment in general-purpose equipment
2. Lower output rates than fixed automation
3. Adaptability to modifications and changes in manufacturing and assembly
4. Most suited to batch production

In low- and medium-volume manufacturing, programmed automated production systems are employed.Parts or goods are often manufactured in batches. To generate each new batch of a different product, the system must be reprogrammed with the new product's set of machine instructions.

The machine's physical configuration must also be altered. Tools must be loaded, fixtures connected to the machine table, and the needed machine setting input. This transition technique is time-consuming. As a result, the normal cycle for a specific product involves a time of setup and reprogramming, followed by a period in which the batch is manufactured. CNC machines machine tools, industrial robots, programmable logic controllers, steel rolling mills, and paper mills are examples of programmable automation.

Flexible Automation

Programmable automation is an extension of flexible automation. A versatile automated system can produce a wide range of parts (or products) with little to no downtime for changeovers from one component type to the next.

There is no downtime when reprogramming the system or changing the physical configuration (tooling, fixtures, machine settings). As a result, instead of needing batch production, the system may generate multiple combinations and schedules of components or products. The fact that the variations between pieces processed by the system are insignificant is what enables flexible automation. It is an example of gentle variation, which means that the degree of transition between types is modest.

The following are some of the characteristics of flexible automation:

1. High cost of a custom-engineered system
2. Continual manufacture of varied product mixes
3. Medium output rate
4. Adaptability to product design modifications

Flexible manufacturing systems for executing machining processes, which date back to the late 1960s, are examples of flexible automation. Figure below depicts the relative positions of the three forms of automation for various production volumes and product variants. For low production quantities and new product launch, manual production is compatible with programmable automation, as shown in the Figure 1.1.

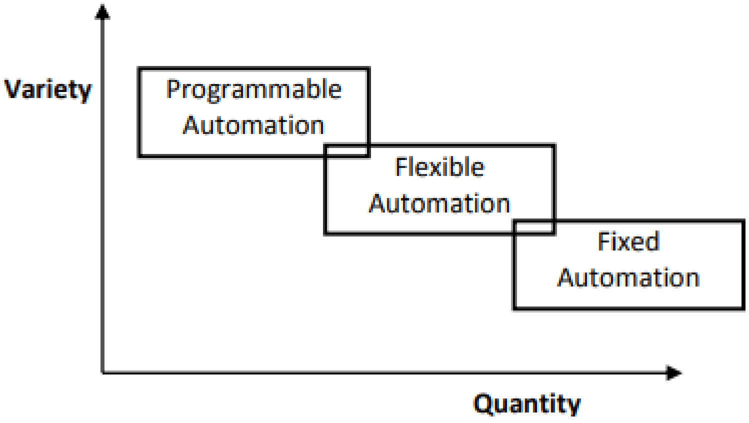

Figure 1.1 Represents the Three Kinds of Automation System

Automation in Production System

A production system is a collection of people, equipment, and processes that are structured to carry out an organization's manufacturing activities. A manufacturing system is made up of facilities and manufacturing support systems (see Figure below):

Facilities the factory, the manufacturing equipment, and how the equipment is placed around the shop floor.

ii. Manufacturing support systems (MSS)—a collection of procedures used to manage production and handle technical and logistical issues that arise throughout the manufacturing process. Product design, control and control, logistics, and other business operations are all part of these systems (Figure 1.2).

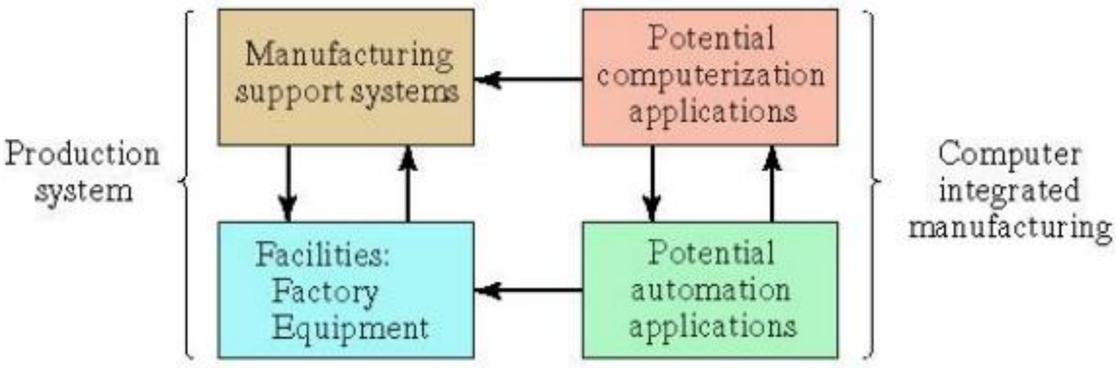

Figure 1.2 Represents the Production System Of Automation

A manufacturing system is a logical arrangement of production equipment and the personnel who run it. Worker-machine systems, manufacturing lines, and machine cells are a few examples. A production system is a broader system that contains a collection of manufacturing systems as well as the support systems that keep them running. A subset of the production system is the manufacturing system. Some aspects of manufacturing systems are automated and/or computerised, while others rely on manual labour People supervise the entire operation of the production system, which includes direct labour personnel for facility operation and professional staff in charge of the manufacturing support systems. The factory, production machinery and tools, material handling equipment, inspection equipment, and computers that govern manufacturing activities are all part of the facilities. Facilities may also comprise the plant layout, which is the physical organisation of the factory's equipment, which is often grouped into logical groups called production systems.

In the factory, automated production systems work on the physical product. They execute tasks like as processing, assembly, certification, or material handling, and in some instances perform many operations in the same system. They are named automated because they accomplish their activities with less human involvement than manual counterparts.

There is almost no human involvement in certain fully automated systems. Automated manufacturing systems include

1. Automated machine tools for processing components
2. Transfer lines for performing a succession of machining operations.
3. Automated assembly system

4. Industrial Robot
5. Material handling and storage systems that are automated to combine industrial operation
6. Quality control inspection methods that are automated

In general, there are two forms of production system automation: manufacturing system automation and computerization of manufacturing support systems. Because production system automation includes some computerization for control and operational reasons, the two categories tend to overlap. The phrase computer-integrated manufacturing refers to the widespread usage of computers in manufacturing systems

Basic Concept of Automation Terminology

Links and joints

A robot's links are its solid structural parts, while its joints are the moveable couplings between them. The manipulator's joints or axes (robotic arm). An industrial robot's joint is analogous to a human body joint. It allows for relative mobility between two bodily components. Joints are classified into two types: main axes, which include the base, shoulder, and elbow, and minor axes, which include wrist pitch, wrist roll, and wrist yaw.

Degree of freedom

Every joint on the robot adds a degree of flexibility. Each dof may be a slider, rotary, or other actuator type. Typically, robots have 5 or 6 degrees of freedom. Three degrees of freedom enable for 3D positioning, while the remaining two or three are employed for end effector orientation. Six degrees of freedom are sufficient to enable the robot to attain all positions and orientations in three-dimensional space. 5 degrees of freedom necessitates a constraint to 2D space, or else orientations are limited. 5 degree of freedom robots are widely used to handle instruments such as arc welders.

Orientation Axes

Essentially, the orientation defines the direction the tool may be directed in if it is maintained in a fixed position. The most frequent orientation axes are roll, pitch, and yaw. The tool may be positioned in any orientation in space, as seen in the picture below. (Imagine you're on an aircraft. If the aircraft rolls, you will be flipped upside down. The pitch of the aircraft varies during takeoff and landing, and it yaws while flying in a crosswind. Production System of Automation (Figure 1.3).

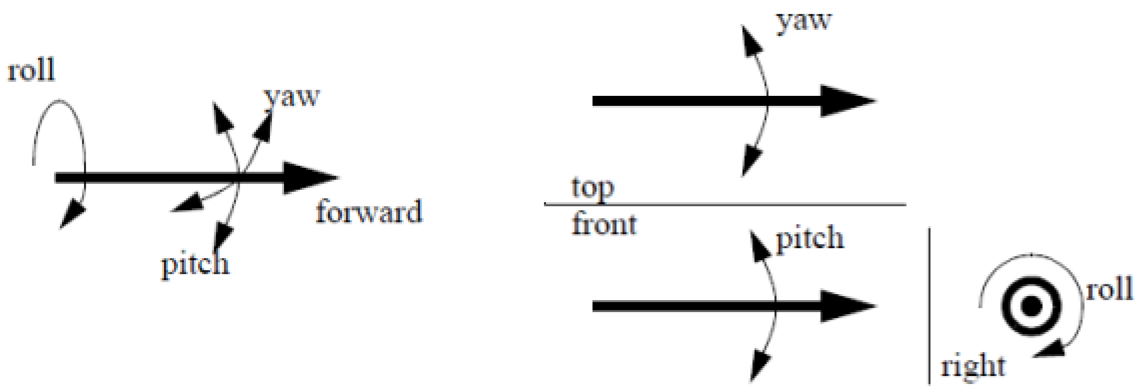

Figure 1.3 Represents the Production System ofAutomation Position Axes

Regardless of orientation, the tool may be moved to a variety of points in space. Various robot geometries are better suitable for various work geometries. (More on it later) A 3-D coordinate system that uses X, Y, and Z coordinates to determine an object's position in 3-D space. A portion of a robot may travel to a location inside its work envelope by employing gadgets that notify it where it is. Degrees of freedom in translation

Tool Centre Point (TCP)

The tool centre point may be found on either the robot or the tool. The TCP is often used to refer to the robot's location as well as the focus point of the tool. (For instance, the TCP may be at the tip of a welding torch.) Depending on the robot, the TCP may be configured in Cartesian, cylindrical, spherical, and other coordinate systems. We often reprogram the robotic for the TCP when tools are updated. The tool midpoint is the reference point for the robot-controlled tools. Figure 1.4 Represent the tool centre point of the robotic system

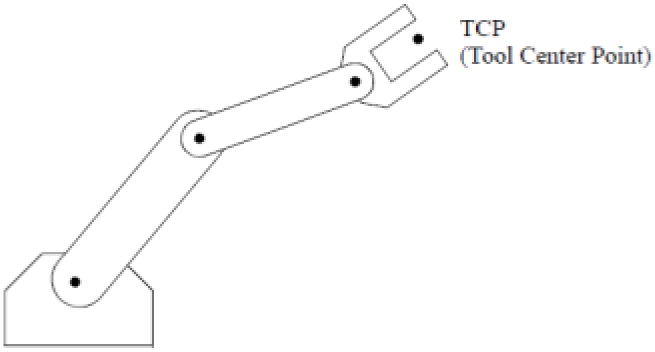

Figure 1.4 Represent the tool centre point of the robotic system

Speed

It relates to the highest velocity that the TCP or individual joints may achieve. This figure is inaccurate in most robots and will fluctuate over the workspace as the robot's shape changes (and hence the dynamic effects). The figure will often indicate the fastest safest speed feasible. Some robots enable the maximum rated speed (100%) to be passed, but only with extreme caution.The pace at which robots travel from point A to point B under the supervision of the software is referred to as speed. It is a measure of the device's speed. Maximum joint velocity (angular or linear) is not a parameter that can be calculated independently.

Longer movements are often restricted by motor speed control bus voltage or maximum permitted motor speed. Even brief point-to-point movements may be velocity restricted for manipulators with strong accelerations. Only gross movements will be velocity restricted for low-acceleration robots. For big robots, typical peak final speeds may reach 20m/s.

Payload

The payload is the greatest mass that the robot can lift before failing or losing significant accuracy. It is possible to surpass the maximum payload while still operating the robot, although this is not recommended. The payload should be smaller than the maximum mass while the robot is accelerating quickly. This is influenced by the capacity to grasp the component securely, as well as the robot structure and actuators.The tooling at the end of the arm should be considered as part of the payload. The maximum payload is given in kilos.

Repeatability

When the degree of ability of a robotic arm to identify targets is appropriately established, it returns to its former position in the work cell. The robot with a high repeatability will be able to perform the job correctly without mistake. The robot mechanism will exhibit some natural variation. This implies that if the robot is repeatedly told to return to the same location, it will not always halt at the same place.

Repeatability is defined as +/-3 times the position's standard deviation, or the point at which 99.5% of all repeatability measurements fall. This number will fluctuate across the workspace, particularly near the workspace's limits, although manufacturers will provide a single value per specifications.

Accuracy

The ability of a robotic arm to travel to a specific spot in the work cell as we input the coordinates in the off-line programming station (off-line programming). The resolution of the workspace determines this. If the robot is told to move to a certain location in space, it will often be wrong by some distance; the greatest distance should be regarded the accuracy. This is the result of a control system that is not always continuous.

Control Resolution

This is the smallest change that the feedback sensors can detect or that the actuators can induce, whichever is greater. If a rotary joint has an encoder that measures every 0.01 degree of rotation and a direct drive servo motor with a resolution of 0.5 degrees is used to drive the joint, the control resolution is about 0.5 degrees (the worst case is 0.5+0.01). The robot's positioning system's capacity to partition the motion range for every joint into tightly spaced points.

Accuracy and Repeatability

Accuracy and reproducibility are dependent on:

1. Resolution- Because of the usage of digital technologies and other considerations, only a limited number of places are available. As a result, user input coordinates are often modified to the next discrete point.

2. Kinematic modelling mistake - the robot's kinematic model does not perfectly match the robot. As a consequence, the needed joint angle calculations include a slight inaccuracy.

3. Calibration errors - The location established during calibration may be slightly incorrect, resulting in a calculation mistake.

4. Unpredictable mistakes – issues develop while the robot performs. Variations inposition may be caused by factors such as friction, structure bending, thermal expansion, transmission backlash/slip, and so on.

Control Resolution

The smallest increment of movements into which the robot may split its work volume is referred to as spatial resolution. Spatial resolution is determined by two factors: the system's control resolution and the mechanical imperfections of the robot. These issues are best understood in terms of a robot with one degree of freedom.The position control system and feedback measurement system of the robot define the control resolution. The controller's capacity to separate the whole range of movement for the specific joint into discrete increments may be addressed. The increments are also known as "addressable pieces" at times. The ability to split the joint range into increments is determined by the control memory's bit storage capacity. The number of distinct, distinguishable increments (addressable locations) for a given axis is given by # of increments 2n = where n is the number of control bits.

A robot with an 8-bit control resolution may segment a motion range into 256 distinct locations. The resolution of the control is about (range of motion)/256. Almost usually, the increments are regular and equal. Precision = Control Resolution/2 if mechanical imperfections are minor.The controller's bit storage capacity is the second constraint on control resolution. If B is the number of bits in the bit storage register dedicated to a certain joint, then 2B is the number of addressable points in that joint's range of motion. As a result, the control resolution is defined as the distance between adjacent addressable points. This electromechanical control resolution is designated by the letter CR. Because of the broad range of joints employed by robots and their unique mechanical properties, it is impossible to define each joint in detail. However, there is a mechanical limit to the ability to split the range of each joint-link system into addressable locations, and that limit is given by CR2 is the controller's bit storage capacity. This is provided by:

$$CR_2 = \frac{R}{2^B - 1}$$

Where CR2 is the robot controller's control resolution; R is the range of the joint-link combination, given in linear or angular components; and B is the amount of bits in the bit storage register assigned to a specific joint. The control resolution is given by the maximum of CR2. Mechanical imperfections that cause the robot's end-of-wrist to return to slightly different places than the programmed point are to blame for repeatability. In the case of a single joint-link mechanism:

$$\mathrm{Re} = \pm 3\sigma$$

Where Re denotes repeatability and is the error distribution's standard deviation.

For accuracy, we have: where CR is controller resolution and is the error distribution's standard deviation.

$$Acc = \frac{CR}{2} + 3\sigma$$

Control resolution, repeatability, and accuracy are three critical factors that influence robot precision.

Basic Component of an Automation System

Automation is the technology that allows a process or operation to be completed without the need for human intervention. It is accomplished by combining an instruction programme with a system that executes the instructions. Power is necessary to automate a process, both to drive the operation and to run the software and control system. Although automation may be used in a broad range of businesses, it is most closely connected with the manufacturing sector.

The word was first used in the context of manufacturing by an engineering manager at Ford Motor Company in 1946 to describe the many automated transfer devices and feed mechanisms that had been put in Ford's production facilities. It is paradoxical that practically all contemporary automation applications are managed by computer technology that did not exist in 1946.

Created to automate industrial procedures. Figure below depicts the place of automation and control technologies within the broader production system. In this chapter, we will offer an overview of automation: What components comprise an automated system? and What are some advanced features that go beyond the fundamental elements? In the next two chapters, we will look at industrial control systems and their hardware components.

These two chapters provide the groundwork for the next chapters on automation and control technology. These are numerical control technologies of numerical control, industrial robotics, and programmable logic controllers. Figure 1.5 represents the basic component of an automation system

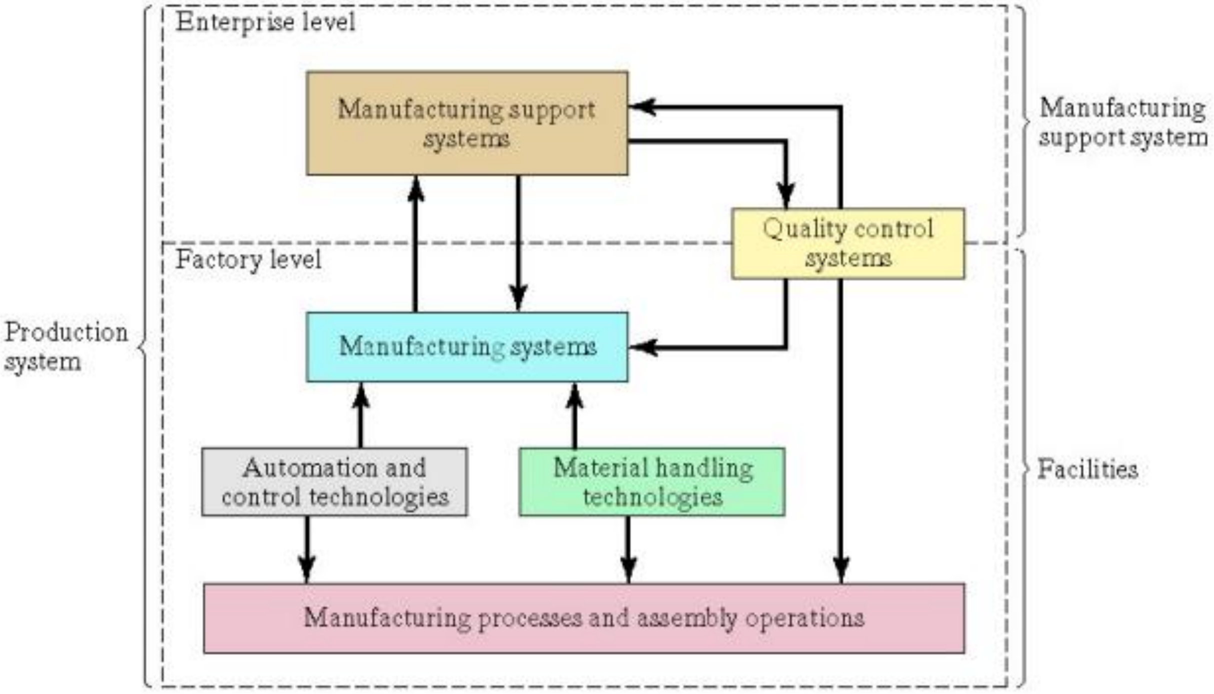

Figure 1.5 represents the basic component of an automation system

An automated system is made up of three main components:

(1) The ability to complete the process and work the system,

(2) As a set of instructions to guide the system. Figure 1.6 Represents the three system of automation system

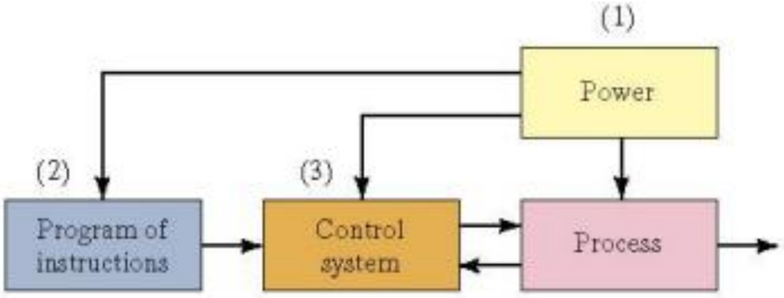

Figure 1.6 Represents the three system of automation system

Power to Accomplish the Automated Process

An automated system is utilized to run a process, and electricity is necessary to power both the process and the controls. Electricity is the primary source of power in automated systems. Electric power provides several benefits in both automated and non-automated processes:

Electrical power is abundantly accessible and reasonably priced. It is an essential component of our industrial infrastructure.

Electrical power can be easily converted to alternative energy forms such as mechanical, thermal, light, acoustic, hydraulic, and pneumatic. Electrical power at low levels can be used to perform functions such as signal transmission, information processing, and data storage and communication. Electrical energy can be stored in long life batteries for use in areas where an external source of electrical power is not readily available.

Fossil fuels, solar energy, water, and wind are examples of alternative energy sources. However, their sole application in automated systems is uncommon. When alternative power sources are employed to power the process, electrical power is often utilised for the controls that automate the operation. In casting or heat treatment, for example, the furnace may be fired by fossil fuels, but the control mechanism to manage temperature and time cycle is electrical. In other circumstances, the energy from these alternate sources is transformed to electricity, which is then used to power both the process and its automation. Solar energy is often transformed in this manner when utilised as a power source for an automated system.

The Process Has Power. The word process in manufacturing refers to the manufacturing activity done on a work unit. Contains a list of typical industrial processes, as well as the kind of power needed and the subsequent action on the work unit. These processes require the majority of the electricity in industrial facilities. The "power form" listed in the table's center column refers to the energy applied directly to the process. As previously stated, each operation's power source is often transformed from electricity. Power is necessary for the following material handling operations in addition to driving the production process.

The work unit's loading and unloading. All of the procedures in Table 2.1 are carried out on separate pieces. For the process to be completed, these pieces must be moved into the right location and orientation, and power is needed for this transport and placement function. The work unit must also be removed at the end of the procedure. If the operation is entirely automated, some type of mechanical power is required used. If the process is manual or semi-automated, human labour may be required to position and locate the work unit.

Moving materials between processes. Work units must be transferred between operations in addition to loading and unloading at a specific operation. The ability to automate. Power is utilized for the following purposes in addition to the fundamental power requirements:

The controller. Modern industrial controllers is based on digital computers, which need electricity to read the programmer of instructions, do control computations, and execute the instructions by sending the appropriate orders to the actuating devices.

The ability to activate control signals. The controller unit's orders are carried out via electromechanical devices called actuators, which include switches and motors. Commands are often conveyed through low-voltage control signals. The actuators demand more power to carry out the orders, thus the control signals must be amplified to give the appropriate power level for the actuating device.Information gathering and processing. Most control systems need data from the process to be gathered and utilised as input to the control algorithms. Furthermore, maintaining records of process performance or product quality may be a requirement of the process. These data collecting and record keeping operations need electricity, although in little quantities.

CHAPTER 2

Program of Instructions

Mr. Ashok Singh Gour, Assistant Professor,
Department of Mechanical Engineering, School of Engineering & Technology,
Jaipur National University, Jaipur, India
Email Id- asgour@jnujaipur.ac.in

A program of instructions defines the activities done by an automated process. Whether the manufacturing operation is low, medium, or high production each component or product type produced needs one or more processing stages that are specific to that style. These processing processes are carried out as part of a work cycle. Per work cycle results in the completion of a new product (in certain manufacturing processes, more than one part is produced throughout the work cycle; for example, a plastic injection molding operation may manufacture many pieces each cycle utilising a multiple cavity mould). A work cycle programme specifies the specific processing stages for the work cycle. In numerical control, work cycle programmes are referred to as part programmes. This sort of software is known by other names in other process control systems.Programs for the Work Cycle. The work cycle in the simplest automated processes consists primarily of one step, which is to keep a single process parameter at a predetermined level, such as maintaining the temperature of a furnace at a certain value for the length of a heat treatment cycle. (We presume that the work units are manually loaded and unloaded into and from the furnace, thus this is not part of the automated cycle.) In this situation, programming consists of just adjusting the temperature dial on the furnace. The operator merely changes device temperature setting to modify the programme. Angeneralisation of this basic instance is when the single-step process is characterised by more than one process variables, such as a furnace that controls both temperature and atmosphere.

In increasingly complex systems, the process entails a work cycle comprised of numerous processes that are repeated without variation from one cycle to the next. This category includes the vast majority of discrete component manufacturing processes. The following is a typical (simplified) sequence of steps: (1) put the component into the manufacturing machine, (2) complete the procedure, and (3) unload the item. There are one or more activities that include changes in one or more process parameters throughout each stage. Process parameters include process inputs such as furnace temperature setting, coordinate axis value in a positioning system, valve opened or closed in a fluid flow system, and motor on or off. Process parameters are distinct from process variables, which are process outputs such as the real temperature of the furnace, the actual position of the axis, the actual flow rate of the fluid in the pipe, and the motor's rotational speed. Changes in process variables values may be continuous (gradual changes throughout the processing step; for example, gradually rising temperature during a heat treatment cycle) or discrete (stepwise changes; for example, on/off). Different process parameters will almost certainly be involved in each phase.

An Automated Turning Operation

Consider an automated turning operation that generates a cone-shaped geometry. Assume the system is automated and that the work unit is loaded and unloaded by a robot. The following stages comprise the work cycle:

(1) Load the first work component

(2) Before rotating, set the cutting tool.

(3) Spinthe work piece,

(4) Relocate the tool to a safe place at the completion of the turning, and

(5) Unload the completed work piece. Identify the activities and process parameter(s) in each operation stage.

Solution: The actions in step (1) comprise of the robot manipulator reaching for the raw work portion. Lifting and putting the item in the lathe's chuck jaws, then withdrawing the manipulator to a safe place while waiting for unloading. The process parameters for these operations are the robot manipulator's axis values (which vary continually), and the gripper value (open or closed). As well as the chuck jaw value (open or closed)the action in step (2) is to move the cutting tool to the "ready" position. The r- and z-axis positions of the tool are the process parameters connected with this activity.

The turning operation is performed in step three. It necessitates the simultaneous management of three process parameters: work piece rotational speed (rev/min), feed (mm/rev), and cutting tool radial distance from the axis of rotation. To cut the conical form, the radial distance must be altered at a steady pace each time the work piece rotates. To achieve a consistent surface finish, the rotating speed must be continually adjusted to maintain a constant surface speed (m/min), and the feed must be set at a constant value. Multiple rotating passes may be necessary to progressively develop the proper shape according to the angle of the cone. Each pass marks a new phase in the process. Stages (4) and (5) entail the same activities as steps (2) and (1), with the same process parameters.

Many manufacturing processes include numerous phases, some of which are more sophisticated than our turning example. Automatic screw machine cycles, sheet metal stamping processes, plastic injection moulding, and die casting are examples of these procedures. Each of these industrial techniques has been around for a long time. Earlier versions of these activities used hardware components such as limit switches, timers, cams, and electromechanical relays to manage the work cycles. In practise, the hardware components and their configurations served (IS the programme of instructions that guided the sequence of stages in the processing cycle. Although these devices were quite adequate for their sequencing function, they had the following drawbacks:

(1) They frequently required significant time to design and fabricate, forcing the production equipment to be used only for batch production;

(2) Making even minor changes in the programme was difficult and time consuming; and

(3) The programme was in a physical form that was not readily compatible with computer data processing and communication.

Digital computers are the foundation of modern controllers utilised in automated systems. Instead of cameras, timers, relays, and other hardware devices, computer-controlled equipment programmes are stored on magnetic tape, diskettes, compact discs (CD-ROMs), computer memory, and other contemporary storage media. To execute their respective processing cycles, almost all new equipment that performs the aforementioned mass production tasks is constructed with some sort of computer controller. The use of digital computers as process controllers enables for enhancements and modifications to control programmes, such as the inclusion of control capabilities that were not anticipated during original equipment design. These kind of control adjustments are often difficult to implement with earlier hardware devices.

The work cycle may contain manual phases in which the operator conducts specific actions while the automated system does the remainder. The operator loading and unloading parts into and out of a numerical control machine between machining cycles, while the machine executes the cutting operation under part programme control, is a frequent example. After the component has been loaded, the operator activates a "start" button to begin the cutting process of each cycle.

Making Decisions in the Programmed Work Cycle. The only two characteristics of an automated work cycle that we discussed before are (1) the number and sequence of processing stages and (2) the process parameter changes in each step. Each work cycle has the identical actions and related process parameter changes, with no variation from cycle to cycle.

Each work cycle, the instructional programme is completely revoked. To deal with fluctuations in the cycle, many automated manufacturing procedures need choices to be taken throughout the intended work cycle. In many situations, the deviations are ordinary aspects of the cycle, and the instructions for dealing with them are included into the normal portion programme. These are some examples:

Interaction with the operator. Although the programme of instructions is designed to be executed without human intervention, the controller unit may need data input from a human operator in order to operate.

In an automated engraving procedure, for example, the operator may be required to input the alphanumeric characters to be etched on the work unit (e.g. plaque, trophy, belt buckle). After entering the characters, the system performs the engraving procedure automatically.A bank client utilising an automated teller machine is an example of an operator engagement with an automated system.

The system processes various component or product styles. In this case, the automated system is set up to complete different work cycles on various component or product styles. An industrial robot doing a succession of spot welding operations on vehicle bodywork in a final assembly factory is one example. These facilities are often constructed to produce multiple body designs, such as two-door and four-door sedans, on the same automated assembly line. As each automobile body reaches a certain welding station on the line, sensors detect the style, and the robot conducts the appropriate set of welds for that style.

Differences in the initial work units. The initial work units in many industrial activities are not constant. A sand casting as the first work unit in a machining process is an excellent illustration. Dimensional variances in raw castings may need an additional machining pass to bring the machined dimension to the prescribed value. When an extra pass is required, the component programme must be programmed to allow for it.

The routine deviations in all of these cases may be handled in the normal work cycle schedule. The software may be written to react to sensor or operator inputs by running the associated subroutine. In other circumstances, fluctuations in the work cycle are not at all regular. They are uncommon and unexpected, such as the breakdown of a machine component. In these cases, the software must contain contingency methods or changes in the sequence to deal with situations that are not part of the typical routine.

Control System

The automated system's control element executes the set of instructions. The control system directs the process to perform its designated function, which in our case is to carry out a manufacturing activity. Let us begin with a quick overview of control systems. The next chapter goes into further information about this critical industrial technology.

An automated system's controls may be either closed system or open loop. A closed loop control system, also known as a feedback control system, is one in which the output variable is compared to an input parameter, and any difference between the two is used to drive the outcome into agreement with the input. The input parameter, also known as the set point, represents the intended output value. The set point in a home temperature control system is the intended thermostat setting. The action or function under management is referred to as the process. The output variable, in particular, is being regulated in the loop. The process of interest in this topic is often a manufacturing activity, and the output variable is some process variable, maybe a vital performance metric in the process, such as temperature, force, or flow rate. To measure the output and complete the loop between input and output, a sensor is utilised.

In a closed loop control system, sensors provide feedback. The controller compares the output to the input and makes any necessary adjustments to lessen the disparity between them.

One or more actuators, which are the hardware devices that physically carry out the control actions, such as a motor or a flow valve, are used to make the adjustment. It should be noted that our model depicts a closed loop control system, although most industrial processes have many loops, one for each process variable to be managed.Figure 2.1 Represents control system.

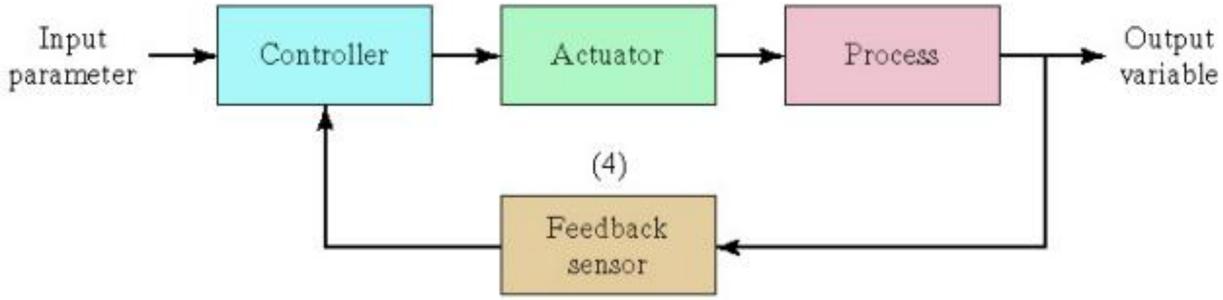

Figure 2.1 Represents control system

An open loop control system, in contrast to a closed loop control system, functions without a feedback loop. The controls work without monitoring the output variable in this situation. As a result, no comparison is conducted between the actual output values and the required input parameter. The controller is reliant on an accurate model of its actuator's influence on the process variable. The drawback of an open loop system is that there is always the possibility that the actuation will not have the desired impact on the process. It has the benefit of being simpler and less costly than a closed-loop system. When the following characteristics are met, open loop systems are typically appropriate: (1) the actions performed by the control system are simple, (2) the actuation function is extremely dependable, and (3) any reaction forces opposing the actuation are tiny enough to have no influence on the actuation. If these qualities do not apply, a control loop may be preferable.

In the instance of a positioning system, consider the distinction between a closed loop and an open loop system. Positioning systems are widely used in manufacturing to position a work component in relation to a tool or work piece head. When the system is activated, it is instructed to move the worktable to a certain place described by a coordinate value in a Descartes (or other) coordinate system. Most positioning systems contain at least two axes (for example, an x-y positioning table), each with its own control system, although our graphic only shows one of these axes. A common actuator for each axis is a dc servomotor coupled to a lead screw. The controller sends a signal indicating the coordinate value (e.g., x-value) to the motor that powers the lead screw, whose rotation is transformed into linear motion of the positioning table. The discrepancy between the real x-position and the input revalue decreases as the table approaches closer to the intended x-coordinate value. A feedback sensor measures the actual repositioning (e.g. an optical encoder). The controller keeps driving the motor until the real table position matches the input positioning value (Figure 2.2).

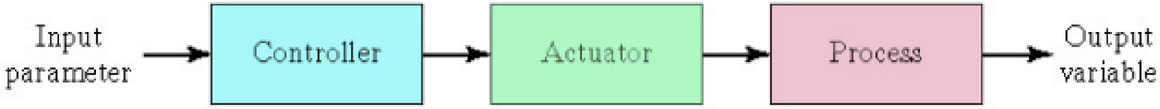

Figure 2.2 RepresentstheInput/outputParameter of Control System.

The positioning system diagram for the open loop example is identical to the previous, except that no feedback loop is provided and a stepper motor is utilised instead of the dc servomotor. A stepper motor is intended to rotate a precise fraction of a turn for each controller pulse.Because the motor shaft is linked to the lead screw, which drives the worktable, each pulse results in a little continuous linear movement of the table. To move the table a specified distance, the appropriate application sends the number of pulses corresponding to that distance to the motor, whose characteristics fit the previous set of operating criteria.

Automation System in an Application

In an application, an automated system consists of a set of workstations linked by a transfer system that moves components between the stations. This is an example of fixed automation since these lines are often set up for extended production runs, potentially producing millions of product units and operating for many years between changeovers. Each station is intended to conduct a particular processing function, allowing the component or product to be built step by step as it moves down the line. A raw work component enters the line at one end, travels through each workstation, and exits at the other end as a finished product. In normal operation, a work component is processed at each station, such that numerous parts are treated at the same time, and a completed part is created with each cycle of the line. For an automated transfer line to function successfully, all of the operations, component transfers, and other activities must be properly scheduled and coordinated. PLCs, or programmable logic controllers, are special computers that permit connections with industrial equipment such as automated manufacturing lines and can execute the timing and sequencing operations necessary to run such equipment.

Many sectors employ automated production lines, most notably automotive, where they are used for procedures like as machining and press work. Machining is a manufacturing process in which metal is removed by a cutting or shaping tool, leaving the desired form on the remaining work component. This method is often used to manufacture machinery and motor components. In many situations, many procedures are necessary to form the component fully. When mass-producing an item, an automated transfer line is often the most cost-effective way of manufacturing. The various processes are distributed across the workstations. Transfer lines date from about 1924.Press work processes include the cutting and molding of sheet metal pieces.

Automobile body panels, outside shells of large appliances, and metal furniture are examples of such pieces. A sophisticated element often demands more than one processing step. Several presses are linked in series by handling devices that move partly finished components from one press to the next, resulting in an automated press work line.

Applications Examples: Single Station Manned Cells

The majority of industrial production activities rely on single-station human and automated cells. Let us add to the list

A CNC machine shop. For each component, the machine runs a part programme. The components are same. At the conclusion of each programme execution, a worker must be present at the machine to unload the previously finished component and put a raw work part onto the machine table.

A turning centre with CNC capabilities. For each component, the machine runs a part programme. The components are same. A worker must dump completed components into a tote pan and then reload raw parts from another tote pan. This machining centre is identical to the one before it, but it uses a different machining method.

The same as before, only the components are not same. For each subsequent work component, the machine operator must invoke the relevant part programme and load it into the CNC control unit.

A pair of CNC turning centres that produce the same component but operate separately from their respective machine control unit. Both machines are loaded and unloaded by a single employee. The component programmes are lengthy enough in relation to the load/unload section of the work cycle that this may be done without forcing the machine to idle. A semi-automatic plastic injection moulding machine with a person present to remove the moulding, sprue, and runner system as the mould opens each moulding cycle. The worker places the parts in a box. Another person must switch the tote box and refill the moulding compound to the machine on a regular basis.

A worker at an electronics assembly workstation in a batch operation loading components into printed circuit boards. The worker must postpone output on a regular basis in order to replenish the supply of components kept in tote bins at the station. Starting and completed boards are kept in magazines, which must be updated on a regular basis by another worker.A worker at an assembly workstation doing mechanical assembly of a basic product or subassembly of a product using components placed in tote bins at the station. Each cycle, a worker is needed to put the blank into the press, activate the press, and then remove the stamping. Completed stampings are kept on four-wheel trucks manufactured specifically for the product.

Applications Examples: Single Station Automated Cells

Here are some examples of single-station automated cells. Each of the previous instances has been used:

A CNC machining centre, with a components carousel and an automated pallet changer.A part programme controls the machining cycle, and the pieces are identical. Each component is kept in place by a pallet fixture. When all of the components in the carousel have been machined, the machine cuts the parts one by one; a worker takes the completed pieces from the rotor and loads beginning work parts. The carousel may be loaded and unloaded while the machine is operating. Figure 2.3 Represents Single Station Automated Cells

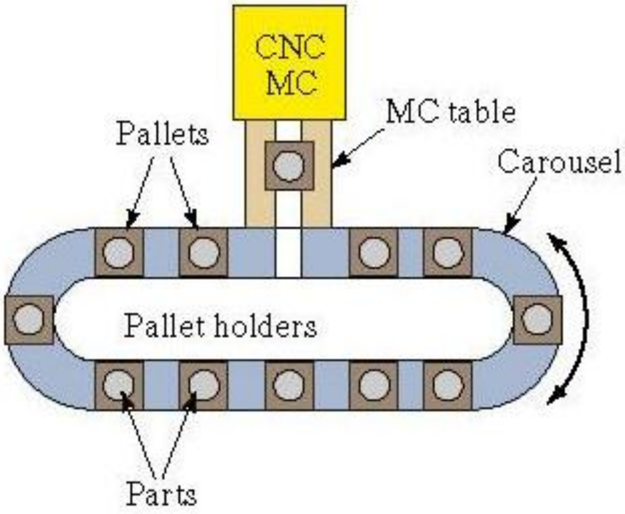

Figure 2.3 Represents Single Station Automated Cells

A CNC turning centre that includes tray and a robot. Each cycle, the robot uses a dual gripper to discharge the finished component and load a beginning work part from the parts storage tray. A specific number of components may be stored in the parts storage tray. In essence, this is the same scenario as the CNC machining centre, with the exception of a different machining procedure. The same as before, only the components are not same. In this situation, the relevant part programme is automatically downloaded to the CNC control unit for each subsequent work part based on either a predetermined production schedule or an automated part recognition system that recognises the raw component.

A group of 10 CNC turning centres, each generating a unique item. For loading and unloading between the machine and the carousel, each workstation has its own components carousel and robotic arm. A single person must attend to all 10 machines by emptying and loading the storage carousels on a regular basis. Because the time needed to service a carousel is little in comparison to the amount of time each machine may operate unsupervised, all 10 machines can be maintained with no machine idle time. An automated plastic injection moulding machine with mechanical mechanism to assure removal of the moulding, sprue, and runner system after each moulding cycle. Under the mould, parts are gathered in a tote box. A worker must switch the tote box and refill the moulding compound to the machine on a regular basis.

A batch insertion machine that assembles electronic components into printed circuit boards. Starling boards and completed boards are kept in magazines for replacement by a human worker on a regular basis. The worker must also change the supply of components, which are held in lengthy magazines, on a regular basis. A robotic assembly cell made up of one robot that assembles eight basic products (or subassemblies of products) from components delivered by various parts delivery methods (e.g. bowl feeders).

A stamping press that punches and produces tiny sheet metal parts from a long coil at a pace of 180 cycles per minute and can stamp 9000 components from each coil. The stampings are gathered in a tote box on the press's output side. When the coil wears out, it must be changed, and the tote box must be replaced at the same time.

Applications Examples: CNC Machining and Turning Centers

CNC machining centres and turning centres were used in many of our single station production cell application examples. The machining centre, which was invented in the late 1950s prior to the introduction of computer numerical control (CNC), is a machine tool capable of conducting numerous machining operations on a work component in a single setup while being controlled by an NC programme. CNC is used in today's machining centres. Typical machining centre cutting operations include milling, drilling, reaming, and tapping, which employ a spinning cutting tool.

Vertical, horizontal, and universal machining centres are available. The label relates to the spindle orientation of the machine. A vertical machining centre features a spindle that is oriented vertically in relation to the machine.A horizontal machining centre has its spindle on a horizontal axis, as does the worktable. This differentiation usually results in a change in the kind of work done on the machine. A vertical machining centre is often used for flat work that need tool access from above. A horizontal machining centre is utilised for cube-shaped items where tool access is easiest on the cube's sides. Work heads on universal machining centres may rotate their spindle axes to any angle between horizontal and vertical, making this an extremely versatile machine tool.

The characteristics of numerical control machining centres are often intended to decrease non-productive time. These characteristics include the following:

Automatic tool switching. A wide range of machining processes necessitates the use of a wide range of cutting tools. The tools are housed in a tool storage unit that is built into the machine tool. When a cutter has to be replaced, the tool drum spins to the correct position, and an automated tool changer (ATC) operates under part programme control to swap the tool in the spindle for the tool in the tool storage unit. The tool storage unit's capacity typically ranges from 16 to 80 cutting tools.

Work part placement that is automatic. Many horizontal and universal machining centres may position the work piece relative to the spindle. This is performed using a rotating table with the work portion fixed to it. The table may be positioned at any angle around a vertical axis, allowing the cutting tool to reach almost the full surface of the item in a single setup.

Pallet changer that operates automatically. An automated pallet changer is often used in machining centres to provide two (or more) different pallets to the cutting tool. While one pallet is in place at the machine for machining, the second pallet is at a secure area away from the spindle. While the current work piece is being machined, the operator may unload the completed component from the previous cycle and then fixture the raw work part for the next cycle in this secure place.

Application Examples: Automation Storage/Retrieval System

An automated storage/retrieval system (AS/RS) is a storage system that conducts storage and retrieval tasks with speed and precision while being automated to a certain degree. Various degrees of automation may be used. At one end of the spectrum, the AS/RS is totally automated. This may comprise a whole range of completely automated, computer-controlled storage tasks linked with overall production or warehouse operations. At the opposite end of the spectrum, human personnel may be used to manage equipment and execute storage/retrieval activities. The

AS/RS system is custom-designed to match the needs of the plant in which it is installed, using modular components available from AS/RS manufacturers.

The AS/fundamental RS's equipment includes a rack structure for storing loads as well as a storage/retrieval (S/R) mechanism in three dimensions of motion (x, y, z). Furthermore, the AS/RS maintains one or more storage aisles served by the S/R mechanism. The S/R mechanism is used to send goods to and retrieve materials from storage racks. Each aisle features an input/output station where storage deliveries are entered or exited the system; these stations are known as pickup-and-deposit (P&D) stations. P&D stations may be operated manually or coupled to an automated transport system, such as a belt or an AGVS (automated guided vehicle system).

Application Examples: Automation Machining with Robot

If we can respond "yes" to all of these questions, the system is flexible, with the first and second most critical criterion for flexibility. Numbers 3 and 4 are softer criteria that may be used at different levels. The automated manufacturing cell with two machine tools and a robot is considered flexible if it can:

Machine different part mixes taken from the carousel by the robot; Allows for changes in the production schedule without affecting the operation of the robotic arm and the two machine tools; Can continue to operate even if one machine tool fails; and Can accommodate new part designs if the CNC machines programmed to do so is written.

Application Examples: Automation Loading/ Unloading System

A machine cell consists of one machine (often a CNC machining centre) that is linked to a parts storage system and may load and unload parts to and from the storage system. It may run in batch mode, flexible mode, or a mix of the two. When in batch mode, the system processes parts of a single style in specific lot sizes before physical and programmed changeover to the next batch specifications; when in flexible mode, the system meets three of the four flexibility tests the exception being error recovery, because if the CNC machine centre fails, the system stops.

Safety Monitoring

One of the primary motivations for automating the manufacturing process is to remove workers from potentially dangerous working conditions. An automated system is often implemented to undertake a potentially hazardous job that would otherwise be performed by human personnel. Even with automated systems, employees are still required to service the system on a regular basis, if not full-time.As a result, it is critical that the automated system be built to function securely when employees are present. Furthermore, it is critical that the automated system carry out its procedure in a non-destructive manner. Thus, there are two reasons for giving a safety monitoring capability to an automated system: (1) to safeguard human employees in the system's area, and (2) to protect the system's connected equipment.

Safety monitoring entails more than the traditional safety precautions used in a manufacturing operation, such as protective shields surrounding the process or the types of manual devices that human employees may use, such as emergency stop buttons. In an automated system, safety monitoring entails using sensors to track the system's functioning and flag circumstances and occurrences that are dangerous or potentially harmful. The safety monitoring system is designed to react appropriately to dangerous circumstances. One or more of the following reactions to different threats are possible:

Full shutdown of the automated system; raising an alert; decreasing the process's running speed; and implementing remedial procedures to recover from the safety violation. This is the most complex answer, implying an intelligent computer executing some advanced plan. This kind of reaction, known as error detection and recovery, is applicable to a wide range of potential accidents, not only safety concerns.Sensors for safety monitoring vary from basic devices to very complex systems.

The following is a list of potential sensors and their uses for safety monitoring:

Limit switches are used to detect the appropriate location of a component in a work holding device, allowing the processing cycle to begin.

Photoelectric sensors that are activated when a light beam is interrupted; this might be used to signal that a component is in the appropriate position or to detect the presence of a human intruder into the work cell.Temperature sensors that signal when a metal work component is hot enough to begin a hot forging process. If the work piece is not appropriately heated, the ductility of the metal may be insufficient, and the forging dies may be damaged throughout the process.

1. To identify fire dangers, use heat or smoke detectors.
2. Floor pads with pressure sensors to detect human intrusions inside the work cell
3. Machine vision systems are used to monitor the automated system and its surroundings.

It should be noted that the capacity of a particular safety monitoring system to react to dangerous situations is limited by the system designer's expected abnormalities. If the designer did not foresee a certain danger and hence did not equip the system with the sensing capabilities to identify that hazard, the safety monitoring system will be unable to notice the event if and when it happens.

Maintenance and Repair Diagnostics

The difficulty of maintaining and repairing modern automated manufacturing systems is growing more complicated and sophisticated. Maintenance and repair diagnostics refers to an automated system's ability to aid in the identification of the cause of possible or present system faults and breakdowns. A contemporary maintenance and repair diagnostics subsystem operates in three modes.

1. Monitoring of status. During normal operation, the diagnostic subsystem monitors and records the status of key sensors and system parameters in the status, monitoring mode. The diagnostics subsystem may show any of these numbers and offer an analysis of the present system condition, perhaps warning of an impending breakdown, upon request.

2. Failure analysis. When a malfunction or failure occurs, the failure diagnostics mode is activated. Its objective is to interpret the present values of the monitored variables and to examine the recorded values before the failure in order to determine the reason of the failure.

3. Repair technique recommendation. In the third mode of operation, the subsystem suggests to the repair team the procedures that need be done to make repairs. Methods for creating suggestions may include the use of expert systems, which pool the aggregate opinions of numerous repair professionals and merge them into a computer programme that employs artificial intelligence methods.

In machine diagnostics, status monitoring performs two crucial functions: (1) giving information for diagnosing a present problem and (2) providing data to forecast a future malfunction or failure. First, when equipment fails, it is sometimes difficult for the repair team to understand the cause of the problem and what procedures should be done to make repairs. It is often beneficial to recreate the circumstances that led up to the failure.The computer is configured to monitor and record the variables and to derive logical conclusions about the cause of the issue based on their values. This diagnostic assists repair professionals in making the required repairs and replacing the essential components. This is particularly useful in electronic repairs, where it is often impossible to establish which components have failed only on visual examination. The second purpose of status monitoring is to detect indicators of approaching failure so that the afflicted components may be replaced before the system fails. These component replacements may be performed during the night shift or at other times when the process is not in use, ensuring that the system continues to function normally.

Error Detection and Recovery

There are hardware failures and unanticipated occurrences that occur during the functioning of any automated system. These occurrences may cause expensive delays and loss of productivity until the situation is resolved and normal functioning is resumed. Traditionally, human employees have rectified equipment problems, maybe with the assistance of a maintenance and repairs diagnostics subroutine. With the rising use of computer control for industrial processes, there is a tendency toward employing the control computer not only to identify problems but also to automatically perform the remedial action required to return the system to normal functioning. When the computer performs these operations, the phrase error detection and correction is employed.

Detection of errors

The phrase error detection and recovery refers to two steps:

Error detection and Error recovery. The mistake detection stage makes advantage of the automated system's various features.

Sensor systems must recognised when a deviation or malfunction has occurred, appropriately interpret the sensor signals, and categories the problem. The classifications of the probable mistakes that might occur during system operation must be the starting point for the design of the error detection subsystem. Manufacturing process faults are often application specific. They must be predicted in order to pick sensors capable of detecting them.

When assessing a specific industrial activity, probable mistakes may be divided into three categories:

1. Random errors
2. Systematic errors
3. Aberrations

Random mistakes arise as a consequence of the process's natural stochastic character. When the process is under statistical control, these mistakes arise. Even when the manufacturing process is statistically controlled, large fluctuations in component dimensions might create issues in downstream activities. Corrective action may be made in following operations by identifying these deviations on a part-by-part basis. Systematic mistakes are ones that can be traced back to a specific source, such as a modification in raw material qualities or a change in an equipment setting. These flaws frequently lead the product to diverge from requirements, making it unsatisfactory in terms of quality. Finally, the third form of error, aberrations, is caused by either equipment failure or human error. Equipment failures include mechanical shear pin fracture, hydraulic line bursts, pressure vessel rupture, and unexpected failure of a cutting tool. Human errors include faults in the control software, poor fixture setups, and the replacement of the incorrect raw materials.

The following are the two primary design issues in error detection: (1) to foresee all conceivable faults in a particular process, and (2) to design the proper sensor systems and accompanying interpretative code so that the system can recognise each error. To solve the first challenge, a systematic examination of the possibilities under each of the three mistake classes is required. If the issue was not predicted, the error detection subsystem will be unable to detect and identify it.

CHAPTER 3

Mechanical System

Mr. Robin Khandelwal, Assistant Professor,
Department of Mechanical Engineering, School of Engineering & Technology,
Jaipur National University, Jaipur, India
Email Id- robinkh16@jnujaipur.ac.in

Elementary Mechanical Concepts

A mechanism is utilised in a machine to generate mechanical change. Any of the following transformations might occur.

1. It can convert one speed to another.
2. It has the ability to change one force into another
3. It has the ability to convert one torque to another.
4. It has the potential to transform force into torque.
5. It can convert one oscillatory position to another
6. It can convert rotational motion to liner motion
7. It has the ability to transform linear motion into rotational motion.

When the crank is cranked, the angular motion of the piston is changed into linear motion, and the input torque is transferred into force on the piston. When the piston is pushed to expand, the linear motion becomes circular motion and the force becomes torque. The piston is a sliding joint, which is known as PRISMATIC in various technical domains like as robotics. The pin joints enable one component to rotate relative to another. In other fields of engineering, they are known as revolute joints.

The input is coupled to a constant-speed motor. This causes the rocking arm to move back and forth, as does the head (which holds the cutting tool). The action of the head may be set to travel forward at a fairly consistent cutting speed depending on the lengths of the individual sections, but the return stroke is rapid. It is important to note that the pin & slider must be allowed to move in the slot or else the mechanism may jam. Because of the sliding connection, this poses issues with the solution.The essential point is that the motion generated is not simple harmonic motion, and the different elements of the mechanism have displacement, velocity, and acceleration at all times. Acceleration causes inertia forces, which increase stress to the components in addition to the stress caused by power transfer. The acceleration of a piston inside of an internal combustion engine, for example, may be considerable, and the connecting rod is exposed to significant strains as a consequence of inertia as well as power transfer.

Mechanisms and Machines:

Machines are devices that change, transfer, and direct forces to achieve a specified goal. A chain saw is a well-known machine that applies forces to the chain in order to cut wood. A mechanism is the mechanical component of a machine that transfers motion and forces from a power source to an output. It is a machine's heart. The mechanism for the chain saw transfers power from a tiny motor to the cutting edge of the chain. Although the whole device may be labelled a machine, the mechanism consists of the sections that accept power from the cylinders and drive the platform's rising and lowering.

A mechanism is made up of stiff pieces that are organised and linked in such a way that they generate the required motion of the machine. The gear in Figure 3.4's function is to elevate the platform and any things put on it. Synthesis is the process of creating a mechanism to meet a set of machine performance criteria. The analysis assures that the mechanism will move in a way that meets the criteria. Figure 3.1 represents the mechanisms and machines

Figure 3.1 represents the mechanisms and machines

Mechanisms are made up of interconnected pieces that transmit motion and force from a power source to an output. A linkage is a device that connects rigid pieces to produce a chain. Because it serves as the frame of reference for all other components' movements, one portion is known as the frame. The frame is generally a non-moving component. Two planar linkages are set to work out of phase in this machine to replicate walking action, including arm movement.The base is termed the frame since it lies on the ground and stays motionless throughout operation. The constituent components of the system are referred to as links. They are stiff bodies that are linked with other linkages to convey motion and forces. In theory, a genuine steel bar does not change form while in motion. Although a real rigid body does not exist, mechanism linkages are engineered to bend as little as possible and are therefore termed rigid. The footrests and arm grips on the exercise machine are made up of several links that are linked together with connecting connections to provide limited motion.

Elastic elements, such as springs, are not stiff and so do not qualify as connections. They have no influence on a mechanism's kinematics and are often overlooked during kinematic analysis. They do provide forces and should be included during the dynamic force analysis.A joint is a moveable connector that permits relative motion between links. The revolute and sliding joints are the two fundamental joints, often known as complete joints. The revolute joint is also known as a pin joint or a hinge joint. It enables for complete rotation between the two links it joins. The sliding joint is also known as a piston joint or a prismatic joint. It enables linear movement between the connections it connects. Kinematic examination of these two major joints they do provide forces and must be included during the dynamic force analysis.

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Mechanical systems may be represented as either lumped mass (rigid body) systems or distributed mass (continuous) systems. The latter are represented by partial differential equations, and the former by ordinary differential equations. Eventually, all systems are continuous in actuality, but in most circumstances, it is simpler and preferable to approximate those using lumped mass models and ordinary differential equations.Machines are mechanical machines that perform tasks. A method is a machine's heart. The mechanical element of the machine is responsible for transmitting motion & forces from a power source to an output. A mechanism is a preset system of rigid parts (linkages) constructed and linked to convey motion. The mechanism is made up of linkages and joints.

Translation or Linear Motion

If a body's velocity and acceleration are both 0, the body is said to be static. Forces acting on the body may create motion. The body will not accelerate if the applied forces are equal and cancel each other out. If the forces are out of balance, the body will accelerate. The body will only translate if all forces act via the centre of mass. Rotation is also caused by forces that do not operate via the centre of mass.

This chapter will exclusively discuss translational systems. Simply put, velocity is the first derivative of position and acceleration is the first derivative of acceleration. In the wrong manner, acceleration may be integrated to obtain velocity, and velocity can be integrated to get position. As a result, if we know a body's acceleration, we can calculate its velocity and location. Finally, when a force is applied to a mass, the acceleration is calculated by dividing the net force by the mass (Figure 3.2).

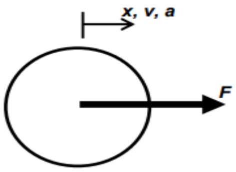

Figure 3.2 Represent Translation Or Linear Motion

The system's beginning circumstances are provided (and are normally required to solve this type of problem). These are then utilised to determine the condition of the system after some time has passed. To begin, integrate the acceleration and use the starting velocity value as the integration constant.

As a result, the velocity will be equal to the original velocity at t = 0. This is then combined once again to produce the object's location. As previously stated, the beginning location is utilised to calculate the integration constant. That equation is then used to compute the location after a certain amount of time has passed. It is important to note that the units are utilised throughout the computations. This is excellent engineering practice for every engineer.

Translation is described as a motion that occurs along a straight or angled route. Acceleration, velocity, plus displacement are the variables used to define translational motion. According to Newton's equation of motion, the algebraic total of external forces acting on a rigid body in a given direction equals the product of the body's mass and acceleration in the same direction. The law may be stated as follows:

Mechanical Work and Power

One method for reliably partitioning and connecting subsystem models is to use power and energy variables to measure system interaction for a mechanical system (a). In this diagram, one port has power flow supplied by the product of force and velocity, F.V, while another has power given by the product of torque and angular velocity, summarises these power conjugate variables (i.e., those whose product gives power) as well as those that would be employed in the electrical and hydraulic energy domains. Other energy domains of interest have similar effort (E) and flow (f) characteristics (e.g., thermal, magnetic, chemical). This foundation ensures energetically accurate models and a consistent manner to link system constituents.

Energy continuity is used to categorise and characterise energetic systems while modelling them.

Paynter's demonstrates how the energy formula, in conjunction with a well specified port idea, serves as the foundation for a generalised modelling framework that finally leads to a bond graph method.

Paynter's reticulated energy continuity equation,

$$-\sum_{i=1}^{l} P_i = \sum_{j=1}^{m} \frac{dE_j}{dt} + \sum_{k=1}^{n} (P_d)_k$$

Identifies the unique power flows, the m separate energy storage, and the n distinct energy dissipaters, in a clear manner. From this point, modelling attempts to improve the descriptions. In a basic mass-spring-damper system, for example, the mass and spring store electricity, a damper releases energy, and

These components' connectivity would explain how electricity travels between them. Some of the specifics for carrying out these modelling stages are covered in subsequent sections. One approach is to identify and classify system element types based on the reticulated energy continuity Eq. Consider a system consisting solely of rigid bodies as energy stores (specifically, kinetic energy) for which = 0 (we can add these later), and in general, there can be ports that can bring energy into this purely (kinetic) energy-storing system that has m distinct ways to put energy into rigid bodies. This is a broad idea that is congruent with many different approaches of modelling physical systems. This, however, is the basis. This gives a generic method for modelling and integrating many sorts of energy systems. The diagram of a permanent-magnet dc (PMDC) motor i shows how power variables are utilised to locate connectivity sites. This example also highlights the need of modelling processes that may describe the flow of energy between two sections of a system, such as the electromechanical (EM) contact. This model depicts a simplified connection between electrical power flow, v. I and mechanical power flow, T., which serves as the foundation for a motor model. Furthermore, this is an ideal power-saving relationship in which just the power flows in the energy continuity equation are present; there are no storage or dissipators.

Mechanical effort and power are critical components in the design of electromechanical systems. The dynamics of the system are controlled by stored energy in the form of kinetic and potential energy, but dissipative energy is often wasted in the form of heat, which must be tightly controlled.

The coordinate s measured along its route from a reference point O specifies the location of a particle P with mass m in curvilinear motion

Motion Conversion

Mechanisms such as levers, gears, linkages, cams, chains, and belts are often used in mechanical systems.

They all perform the same fundamental function: they convert the motion of an input item into the kinematically similar motion of an output member.In many circumstances, the real system may be reduced to a fictional yet dynamically comparable one.

This is performed by "referring" all of the system's parts (masses, springs, dampers, and driving inputs) to a single place, which might be the input, the output, or a designated interior point. Instead of writing numerous equations for the real system, a single equation may be written for this analogous system. This procedure is not required, but it typically speeds up work and minimises mistakes.

The fundamental kinematic component is the link. A stiff moving portion is a link. A linkage is a collection of links connected by joints. A joint is a flexible connector. There are two kinds of joints (Figure 3.4).

1. The pivot relies on rotation.
2. The translation of the slide (piston)

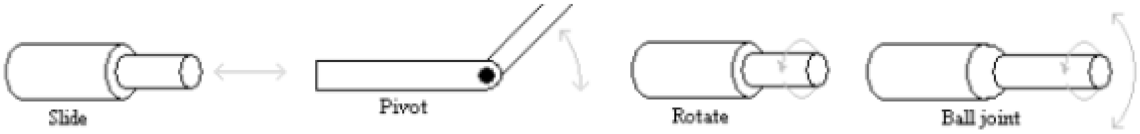

Figure 3.4: Represent the process of joints

A kinematic model is constructed using a kinematic chain and the geometry that surrounds it.

1. Rigid geometry cannot be deformed.
2. Deformable geometry is referred to as the skin or envelope.

A simple mechanism is used to modify the magnitude and/or direction of applied force.

1. Lever
2. Plywood
3. Angled plane
4. Wedge
5. Screw

A machine (mechanism) is a connected (usually rigid) bodily system that alters, transfers, and directs force in a predetermined way.

The mobility of machine components distinguishes them.Straight motion is followed by translational motion, which is followed by circular motion, which is followed by rotary motion.Movement may be both omnidirectional and continuous.Oscillatory and reciprocal relationships

Linkages

A linkage is a mechanism that connects two or more forces or causes two or more things to move at the same time. Many various fasteners, including as pins, end-threaded bolts with nuts, and loosely fitting rivets, are used to join links while allowing them to move freely. There are two types of connections: basic planar linkages and more complicated specialised linkages; both may execute jobs like defining straight lines or curves and executing movements at different rates. The names of the connection mechanisms shown here are commonly used, but not uniformly approved in all textbooks and references.

Linkages are categorized based on their major functions:

1. Route generation: the path of a tracer point
2. Function generation: the relative motion of the connections attached to the frame
3. Motion generation: the coupler link's motion

Simple Planar Connections

Four distinct simple planar links are indicated by function Reverse-motion linkage allows objects or forces to move in opposite directions by employing the input link as a lever. When the stationary pivot is equidistant from the moving pivots, output link movement equals input link movement, but in the opposite direction. Output link movement will not match input link movement if the fixed pivot is not centered. The linkage may be constructed to provide various mechanical benefits by adjusting the location of the fixed pivot. This connection may also be turned 360 degrees.

Push-pull linkage may cause items or forces to move in the same direction as the input link; the output link travels in the same position as the input link. It is technically a four-bar connection that can be rotated around 360° without compromising its function. Figure 3.5: Represents Translation or Linear Motion

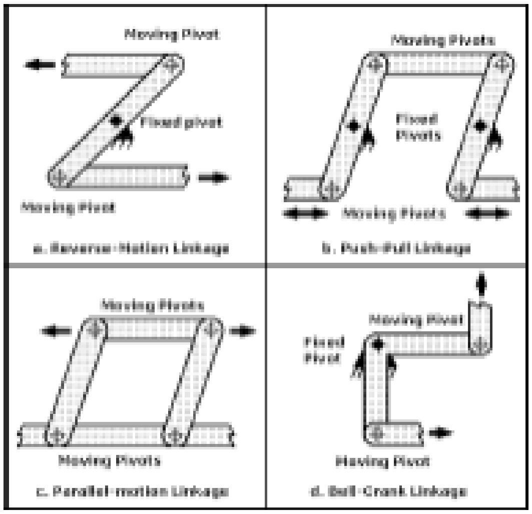

Figure 3.5: Represents Translation or Linear Motion

Parallel-motion coupling allows objects or forces to move in the same direction but at different speeds. For this connection to operate properly, the pivots on the opposing links in the parallelogram must be equidistant. This linkage, which is technically classified as a four-bar linkage, may also be turned around 360° without modifying its function. Pantographs use parallel-motion linkage to provide electricity for electric trains from overhead wires. This connection is also used in drawing pantographs, which allow original drawings to be physically duplicated without tracing or photocopying; in its most basic version, it may also maintain tool trays horizontal when the toolbox lids are opened.

The bell-crank connection, may shift the orientation of objects or forces by 90 degrees. Before electric clappers, this connection rang doorbells. This device has recently been developed for bicycle brakes. To construct tongs, two bell cranks bent 90° in opposing directions were pinned together. Squeezing the two handlebar levers connected to the input ends of each crank causes the output ends to move in unison. The bicycle is stopped when the rubber plates on the output ends of each crank push against the wheel rim. Link motion will be equal if the pins that create a fixed pivot are at the cranks' midpoints. Mechanical advantage may be realised if such distances fluctuate.

Specialized Linkages

Many specific operations are available, such as drawing or tracing straight lines, moving objects or tools quicker in a retraction strokes than in an extension stroke, and converting rotational motion to linear motion and vice versa. Four-bar links are the most basic specialised connectors. These connections are adaptable enough to be used in a wide range of applications. Four-bar connections feature one fixed link and four pin joints or pivots in addition to three moving links. A good mechanism must contain at least four links, however three-link closed-loop assemblies are valuable structural components. Both the parallel-motion and push-pull links stated previously are technically machines since each linkage with at least one fixed link is a mechanism (Figure 3.6).

1. Four-bar connections have three rigid movable links, two of which are hinged to fixed bases that create a frame. By spinning a crank, link mechanisms may provide rotational, oscillating, or reciprocating motion.
2. Linkages may be used to transform rotation into another kind of continuous rotation with a fixed or variable angular velocity ratio.
3. With a constant or variable velocity ratio, constant rotation into oscillation or continuous oscillation into rotation
4. With a constant or variable velocity ratio, one type of oscillation into the next form of oscillation, or one type of reciprocation into another form of reciprocation.

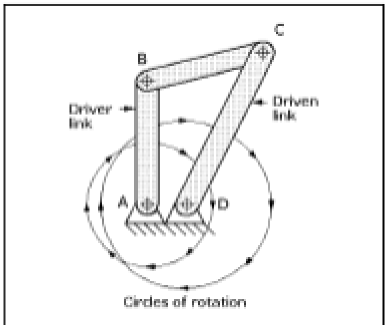

Figure 3.6: Represent Specialized Linkages

Four-bar connections may conduct inversions or full rotations around fixed pivot points in four distinct ways. One pivoting link is designated as the input or driver member, while the other is designated as the output or driving member. The remaining moving connection is referred to as a connecting link. The foundation link is a fixed link that is hinged at both ends by pins or pivots.

They are composed of the connections AB, BC, CD, and AD. The positions of the shortest links with regard to the foundation link establish the shapes of the three inversions. The roles of the driver or driven links are determined by their capacity to rotate completely around their pivots.The first inversion is shown via the drag-link mechanism the foundation link is the shortest connection AD between the two fixed pivots, and both driver link AB and driven link CD may complete full rotations.

The second inversion is shown by the crank-rocker mechanism The foundation link, AD, is near to the shortest link, AB. Link AB can complete a full 360° rotation, but link CD can only oscillate and define an arc.

The third inversion is shown by a double-rocker mechanism

The foundation link is AD, and it is located opposite the shortest link BC. Although link BC may rotate 360 degrees, pivoting links AB и CD can only oscillate and define arcs.

The fourth inversion is a crank-rocker mechanism that works similarly to the system except that the longest link, CD, is the foundation link. Because these two methods are so similar, the fourth inversion is not shown here. A drag-link mechanism may generate either a non-uniform or uniform output from a uniform input rotation rate.

Straight-Line Generators

A short vertical straight line may be described using Watt's straight-line generator. Links of equal length AB and CD are hinged at A and D, respectively. Over the whole mechanism excursion, the midpoint E of connecting link BC follows a figure eight pattern, but a straight line is traced in part of the excursion because point E diverges to the left at the top of the stroke and to the right at the bottom of the stroke. In about 1769, Scottish instrument maker James Watt utilised this linkage in a steam-driven beam pump, and it was a significant mechanism in early steam-powered devices.

The straight-line generator by Scott Russell, may also define a straight line. At point A, link AB is hinged and pinned to link CD at point B. Link CD is hinged to a roller at point C, limiting its movement to horizontal oscillations.This design restricts point D to a vertical straight line motion. Points A and C are both in the same horizontal plane. This connection is valid if the length of link AB is about 40% of the length of CD and the distance between points D and B is approximately 60% of the length of CD.

Peaucellier's straight-line linkage can define more exact straight lines across its range than the Watt's or Scott Russell links. To make this connection operate properly, the length of link BC must meet the distance between points A and B determined by the spacing of the fixed pivots; in this example, link BC is 15 units long, while links CD, DF, FE, and EC are all 20 units long. Point F may define arcs of arbitrary radius as connections AD and AE are shifted. However, by specifying link lengths for AD and AE, the connection may be limited to tracing straight lines (infinite radiuses). They are 45 units long in this figure. Captain Charles-Nicolas Peaucellier, a French engineer, devised this connection in 1873.

The straight-line generator of Tchebicheff,may also describe a horizontal line. As connections AB and DC are relocated to the left and right of centre, link CB with E as its midpoint follows a horizontal straight line for the most of its transit. The length of the foundation link AD must be double the length of link CB to depict this straight line. CB is 10 units long, AD is 20 units long, and both AB and DC are 25 units long in order for this mechanism to function as a straight-line generator. With these dimensions, connector CB will adopt a vertical posture when it reaches the extremities of its journey excursion to the right and left. PafnutyTchebicheff or Chebyshev, a nineteenth-century Russian mathematician, established this relationship.

Rotary/Linear Linkages

Depending on the application, a slider-crank mechanism (or a plain crank) transforms rotational to linear motion and vice versa. Because point C is hinged to a roller, which confines it to linear motion, link AB is free to revolve 360° around the hinge, while link BC oscillates back and forth. The driver might be either the slider or the rotating link AB. This mechanism is more recognised as the piston, connecting rod, and crankshaft of an internal-combustion engine. The piston is represented by the slider C, the connecting rod by link BC, and the crankshaft by link AB. The piston in a four-stroke cycle is dragged down the stroke.

The piston is propelled down the cylinder by the crankshaft, admitting the air-fuel mixture; during the compression stroke, the piston is driven up the cylinder by the crankshaft, compressing the air-fuel combination. However, during the combustion stroke, when the engine drives the crankshaft, the roles reverse. Finally, the roles reverse during the exhaust stroke, when the crankshaft forces the piston rod to discharge the exhaust gases.

Operates similarly to the basic crank mechanism, except that its linear output motion is sinusoidal. As the driver, wheel a, spins, the pin or roller bearing at its perimeter applies torque inside the closed yoke B, causing the associated sliding bar to reciprocate and trace a sinusoidal pattern. The sliding bar with the roller at 270°, whereas Part B depicts the sliding bar with the roller at 0°. The rotary-to-linear mechanism transforms a uniform rotational motion into an intermittent due to the supply. The three input rotor teeth make contact with the steps in the frame or yoke, exerting torque three times every rotation and moving the yoke with connected bar.The yoke's full linear movement is completed in 30° of rotor rotation, followed by a 30° wait before returning the yoke. The reciprocating cycle is repeated three times for every rotation of the input. A step function produces the output.

Couplers

The word coupling refers to a mechanism that connects two shafts at their ends in order to convey electricity. Couplings are classified into two types: stiff and flexible. A mobile robot designer's career will need the coupling of two shafts at some point.Fortunately, there are several available on the market couplers to choose from, each with its own set of advantages and disadvantages. Couplers are classified into two types: solid and flexible. Solid couplers must be strong enough to connect the ends of the shafts as if they were one shaft. Flexible couplers allow for misalignment and are used when two shafts are already operating in their respective bearings but are slightly misaligned. The only additional problem is that the shafts may have varied diameters or end features such as splined, keyed, hex, square, or smooth. The coupler merely has two ends that take the shafts that it is connecting.

Solid couplers are very basic devices. They grip each shaft tightly enough to transfer torque from one shaft to the other. The shaft styles at either end of the coupler might be same or dissimilar. For shaped shafts, the coupler just has to have the same form and size as the shaft, and bolts or another clamping device must be used to secure the coupler to the shaft. For smooth shafts, the coupler must be tight enough to the shaft to impart torque by friction with the shaft surface. This technique demands very high clamping pressures, yet it is popular since it eliminates the need for shaft cutting.When connecting a creator god to a piece of driven equipment, a coupling is employed. A coupling's primary function is to transfer rotational motion and torque from one piece of equipment to another. Couplings may also accommodate misalignment between shafts, compensate for axial shaft movement, and aid in the isolation of vibration, heat, and electrical eddy currents from one shaft to another.

Stiff Couplings Rigid couplings are used to connect equipment when perfect alignment of shafts is necessary. They are also utilised in drive trains where one machine's rotor is used to support and position the other rotor. Because a stiff coupling cannot allow shaft misalignment, careful alignment of equipment is required when one is employed.Rigid couplings are classified into two categories. One form is made up of two flanged stiff pieces, each of which is installed on one of the linked shafts A number of bolt holes are provided on the flanges to connect the two half-couplings. It is feasible to transfer the torque load totally by friction from one flange to the other by properly designing and installing the coupling, ensuring that the flange bolts do not incur shearing stress. This configuration is particularly beneficial for drive systems with torque oscillations because it minimizes shearing stress on the flange bolts.

The split rigid is a form of rigid coupling that is divided along its horizontal midline. A number of bolts distributed axially along the connection holds the two sections together. The rigid coupling and machine shafts may be provided with standard keyways, which are then fitted with keys to transfer the torque load, or in certain circumstances, the frictional clamping force may be sufficient to allow torque transmission by friction between shaft and rigid coupling. This form of coupling is often used to join line shafting components in a drive train.

Applications

Vertical drives, in which the prime mover (often an electric motor) is located above the pump, are a popular use for stiff couplings in the pump sector. In such instances, both machines may use a shared thrust bearing, which is often found in the motor. Any down force from the pump to that same motor must be transmitted through the coupling flange bolts. In instances where the pump's thrust is directed toward the motor, shoulders on the shafts are often used to convey the axial force.

Many pump drive systems need a stiff coupling with axial adjustment to compensate for wear in the suction pipe or impellers. This is accomplished via the use of an adjustable stiff coupler. The threaded adjustment ring, which is coupled to a matching threaded prolongation of the pump shaft, allows the impeller or impellers to be vertically positioned. The hub, which is placed on the pump shaft, has a clearance light and toothed key that allows the hub to glide relative to the shaft.Because no load can be conveyed through interference fit, the load capacity of this form of coupling is normally limited by the tension on the pump shaft key.

A word of caution should be issued about the usage of stiff couplings since there is no flexibility in the connection to tolerate shaft misalignment, proper alignment of machine bearings is very important. Second, precision in manufacturing is critical. To prevent the transmission of eccentric motion from one machine to the next, the coupling surfaces that interface between the driving and driven shafts must be constructed with high degrees of concentricity and squareness.

Adaptive Couplings Flexible couplings fulfil the basic function of any coupling, which is to transfer driving torque between the prime mover and the driven machine. They also have a secondary purpose in that they tolerate inadvertent shaft misalignment. There are several designs for flexible couplings, which may be divided into two types: mechanically flexible and materially flexible.

Couplings that are mechanically flexible.

Mechanically flexible couplings compensate for misalignment between two linked shafts by clearances included into the coupling design.

The gear, or dental, coupling is the most common form of mechanically flexible coupling this coupling is made up of two pairs of clearance fit splines. The two machine shafts are fitted with hub members with external splines cut integrally on the hubs in the most usual design. A sleeve member with matching internal gear teeth connects the two hubs. Backlash is included into the spline connection on purpose, and it is this backlash that compensates for shaft misalignment. Sliding motion occurs in this sort of coupling, hence a supply of clean lubricant (grease or oil, depending on the design) is required to avoid rubbing surface wear.

Constantly lubricated couplings are utilised when operation cannot be halted to oil the couplings, as these are made up of an oil-tight enclosure fastened to the stationary component of either the driving or driven piece of equipment at one end. The enclosure's opposite end has a slip fit within a cover that is attached to the other piece of equipment.

To avoid lubricant loss at the slip joint, some type of packing is utilised. Oil is forced into the enclosure and impinges on the meshing gear teeth of the coupling, with the surplus collected at the enclosure's bottom and returned to the oil reservoir.The roller-chain flexible coupling is a second form of mechanically flexible coupling that is widely used, particularly in low-cost drive systems.This coupling consists of two sprocket-like components, one installed on each of the two machine shafts and joined by a roller chain annulus. The gap between the sprocket and the roller, as well as the crowning of the rollers in certain circumstances, give mechanical flexibility for misalignment.

This kind of connection is often used in low-speed equipment.

Materially Versatile Couplings

These couplings depend on the coupling piece bending to adjust for shaft misalignment. The flexing element may be made of any appropriate material (metal, elastomer, or plastic) that has enough fatigue resistance to give an acceptable life. Some materials, like steel, have a fatigue limit. A coupling constructed of such material must be operated under load and misalignment circumstances that ensure the stress created in the coupling element stays within that limit. Other materials, such as elastomers, lack a well-defined fatigue limit. In certain circumstances, however, excessive heat generated in the material as the connection bends might cause failure.

The metal-disk coupling is one sort of material-flexible coupling. This coupling is made up of two groups of thin sheet-metal discs that are attached to the driving and driven hub elements. Each disc set is made up of a number of thin laminations that are individually flexible and use this flexibility to correct for shaft misalignment. These discs may be stacked as needed to provide the requisite torque transfer capabilities. This sort of coupling does not need lubrication; nonetheless, alignment of the equipment must be kept within acceptable limits so as not to exceed the material's fatigue limit.

The flexible diaphragm coupling is another example of an all-metal material-flexible coupling. This coupling functions similarly to the metal-disk coupling in that the disc bends to compensate for misalignment. The diaphragm type, on the other hand, is made up of a single element with a hyperbolic shape that is meant to provide homogeneous stress in the member from inner to outer diameter. Because the material is used more effectively, the weight is lowered, making this coupling suited for high-speed applications.Material-flexible couplings made of elastomer materials are various and come in a variety of designs. An elastomer is a substance with a high degree of elasticity and resilience that will return to its original shape after large-amplitude deformations. The pin-and-bushing coupling is an example of an elastomer coupling. One hub's flange is equipped with pins that extend axially toward the neighbouring shaft. The opposite flange is outfitted with rubber bushings with a metal sleeve in the middle. The pins are inserted into these sleeves and transmit torque via the bushings. Because the bushings are formed of a flexible material, they may tolerate little angularity or offset between the two flanges.

A second kind of elastomer coupling uses a sleeve-like element attached to a hub member on each shaft and transfers torque by shearing of the flexible element. The flexible element may be joined to the machine hubs in a variety of ways: chemically bonded, mechanically coupled by loose fitting splines), or clamped to the hubs and kept in place by friction. The elastomer sleeve flexes to allow misalignment between shafts.

A third kind of coupling uses an elastomer part that is compressed to transfer load from one shaft to the other. The elastomer material is freely inserted into cavities made by firmly attached parts on the two shafts when torsional damping is necessary, the elastomer material deflects to compensate for shaft misalignment.

The rubber jaw coupling is another form of elastomer coupling that is widely utilised on low-power drive systems. The "spider" element is at the centre of this coupling, with a number typically three of segments spreading radially from a central portion. Each hub, which is positioned on the driving and driven shafts, has a set of jaws that corresponds to the number of spiders on the flexible element. The spider fits between the two jaws, acting as a flexible "cushion" between them. This cushion transfers torque while adjusting for misalignment.

Spring-Grid Coupling

A commercially accessible flexible coupling combines the properties of mechanically flexible plus material-flexible couplings.This design has two hubs, one on each machine shaft. Each hub has a raised section with tooth-like grooves carved into it. Between the slots on the two hubs, a spring steel grid component is fitted or woven. To accommodate the shaft, the grid element may move into the slots misaligned, and flexes like a leaf spring to transfer torque from one machine to the next. Unlike other material-flexible couplings, this design needs frequent lubrication to avoid excessive grid member wear.

Applications

The best flexible coupling for a given application is determined by a variety of parameters, including power, rotational speed, and shaft separation, degree of misalignment, cost, and dependability. The designer's purpose when designing a system is to employ the least expensive coupling that will accomplish the task. In low-cost systems, cost may be the most significant factor, and the least price coupling that transfers the specified power and takes some minor misalignment is usually chosen, although at the expense of reliability and longevity. High-power, high-speed machinery, on the other hand, is often an essential piece of equipment for a power station, sewage plant, or other important operation, and in these circumstances, a coupling should be chosen that will not jeopardise the overall dependability of the system.

Low-power electric-motor-driven pumps (up to roughly 200 hp, 150 kW) may typically be satisfactorily linked by any of the couplings detailed below. Selection techniques vary by manufacturer, but in general, the following information is required: power rating, speed, projected misalignment, and pump type (reciprocating, vane, centrifugal, and so on).Pumps with similar power ratings are often powered by reciprocating engines (diesel, gasoline, natural gas). This is fairly frequent in isolated regions, such as pipeline pumping stations, where there is no access to electricity. Because this sort of prime mover generates pulsing power, a torsional vibration study of the drive system is often required to guarantee that the typical operating speed is far distant from a speed that may induce a torsional resonant vibration. The torsional stiffness of the connection must be determined for such an analysis.

By choosing the right coupling stiffness, it is often feasible to tailor the drive system to prevent running in a resonant situation. The selection data necessary for this sort of system are the same as those described above. To compensate for fatigue effects caused by torque changes, most coupling manufacturers will apply a greater service factor to an application employing a reciprocating primary mover. Furthermore, the distant position of several engine-driven pumps implies a unique necessity to assure the system's high level of dependability.

Chapter 4

The Concept of Power Transfer

Mr. Dipendra Kumar, Associate Professor,
Department of Mechanical Engineering, School of Engineering & Technology,
Jaipur National University, Jaipur, India
Email Id-dipendra1987@jnujaipur.ac.in

Power transmission techniques are often classified into five broad categories:

1. Belts (flat, round, V-belts, timing)
2. Chain (roller, ladder, timing)
3. Chain made of plastic and cable (bead, ladder, pinned)
4. Drive by friction
5. Gears

Some of them, such as V-belts and friction drives, may also be used to mechanically alter the output speed. This capacity is not normally needed in a mobile robot, and in some circumstances it might pose control issues because the computer has no direct control over the actual speed of the output shaft. Other power transfer devices, such as timing belts, plastic-and-cable chain, and all forms of steel chain, mechanically link the input to the output through teeth, exactly like gears. These devices are all synchronous in the sense that they maintain the input and output shafts in sync, although roller chain is typically excluded from this group since the rollers allow some relative motion between the chain and the sprocket. The word "synchronous" is normally given solely to toothed belts that fit considerably tighter on their sprockets than roller chain.

A mechanism to cope with misalignment and vibration should be included in power transfer systems that involve linking one shaft to another, such as motor-mounted gearboxes driving a separate output shaft. This is accomplished using shaft couplers and flexible drives. A technique of preventing against overloading and damaging the power transmission system should be incorporated in certain circumstances when shock loads may be high. Torque limiters and clutches are used to accomplish this. Let's take a look at each strategy individually. We'll start with systems that transmit power across non-inline shafts, then move on to couplers and torque limiters. Each part concludes with a brief assessment of how well the technique applies to mobile robots.

One of the most typical machine activities is the transmission of power from a source, such as an engine or motor, via a machine to an output actuation. The rotating motion of a shaft supported by bearings is an effective method of transferring power. To deliver torque and speed adjustments between shafts, gears, belt pulleys, or chain sprockets may be used. Most shafts are cylindrical (solid or hollow) and have graduated diameters with shoulders to allow for the placing and support of bearings, gears, and other components. The design of a power transmission system requires careful consideration of the design and selection of individual components (gears, bearings, shaft, etc.). However, as is often the case in design, these components are not self-contained. For example, in order to design the shaft for stress and deflection, the applied forces must be known. If the forces are communicated by gears, the gear specifications must be known in order to calculate the forces that will be sent to the shaft. However, stock gears have certain bore diameters that need knowledge of the required shaft diameter.

Electrical Analog

Analogous systems are systems that may be described by the same mathematical model yet vary physically. Thus, similar systems are characterised by the same set of differential or integral differential equations. For the following reasons, the idea of comparable systems is quite helpful in practice.

The answer to an equation that describes one physical system may be applied directly to equivalent systems in any other discipline.Because one type of system may be easier to deal with experimentally than another, instead of building and studying a mechanical system (or hydraulic system or pneumatic system), we can build and study its electrical analogue, because electrical or electronic systems are much easier to deal with experimentally in general.Analogies between mechanical and electrical systems are presented in this section. However, the notion of comparable systems may be applied to various types of systems, and analogies between mechanical, electrical, hydraulic, pneumatic, thermal, and other systems can be developed.

End Effectors

"A robotic end-effector is any device connected to the robot flange (wrist) that provides a purpose," according to ATI Industrial Automation.

An end effector is a device at the end of a robotic arm that is meant to interact with the surroundings. The precise nature of this gadget is determined by the robot's application. The end effector, according to the formal definition derived from serial robotic manipulators, is the final link (or end) of the robot.The tools are connected at this stage.

In a broader sense, an end effector is a component of a robot that interacts with its surroundings. This does not include a mobile robot's wheels or a humanoid robot's feet, which are not end effectors but are part of the robot's mobility.End effectors may be either a gripper or a tool. The gripper may be two, three, or even five fingers long.End effectors that may be employed as tools serve a variety of functions. For example, spot welding in an assembly, spray painting when consistency of paint is required, and other applications where the working circumstances are hazardous to humans. Surgical robots feature end effectors that are designed exclusively for doing surgery. Robotic grippers, robotic tool changers, robotic collision sensors, robotic rotary joints, robotic press tooling, compliance devices, robotic paint guns, robotic deburring tools, robotic arc welding guns, robotic transguns, and so on are examples.

Grippers serve as active linkages between the handling equipment and the work piece, or, more broadly, between the grasping organ (often the gripper fingers) and the thing to be obtained. Their functions vary depending with the application, but they include: temporary preservation of a defined position and orientation of the work item relative to the gripper and handling equipment.

Keeping static (weight), dynamic (motion, acceleration, or deceleration), or process-specific forces and moments.

Using wrist axes, determine and alter the position and orientation of the item with relation to the handling equipment.Technical activities carried out using or in combination with the gripper.Grippers are not just essential for industrial robots; they are also a ubiquitous component in automation. Grippers work with industrial robots (handling and manipulation of objects).

1. The use of hard automation (assembling, micro-assembling, machining, and packaging).
2. Special purpose machines and NC machines (tool change).
3. Hand-held manipulators (remote prehension, medical, aerospace, nautical)
4. In manufacturing technology, work piece turret devices are used.
5. Rope and chain lifting equipment (load-carrying equipment).
6. Robots that provide services (prehension tools potentially similar to prosthetic hands).

Mechanical Gripper

Grippers are among the functional components with the widest range of designs in robotics technology. This is because, whereas the robot is a versatile machine, the gripper performs a much more particular duty.

However, these functions are not confined to prehension, which is why the more general term "end-effector" is often used.The wide range of requirements, numerous work items, and the demand for well-suited and dependable solutions will drive additional advancements in gripper design in the future. Many experts believe that the gripper's capabilities are critical to the economic success of robotic assembly systems. Experience suggests that in the future, only adaptable designs for assembly equipment will be available to react to actual needs. As a result, grippers must become more adaptable. Assembly includes not only grasping and manipulating items, but also pressing, fitting, and connecting activities.

Many grippers are used for loading production lines, packing and storage, and item handling in laboratory test and inspection systems.Miniaturized grippers have recently been designed to handle fragile components in microtechnology. This has coincided with the advent of several unique prehension techniques. Grippers are increasingly being employed in non-industrial fields such as civil engineering, space exploration, handicraft, medical and pharmaceutical engineering. Hand-guided (tele-operation) or automated manipulators are typically employed as handling machines in these sectors. There are several application specialised grippers in addition to standard grippers, which include gripper jaws that are designed to fit the work piece profile. This explains why the vast majority of comparable patent literature is dedicated to prehension ideas of unusual design. End-effectors are often not within the delivery remit of robot manufacturers. They are chosen as tooling manufacturer accessories or particularly created for the intended function, depending on the individual needs.

Definitions and Conceptual Foundations: Grasping organs or tools are the end of the kinematic chain of an industrial robot's joint system and permit contact with the work environment.Although universal grippers with broad gripping ranges may be utilised for a variety of object forms, they must be customised to the unique work piece shape in many circumstances.

Grippers are handling mechanism subsystems that give momentary contact with the item to be gripped. When transporting and mating the item to the handling equipment, they secure its position and orientation. Prehension is produced by the use of force generating and shape matching parts. The word "gripper" is sometimes used in situations when there is no physical grabbing but rather holding of the item, such as in vacuum suction, where the retention force might operate on a point, line, or surface.

It is important to distinguish between gripping (prehension) and holding (retention) forces. While the grabbing force is delivered at the first point of prehension (during the grasping process), the holding force maintains the grip after that (until object release). In many circumstances, the retention force is less powerful than the prehension force. The energy necessary for the mechanical motion that results in a static prehension force determines the gripping force. However, the functional chain drive - kinematics - holding system is only provided for mechanical grippers.Such kinematics are not required for restrictive vacuum suction grippers.

There are certain terminologies that are often used in prehension technology. Grippers are made up of numerous modules and components. The most important terminology will be defined in the following sections, using a mechanical gripper as an example. A dictionary of further significant terminology used in gripper technology is provided below.

Gripper with a tight grip: A field-produced binding force is constrictive. This field might be air movement (vacuum suction), magnetism, or electrostatic charge displacement.

The basic jaw (universaljaw) is the moving element of an impactive gripper. The fundamental jaw, which is an essential component of gripper mechanics, is typically not interchangeable. However, depending on the situation, the basic jaws may be supplemented by extra fingers.

Grippers are end effectors that are utilised throughout the work cycle to grip and handle items. Typically, the items are workparts that are transported from one position in the cell to another. This category includes machine loading and unloading applications. Grippers are often custom made because to the wide range of component forms, sizes, and weights.

The following gripper types are utilised in industrial robot applications:

Mechanical grippers, which are made up of two or more fingers that may be activated by the robot controller to open and grab the work part; depicts a two-finger gripper.

1. Vacuum grippers, which employ suction cups to grasp flat things
2. Magnetic devices used to retain ferrous components
3. Sticky devices, which employ an adhesive substance to retain a flexible material, such as cloth; and basic mechanical devices, such as hooks and scoops.

Mechanical grippers are the most frequent form of gripper. Among the mechanical gripper technology improvements and advancements are:

Dual grippers, which comprise of two gripper devices in one end effector and are excellent for loading and unloading machines. With a single gripper, the robot must enter the manufacturing machine twice: once to discharge the completed item and again to put the next part into the machine. The robot takes up the next workpart with a dual gripper while the machine is still running.

When the machine finishes, the robot reaches inside the machine once to remove the completed component and load the next part. This cuts down on cycle time per component.

1. Replaceable fingers for use on a single gripper mechanism. Various fingers are fitted to the gripper to accept different pieces.
2. Sensory input in the fingers that allows the gripper to do things like (1) detect the existence of the workpart or (2) apply a defined limiting force to the workpart while grasping (for fragile workparts).
3. Multi-finger grippers with the general structure of a human hand.

4. Commercially available standard gripper products, minimising the requirement to custom-design a gripper for each individual robot application.

In situations where the robot must execute some processing operation on the work portion, tools are employed. As a result, the robot manipulates the tool in relation to a fixed or slowly moving item (for example, a work component or subassembly). Robot end effector tools include: spot welding gun, arc welding tool,spray painting gun, rotating axis for drilling, routing, grinding, and so on assembly tool (e.g., automated screwdriver), heating torch, water jet cutting tool.

The Grapping problem

Robotic gripping is a complicated subject.

1. High-level hand design (number of fingers, dynamical structure, etc.) and low-level hand design (mechanism design, motors, materials, etc.);
2. High-level hand control algorithms (find an appropriate posture for a given task) and low-level hand control algorithms (execute the desired posture); Sensor information (tactile, vision, range sensing, etc.); Any prior knowledge of object shape, semantics, and tasks (e.g., a cup is likely to be found on a table, should not be held upside-down, etc.);
3. Robotic Grasping vs. Human Grasping
4. Human performance serves as both a standard against which to compare and a functioning example from which to learn. However, it has been difficult to replicate:

Humans benefit from an unrivalled mix of visual and tactile perception; Humans constantly practise grabbing and manipulation, and the quantity of data they are exposed to dwarfs anything explored so far in robots;

Grasping Stability

Numerous research projects have focused on robotic grasping. Bicchi and Kumar have described this well. The basic purpose of gripper design is to achieve stable object grabbing. The most stable hold is to encircle the object's centre of gravity with the gripper jaws or finger. Taylor and Schwarz discovered six primary gripping patterns for human hands while researching robotic limbs. Figure 3.65 depicts six gripping forms: (1) spherical, (2) cylindrical, (3) hook, (4) lateral, (5) palmar, and (6) tip. Only the cylindrical, hook, and lateral grips are applicable to the traditional two-dimensional grippers described in the preceding sections. For plane motion grippers, the cylindrical and lateral grips are efficient for firmly grasping an item. Most end effectors/grippers have two-jaw systems that most nearly resemble the cylindrical grab. Kaneko also considers grab stability in articulating multi-fingered robots. Envelope or spherical grabbing is the most resilient since it contains the most touch sites for an item encompassed by articulating fingers.

Stability may be described similarly for plane-motion grippers that use a cylindrical kind of grab.

Stability rises when the item makes more points of contact with the gripper jaws and when the object's centre of gravity is closest to the centre of the grasp. If feasible, while employing a cylindrical grip, grab an item in a safe, non-slip way. When grabbing a cylindrical item with a flange, for example, the gripper's jaws should be just beneath the flange. This permits the flange to make contact with the top of the gripper jaws, eliminating the danger of slippage. A frictional grip must be employed if a vertical touch feature is not available.Figure 4.1 Represents grasping stability of material

(1) spherical (2) cylindrical (3) hook

(4) lateral (5) palmar (6) tip

Figure 4.1 Represents grasping stability of material

Friction and Grasping Forces

While a slip-proof grasp is preferable for end effectors, in the majority of circumstances, a frictional hold is all that is possible. When correctly engineered, frictional grip is quite effective.To avoid moments at the jaw surfaces, the centre of gravity for grabbed items and the end effector should be coincident in the Z-direction.The applied gripping frictional force on each jaw of a two-jaw gripper must be equal to or more than half the vertical weight and acceleration payload in order to properly grab an item. Divide the needed friction force by the static coefficient of friction to get the applied gripping normal force. Typically, a safety factor is used. Friction coefficients vary depending on the substance and surface geometry. Standard references may be used to obtain estimates. The static coefficient of friction on most surfaces is larger than 0.2. The static coefficient of friction for metal-to-metal interactions is substantially greater (e.g., 0.6 for aluminium to mild steel and 0.78 for mild steel to hard steel). In addition to the weight of an item, surface texture, stiffness, and possible damage must all be addressed when selecting or designing an end effector or gripper. Pads are utilised on the jaws of the end effector to protect the object's surface. Pads may also be utilised to improve the coefficient of friction between gripper jaws and the item.

Types of Robotic Grippers

1. Impactive - jaws or claws that physically grab an item by direct impact.
2. Ingressive - pins, needles, or hackles that physically pierce the object's surface (used in textile, carbon, and glass fibre handling).
3. Astrictive - suction forces (including magnetic) applied to the surface of an item.
4. Contiguous - necessitating direct contact allowing adhesion to occur (such as glue, surface tension, or freezing)
5. Additional features like as light weight, quick response time, and fail-safety are necessary. There are several methods for grasping pieces.

Grippers are often categorised into five categories based on their performance principle:

1. Grippers mechanical
2. Vacuum cleaner grippers
3. Magnetic gadgets
4. Versatile pneumatic devices

Special-purpose tools and equipment

Mechanical grippers are the most widely utilised, accounting for 66% of the market. Mechanical grippers are classified according to the kind of closing action and the number of fingers.

i. A three-finger centric gripper is often used to grasp round and spherical items.

ii. Two finger parallel grippers grab with their fingers parallel to the gripping action, ensuring stable holding since only forces parallel to the gripping motion occur.

Vacuum grippers are utilised to handle damaged components since these gripper types may cause damage to the component surface. Vacuum grippers can also handle two-dimensional items like sheet metal. An air jet creates a vacuum in the suction cup that retains the pieces using the Venturi nozzle concept. The pieces are immediately freed when the air jet is switched off. Heavy pieces, such as shafts, are lifted using electromagnetic grippers rather than mechanical grippers. When employing these grippers, however, stable handling rather than precise placement is required. Grippers are used to handle tiny and light item. Alternative physical principles, such as electrostatic and adhesive grippers, are utilised since they do not apply pressure on the part, which may harm it. Micro assembly and electronics manufacture are two examples of applications.

Remote Centered Compliance Devices

The exact matching of closely spaced pieces often demands physical modification of the components in issue. Rather than increasing the precision of the robot, lowering the total accuracy requirement is typically a more cost-effective alternative. Examples of "design for automation" include countersunk holes and chamfered shaft tips. Another necessity is that the gripper be able to accommodate these intentionally induced tolerances. As a result, the adoption of regulated, or at least predictable, compliance may be quite beneficial.The Remote Centre Compliance, or RCC, is a passive compliance mechanism that was intentionally added to robots to reduce the need for substantial sensing and data processing.Nonetheless, the use of instrumentation, such as force sensing, may aid in error recovery systems for identifying mismatch and avoiding jamming.

Early solution developed at Draper Laboratories for an RCC with 6 degrees of freedom. It is appropriate for inserting small bolts (diameter 12 to 58 mm, length 25 to 100 mm) with mechanical play ranging from 12 to 24. It has been established that lateral inaccuracies of up to 2 mm and angle errors along the insertion axis of up to 2.5° may be compensated for. The RCC is built in such a manner that the position and angle variations have their own structural components. In the case of angle error correction, the assembly component rotates around a virtual centre of rotation placed in the middle of the workpiece's lower front surface. Angle and position error compensation are separated and operate independently of one another.

The concept and function of each component in a simple RCC, the compliance function is a conventional mechanical second order model consisting of a mass (gripper and workpiece), a spring force, and a damper.

The springs might be made of metal or elastomer. Rubber-metal composites with a defined axial hardness and shear resistance are used to create elastomer connections. Many RCC unit design examples have been published in the literature, and further information may be obtained elsewhere. The orientation movements imposed by the force field caused by contact between the robot and gripper flanges are directly connected to vertical forces.

Compensation actions are divided into two stages:

a. Compensation for position variation (s) during workpiece sliding along the chamfer of the workpiece receiver (single point contact).
b. Compensation of position variation (s) during part insertion into workpiece recipient (two point contact) by rotation around the ideal axis (8).

Identify Stepper Motors

Here's how to tell what you have if you're gazing at a bunch of stepper motors at a surplus store or have taken one out of secondhand equipment. First, count the amount of wires that are coming out.

Turn the shaft to ensure you have a stepper motor. You should be able to feel the little detents that indicate each step. After that, read the label on the side. If you're fortunate, the voltage and step size will be written on it, or it will be in a container with the voltage noted. Search for 12V steppers. If you have a huge 5V stepper, the currents will most likely be too large for simple control. Small 5V steppers work well. If you can't determine what the voltage is, you should probably search for another stepper.

Then, take out your digital ohmmeter and begin measuring resistance between the leads. Depending on whatever pair of leads you measure, you will obtain different results. The coil resistance is the lowest resistance you discover. To calculate the coil current, use I=V/R. If it is less than 250 mA, you are in excellent condition. Examine the output shaft to see whether it is something you can manage. Plain shafts with diameters of 0.125, 0.196, or 0.250 are used in steppers. Gears that press fit onto the shaft might be useful or removed.

Consider the stepper's size and weight. Large or heavy steppers will almost certainly demand more current than you can regulate. Many steppers are available in NEMA (National Electrical Manufacturers Association) standard sizes. NEMA 14, 15, or 16 are generally cubic in form, with a front mounting flange ranging from 1.38 to 1.65 inches on a size, and are ideal for robots. NEMA size 23 is cylindrical, having a square mounting flange that measures 2.22 inches on each side. Size 23 motors may demand too much current, therefore double-check the parameters. Stacked cans with a diamond-shaped mounting flange are another popular style. Smaller sizes are also advantageous in robotics.

Stepper motors vary from normal kinds in that they revolve continuously when a voltage is supplied to their terminals. When electrical command pulses are supplied to the shaft of a stepper motor in the correct order, it turns in discrete increments. Every rotation is split into stages, and the motor requires a voltage pulse for each step. The quantity of rotation is related to the number of pulses, and the rotational speed is proportional to the frequency of those pulses. A 1-degree-per-step motor requires 360 pulses to complete one rotation; the degrees per step are referred to as the resolution. When halted, a stepper motor keeps its place intrinsically. Stepper systems are most often employed in "open-loop" control systems, in which the controller merely informs the motor how many steps to take and how quickly to move, but has no means of knowing what position the motor is in.

Because the movement produced by each pulse is accurate and repeatable, stepper motors are ideal for load-positioning applications. A threaded nut and lead screw convert rotational motion to linear motion within a linear actuator. Stepper motors typically generate less than 1 horsepower and are hence often utilised in low-power position controllers. Permanent magnet, variable reluctance, and hybrid stepper motors are the three primary types. Both hybrid and PM stepping motors may be driven by the same controller circuit.

Principles of stepper motor operation

The capacity of the stepping motor to transform switched excitation variations into precisely defined increments of rotor position ('steps') is its important attribute. Stepping motors are classified as doubly salient machines because they contain magnetically permeable teeth on both the fixed (the'stator') and revolving parts (the 'rotor'). Magnetic flux travels via the little air space between the motor's two sections. The flux source may be a permanent magnet, a current-carrying winding, or a mix of the two, depending on the kind of motor.The impact, however, is the same: the teeth are subjected to equal and opposing pressures that seek to bring them closer and close the air space between them. As seen in the picture, the normal force (n) attempts to close the air gap, but for electric motors, the more important force component is the smaller tangential force (t), which attempts to shift the teeth sideways with regard to each other. The forces of attraction are reduced to zero as soon as the flux travelling between the teeth is withdrawn or redirected to other sets of teeth.

The parts that follow illustrate how this extremely basic theory is used in real stepping motor designs. Most stepping motors are variants on one of two fundamental types: variablereluctance or hybrid. The primary source of magnetic flux for the hybrid motor is a permanent magnet, while dc currents running in one or more windings guide the flux down various channels. The variable-reluctance stepping motor is available in two configurations, but the magnetic field is created simply by the winding currents in both.Magnetic flux is generated by current carrying windings placed on the stator teeth of a multi-stack variable-reluctance stepping motor. These windings are stimulated in a certain order to facilitate the alignment of succeeding sets of stator and rotor teeth, giving the motor its distinctive stepping movement.The multi-stack variable-reluctance stepping motor is separated into magnetically isolated parts ('stacks') along its axial length, each of which may be activated by a distinct winding ('phase'). A cutaway view of a motor with three stacks and three phases, however motors with up to seven stacks and phases have been constructed.

Each stack consists of a stator, which is kept in place by the motor's outer casing and contains the motor windings, and a spinning element. The rotor parts are manufactured as a single unit that is supported at either end of the machine by bearings and contains a projecting shaft for connecting external loads. Both the stator and the rotor are made of electrical steel, which is commonly laminated so that the magnetic fields inside the motor may vary quickly without creating substantial eddy current losses. Each stack's stator includes a number of poles, such as four, and a portion of the phase winding is twisted around each pole to generate a radial magnetic field in the pole. Adjacent poles are coiled in the opposite way, resulting in radial magnetic fields in opposing directions.

The whole magnetic circuit for each stack is from one stator pole, through the air gap into the rotor, through the rotor, across the air gap into a neighboring pole, through this pole, returning to the original pole via a closing piece, termed the 'back-iron'. This magnetic circuit is cycled for each pair of poles, resulting in four primary flux channels in the example. The normal forces of attraction between the four sets of stator and rotor teeth wipe each other out, leaving only the tangential forces to generate the resultant force between the rotor and stator.

When the phase winding is stimulated, the position of something like the rotor relative to the stator in a certain stack is precisely specified. The same number of teeth on the stator and rotor tend to align to lower the reluctance of the stack magnetic circuit, resulting in positional precision. When the stator and rotor teeth are perfectly aligned, the circuit reluctance is reduced and the magnetic flux in the stack is maximized.

The stepping motor inas eight stator/rotor teeth and is at the position that corresponds to stack A excitation. Looking along the axial length of the motor, the rotor teeth in each stack are aligned, but the stator teeth have varied relative orientations across stacks, thus the stator and rotor teeth are slightly misaligned in stacks B and C. Changing the excitation from stack A to stack B causes the stator and rotor teeth in stack B to align. This new alignment is made possible by a clockwise rotation of the rotor; the motor moves one'step' as a consequence of the excitation change. By deactivating stack B and activating stack C, another step in the clockwise direction may be formed. The procedure concludes with the excitation being returned to stack A. The stator and rotor teeth in stack A are perfectly aligned once again, except that the rotor has shifted one rotor tooth pitch, which is the angle described in Fig. 4.5b. As a result, three changes in excitation create a rotor movement of three steps or one rotor tooth pitch in this three-stack motor. Repeating the excitation sequence: A, B, C, A, B, C, A, B, C, A, B, C, A, B, C, A, B, C, A.

Alternatively, the sequence: A, C, B, A, C, B, A, C, B, A, C, B, A, C, B, A,A multi-stack motor must have at least three stacks if bidirectional operation is necessary, so that two separate excitation sequences are possible.

For a multi-stack variable-reluctance motor, there is a straightforward link between the number of stator/rotor teeth, the number of stacks, and the step length. If the motor has N stacks (and phases), the fundamental excitation sequence is to excite each stack in turn, resulting in a total rotor movement of N steps. At the start and conclusion of the sequence, the same stack is stimulated, and if the stator and rotor teeth are aligned in this stack, the rotor has shifted one tooth pitch. Because one tooth pitch equals (360/p), where p is the number of rotor teeth, the distance travelled for one excitation change is step length = (360/Np)°.

Three stacks and eight rotor teeth, the step length is 15°. Step lengths for the multi-stack variable-reluctance stepping motor are typically in the 2-15° range. Successful multi-stack designs often include extra stacks to provide the customer a choice of step length; for example, a three-stack, 16 rotor teeth motor has a step of 7.5° and a 5.625° step is possible by incorporating an extra stack (along with reorientation of the existing stacks). Although greater stack numbers are advantageous to the manufacturer, it should be noted that more phase windings need more drive circuits, hence the user must pay a penalty in terms of drive circuit cost. Furthermore, it can be shown that greater stack number motors have no meaningful performance benefits above three-stack motors.

Aspects of Design

When stimulated by a dc current, each pole of the multi-stack stepping motor has a winding that creates a radial magnetic field in the pole. The stepping motor's performance is determined by the intensity of this magnetosphere; a high flux value results in a strong torque, which keeps the motor in its step position.

The reluctance of the primary flux channel is at its lowest when the rotor and stator teeth are properly aligned, as seen in stack A of The flux density in the stator/rotor iron is minimal for low values of current in the pole windings, and the reluctance of these regions of the flux route is significantly smaller than the reluctance of the air gap between the stator and rotor teeth. However, when the winding current increases, the flux density in the steel finally achieves saturation. Winding current increases offer a declining return in terms of enhanced flux level. Another factor limiting pole field strength is the heating impact of winding currents. Because the power lost in the windings is related to the square of the current, the winding temperatures rise fast with larger currents. In most cases, the capacity of the winding insulation to survive a given temperature increase is what restricts the current to its rated value. Limitations on pole flux density and winding temperature increase are both effective for a well-designed variable-reluctance stepping motor. At the rated winding current, the stator/rotor iron approaches magnetic saturation.

Each stack of the three-stack motor seen in Figure 4.2 has four poles and hence four pole windings. Because all four windings in a stack must be stimulated at the same time, it is usual practise to link the windings to produce one phase. Increase, the corresponding rated phase current is also affected by the interconnection, as indicated. The rated phase voltage is the voltage that must be delivered at the phase terminals in order for the rated current to flow in the windings. The phase current is lower and the voltage is higher in the series connection than in the parallel connection, but the power provided to the phase is the same. Most manufacturers supply a given stepping motor design with a variety of winding connectivity, allowing the customer to choose between a low-voltage, high-current drive with a parallel connection and a high-voltage, quick temper with a series connection. Figure 4.2 Represents design of automotive system

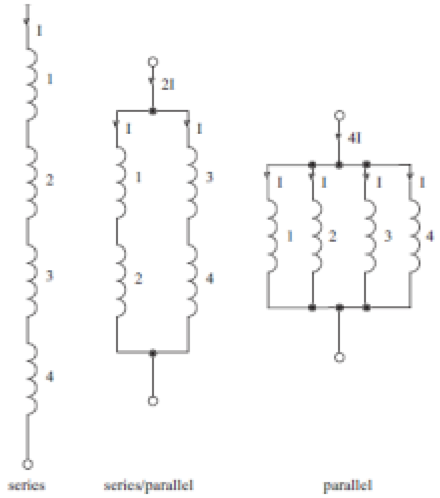

Figure 4.2 Represents design of automotive system

Half Step Mode Operation

We've previously shown how to step the motor in 308 increments by electrifying the phases one at a time in the ABCA, etc. sequence. Although the 'one-phase-on' mode is the most basic and generally utilised, there are two more modes that are also often used. These are known as the 'two-phaseon' and 'half-stepping' modes. The two-phase-on mode may give more holding torque and a considerably better damped single-step response than the one-phase-on mode, while the half-stepping mode allows the effective step angle to be halved, doubling the resolution and producing a smoother shaft rotation.Two phases are activated concurrently in the two-phase-on mode. When phases A and B are activated, for example, the rotor feels torques from both phases and comes to rest in the middle of the two neighboring complete step positions. If the phases are swapped in the order AB, BC, CA, AB, etc., the motor will execute complete (308) steps, but its equilibrium positions will be interleaved between the full steps positions, as in the one-phase-on mode.

To achieve 'half stepping,' the phases are stimulated in the order A, AB, B, BC, and so on, alternating between one-phase-on and two-phase-on modes. This is referred to as 'wave' excitation, because it causes the rotor to move in 158-step increments, or half the complete step angle. Continuous half stepping, as predicted, gives a smoother shaft rotation than full stepping and doubles the resolution.

The static torque curve may be seen when two phases are stimulated by superposition of their respective phase curves. As predicted, the stable equilibrium (half-step) position is at 158. The greater holding torque comes at the expense of increased power dissipation in the windings, which is doubled as compared to the one-phase-on mode. Because the holding torque rises by a factor of less than two, the torque per watt (a relevant figure of merit) decreases.

A word of caution is in order when combining the two independent one-phase-on torque curves to get the two-phase-on curve. Such a strategy is strictly valid only when the two phases are magnetically independent or the common sections of the magnetic circuits are unsaturated. Most motors, however, have the phases share a single magnetic circuit that runs under extremely saturated circumstances. Direct addition of the one-phase-on curves cannot therefore be anticipated to get a precise result for the two-phase-on curve, but it is simple and yields an acceptable approximation.Aside from the increased holding torque in the two-phase-on mode, there is another significant distinction that separates static behaviour from one-phase-on mode. The equilibrium or step locations in the one-phase-on mode are purely defined by the geometry of rotor and stator: these are the points where the rotor and stator are in line. However, in the two-phase-on mode, the rotor is meant to come to rest at positions when the rotor poles are aligned halfway between the stator poles. This position is not clearly defined by the 'edges' of opposing poles, as in the another scenario, and the rest position will be precisely halfway only if (a) there is perfect geometrical symmetry and, more significantly, (b) the two currents are equal. If one of the phase currents is greater than the other, the rotor will come to rest closer to the higher current phase rather than midway between the two. Having to balance the currents in order to achieve exact half stepping is plainly a disadvantage of this approach. However, as we will see, the machine's features with uneven phase currents may occasionally be used to good purpose.

Micro-step Mode

Some applications (for example, printing and phototypesetting) demand extremely fine resolution and a motor with a very tiny step angle - sometimes just a fraction of a degree. We've previously observed that increasing the number of rotor teeth and/or the number of phases reduces the step angle, but in reality, having more than four or five phases is cumbersome, and manufacturing rotors with more than 50-100 teeth is challenging. This implies that motors with step angles less than 18 are uncommon. Micro-stepping (ministepping or step division) is a method used when a smaller step angle is needed.Micro-stepping is a method based on two-phase-on operation that allows each entire motor step to be divided into a number of'substeps' of equal size. Unlike half stepping, where the two currents must be maintained equal, the currents are intentionally made uneven.The rotor equilibrium position may be modified to reside anywhere between the step locations for each of the two independent phases by appropriately selecting and managing the respective amplitudes of the currents.

To prevent the current from changing due to temperature changes in the windings or variations in the supply voltage, closed-loop current control is required; and if it is necessary to ensure that the holding torque remains constant for each micro-step, both currents must be changed according to a prescribed algorithm. Despite the challenges mentioned above, mini-stepping is widely utilised, particularly in photography and printing applications that need a high resolution. Schemes involving 3 to 10 micro-steps for a 1.88 step motor are many, and up to 100 microsteps (20 000 micro-steps/rev) have been successfully accomplished in certain cases.

So far, we've focused on features of behaviour that are solely dependent on the motor, i.e. static performance. The shape of the static torque curve, the holding torque, and the slope of the torque curve near the step position have all been shown to be critical indicators of how the motor will function. All of these properties, however, are dependent on the current(s) in the windings, and while the motor is operating, the instantaneous currents will be determined by the sort of drive circuit used, as explained in the next two sections.

Micro-stepping is typically referred to as "sine cosine micro-stepping," in which the winding current approximates a sinusoidal AC waveform. The most frequent type is sine cosine micro-stepping, however other waveforms may be utilised. Whatever waveform is utilised, as the micro-steps increase smaller, motor performance becomes smoother, considerably lowering resonance in any components to which the motor is linked, as well as the motor itself. The mechanical station will restrict the resolution.Backlash, as well as other causes of inaccuracy between the motor and the final item. To improve positional resolution, gear reducers might be utilised.

Step size repeatability is a key attribute of step motors and a primary rationale for its usage in positioning. Many current hybrid step motors, for example, are rated such that the trip of each full step (for example, 1.8 degrees per full step or 200 complete steps per revolution) is within 3% or 5% of the journey of every other full step, as long as the motor is run within its defined operating limits. Several manufacturers demonstrate that their motors can readily maintain 3% or 5% step travel size equality when step size is lowered from full stepping to 1/10 stepping. Then, as the number of micro-stepping divisors increases, the step size repeatability decreases. At high step size reductions, several micro-step orders may be sent before any motion occurs, and the motion can then be a "jump" to a new place.

Additional Methods of Damping Rotor Oscillations

After each excitation modification, the motor comes to rest at the suitable equilibrium position at extremely low stepping rates. The single-step response of the system to each excitation modification is often quite oscillatory (Russell and Pickup, 1996); a typical response is depicted in Fig. 4.8. This inadequately damped reaction might be a significant drawback in applications demanding frequent precise placement. For example, if a stepping motor is used to move a printer carriage, the machine must come to a stop for each letter to be printed. The time it takes for the system to settle to the acceptable precision at each letter location limits the printer's operational speed. If the system is minimally damped, the frequency of oscillation for each motor/load combination may be predicted using the static torque/rotor position characteristic. The motor torque at a rotor position different from the equilibrium position is - T', where T' is the stiffness of the torque/position characteristic. If no load torque exists, this motor torque is employed to accelerate the motor/load inertia (J); so

$$-T'\theta = J\left(\frac{d^2\theta}{dt^2}\right)$$

$$J\left(\frac{d^2\theta}{dt^2}\right) + T'\theta = 0$$

The basic oscillation frequency analysis assumes that the system is undamped. In actuality, there is a little amount of viscous friction in the system, which dampens the oscillations and causes the rotor to settle at the equilibrium position. Friction effects are typically undesirable in an electromechanical system since they induce wear in the moving components and are changeable because they are a function of this wear. Because the designer strives to minimise friction as much as possible, most stepping motor systems have very low inherent damping and, as a result, a weakly damped single-step response.

The rise time is the time it takes for the motor to reach the desired step position at maximum velocity. As a result, the system overshoots the goal, and the magnitude of the initial overshoot is stated as a percentage of the overall step, yielding the percentage overshoot. Finally, the settling time is the amount of time it takes for the oscillation to diminish to the point when the system is within 5% of the objective.The occurrence of resonance effects at stepping rates up to the natural frequency of rotor oscillation is one result of the highly oscillatory single-step response. Figure 4.9 depicts two motor responses to a sequence of steps at various speeds. The stepping rate in the first response is about 0.6 times the natural frequency, thus the rotor is behind the equilibrium position and has a low velocity when the next excitation change occurs. The rotor soon settles into a consistent reaction to each stride. The rotor is in the equilibrium position with a positive velocity at the end of the first step in the other response because the stepping rate is almost equal to the natural frequency. The reaction to the second step is more oscillatory as a consequence of this starting velocity; the rotor swings more away from the equilibrium position.

The amplitude of the rotor oscillations increases as the steps are accomplished until the rotor lags or leads the required step position by more than half a rotor tooth pitch. When the amplitude of the oscillation is surpassed, the motor torque forces the rotor to shift to an alternate step location that is a full rotor tooth pitch away from the intended position. The relationship between rotor position and number of excitation changes has now been lost, and subsequent rotor movement is unpredictable. It is worth noting that motors with a high number of phases have an advantage here since a step length is a tiny fraction of the rotor tooth pitch, allowing the rotor to be many steps away from the desired position without losing synchronism.The system's resonant nature causes a loss of motor torque at well-defined stepping rates, as seen by the dips in the pull-out torque/speed characteristic. If the natural frequency is known through direct measurement of the single-step response, the position of these dips may be anticipated.

If the rotor is ahead of the equilibrium position and has a positive velocity at the conclusion of the excitation time, resonance is probable. These areas are the rotor must travel through these areas at intervals that are multiples of the rotor oscillation period (1/fn), and therefore

This answer is not exact since the oscillation frequency is affected by the quantity of damping, but it is enough for most uses. Lawrenson and Kingham's approach includes the extra difficulty of damping-dependent oscillation frequency (1977). The system's high overshoot may be used for applications that need repeated quick positioning in a single step. If the step, for example, corresponds to a change in excitation from phase A to phase B, the half-step with both phases A and B excited is initially taken the system exceeds the required position for A and B excited, eventually coming to rest near the phase B equilibrium point. At this point, the excitation is limited to phase B, and the transition to the last step is performed with a little initial mistake and, as a result, a slight overshoot the difference between this reaction and the impact of switching immediately from single-phase stimulation of A to B. Unfortunately, with this intermediate half-step control, the timing of the excitation changes is essential and significantly dependent on load circumstances As a result, it can only be used in circumstances where the load is constant or in closed-loop position control systems.

A stepping motor system's resonant tendencies may be decreased by increasing damping and therefore decreasing the amplitude of oscillation in the single-step response. The next sections address two major ways for enhancing damping, which use either electrical or mechanical methods. Figure 4.3 represents the Damping Rotor Oscillations

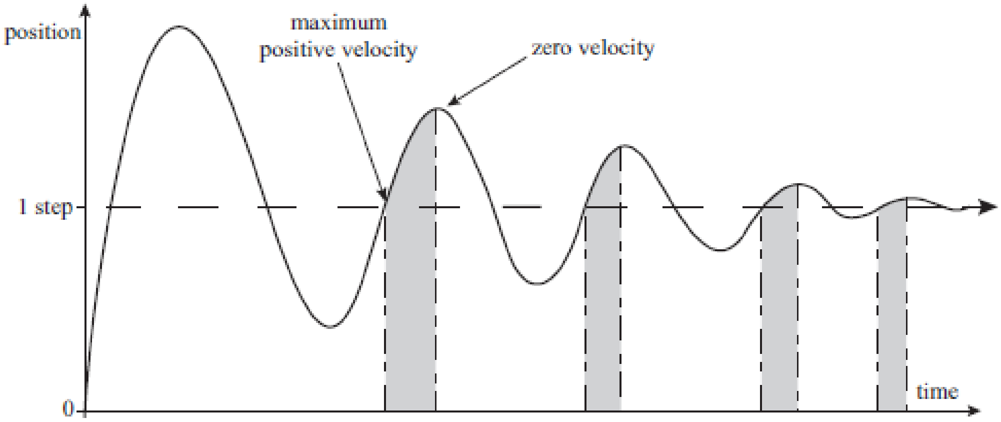

Figure 4.3 represents the Damping Rotor Oscillations

The viscously coupled inertia damper

One mechanical approach of dampening the single-step response is to supply extra viscous friction (torque proportional to speed), causing the rotor oscillations to fade quicker.The use of plain viscous friction, on the other hand, is undesirable since the friction torque greatly limits the performance of the motor at high speeds. The viscously coupled inertia damper (VCID), also known as the Lanchester damper, is one solution to this issue. This device provides a viscous friction torque for quick speed variations, such as those seen in the single answer, but does not interfere with constant-speed operation. Externally, the damper looks as a cylindrical inertial load that may be fastened to the motor shaft and spins at the same speed as the motor. Internally, the damper features a rotor with a high inertia that is isolated from the housing by a viscous fluid. As a result, the housing and inner rotor may spin relative to each other, but are only weakly connected by the viscous fluid. There is a mutual drag torque when the damper components move relative to one another.

Electromagnetic damping

When the system inertia is moving, the main goal of any dissipation scheme is to extract stored mechanical energy in the form of rotating kinetic energy. Damping with the VCID is accomplished by moving the system's mechanical energy back and forth between the damper housing and rotor through an inefficient mode of coupling (the viscous fluid), resulting in some energy dissipation with each transfer.As a result, mechanical energy is employed to heat a coupling fluid in the VCID. The mechanical energy gained by the system while moving between step locations is transmitted to the motor's electrical circuit and wasted in the motor winding and forcing resistances in electromagnetic damping schemes.

The voltages produced in the phase windings as the rotor oscillates send energy to the electrical circuit, hence these voltages are studied first. The magnet flux associated to the two phase windings of a hybrid motor fluctuates when the rotor position moves across a rotor tooth pitch. This characteristic has a sinusoidal shape with a wavelength equal to the rotor tooth pitch, and the sinusoids for the two phases are offset by /2p. The pace at which flux linkages change

shows the rotor position with the right phase connection to For example, when the flux couplings in phase A are at their maximum, the rate of change of flux associated with phase A is zero.The torque generated by one phase for a given phase current is proportional to the rate of change of flux linkages with rotor position, and so the static torque/rotor position features for positive excitation of the two phases may be determined (Figure 4.4).

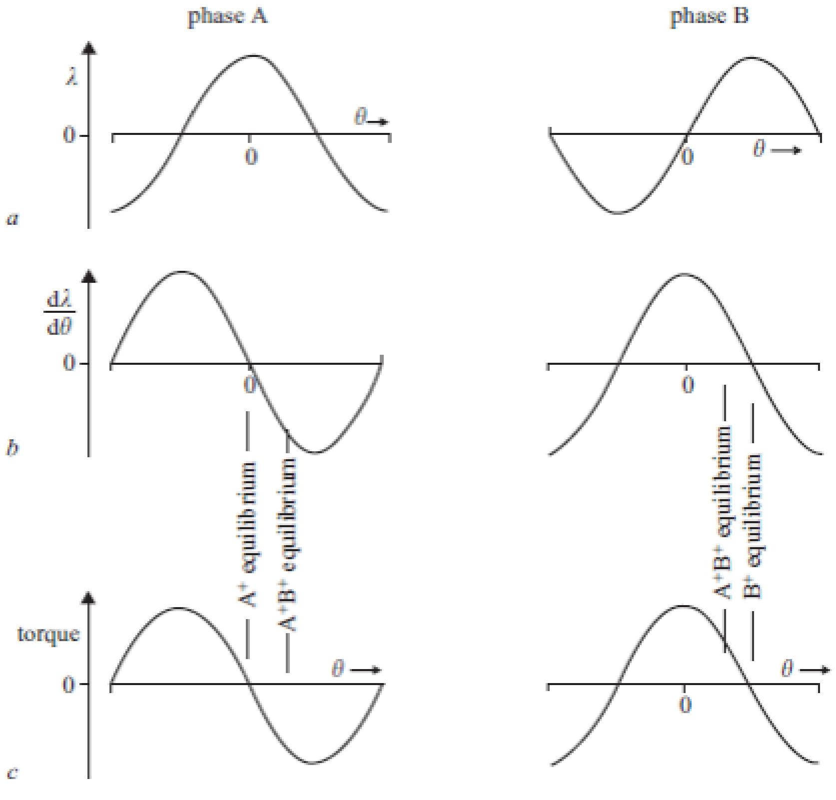

Figure 4.4 represents the Electromagnetic damping fluctuations.

With just one phase activated, the rotor travels to the phase equilibrium point, where the torque is zero and the rate of change of flux linkages is likewise zero If the rotor oscillates around this one-phase-on equilibrium point, the flux coupled with the phase winding varies just little, and the voltage produced by the magnet flux is negligible. Consider the case when two phases are excited. Because the equilibrium position is located between the two distinct phase equilibrium locations, the rate of change of flux connections with rotor position is particularly high. As a result, if the rotor oscillates around the two-phases-on equilibrium position, the magnet flux induces a voltage in each phase at a frequency equal to the frequency of rotor oscillation. These induced voltages are responsible for extracting energy from the mechanical system and providing electromagnetic dampening.

Hughes and Lawrenson (1975) conducted a detailed examination of the processes involved in electromagnetic damping, demonstrating that the single step response is third-order when the electrical circuit is included. The results of this research reveal that in order to have a well-damped response, the phase resistance (winding forcing) must be adjusted at an optimal value that relies on numerous motor and load characteristics. Damping occurs with two-phases-on excitation because the induced voltages are large. Produce extra alternating current phase current components that are overlaid on the continuous dc phase current. When the rotor oscillates, these alternating current components cause additional power losses in the phase resistance, therefore mechanical energy is removed from the system to provide this extra power. The ac current element is low and the power losses I 2 r) are minor when the phase resistance is set too high. In contrast, if the phase resistance is less than the optimal value, the alternating current is strong, but there is very little resistance through which the current may lose power. The best value of phase resistance for maximal electromagnetic damping in a hybrid stepping motor is

$$\boldsymbol{R = \sqrt{\frac{T'}{J}}\; x\, L\, x\, (1 + \frac{k}{2})}$$

Where L denotes the phase winding's inductance. The factor k is a motor parameter that is determined by the ratio of the magnet flux connecting the phase winding to the flux linkages caused by the winding current. Typical k values vary from 0.25 to 1.0. A similar conclusion to eqn applies to variable-reluctance motors, with the exception that the parameter k is defined differently.

Although the optimal phase resistance may be computed, determining the optimum empirically is a very straightforward process. The single-step response may be tested through a wide variety of forcing resistance values (with appropriate supply voltage modifications to ensure constant phase current) until an acceptable response is found. The focus of the discussion has been on two-phase hybrid motors, although electromagnetic damping may be induced in any kind of motor if more than one phase is stimulated as the rotor is settling to the equilibrium position. In certain circumstances, adding a dc bias to all phases of the motor will improve the electromagnetic damping effect.The design of a system for excellent damping employing electromagnetic means, like the VCID, is often in direct conflict with the requirement of high-speed operation. In the next chapter, it is shown that the system needs a high forcing resistance to work at high speeds, and that in most circumstances, the total phase resistance is substantially higher than the optimum for electromagnetic damping. As a result, the system designer is forced to make a compromise decision of inducing resistance based on the application.

Permanent Magnet Stepper Motors

Permanent-magnet stepper motors feature smooth armatures and a magnetic core that is magnetised either widthwise or perpendicular to the rotation axis. These motors are often equipped with two separate windings, or with or without centre taps. The most frequent step angles for PM motors are 45° and 90°, however motors with 1.8° every step, as well as 7.5, 15, and 30° per step, are also available.

To generate torque, the stator poles are alternately activated and de-energized, resulting in armature rotation. A 90° stepper has four poles, whereas a 45° stepper has eight poles that must be powered in order. Permanent-magnet steppers step at modest rates, but they may generate enormous torques and have excellent damping properties.

Permanent magnet (PM) stepper motors are built similarly to single stack, variable reluctance stepper motors, with the exception that the rotor is formed of a permanent magnet. The circuit architecture and multiple operating modes for a 2-phase, permanent magnet stepper motor that rotates anticlockwise with a 90° step each phase PM switching sequence

When compared to variable reluctance motors, PM stepper motors have various advantages, including:

1. Greater inertia, resulting in reduced acceleration (deceleration) rates.
2. Higher maximum step pulse rate of 300 pulses per second compared to 1200 pulses per second for variable reluctance stepper motors.
3. Larger step sizes ranging from 30° to 90° compared to variable reluctance stepper motors with step sizes as low as 1.8°.
4. Produce more torque per amp of stator current than variable reluctance motors that move in steps

Stepper motor drives circuit

The motor would work well if it were powered by an ideal drive circuit, which is capable of sending rectangular pulses of current to each winding when needed and independent of the stepping rate. No practical drive circuit can do this due to the inductance of the windings, although the most complex (and costly) ones can achieve near-ideal functioning up to extremely high stepping rates.The full drive's main job is to transform the step command input signals into suitable current patterns in the motor windings. This is accomplished in two steps, as seen in Figure 4.18 for a three-phase motor.

The incoming train of step command pulses is translated by the 'translator' stage into a series of on/off instructions for each of the three power stages. For example, in the one-phase-on mode, the first step command pulse will be routed to turn on phase A, the second to turn on phase B, and so on. In a very basic drive, the translator will most likely only support one mode of operation (e.g., one-phase-on), while most commercial drives support one-phase-on, two-phase-on, and half-stepping. Single-chip integrated circuits having these three operating modes and three-phase and four-phase outputs are widely available.

The current to the windings is supplied by the power steps (one per phase). There is a wide range of kinds in use, from basic ones with one switching transistor per phase to complicated chopper-type circuits with four transistors per phase. However, at this point, it is useful to identify the functions needed by the 'ideal' power stage. The first is that when the translator requests that a phase be activated, the whole phase is activated (rated).

The current should be created instantly; secondly, it should be kept constant (at its rated value) for the length of the 'on' time; and third, when the translator asks for the current to be shut off, it should be quickly lowered to zero.The optimal current waveforms for continuous stepping with one phase-on operation. The currents have a square shape because this results in the best operating torque from the motor. However, due to winding inductance, no practical drive will reach the perfect current waveforms, but many drives may get near, even at relatively high stepping rates.

Constant-current drives are, unsurprisingly, those that generate such rectangular current waveforms. We will now examine the operating torque generated by a motor when it is powered by an ideal constant current drive. This will serve as a benchmark for evaluating the performance of other drives, all of which will be found to be subpar. Figure 4.5 Stepper motor drives circuit.

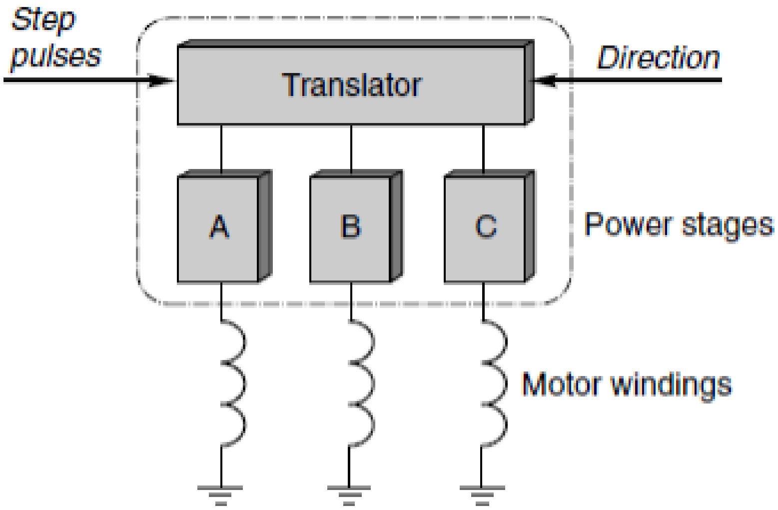

Figure 4.5 Stepper motor drives circuit.

Pull-out torque under constant-current conditions

If the phase currents are assumed to be ideal, that is, they are switched on and off instantly and remain at their full-rated value during each 'on' period, we can imagine the magnetic Weld's axis advancing around the machine in a series of steps, with the rotor urged to follow it by the reluctance torque. If we assume that the inertia is large enough that rotor velocity variations are extremely tiny, the rotor will rotate at a constant rate that matches perfectly to the stepping rate.Now, if we examine a case in which the rotor axis always, on average, trailing behind the moving Weld axis, it should be obvious that the rotor will suffer driving torque. The greater the lag, the greater the average forward torque operating on it, but only up to a point. We already know that if the rotor axis is moved too far away from the Weld axis, the torque begins to decrease.

As a result, we conclude that, although raising the rotor lag angle would provide greater torque, there will be a limit to how far this can be carried.To examine the torque on the rotor quantitatively, we will take the static torque-displacement curves presented before, and see what occurs when the load on the shaft is adjusted while the stepping rate remains constant. The phases will be ignited in the ABC sequence using clockwise rotation. The instantaneous torque on the rotor may be calculated by remembering (a) that the rotor speed is constant and that it spans one-step angle (308) between step command pulses, and (b) that the rotor will be 'acted on' sequentially by each of the torque curves.

When the load torque is zero, the rotor's net torque must be zero (apart from a very little torque necessary to overcome friction). The thick line represents the immediate torque, and it is evident that each phase applies a clockwise torque initially, then an anticlockwise torque when the rotor angle rotates through 308. Because the average rotor lag angle is zero, the average torque is zero, as is the load torque.

When the load torque on the shaft is increased, the rotor immediately falls back in reference to the Weld. This increases the clockwise torque while decreasing the anticlockwise torque. When the lag angle has grown enough for the motor torque to match the load torque, equilibrium has been attained. The maximum average torque that can be developed: if the load torque exceeds this value (known as the pull-out torque), the motor loses synchronism and stalls, and the critical one-to-one correspondences between pulses and steps are lost.

Because we assumed an ideal constant-current drive, the pull-out torque will be independent of the stepping rate, resulting in the pull-out torque-speed curve I_L. The shaded zone shows the allowable operating region: at any given speed (stepping rate), the load torque may be any value up to the pull-out torque, and the motor will continue to work at that speed. However, if the load torque exceeds the knock torque, its motor will abruptly lose synchronism and stall.

Uni-polar Drive Circuit

On Mode: When a sufficiently strong base current flows through the transistor base, the transistor becomes ON and behaves ideally like a short circuit. As a result, the supply voltage is applied across the phase winding and the external resistor (Rext) linked in series with it. When the switch is switched on, the magnitude of the DC source is adjusted to provide the rated phase current. As a result, Vs = I (Rph + Rext), where Vs is the DC source voltage in V, I is the rated current of the phase winding in A, Rph is the resistance of the phase winding in, and Rext is the external resistance connected in series to the phase winding in. The phase winding inductance is quite considerable, resulting in a sluggish pace of developing the phase winding current, which may result in suboptimal stepper motor operating at high stepping rates. As a result, to lower the time constant, the external resistance is linked in series with the phase winding. The net ON Mode circuit time constant will be quite big, and it may be stated as follows:

$$V_s = I\,(R_{ph} + R_{ext})$$

$$\tau\tau_{ON} = \frac{L_{ph}}{(R_{ph} + R_{ext})}$$

OFF Mode: In this mode, the transistor's base driving current is eliminated, and the switch is switched OFF, acting as an open circuit. The freewheeling channel established by the freewheeling diode (Df) and the freewheeling resistance will continue to carry the phase winding current (Rf). The greatest OFF state voltage (VCE (max)) that emerges across the transistor (switch) may be stated as,

$$VV_{CE(max)} = V_s + IR_f$$

The phase current in the OFF mode circuit decays with a net OFF Mode circuit time constant that may be represented as,

$$\tau_{OFF} = \frac{L_{ph}}{(R_{ph} + R_{ext} + R_f)}$$

During the switch turn OFF period, the energy accumulated in the phase inductance during the ON mode is dissipated in the OFF state circuit resistances. Figure 4.6 represents Uni-polar Drive Circuit.

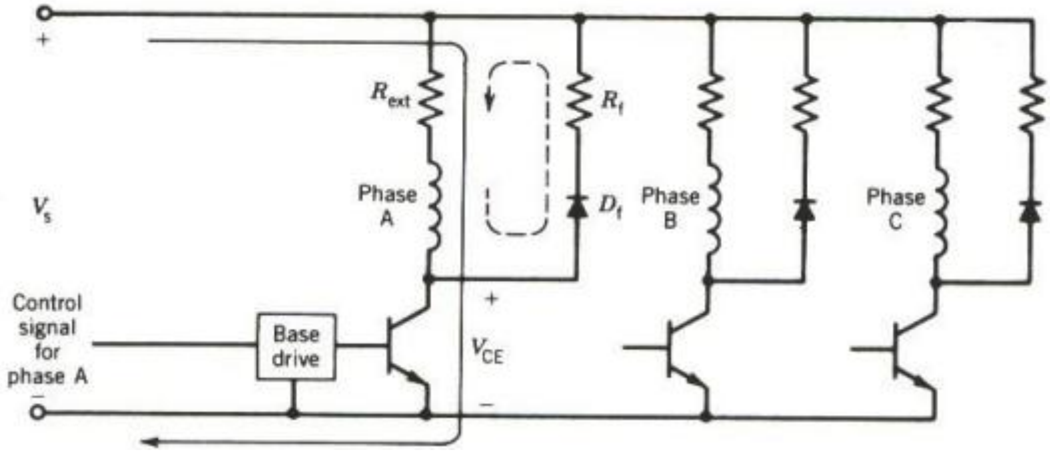

Figure 4.6 represents Uni-polar Drive Circuit

Bi-polar Drive Circuit

This circuit may be used with either permanent magnet or hybrid stepper motors. Each phase winding of the motor is controlled by a separate drive circuit with a configurable power switch (a transistor). The same DC source powers all of the driving circuits. Each phase winding's two transistors (power switches) are switched on at the same time.

There are two ways of operation:

T1 and T2 are turned on: This is accomplished by simultaneously infusing a sufficiently enough base current via their bases. Each transistor functions optimally as a short circuit. As a result, the current will flow as shown by the solid line in the inductor is then turned on.

D3 and D4 are in the On Mode, which occurs when T1 and T2 are turned off. Because of the phase winding inductances, the phase winding current cannot change direction or decrease to zero instantly after turning off T1 and T2. As a result, the current continues to flow through D3 and D4, as seen by the dotted. The inductor discharges, and the energy is returned to the direct current source.

CHAPTER 5

Linear Stepper Motors

Mr. Robin Khandelwal, Assistant Professor,
Department of Mechanical Engineering, School of Engineering & Technology,
Jaipur National University, jaipur, India
Email Id-robinkh16@jnujaipur.ac.in

Linear actuators with axial integrated threaded shafts and bolt nuts are offered to convert rotational motion to linear motion. These linear actuators can place light weights and are powered by fractional hp permanent-magnet stepper motors. Digital pulses applied to the actuator force the threaded shaft to revolve, advancing or retracting it, allowing a load attached to the shaft to be moved backwards or forwardsbidirectional digital linear actuator that may deliver linear resolution as fine as 0.001 in. per pulse. The pitch of the lead screw and the step angle of the motor define the travel per step. For the model illustrated, the maximum linear force is 75 oz. Figure 5.1 Represnts linear stepper motors.

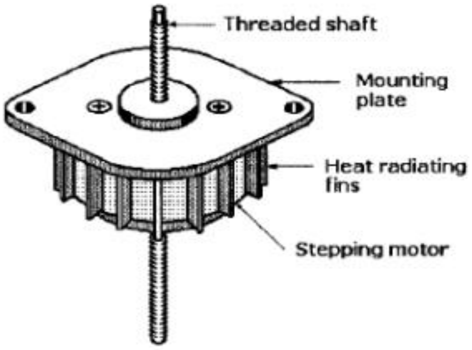

Figure 5.1Represnts linear stepper motors

Apply control method of actuators

A system may use continuous actuators to position or alter outputs throughout a large range of values. Continuous actuators, even in their most basic form, are mechanically complicated devices. A linear slide system, for example, might consist of a motor with an electronic controller driving a hardware slide with a ball screw. These actuators may potentially cost more than the control system itself. These actuators also need complex control strategies, which will be covered in subsequent chapters. In general, it is preferable to employ discrete actuators to save costs and complexity.

Apply control method for Brushless DC Motors

Another form of servomotor is the DC brushless motor, which requires feedback for reliable operation. Because the rotor has a permanent magnet and the stator contains windings, an ADC brushless motor is similar to a DC brush motor flipped inside out. When compared to a DC brush motor, the windings are electronically commutated, therefore a mechanical commutator and brushes are no longer necessary. In contrast to DC brush motors, DC brushless motors are extensively utilised in robotics applications because to its high speed capabilities, greater efficiency, and reduced maintenance. Because the mechanical commutator has been removed, they may operate at faster speeds. They are more efficient because heat from the stator windings may be dispersed faster via the motor housing. Finally, they need less maintenance since they do not have brushes that need to be replaced on a regular basis. However, owing to the complexity of electronic commutation, the overall system cost of brushless motors is greater than that of DC brush motors.

The rotor's location must be understood so that the polarity of current in the stator's windings may be switched at the appropriate moment. Brushless motors employ two forms of commutation. Because trapezoidal commutation requires the rotor position to be known to within 60°, just three digital Hall Effect sensors are commonly utilised. When the motor's torque ripple must be decreased, sinusoidal commutation is used instead of trapezoidal commutation. In this instance, the rotor position must be calculated more precisely, which necessitates the use of a resolver or an encoder in addition to Sensing Elements. The Hall Effect sensors, in conjunction with the encoder, are required to give rotor shaft position upon starting. Because the resolver gives absolute rotor shaft position information, the Hall Effect sensors are not needed for starting.

Brushless motors employ a permanent magnet on the rotor and stator windings. As a result, brushes and a commutator are not required to flip the polarity of the voltage on the coil. Because there are no brushes, these motors need less maintenance than brushed DC motors. Typical Brushless DC motor with three poles, each matching to one power input. Each coil is regulated independently. To attract or repel the permanent magnet rotor, the coils are turned on. The current in the stator coils must alternate continually in order for these motors to revolve continuously. The motor will revolve continuously if the power provided to the coils is a 3-phase AC sinusoidal waveform. The applied voltage may also be trapezoidal for a similar result. The shifting waveforms are controlled by a controller that selects switching times based on position data

Solenoid Type Devices

Solenoids are the most basic electromagnetic actuators used in linear and rotational actuation of valves, switch, and relays. A solenoid is made up of a fixed iron frame (stator), a coil (solenoid), and a ferromagnetic plunger (armature) at the middle of the coil, as the name implies.A magnetic field is created within the coil when it is activated. By closing the air gap between the plunger and the fixed frame, the moveable plunger increases the flux linkage. The resultant magnetic force is roughly proportional of the applied current I and directly proportional to the distance of the air gap, which is the solenoid stroke.

When powered, all linear solenoids draw the plunger into the coil. Push-type solenoids are created by extending the plunger through a hole in the back-stop,when activated, the plunger is still dragged into the coil, but the expanded providing a pushing action from the solenoid's rear end. When the coil is de-energized, the load (i.e., the weight of both the load) and/or a return spring, which may be supplied as an integrated component of the solenoid assembly, provide return motion.Rotational solenoids transform linear motion to rotary motion by using ball bearings that run along sloped raceways. When the coil is turned on, the plunger assembly is drawn towards the stator and rotated along an arc indicated by the coining of the raceways. A solenoid is used in an electromechanical relay (EMR) to shut or open a mechanical contact (switch) between high voltage electrical lines. A relay functions similarly to a power transistor in that it uses very little electrical energy to switch a huge quantity of currents. A relay, on the other hand, has the potential to manage a considerably higher current level. Some relays contain several contacts, some are encased, others have built-in circuits that delay contact closure after actuation, and some, like early telephone circuits, move through a sequence of states as they are powered and de-activated.Considerations for Design/Selection. The four key design/selection factors for solenoids are force, stroke, temperature, and duty cycle. A linear solenoid may generate up to 30 lb of force from a unit that is less than an inch long. A rotary solenoid may produce more than 100 lb of torque from a device that is less than an inch long.The connection between force and stroke may be changed by modifying the design of several internal components, Increase the current to the coil winding to attain higher performance, such as force output. Higher current, on the other hand, tends to raise the temperature of the winding. The wire resistance increases as the winding temperature rises. This lowers the output force level.

Solenoids are often rated as having a continuous duty cycle or an intermittent duty cycle. A 100% duty cycle solenoid may be constantly activated at its rated voltage since its total coil temperature will not exceed maximum permitted ratings, but an intermittent phase shift solenoid has an associated allowable "on" duration that must not be exceeded. Intermittent duty coils provide far more force than continuous duty solenoids. The rated temp of the insulating material used for the winding determines the maximum working temperature of a solenoid.

Voice-Coil Motors (VCMs)

The voice-coil motor was initially designed for loudspeakers, as the name implies. It is presently widely employed in the movement of read/write heads in hard disc drives. VCM is also known as a moving-coil actuator since the coil is in motion. The VCM is made up of a moving coil (armature) in a gap and a permanent magnet (stator) that generates the magnetic field in the gap, as shown in Because most voice coils are constructed with the flux perpendicular to the current direction, the resulting Lorentz force is given as where l is the coil length per turn, B is the flux density, N is the total number of turns in the coil, I is the current, and is a coil utilization factor. It is critical to understand that the force is proportional to the applied current amplitude, and the proportional constant KF is often referred to as the force constant.

The coil is often hung in the gap by springs and connected to a load such as an audio speaker's diaphragm, the spool of a hydraulic valve, or the read/write head of a disc drive. The linear connection between output force and applied current, as well as the bidirectional capabilities, make voice coils more appealing than solenoids. However, since the voice coil's regulated output is force, some form of closed loop control or spring suspension is required.

Design/Selection Consideration. The force constant is proportional to the flux density and the number of wires that can then be packed into the gap. There are two ways to raise the force constant. The first is to raise the flux density, which may be done by employing stronger magnetic material, and the second is to increase either N or l, which means packing more turns and/or making a bigger diameter coil. Given a certain gap volume, the only method to increase the number of turns is to use larger gauge (thinner) wires.

Greater gauge wires, on the other hand, have a higher resistance, which increases the resistive heating of the winding and limits the permissible current. Furthermore, the increased insulation takes up more space and tends to lessen the impact of raising N. To summarise, a designer may enhance the performance of the voice coil by using a better magnetic material or by making the motor larger by making the coil wider (increasing D) or longer (increase N).

Electric Motors

The most common electromechanical actuators are electric motors. They are categorised based on functionality or electromagnetic properties. Electric motors vary primarily in their rotor design and way of producing a magnetic field. A permanent magnet DC motor. The following are some popular terms for electric motors:

1. The stator is the motor's stationary outer / inner housing that holds the material that provides the required stator magnetic field. It may be constructed from a permanent magnet or coil windings.
2. The field coil (system) is the part of the stator that generates the magnetic flux in the stator (field).
3. The rotor is the motor's spinning component. It may be a permanent magnet or a ferromagnetic core with coil windings (armature) to generate the proper armature field to interact with the stator field to create torque, depending on the architecture.
4. The rotor winding that conducts electricity and creates a magnetic field is known as the armature.
5. The air gap is the little space between the rotor and the stator where the two magnetic fields interact and produce torque.
6. A brush is the component of a direct current motor that supplies current to the armature (rotor). Slip rings are used to do this in synchronous AC motors.

The commutator is the component of the rotor of a direct current motor that comes into contact with the brushes and controls the armature current direction. Commutation may be defined as the process of controlling the current directions in the stator and/or armature coils in order to maintain a desired relative stator and rotor magnetic flux direction. Commutation in AC motors is accomplished by the application of AC current as well as the design of the winding geometry. Commutations are performed in the drive electronics and/or motor instructions for stepping motors and brushless DC (BLDC) motors.

The interaction of the armature current and the stator magnetic field (Lorentz Law) or the interaction of the stator field and the armature field generates torque in an electric motor.

Electrostatics Electrical Field

Because electrical fields have a lower energy density than magnetic fields, their usual uses are confined to measuring devices and accelerating charge particles, where the needed energy density is modest. With the advancement of micro-fabrication technology, modest electrostatic forces may now be applied to microelectromechanical actuators such as comb actuators.

When compared to electromagnetic actuation, electrostatic actuation has a greater switching rate and reduced energy loss. However, the force, travel, and high operating voltage limitations must still be addressed. The principal actuation for moving charged ink in electrophotographic (xerographic) technologies, such as laser printers, is electrostatic actuation.

Piezoelectric

Piezoelectricity refers to the property of some crystals that creates a voltage when mechanically deformed or undergoes mechanical displacement when exposed to a voltage. When mechanical strain is applied to a piezoelectric material, it causes an asymmetric movement in the crystal structure and the charge centre of the affected crystal ions. As a consequence, charge separation occurs. It is possible to detect an electric potential proportional to mechanical strain. This is referred to as the direct piezoelectric effect.

When an electric potential is supplied, the material deforms but does not change volume.

Mechanical actuation may be achieved via the reciprocal piezoelectric effect. Piezoelectric materials are classified into two types: sintered ceramics such as lead-zirconate-titinate (PZT) and polymers such as polyvinylidene fluoride (PVDF) (PVDF). Piezoceramics have a higher force output thus are more often employed as actuators. PVDFs produce greater deformation and are more often employed in sensing applications.

Apply control method for Hydraulic Actuators

An actuation system that is part of an automated machine comprises of a power component and a control part. The power section includes all of the equipment used to carry out the motions or activities. The control part processes the information and creates the automated cycle and the laws of variation of the reference signals in accordance with the established regulating procedures and the enabling and feedback signals from the sensors mounted on the operational part. The control portion's order signals are transferred to the operational component through interface devices, which transform and amplify the signals as needed so that they may be utilised directly by the actuators. These connections may include electric motor speed drives or contactors, as well as distributor valves in hydraulic and pneumatic actuators.A fluid actuation system The power portion comprises of the actuator—in this example, a double acting cylinder—the front and rear chambers of which are supplied by a 4/2 distributor valve, which serves as the fluid power adjustment interface. The order from the control component is the valve switching command. This order is delivered in line with the movement strategy, which is established by the intended operating cycle of the cylinder in the control section, based on feedback signals from the cylinder sensors, which are represented in the figure by the limit switches.Then, depending on the sort of automation implemented, there are discontinuous actuation systems and continuous actuation systems, with both the control and actuation parts retained. Continuous actuation systems, on the other hand, are found in continuous process plants and as continuous or analogue control devices for the necessary magnitudes, and form fluid servo systems. Figure 5.2 Represents the Hydraulic Actuators.

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Hydraulic Actuation Systems

Pumps

Pumps convert mechanical or electrical energy into hydraulic energy. They are the hydraulic system's fluid flow generator, since the pressure is governed by the fluid resistance downstream from the generator. Centrifugal pumps provide for high delivery rates at low pressures. They have no internal valves, but a substantial space between the rotor and stator parts ensures a suitably stationary flow.

In contrast, the most often used dynamic or positive displacement pumps ensure high pressures with restricted deliveries. They have elements such as valves and caps that allow the delivery zone to be separated from the intake zone, and they may introduce pulses in the flow in the delivery line. They generally require the use of a fluid with sufficient lubricating properties and load capacity to reduce friction between the pump's sliding parts. Pumps are classified as either constant displacement or variable displacement. Positive displacement pumps are classified into three types: gear, rotary vane, and piston.

Gears pump

Pumps with external gears, pumps having internal gears, and screw pumps are the three types of gear pumps. The pump is always constructed comprised of two toothed wheels fitted inside a casing with low slack to avoid leaking depicts a pump with external gears. The oil trapped between the teeth and walls of the gear is transferred from the intake to the outlet by the opposing rotation of the wheels. External gear pumps are classified into spur gear, helical gear, and lobe gear types based on the shape of the teeth.

Pumps with internal gears work similarly to those described above, however the gears in this instance revolve in the same direction. A section plane of a two-stage pump is shown in Figure The components of screw pumps, which may have one or more rotors, feature helical toothing similar to a threaded worm screw. The fluid is transferred in an axial direction once the screw is rotated. These pumps provide a very smooth flow transfer with minimal pulsation and noise levels.

Rotation rates are typically between 1000 and 3000 rpm, with outputs ranging from 1 to 100 kW.

Delivery pressures may exceed 250 bar, with greater values possible with external gear pumps.

The transmitted flow is determined by the pump displacement and the angular input speed, with values ranging from 0.1 to 1000 cm2/rev. These values may be increased by using double pumps. With values around 90%, gear pumps offer excellent performance levels.

Pumps with rotary vane

Vane pumps (Fare made up of a stator and a rotor that may revolve eccentrically in relation to one another. Vanes may travel via particular slots in the stator or rotor to delimit suitable variable volumes. Like in most configurations, are carried by the rotor, which may revolve within the stator. The movement of quantities of fluid contained between two successive vanes from the intake environment to the delivery environment is caused by rotation. This kind of pump allows for operating pressures of up to 100 bar and, as compared to gear pumps, ensures lesser pulsing of the delivery flow and better quiet.

Pumps with pistons

Volumetric piston pumps may contain one or more valves; that is, each cylinder can have a piston moving in it. The displacement of the piston within the cylinder, which is equipped with the input and output valves or shutters, determines the volume transfer of fluid from intake to delivery.

Piston pumps are classified as axial (bent axis type and swash plate type) or radial (depending on the geometrical placement of the cylinders with regard to the spinning motor shaft). The operating pressure range accessible with piston pumps is higher than in prior examples, with pressures in the 400-500 bar range possible, but with the drawback of more irregular flow.

Actuators of Motion

Motion actuators transform the hydraulic fluid of a pressurised liquid into mechanical energy. These actuators are thus volumetric hydraulic motors and are classified, similarly to pumps, based on the type of movement produced as rotary motors, semi-rotary motors or oscillating motors, which produce constrained rotation by the output shaft, and linear reciprocating motors, which are hydraulic cylinders.

Motors, both rotary and semi-rotary

Rotary motors and rotary pumps are similar in terms of construction. As a result, radial or axial gear, vane, and piston motors are offered. The working concept is obviously the inverse of what has been said for pumps hydraulic rotary motor symbols. Semi-rotary motors provide oscillating motion either directly, by rotating a vane linked to the output shaft, or indirectly, by linking with a rack, powered by a piston, with a toothed wheel attached to the output shaft,. Semi-rotary vane motors have a large instantaneous torsional torque on the output shaft, which is why they are also known as hydraulic torque-motors.

Linear Actuators

Linear hydraulic motors are the most prevalent form of actuator. They offer rectilinear movement through the stroke of a rod attached to a piston that slides within the cylinder. Cylinders are classified as single acting or double acting. The former only allow a single work stroke, thus fluid pressure is exerted on the surface of the piston in just one direction; the retract stroke is created by applying force externally to the cylinder rod, or by using a helical spring integrated with the actuator within a chamber. The latter allow both strokes, causing the fluid to act alternately on both sides of the piston, resulting in both advance and retract strokes.

A single rod or a double through rod is used in double acting cylinders. These are made up of a tube with two heads at the ends and a moveable piston within the barrel with one or two rods linked externally to the load to move. The piston splits the cylinder into two chambers since it is supplied with sealing gaskets. By forcing oil into one of the chambers through specific pipes in the heads, a pressure differential is created between the two surfaces of the piston, resulting in a push conveyed to the outside via the rod. Because the working area on the rod side is less than the area of the piston due to the section of the rod itself, single rod actuators are also known as asymmetrical cylinders.

This requires actuation forces and feed rates that vary in the two directions while maintaining the same feed pressure in the two thrust chambers. Hydraulic actuators can withstand external overloads because if the load exceeds the available thrust force, the rod stops or reverses but is not damaged.Cylinders may be damaged, or at least suffer a decrease in performance, when they must support loads that are not applied along the axis of the rod, that is, with components in the radial direction, as reactions are generated on the rod supports and piston bearings, resulting in fast wear and oil leakage. The diameter, stroke, maximum working pressure, and type of working fluid are the primary characteristics of a linear actuator.

Pneumatic Actuation Systems

A pneumatic actuation system consists of the following components: the compressed air generation system, which includes the compressor, cooler, possibly a dryer, storage tank, and intake and output filters; the compressed air treatment unit, which includes the FRL assembly (filter, pressure regulator, and possibly a lubrifier), which allows for filtration and local regulation of the supply pressure to the actuator valve; and the valve, which is the regulator.Some pneumatic actuation system components, including as compressors, treatment units, and valves utilized in pneumatic servo systems, are discussed here. The actuators operate and are manufactured similarly to hydraulic actuators, however they are significantly lighter due to the reduced operating pressure.

Compressors

Summarizes the many kinds of turbines used to create compressed air. In volumetric compressors, air or gas is pulled into the compression chamber through a valve, where its volume is lowered to induce gas compression. When a preset pressure is attained, the delivery valve is opened, causing the air mass to be distributed to the user.

In dynamic or turbo compressors, kinetic energy is transformed into pressure energy and delivered to the gas as a consequence of the impeller's rotating motion. The compression of the gas is determined by the motion of the piston, which is driven by a connecting rod and crank mechanism within a gas-tight cylinder. They may be single or double acting, and have one or more pistons and stages. They enable pressures of hundreds of bar in the case of many stages and flow rates of thousands of cubic metres per hour in the case of multiple cylinders. Vane compressors feature a rotor that is eccentrically connected to the axis of the cylinder in which it spins, resulting in a specific number of vanes that may move radially with regard to its axis. The vanes are centrifuged in contact with the seat of the stator throughout the continuous rotation motion of the rotor, isolating chambers whose volume changes gradually with the angular stroke, ensuring input suction on the one hand and compressed gas output on the other. Compression pressures are less than 15 bar, and maximum flow rates are 500 m3/h. They feature less flow pulsation, less vibrations, and are more compact than reciprocating piston compressors.

Inside a stator, two rotors rotate in opposing directions, one having convex lobes and the other with concave lobes. The connection of the two rotor profiles causes a drop in volume throughout the angular stroke and, as a result, compression of the gas. With pressures generally less than 15 bar, they offer a suitably constant flow up to 3000 m3/h.

Roots compressors, also known as superchargers, are made up of two figure-of-eight shaped rotors that counter-rotate within a stator to convey quantities of gas from suction to delivery. Because of leakage between the rotors and between the lobes and the casing, their efficiency is limited, and they are consequently employed for modest compression pressures, less than 2 bar. However, they, like screw compressors, may operate without lubrication, allowing oil-free air to be produced.

High compressed air flow rates ranging from a few thousand to 100,000 m3/h are obtained using both axial and radial dynamic compressors.

Units for Compressed Air Treatment

A local gas treatment unit, consisting of a filter linked to a compressed gas distribution and generation network, a pressure regulator, and, in certain cases, a lubricator L, provides pneumatic supply to a servosystem. The air is filtered by the deflector after passing through the filter, and solid and liquid contaminants in contact with the walls are deposited on the bottom of the cup as a result of the conical bottom screen, which is placed below the porous cylindrical element in sintered bronze or fabric.

The filtered air then enters the pressure regulator's intake, which is made up of an obturator in pressure, force equilibrium. The location of the primary obturator, which controls the flow towards the outlet, determines downstream pressure control. The passage aperture closes when the force due to downstream pressure, acting on a diaphragm and a translating piston, equals the force of the top spring, the preload of which is regulated by turning the control knob. If the pressure force is less than the intended value, the flow provided to the user tends to adjust for the pressure mistake, with the obturator shutting again when the set point is achieved. If the regulated pressure is higher than the intended value, an aperture channel opens between the user and the discharge.

Pneumatic Vessels

Because pneumatic valves are functionally comparable to those used in hydraulic systems, the basic principles outlined above should be followed. This is especially true for directional valves of the digital and proportional varieties. There are digital spools or poppet two-, three-, or four-way distributors with two or three working positions that may be operated manually, mechanically, pneumatically, or electrically in pneumatic systems.

Flow proportional valves are comparable to hydraulic valves in that they are available with a torque motor electromechanical converter (servovalve) as well as a servosolenoid operating directly on the spool. In addition to these components for managing gas flow, digital electrically controlled two- or threeway valves are utilised, and their control signals are modulated using PWM, PFM, PCM, PNM, or a combination of these.

For pneumatic actuation, three-way pressure proportionality valves are available, which transform an electrical reference signal with standardised input into a regulated output pressure with excellent dynamics and high accuracy.

Valves using PWM (Pulse Width Modulation)

PWM valves have a similar construction to the comparable electrically controlled unistable digital valves, but they employ a mechanism for modulating the width of the pulses transmitted to the solenoid to provide proportional control of the flow rate. A particular driver converts the input voltage reference analogue signal VREF (for example, 0-10 V) into a digital VPWM (ON/OFF) signal with pulse length proportionate to the input signal. A digital controller, such as a PLC, may also create the modulated signal directly.

The PWM working principle is shown in Figure 4.58. The digital voltage signal transmitted to the valve solenoid is composed of a pulse train with constant amplitude and period T, but the duration t of each pulse is a linear function of the analogue value of the reference voltage. The average valve opening value, and therefore an initial estimate of the produced flow, is a function of the pulse duration t, specifically of the duty cycle t/T, and rises as the latter rises.

PWM valves often lack feedback, therefore the value of the downstream pressure, and hence the flow rate, is determined by the kind of pneumatic circuit used. The functioning of two-way, two-position valves using PWM as a flow regulator and a pressure regulator. In plan a, the valve regulates the flow between the two sites proportionately at pressure PS (feed pressure) and pressure PV (downstream pressure) kept constant. Because the flow is just a function of the valve's aperture in this example, the proportionality is linear. In plan b, the cross-fitted valves regulate the mass flow rate G1 and discharge flow G2 while controlling the pressure PR, for example, within a fluid capacity of volume V. The regulated pressure PR time gradient corresponds to the resultant flow G entering the reservoir.

The following factors influence the performance of a PWM on/off valve regulation:

1. Times for valve opening and shutting
2. Reliance on the upstream and downstream pressures' opening and shutting timings
3. Valve size period T or modulation carrier frequency f = 1/T
4. Valve operating life

While short opening/closing durations and large flow capacity are usually opposing qualities in an on/off valve, it is always required to strike a compromise when building the system between the necessity for strong control resolution and linearity and a high reaction dynamic.Typical carrier frequency values f = 1/T in pneumatic servosystem applications vary between 20 and 100 Hz, requiring valves with opening/closing periods of 1 5 ms. typically closed 2/2 valve that provides minimal opening times These properties are attained by lowering the mass of the moving components using a poppet attached to a tiny oscillating bar, while almost eliminating friction between the parts in relative motion.

Valves with Proportional Pressure Regulator

These valves are often three-way, with either double poppets or a spool. Poppet valves work similarly to pressure regulator valves. As with pressure regulators, the poppet that separates the high pressure environment from the controlled pressure environment is in equilibrium between the force due to the regulated pressure and that exerted by the control block's action. The latter may be the force of the servo-solenoid armature directly or that caused by a pressure regulated by the control block acting on a piston or a diaphragm coupled to the poppet.

The equilibrium of the forces acting on the piston of poppet 3, specifically the force FR of the regulation pressure PR in the servochamber 4 directed downwards and the force FC due to the action of the regulated pressure Pc on the outlet, directed upwards, determines the opening of the feed aperture between the ports P and A. If FR = FC, the valve's movable bodies are in the positions depicted in the figure, and the chamber at controlled pressure PC is isolated from both supply and discharge. If FR > FC, the two poppets descend and the feed aperture opens, directing the air mass to the output and rebalancing the pressure PC to the required value. If FR FC, the regulating poppet travels higher, but while staying at the top end of its stroke, the seal 5 opens, allowing the masses to flow from port A to the exhaust E. The modulated control signal from the regulation block is received by the two 2-way PWM valves. These are configured such that one controls the flow entering the control chamber 4and the other controls the flow departing towards discharge. The control signal is turned into a pressure proportional signal by suitable action.

General Characteristics of sensor

Sensors and actuators are both essential components of any closed loop control system. A control system is another name for such a system. Typical control system comprises of a sensing unit, a controller, and an actuation unit. A sensing unit might be as basic as a single sensor or as complex as filters, amplifiers, modulators, and other signal conditioners. The controller receives data from the sensing unit, makes judgements using the control algorithm, and sends instructions to the actuating unit. The actuating unit is made up of an actuator and, if desired, a power supply and a connection mechanism.

A sensor is a device that creates a proportionate output signal when subjected to a physical phenomenon (temperature, displacement, force, etc). The terms transducer and sensor are often used interchangeably. A sensor, on the other hand, is ideally a device that reacts to a change in a physical phenomenon. A transducer, on the other hand, is a device that changes one kind of energy into another type of energy. Sensors are transducers when they detect one kind of energy input and output another type of energy. A thermocouple, for example, reacts to temperature changes (thermal energy) by producing a proportionate change in electromotive force (electrical energy). As a result, a thermocouple might be referred to as a sensor or transducer (Figure 5.3).

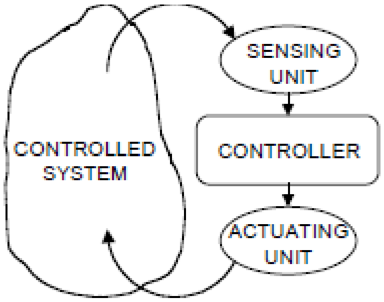


Figure 5.3 Represents General Characteristics of sensor

Sensory input is required by industrial robots to:

1. Locate randomly placed things

2. Allow for changes in object form

Protect against unsafe and unexpected circumstances. Especially if the robot needs operate in close proximity to humans

1. Allow "intelligent" mistake recovery
2. Perform quality control

Sensors will enable robots to become more intelligent. However, the linked robotic software must be able to accept data from sensors and interpret the required real-time information and directives for decision making.

In general, robotic sensors are classified into two types:

i. Internal state sensors - a device that measures the position, velocity, and acceleration of a robot joint or end-effector. Potentiometers, tachometers, resolvers, encoders, differential transformers, optical interrupters, optical encoders, and accelerometers are examples of these devices.

ii. External state sensors - a device used to monitor the robot's kinematics and/or dynamics in connection to its task, surroundings, or the item being controlled.

Furthermore, sensors may be categorised according to:

1- Mechanical sensors monitor location, shape, velocity, force, torque, pressure, vibration, strain, and mass.

2- Voltage, current, charge, and conductivity are all measured by electrical sensors.

3- Magnetic sensors determine the magnetic field, flux, and permeability.

4- Temperature, flux, conductivity, and specific heat are all measured using thermal sensors.

Acoustic, ultrasonic, chemical, optical, radiation, laser, and fibre optic are some of the other forms.

Furthermore, depending on the kind of output signal, sensors are categorised as analogue or digital. Analog sensors provide continuous signals that are proportional to the perceived parameter and, in most cases, need analog-to-digital conversion before being sent to a digital controller. In contrast, digital sensors provide digital outputs that may be readily interfaced with the digital controller. Adding an analog-to-digital converter to the sensing device often results in digital outputs. If a large number of sensors are needed, it is more cost effective to use basic analogue sensors and link them to a control system equipped with a multi-channel analog-to-digital converter.

Sensor generalities

Several industrial sensing devices allow the robot to position things in certain areas or to carry out different production processes:

a. Transducers. Nonelectrical signals are converted into electrical energy through sensors.
b. Contact detectors (limit switches). Switches that are activated or deactivated by applying pressure to a lever or roller that activates the switch.
c. Sensors that do not need touch. Sensors that detect pressure variations, temperature, or an electromagnetic field.
d. Sensors for proximity. Devices that use inductance, capacitance, light reflection, or eddy currents to detect the presence of a nearby item.

e. Distance sensors. Laser-interferometric gauges, for example, enable an accurate distance measurement.
f. Sensors for touch. Tactile sensors are devices that utilise touch to detect the presence of an item; strain gauges may be used as tactile sensors.
g. Sensors for displacement. Indicate the precise position of a gripper or manipulator. Resistive sensors, typically wire-wound ohms with a slider contact, are often utilised. The circuit resistance varies when force is applied to the slider arm.
h. Accelerometers. Tachometers are devices that measure the speed of the motor shaft.
i. Sensors for torque. Calculate the amount of effort necessary to rotate a mass via an angle.

Sensors for vision. Dissectors, gliding scanners, vidicons, orthicons, plumbicons, and chargecoupled devices are examples of devices that allow a robot to perceive an object and create modifications suited for object handling.

Encoders make use of spinning discs with optical windows. The encoder includes an optical disc with finely carved windows. Light from emitters is directed to detectors through perforations in the disc. The light streaks are broken when the encoder shaft rotates. The encoder seen above is a quadrature encoder, which will be explored more below. There are two kinds of encoders: absolute and incremental.

A single revolution of the shaft will be measured by an absolute encoder. The same shaft inclination will always provide the same result. Typically, the result is a binary or grey code number. An incremental (or relative) encoder generates two pulses that may be used to calculate displacement.

The direction of rotation is determined using logic circuits or software, while the displacement is determined using count pulses.

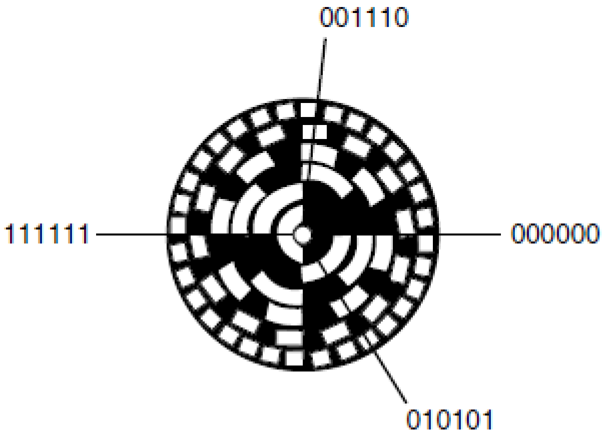
The time between pulses may be used to calculate velocity.

Absolute Encoders

If the application demands information of the location of the motors immediately upon system startup, an absolute encoder may be read. An absolute encoder is similar to an incremental encoder, except that the disc utilised contains several concentric code tracks and each code track has its own photodetector. As illustrated in Figure 5.6, the number of code tracks is equal to the encoder's binary resolution.

There are eight coding tracks in an 8-bit absolute encoder. The 8-bit output is read to create an 8-bitword that indicates absolute location. While absolute encoders come in a number of resolutions, the most prevalent are 8-, 10-, and 12-bit binary.

Absolute encoders are often more costly than quadrature encoders due to their complexity. Position may be output in either parallel or serial format by absolute encoders. Because absolute encoders come in a variety of output formats, it is essential to verify that the robot controller or intelligent drive is compatible with the specific model of the absolute encoder.Figrue 5.4 represents the Absolute Encoders.



Figrue 5.4 represents the Absolute Encoders

Analog sensor

Displacement, force, speed, acceleration, and strain sensors are popular analogue sensors used in robotic applications. These sensors, like encoders, may be employed in either an open-loop or closed-loop form inside the robot system. A force sensor, for example, may be used to measure the weight of things being constructed for quality control. Alternatively, a force sensor might be attached to the gripper in a robot end effector to provide feedback to the glove actuator. Using the gripper control system, items may be held with a consistent force.

Sensors for Analog Displacement

These sensors can monitor angular and translation position relative to a reference location. They emit a constantly changing signal proportional to the location of the detected item. The following are the most popular sensors and technologies used for displacement measurement:

1. The potentiometer
2. Contact sensor (LVDT)
3. Resolvers
4. Inductive terms
5. The capacitive
6. The optical
7. Ultrasonic technology
8. The Hall effect

Sensors that are digital

A digital sensor will either provide a "on" or a "off" electrical signal. Aside from encoders, the majority of digital sensors used in robotic applications are static digital sensors, meaning their value is dependent only on the digital state of the output rather than the frequency of an output pulse train. For acquisition, static digital sensors do not need counter electronics. Digital sensors may be employed in a broad range of robotics applications. These are some examples:

Digital Sensors Using Switches a mechanical switch is the most basic and least expensive sort of digital sensor used in robotics.

Noncontact Digital Sensors - Noncontact digital sensors such as inductive, capacitive, optical, and hall-effect are extensively employed in robotics to decrease contact wear and switch bounce.

Solid State Output –

1. Transistors are widely used as the output driver technology in digital sensors.
2. Proximity detectors
3. Limit switches
4. Sensors for safety, such as light curtains

Angular and Linear Position Sensors

Linear and angular (rotational) position sensors are two of the most basic measures found in every mechatronics system. Lists the most popular types of position sensors. In general, position sensors provide an electrical output proportionate to the movement they detect.

Contact sensors include strain gauge, LVDT, RVDT, tachometers, and so on. Encoders, Hall Effect, capacitance, inductance, and interferometers are examples of noncontact devices. They may also be classed according to their measuring range. High-resolution sensors, such as Hall Effect, fibre optic capacitance, capacitance, and strain gauge, are often only suited for extremely tiny ranges (about 0.1 mm to 5 mm). Differential transformers, on the other hand, offer a considerably wider range and better resolution.

Interferometer sensors provide both extremely high resolution (in microns) and a wide range of readings (typically up to a meter). However, interferometer sensors are huge, costly, and take a long time to set up.

Among various linear displacement sensors, the strain gauge has the highest resolution with the lowest noise level and is the least costly. A typical resistance strain gauge is made up of resistive foil, depicts a common setup for measuring the normal strain of a part loaded under tension. Strain gauge 1 is attached to the loading member, while strain gauge 2 is bonded to a second, unloaded member composed of the same material. This configuration adjusts for any temperature influence. When the member is loaded, gauge 1 elongates, altering the gage's resistance. The voltage sensitive wheat stone bridge circuit converts a change in resistance into a change in voltage. Assuming that all four arms' resistances are originally equal, the change in output voltage.

Methods of angular position measurement

Linear translation along a fixed axis and angular rotation around a fixed axis are by far the most prevalent movements in mechanical systems. Composing these smaller movements frequently results in more complicated motions.

This chapter provides an overview of some of the many methods for detecting linear and rotational motion along a single axis. We organised the sensing modalities based on the physical effect used to generate the measurement.

i. Resistance

Using a variable resistor known as a potentiometer or rheostat to detect rotational or linear motion is one of the simplest and least costly methods. We will concentrate on rotary potentiometers, or "pots," although the principle of functioning is the same for the linear case.

A pot has three terminals. Terminals 1 and 3 link either side of a length of resistive material, such as partly conductive plastic, ceramic, or a long thin wire. (To save space, the long wire is coiled around in loops to form a coil, thus the term wire wound potentiometer.)

Terminal 2 is attached to a washer, which glides across the material while the pot shaft spins. The overall resistance of the pot R13 is the sum of the resistances R12 between terminal 1 and the wiper and R23 between terminal 3 and the wiper. Typically, the wiper may spin from one end of the resistive material to the other (R13=R12) or vice versa (R13=R23). A single-turn pot is one in which the whole action of the wiper is generated by one rotation of the shaft or less. A multi-turn pot is one in which the whole motion is generated by many rotations. Typically, a pot is utilised by connecting terminal 1 to a voltage V, terminal 3 to ground, and measuring the rotation by the voltage at the wiper at the wiper is V (R23/R13) and is a linear function of shaft rotation. The string pot or draw-wire sensor is a wonderfully simple absolute sensor for a broad variety of distances. It is made up of a string wrapped around a spool and a potentiometer to monitor spool rotations. The string is kept tight by a return spring. Sensors with multi-turn pots may measure lengths of up to several metres. Using smaller single-turn pots and a small spool, the same approach may be used for short lengths (a few millimeters). Both are tolerant of misalignment or arc-like motion. String pots are prone to string breakage in exposed applications, although the sensor element is tiny and inconspicuous. RDP Electronics, SpaceAge Controls, and UniMeasure are among the manufacturers.

The flexible bend sensor is another sort of resistive sensor. The resistance of conductive ink between 2 electrical connections on a flexible material varies as the material bends and expands. The analogue voltage may be used to measure the bend in a voltage divider with a fixed resistor. A sensor like this might be used to detect touch (like a whisker) or to provide a rough estimate of the deformation of a surface to which it is connected.

CHAPTER 6

Capacitive

Mr. Dipendra Kumar, Associate Professor,
Department of Mechanical Engineering, School of Engineering & Technology,
Jaipur National University, Jaipur, India
Email Id-dipendra1987@jnujaipur.ac.in

Capacitance may be used to assess millimeter-level closeness or linear motion. A parallel plate capacitor's capacitance where is the permittivity of the dielectric between the plates, A is the area of overlaps of the two plates, and d is the plate spacing. C is a nonlinear function of the distance d as the plates translate with in direction normal to their planes. C is a linear function of the area of overlap A as the plates translate relative to each other in their planes. Capacitive sensors can detect metallic or nonmetallic objects, liquids, or any item with a dielectric constant larger than air when used as proximity sensors.

One popular sensing arrangement has one sheet of the capacitor enclosed in an insulator within a probe. The external target item serves as the capacitor's second plate, and it must be connected to the proximity sensor ground. As the sensor gets closer to the target, the capacitance rises, altering the oscillation of a detector circuit that includes the capacitor. This changed oscillation may be utilised to communicate closeness or to calculate distance. Cutler-Hammer and RDP Electronics are two capacitive sensor manufacturers.

AC Inductive

The linear variable differential transformer, or LVDT, is the most well-known AC inductive sensor. The LVDT is a tube with a plunger, and the variable to be monitored is the motion of the plunger. The tube is wrapped with at least two coils, one for excitation and one for pickup. An alternating current current (usually 1 kHz) is transmitted via the excitation coiled, and an alternating current signal from the pickup coil is detected and compared in amplitude and phase (0 or 180°) to the excitation current.

Demodulation, also known as synchronous detection, necessitates the use of support electronics. A ferromagnetic slug is carried by the plunger, which improves magnetic coupling from excitation coil to the pickup coil.

The detected signal may be zero (when the ferrite slug is centred in the pickup coil) or growing in amplitude in one or both phases, depending on the slug's motion inside the pickup coil. LVDTs are a highly developed technology that can be very precise, down to the micron level in certain situations. They have displacement ranges ranging from millimetres to metres. They do not tolerate misalignment or nonlinear motion in the same way that a string pot does. Figure 6.1 Represents the AC Inductive

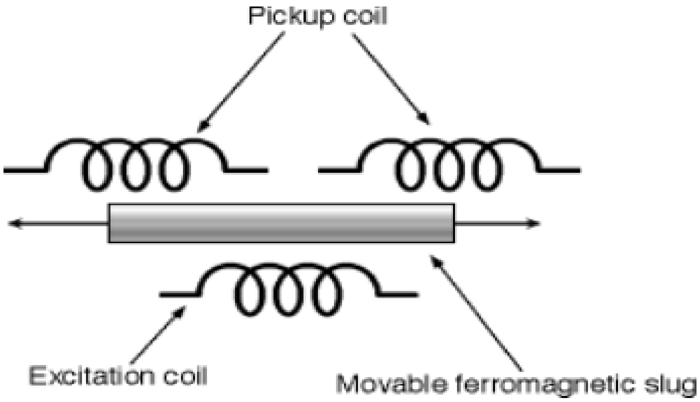


Figure 6.1 Represents the AC Inductive

As illustrated in Figure Above, a linear variable differential transformer (LVDT) is a sensing transformer that consists of a main winding, two neighboring secondary windings, and a ferromagnetic core that can be changed axially inside the windings. Depending on how they are mounted, LVDTs may measure position, acceleration, force, or pressure. LVDTs give position feedback in motion control systems by sensing the change in mutual inductance between their main and secondary windings generated by the linear movement of the ferromagnetic core.

A spring-loaded sensing shaft connects the core. When the shaft is pushed, the core travels axially inside the windings, connecting the excitation voltage in the main (middle) winding P1 to the two adjacent secondary windings S1 and S2. A schematic representation of an LVDT 5. The voltages produced in S1 and S2 have similar amplitudes and are 180o out of phase when the core is centred between S1 and S2. Because both voltages cancel with a series-opposed connection, the net voltage across the secondaries is zero. This is referred to as the null location of the core.However, moving the core to the left causes secondary winding S1 to be more firmly linked to primary winding P1 than secondary winding S2, resulting in an output sine wave in phase with both the primary voltage. Similarly, moving the core to the right causes winding S2 to be more tightly linked to primary winding P1, resulting in an output sine wave that is 180° out of phase with the main voltage. The amplitudes of the LVDT's output sine waves fluctuate symmetrically with core movement, to the left or right of the null point.

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Resolvers

As an alternative to an encoder, a resolver is simply a rotary transformer that may give position feedback in a servosystem. Resolvers that detect position in closed-loop motion control applications contain one rotor winding and two stator windings that are arranged at 90o. The stator is constructed by winding copper wire through a stack of iron laminations affixed to the housing, while the rotor is constructed by winding copper wire through a stack of laminations installed to the resolver's shaft.

The resolver's rotor is mechanically connected to the driving motor and load in a servosystem. When a rotor winding is activated by an alternating current reference signal, it creates an alternating current voltage output whose amplitude changes with the sine and cosine of shaft position. The phase shift between the applied signal to the rotor and the induced signal appearing on the stator coil may be used to calculate rotor position. The ratio of the sine load is applied to the cosine output amplitude as the resolver shaft spins one revolution may be used to calculate the absolute location of the load being driven.

Brushes and slip rings may be used to connect certain resolvers to the rotor, although brushless resolvers are commonly used in motion control applications. A revolving transformer on the rotor inductively links the signal to the rotor. Brushless resolvers are more durable than encoders and have operational lifetimes up to ten times that of brush-type resolvers since they lack slide rings and brushes. The most common reason of resolver failure is bearing failure. Because these resolvers lack brushes, they are insensitive to vibration and impurities. Brushless resolvers typically have diameters ranging from 0.8 to 3.7 in. Threaded and splined rotor shafts are common.

Most brushless resolvers can work between 2 and 40 volts, and their winding is driven by an alternating current reference voltage at frequencies ranging from 400 to 10,000 hertz. The magnitude of any stator winding voltage is proportional to the cosine of the angle, q, between the rotating coil axis and the stator coil axis. The vector sum of the voltages across the two linked coils will be induced across any pair of stator terminals. Accuracy of 1 arc-minute is possible. The stator's sinusoidal output signals are routed to a resolver-to-digital converter (RDC), a specialised analog-to-digital converter (ADC) that transforms the signals to a digital representation of the real angle needed as an input to the motion controller in feedback loop applications.

Optical

The features of an optical frequency electromagnetic wave are principally modulated in optical sensing systems. In the case of optical sensors, the measurand directly alters the electromagnetic wave's characteristics. The miniature sensor communicates with the measurand in the case of micro-sensors that employ optical interfacing. The microsensor then modifies an optical signal characteristic to offer an indicator of the measurand. The electromagnetic wave's characteristics may be changed in the following ways:

1. Intensity;
2. Phase;
3. Wavelength;
4. Spatial location;
5. Frequency; and
6. Polarization.

Optical sensors have indeed been making their way into an expanding variety of applications for decades. The advancement of semiconductor technology in the 1940s and 1950s resulted in lower-cost, more compact, more efficient light-sensing devices. Camera light metres, street lights, and traffic counts all employed photodetectors. Because of fibre optics, delicate equipment might operate in electrically loud surroundings. Sensors that were bundled with small integrated circuits produced detectors that were easier to operate. At a modest cost, optical sensors have increased the efficiency and reliability of control systems.

The phrase "optical sensor" refers to a class of sensors that employ different wavelengths of light to accomplish certain activities. Some employ lasers, while others use available light, but all types of optical sensors may be generally classified based on the work they do.

Photoelectric (Optical) Sensors

Light sensors have been around for over a century; initially, photocells were employed to read audio tracks on motion films. However, current optical sensors are much more complex. Optical sensors need a light source (emitter) as well as a detector. Emitters will use LEDs and laser diodes to generate light beams in the visible and invisible spectrums.

Photodiodes or phototransistors are often used in detectors. When an item is present, the emitter and detector are positioned such that it blocks or reflects the beam.

On the left, a light beam is created and focussed by a lens. A second lens on the detector side focuses the beam on the detector. If the beam is disrupted, the detector will detect the presence of an item. The oscillating light wave is employed by the sensor to filter out ambient light.

The light from the emitter is switched on and off at a promotes physical. When the detector detects light, it checks to see whether it is of the same frequency. If light is received at the correct frequency, the beam is not fractured. The oscillation frequency is in the KHz range and is too quick to be detected. The frequency approach has the advantage of allowing the sensors to be utilised at lesser power over greater distances.

Opposed mode refers to the configuration of an emitter to point directly towards a detector. The component will be recognised when the beam is brokenthis sensor requires two distinct components. This configuration works well with opaque and reflecting objects, with the emitter and detector separated by hundreds of feet. Figure 6.2 represent the opposed mode optical sensor.

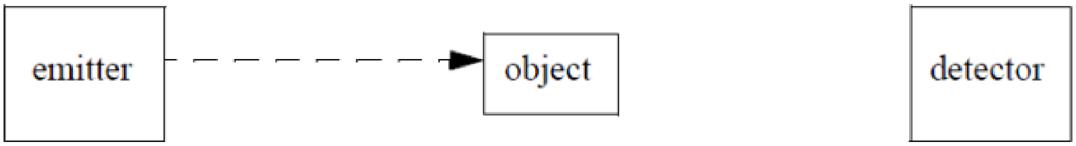

Figure 6.2 represent the opposed mode optical sensor

Having the emitter and detector separate raises maintenance issues and necessitates alignment. The emitter and detector should be housed in the same unit if possible. However, while these sensors are ideally adapted to bigger objects up to a few feet away, light must be reflected back.

The emitter emits a light beam. When light is reflected back from the reflector, the majority of the light beam is returned to the detector. When an item blocks the path of the beam between the emitter and the reflector, the beam is no longer reflected back to the detector, and the sensor activates. One possible issue with this sensor is that reflected items may provide a decent beam. This issue is solved by first polarising the radiation at the emitter (through a filter) and then employing a polarised filter at the detector. The reflector employs tiny cubic reflectors, and the polarity is rotated by 90 degrees when the light is reflected.

Photo resistors

Photoresistors, also known as light intensity sensors, are devices that detect and quantify the intensity of light. These sensors are employed in a variety of applications in science and current technology. In many mobile phones, for example, intensity sensors are employed in liquid crystal displays to change the screen brightness based on the brightness of the surroundings. They are also employed in contemporary cameras to change the image's exposure.

Proximity Sensors Proximity sensors detect movement by reading changes in the ambient light environment. These sensors have a wide range of current uses. They are employed in trap cameras in the hunting business, where the sensor triggers the camera to snap a picture of passing animals. They are also used in traffic cameras, and work on the same concept. The most apparent use is in holiday decorations that activate as a person approaches.

Photodiodes are optical sensors that convert light to electrical current. This sort of sensor is often seen in consumer electronics. They may be found in remote control sensors, compact discs, and other electronic components. Photodiodes are also used in many types of disc players.Photodiodes are more sensitive than photo resistors, yet they share many uses.

The Benefits and Drawbacks of Optical Sensors

R&D in the optical sensor sector is driven by the anticipation that optical sensors will offer considerable benefits in terms of attributes over traditional sensor kinds. Some of the benefits of optical sensors over nonoptical sensors Taking use of optical fibres' ability to transmit and receive optical signals over great distances, a contemporary trend is to build sensor networks, or sensor arrays.

This eliminates the need to convert between transistors and photonics at each sensor point, lowering costs and boosting flexibility. Interference from various effects is a problem for all sensors, optical and non-optical. A strain or pressure sensor may be very temperature sensitive.

Over the past five years, intense R&D has been done for optical sensors to give ways of discriminating between diverse impacts.

.Advantages of Optical sensor:

i. increased sensitivity
ii. Electrical passivity Freedom from electromagnetic interference
iii. Wide dynamic range
iv. Both point and dispersed configurations are possible.
v. Capabilities for multiplexing

Encoders Schemes

As demonstrated in figure below encoders employ spinning discs with optical windows. The encoder includes an optical disc with finely carved windows. Light from emitters is directed to detectors through the perforations in the disc. The light beams are broken when the encoder shaft rotates (Figure 6).

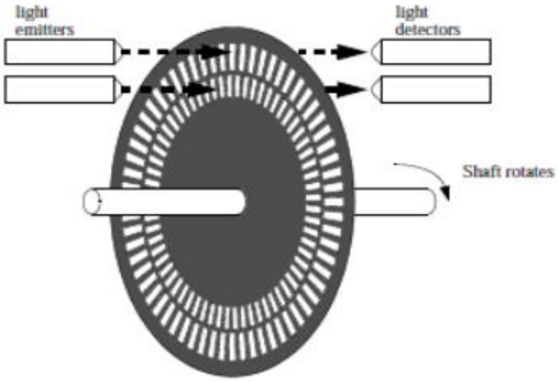

Figure 6.3 represents the Encoders Schemes

There are two kinds of encoders: absolute and incremental. A single revolution of the shaft will be measured by an absolute encoder. The same shaft angle will always provide the same result.Typically, the result is a binary or grey code number. An incremental (or relative) encoder generates two pulses that may be used to calculate displacement. The direction of rotation is determined using logic circuits or software, while the displacement is determined using count pulses. The time between pulses may be used to calculate velocity shows encoder discs. The absolute encoder has two rings: the outer ring is the encoder's most significant digit, while the inner ring is the encoder's least significant digit.

The relative encoder consists of two rings, one rotated very few degrees ahead of the other but otherwise identical. Both rings detect motion to one-quarter of the disk's circumference. To improve the absolute encoder's accuracy, additional rings and emitters and detectors must be added to the disc. To improve the relative encoder's accuracy, just add additional windows to the current two rings. Encoders typically have 2 to thousands of windows per ring.

When employing absolute encoders, the location is measured immediately throughout a single spin. The total number of revolutions must be counted individually if the encoder turns numerous times.

When utilising a relative encoder, the rotational distance is calculated by counting the pulses from one of the rings. If the encoder only spins in one direction, the entire distance may be calculated by counting the pulses from one ring. A second ring must be utilised to identify when to remove pulses if the encoder may spin in both directions depicts the quadrature system with two rings. The signals are configured in such a way that one is out of sync with the other. Take note that for various rotational orientations, input B can leads or lags A.When a controller is switched on, absolute and relative encoders often need a calibration phase. Typically, this entails moving an axis until it hits a logical sensor that indicates the end of the range. The range's end point is then utilised as the zero location. Machines that employ encoders and other relative sensors stand out because they often shift to an extreme position before usage.

Encoders that rotate

Rotary encoders, also known as rotary shaft encoders or rotary shaft-angle encoders, are electromechanical transducers that convert shaft rotation into output pulses that can be counted to determine the number of shaft revolutions or angles. In servo feedback loops, they offer rate and positioning information. Per revolution, a rotary encoder may detect a number of distinct points. The figure is known as points per revolution and is comparable to the steps a revolution of a stepper motor. An encoder's speed is measured in counts per second. Rotary encoders may indirectly report position by measuring the motor-shaft or leadscrew angle, but they can also directly monitor the reaction of spinning machinery.

The two types of rotary encoders that are most often used are incremental optical shaft-angle encoders and absolute optical shaft-angle encoders. Direct contact or brush-type and magnetic rotary encoders are also available, although they are less common in motion control systems. Rotary encoders are commercially available as standard or catalogue devices, or they may be custom manufactured for uncommon applications or survival in severe conditions. Rotary encoders are typically packed in cylindrical casings with diameters ranging from 1.5 to 3.5 in.

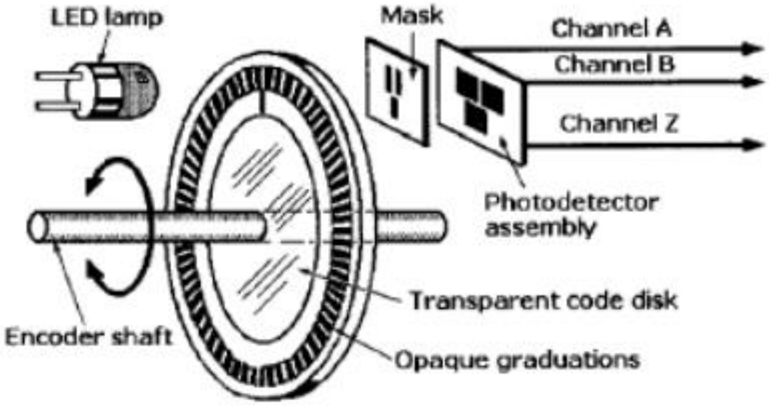

Figure 6.4 Encoders that rotate

The resolution varies between 50 cycles per shaft rotation and 2,304,000 counts per revolution. The hollow-shaft encoder, a variant of the typical layout, removes the challenges associated with normal versions' installation and shaft run out. Hollow shaft models are offered for attachment on shafts ranging in diameter from 0.04 to 1.6 in (1 to 40 mm). On the encoder shaft, a glass or plastic code disc spins between internal light sources, often a light-emitting diode (LED) on one side and a mask and matching photo-detector assembly on the other. As depicted, the incremental code disc has a pattern of evenly spaced opaque and transparent segments or spokes radiating out from its centre. The encoder's electronics board generates electrical signals that are supplied into a motion controller, which calculates position and velocity information for feedback purposes an exploded view of an industrial-grade incremental encoder, with glass code discs with finer graduations capable of 11- to more than 16-bit resolution used in high-resolution encoders and plastic (Mylar) discs capable of 8- to 10-bit resolution used in more rugged encoders subject to shock and vibration. Figure 6.4 Encoders that rotate.

The most common kind of incremental encoder is the quadrature encoder. Light from the LED is "chopped" before it reaches the photodetector assembly after going through the revolving code disc and mask. As illustrated in the diagram, the assembly's output signals are transformed into two streams of square pulses (A and B).The number of square pulses in each channel is the same as the number of code disc segments passing through the photodetectors as the disc spins, but the waveforms are 90o out of phase. If the pulses in channel C lead those in channel B, for example, the disc is revolving clockwise; if the pulses in channel Alag those in channel B, the disc is moving anticlockwise. The location and direction of rotation may be established by monitoring both the number of pulses and the relative phases of signals A and B. Many incremental polygonal encoders feature a third output Z channel to provide a zero reference or index signal once each rotation. This channel may be gated to the A and B quadrature channels and utilised to correctly trigger events inside the system. In addition, the signal may be utilised to align the encoder shaft with a mechanical reference.

Encoders that are absolute

An absolute shaft-angle optical encoder with numerous light sources and photodetectors, as well as a code disc with a maximum of 20 tracks of segmented patterns organised as annular rings. The code disc generates a binary output that uniquely specifies each shaft angle, resulting in an absolute measurement.This sort of encoder is constructed in the same manner as the incremental encoder except that the code disc moves between radially arranged linear arrays of LEDs and photodetectors, and an LED opposes a detector for each track or annular ring.

The arc lengths of the opaque nor transparent sectors decrease as the radial distance from the shaft increases. These glass or plastic discs generate either the natural binary or Gray code.The amount of annular rings or lines on the disc determines the precision of the shaft location. Light travelling through each train or annular ring provides a constant stream of signals from the detector array while the code disc spins. The output is converted into a binary word by the electronics board.

The output code word's value is read radially beginning from the most significant bit (MSB) on the disk's inner ring to the least significant bit (LSB) on the disk's outer ring. The main advantage of using an absolute encoder over an incremental encoder is that its code disc remembers the previous angular position of the encoder shaft after it stops moving, whether the machine is turned down intentionally or due to a power outage. This ensures that the most recent reading is retained, which is a critical feature for many applications. An absolute optical rotary encoder requires a binary-code disc. The opaque sectors have a binary value of 1, whereas the transparent sectors have a binary value of 0.

Velocity and Acceleration Sensors

Motion-related acceleration is an essential component of kinematic quantities such as location, velocity, acceleration, and jerk. Each of these values has a linear connection with the ones next to it. In other words, all kinematic quantities may be deduced from a real case. Acceleration, for example, may be calculated by differentiating the associated velocity or integrating the jerk. Similarly, velocity may be calculated by either differentiating the location or integrating the acceleration. Only integration is generally utilised in practise because it gives superior noise characteristics and dampening.

There are two types of acceleration measuring techniques: direct measurements using particular accelerometers and indirect measures that discern velocity. These approaches' usefulness is determined by the kind of motion (curvilinear, angular, or curvilinear motion) or equilibrium-centered vibration. Direct measurement accelerometers are suitable for rectilinear and curved movements. However, angular acceleration is often assessed indirectly.

Acceleration is a critical metric in absolute motion measurements, vibration, and shock sensing. Accelerometers are commercially available in a broad range and many distinct varieties to fulfil a variety of application needs, mostly in three areas: Commercial applications include automobiles, ships, appliances, sports, and other hobbies; industrial applications include robotics, machine control, vibration testing, and instrumentation; and high reliability applications include military, space, and aerospace, seismic monitoring, tilt, vibration, and shock measurements.Accelerometers have been around for a long time. Initially, accelerometers were mechanical devices that relied on analogue circuitry. Although early accelerometers are still widely used, current accelerometers are basically semiconductor sensors embedded into electronic chips and combined with signal processing circuitry. Mechanical accelerometers measure the force applied to a mass as it accelerates. The thermal kind of accelerometer detects position by heat transfer.

Acceleration measurement is critical for systems susceptible to stress and vibration. Although acceleration may be calculated using time history data obtained from linear or rotational sensors, a voltmeter whose output is directly proportional to acceleration is preferable. The seismic mass type and the piezoelectric accelerometer are two typical kinds. The elastic mass type accelerometer is based on the motion of a mass relative to its supporting structure. The seismic mass's intrinsic frequency restricts its usage too low to medium frequency applications. The piezoelectric accelerometer, on the other hand, is more compact and ideal for high frequency applications.

Tach generator

A tachogenerator (tachometer) is a DC generator that may offer servo system velocity feedback. The output voltage of the tachometer is related to the rotational speed of the armature shaft that drives it. It is mechanically linked to the DC motor in a typical servo system application and sends its output voltage back to the controller and amplifier to regulate the drive motor and load speed. A cross-sectional illustration of a tachometer housed in the same enclosure as the DC motor and a resolver. Encoders and resolvers are components of independent loops that give position feedback.

Lines of force are cut when the tachometer's armature coils spin through the stator's magnetic field, inducing an electromotive force in each of its coils. This emf is proportional to the pace of change. Magnetic lines of force are severed and are proportional to the velocity of the motor's driving shaft. Fleming's generator rule sets the direction of the emf.

The tachometer's commutator converts the armature coil's AC to DC, and its value is directly proportional to shaft rotation speed, while its polarity relies on shaft rotation direction. Shunt wound and permanent magnet (PM) tachometers are the two most common forms of DC tachometers used in servosystems nowadays. Moving-coil tachometers, like motors, do not contain iron in their armatures. The windings of the armature are coiled from tiny copper wire and fused with glass fibres and polyester resins into a stiff cup that is connected to its coaxial shaft.

This armature is iron-free, has a lower inertia than typical copper and iron armatures, and has a low inductance. As a consequence, the moving-coil tachometer responds more quickly to variations in speed and produces a DC output with extremely low ripple amplitudes.Tachometers may be purchased as stand-alone units. They may be firmly attached to the servomotor housings and mechanically linked to the servomotor shafts. If the DC servomotor is brushless or moving-coil, the standalone tachometer will be brushless as well, and they will share a similar armature shaft while being housed separately. Figure 5.29 depicts a brush-type DC motor with feedback provided by a brush-type tachometer. Furthermore, separate tachometer bearings are no longer required. In cases where accurate location in addition to speed regulation is needed, an incremental encoder may be installed on the same shaft.

Optical Incremental Encoders

The most prevalent kind of feedback device for robotic systems is incremental encoders. They generally generate TTL-level digital pulses. Rotary encoders are devices that are used to determine the angular position and direction of a motor or mechanical driving shaft. Linear encoders are devices that measure linear position and orientation. They are often used in linear stages and linear motors. In addition to location and direction of motion, rotary or linear encoder inputs may be used to calculate velocity.

A glass or metal disc is coupled to a motor or mechanical driving shaft in a rotary incremental encoder. A code track is a pattern of solid and transparent sectors on the disc. A light source is on one side of the disc, and a photodetector is on the other. The code track interrupts the light projected onto the photodetector as the disc spins with the motor shaft, resulting in a digital signal output. The number of opaque/transparent sector pairs on the code track, also known as line pairs, correlates to the number of cycles the encoder will produce every rotation. The encoder's basic resolution is defined by the number many cycles per revolution (CPR).

Quadrature Encoders

Another sort of incremental encoder is quadrature encoders. A two-channel quadrature encoder detects both position and direction using two light detectors. The photo detectors are 90 degrees apart with relation to one line pair on the code track. Because the two output signals, A and B, are 90 degrees out of phase, one will trail the other as the disc spins. If A precedes B, the disc rotates clockwise, as. If B comes before A, the disc rotates anticlockwise, as show four distinct pulse edges that occur throughout each cycle. Each rising and falling edge generates a distinct encoder count, essentially quadrupling encoder resolution, such that a 500 CPR (cycles per revolution) encoder gives 2000 counts per revolution with quadrature decoding.

To increase noise immunity, the electrical complements of channels A and B might be incorporated as differential signals. This is particularly significant in cases where the encoder and motion controller or electrical drive are separated by extensive wire lengths.

A third output channel, known as an index or zero pulse, is included in certain quadrature encoders. This signal provides a single pulse each rotation and is used to reference the system's location. During system startup, the motor may be turned until the index spike occurs. This describes the motor's present position in reference to the rotation.

Moving to the index position is insufficient for determining the motor or mechanical system location during system starting. The absolute location is normally obtained by moving the system to limit switches or sensors during a homing process. After commanding the robot to advance to the boundaries, the encoder readings may be reset to zero or another position value to specify the absolute position.The encoders measure subsequent motion in relation to this absolute location.

Encoders may be coupled to components other than motors to measure and control a mechanical system. A rotary motor, for example, might be connected to a belt drive, which is then connected to a payload under test. A rotary encoder is coupled to the motor to give control feedback, but an additional rotary encoder may be added to the payload to offer extra feedback for enhanced placement. Dual-loop feedback control is a method that helps lessen the effects of backlash in the mechanical components of a motion system.

Some encoders generate analogue sine and cosine signals rather than digital pulses. These encoders are often utilised in extremely high precision applications that demand submicron positional accuracy. An interpolation module is required between the encoder output and the robot controller or intelligent drive in this instance. This feature might be included into the robot controller. Interpolation modules improve the encoder's resolution by an integer value and give a digital quadrature output to the robot controller. Interpolation modules are available from certain encoder manufacturers in a variety of multiplier settings. BEI, Renco, US Digital, Renishaw, Heidenhain, and Micro-E are among encoder manufacturers.

Photo-interrupters are used in optical encoders to transform motion into an electrical pulse train. The motion is "encoded" by electrical pulses, which are counted or "decoded" by circuitry to generate the displacement measurement. The motion might be linear or rotational, however we will concentrate on the mo Rotary optical encoders are classified into two types: incremental encoders and absolute encoders. A disc (or code-wheel) mounted to a rotating shaft rotates between two photo-interrupters in an incremental encoder. A radial pattern of lines is placed on a transparent plastic or glass disc or carved out of an opaque disc, such that when the disc spins, the radial lines alternate pass and block the infrared light to the photo-detectors. In the light path from the emitters to the detectors, there is usually a stationary mask with the same pattern as the revolving codewheel. This produces pulse trains from every one of the photodetectors at a frequency corresponding to the disk's angular motion. These signals, designated A and B, are 1/4 cycle out of phase with one another. The signals may be created by two independent tracks of lines at different radii on the disc, or they may be generated by the same track, with the photo-interrupters arranged relative to each other to produce out of phase pulse trains.

The rotation of the shaft may be calculated by measuring the number of pulses and knowing the number of radial lines in the disc. The rotational orientation is defined by the phase relationship between the A and B pulse trains, or which signal comes first. A rising edge of A when B = 1, for example, may imply anticlockwise rotation, while a rising edge of A while B = 0 implies clockwise rotation. Quadrature signals are the two out-of-phase signals. A third output signal, denoted I or Z, is typically used by incremental encoders. The index signal is obtained from a separate track that produces a single pulse per disc rotation, giving a home signal for absolute direction. Multiple photointerrupters may be substituted in practise by a single source and a single arrays detecting device.

To decode the pulse trains, IC decoder chips are available. The A and B signals are supplied into the chip, and the outputs are one or more pulse trains to be fed into a counter chip. For example, the US Digital LS7083 generates two pulse trains, one for clockwise rotation and one for anticlockwise rotation, which may be fed into the inputs of a 74193 counter chip (Fig. 5.32). For quadrature input, standard decoding techniques include 1X, 2X, and 4X resolution. In 1X resolution, a single count is produced for each rising or falling edge of a single pulse train, such that the total number of encoder counts for a single revolution of the disc equals the number of lines in the disc. A count is created for each rising and falling edge of both pulse trains in 4X resolution, resulting in three times the angular resolution. Decoding an encoder with 1000 lines on the code wheel at 4X resolution results in an angular resolution of 360 / (4 x 1000) = 0.09°. A singleended output encoder produces signals A, B, and potentially Z, but a differential output encoder produces complementary outputs A', B', and Z'. Differential outputs, when combined with a differential receiver, may improve the encoder's electrical noise immunity. One disadvantage of the incremental encoder is that even the absolute location of the shaft at power-up cannot be determined without turning it until the index pulse is received. Furthermore, if pulses get garbled for a brief period of time owing to electrical noise, the estimate of shaft rotation is lost until the index pulse is received. The absolute encoder offers a solution to these issues. An absolute encoder employs k photo interrupters and k code tracks to generate a k-bit binary word that uniquely represents 2k various disc orientations, yielding an angular resolution of 360 °/2k.

The tracks' radial patterns are designed in such a way that while the encoder spins in one direction, the binary word increases or decline according to a binary code. Although natural binary code is an option, Gray code is the most often used approach. Incrementing by one changes many or all of the bits in natural binary coding; for example, 7 to 8 in arithmetic is 0111 to 1000 in natural binary. Only one bit changes when the number advances or decrements in Gray code; for example, 7 to 8 in decimal equals 0100 to 1100 in Gray code. During a Gray code transition, the rotational uncertainty is simply one count, or 360°/2k. An infinitesimal mismatch between the lines and the photo interrupters in the natural binary code may cause the reading to temporarily jump from 0111 (7) to 1111 (15) during the transition to 1000. Incremental encoders, in general, give better resolution at a cheaper cost and are the most prevalent option for many industrial and robotic applications.

Sagnac interferometer

The Sagnac effect (also known as Sagnac interference) is a rotation-induced phenomena in interferometry named after French scientist Georges Sagnac. The Sagnac effect may be seen through a technique known as ring interferometry. A light beam is divided, and the two beams are set to follow opposing trajectories. The trajectory must encompass a region in order to function as a ring. When the light returns to the entrance point, it is permitted to escape the device in such a manner that an interference pattern is produced. The location of the interference fringes is determined by the setup's angular velocity. This configuration is also known as a Sagnac interferometer. The Sagnac effect is the electromagnetic analogue of rotation mechanics. After spinning up, a gimbal-mounted gyroscope continues pointed in the same direction and may therefore be used as a reference for an inertial navigation system. A Sagnac interferometer monitors its own angular velocity in relation to the local inertial frame and, like a gyroscope, may serve as a reference for an inertial guiding system. The ideas behind the two devices, however, vary. The concept of conservation of angular momentum is used by a gyroscope, but relativistic effects impact an interferometer.Several mirrors are usually employed to create a triangle or square trajectory for the light beams.

Fiber optics may also be used to direct light. The ring interferometer is mounted on a rotating platform. When the platform rotates, the lines of the interference pattern are shifted relative to their location when the platform is not spinning. The displacement is proportional to the spinning platform's rotational velocity. The axis of rotation does not have to be located inside the enclosed space.When the platform rotates, the point of entry/exit shifts throughout the light's travel period. As a result, one beam has travelled less distance than the other. This causes the interference pattern to alter.

As a result, the interference pattern formed at each angular velocity of the platform has a unique phase-shift for that angular velocity. The rotation indicated in the preceding section is rotation with regard to an inertial reference frame. Figure 6.5 Sagnac interferometer

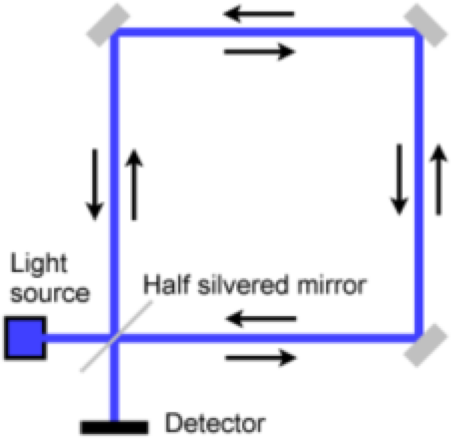

Figure 6.5 Sagnac interferometer

The shift in interference fringes may be explained simply as a result of the varied lengths light travels according to the observer's rotation. The easiest derivation is for a circular ring revolving at an angular velocity of, although the conclusion is valid for various loop geometries. If a light source emits in both directions from a single location on the revolving ring, light going in the rotation direction will traverse more than one circle around the ring and strike the light source from behind after t1 seconds.

Micromechanical Angular Velocity (Gyroscope)

Due to the Coriolis force, almost all micromachined gyroscopes depend on a mechanical structure that is forced into resonance and generates a secondary oscillation in either the same or a different structure. This secondary oscillation's amplitude is proportional to the rate signal to be measured. The Coriolis force is a virtual force that is determined by the observer's inertial frame. Consider a guy on a spinning disc rolling a ball away from himself at a velocity of. The person in the revolving frame will see the ball's bent trajectory. This is due to the Coriolis acceleration, which causes a Coriolis force to act perpendicular to the radial component of the ball's velocity vector. To understand the source of this acceleration, consider the ball's present angular velocity as it moves from thecentre of the disc to its edge.

The angular velocity of the ball rises as it moves away from the centre (= r), but any change in velocity causes acceleration in the same direction. This acceleration is produced by the cross product of the disk's rotational velocity and the ball's radial velocity:

$$\text{Coriolis acceleration: } \vec{a}_c = 2\vec{\Omega} \times \vec{v}_r; \quad \text{Coriolis force: } \vec{F}_c = 2m\vec{\Omega} \times \vec{v}_r$$

Macroscopic mechanical gyroscopes generally use a flywheel with a high mass and spin speed, and hence a large angular momentum, to counteract all external tension and establish an inertial reference frame that maintains the spin axis orientation constant. This technique is unsuitable for a micromachined sensor since the scaling laws are adverse in terms of friction, and hence there are no high-quality micromachined bearings. As a result, almost all MEMS thrusters use a vibrating structure to link energy from a primary, forced oscillation mode to a secondary, sense oscillation mode.

The proof mass is stimulated to oscillate with a consistent amplitude and frequency along the x-axis. Energy is coupled into an oscillation along the y-axis whose amplitude is proportional to the rotational velocity by rotation around the z-axis. A force-feedback loop may integrate the sensing mode, much as closed loop micromachined accelerometers. Any motion and along sense axis is measured and counterbalanced by a force. The needed force magnitude is then used to calculate the angular rate signal.

One issue is that the Coriolis force has a modest amplitude in comparison to the driving force.

The Coriolis acceleration is given by for a sinusoidal driving vibration, where is the amplitude of the oscillation and is the drive frequency. The Coriolis speed is just 4.4 mm/s2 when using normal values of and 20 kHz. The displacement amplitude is just 0.0003 nm if the sensing element along the sense axis is modelled as a second order mass-spring-damper system with Q = 1. One method for increasing displacement is to build sensing components with a high Q structure and then tune the driving frequency to the sense mode's resonant frequency. However, very high Q structures need vacuum packing, making the production process considerably more difficult. Furthermore, the gyroscopes' bandwidth is proportional to /Q; hence, if a quality factor of 10,000 or higher is reached in vacuum, the sensor's bandwidth is reduced to just a few hertz. Finally, owing to manufacturing limitations, it is impossible to design structures for a precise resonance frequency.

One method is to design the sense mode to have a greater resonant frequency than the drive mode, then reduce the resonant frequency of the sense mode by adjusting the mechanical spring constant using electrostatic forces. Tuning the sensing mode's resonance frequency close to the driving frequency (within 5% to 10%) is an acceptable compromise between bandwidth and sensitivity. A second major issue with vibratory rate micromachined gyroscopes is quadrature inaccuracy. This sort of mistake is caused by manufacturing tolerances manifesting as a misalignment of the driven oscillation's axis from the nominal drive axis. As a consequence, only a tiny amount of the driven motion will be parallel to the sense axis. Even if the misalignment angle is extremely tiny, the resultant motion along the sense axis owing to the minute Coriolis acceleration may be substantially bigger than the motion induced by the Coriolis acceleration (Figure 6.6).

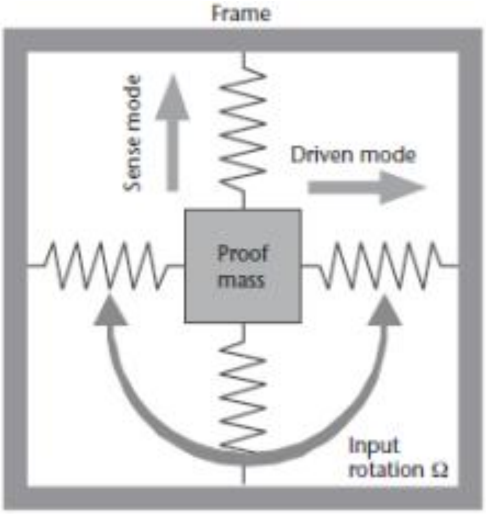

Figure 6.6 Micromechanical Angular Velocity

To measure angular rate, a conventional-scale gyroscope makes use of the spatial coupling of the angular momentum-based gyroscopic effect. A disc is spun at a continuous high rate around its main axis in these devices, such that when the disc is rotated about an axis that is not colinear with the primary (or spin) axis, a torque arises in an orthogonal direction proportionate to the angular velocity. These devices are often installed on gimbals with low-friction bearings, have motors that keep the spin velocity constant, and use strain gauges to detect the gyroscopic torque (and thus angular velocity). Due to various issues, such as the declining influence of inertia (and hence momentum) at tiny scales, the absence of proper bearings, the lack of acceptable micromotors, and the lack of adequate three-dimensional microfabrication methods, such a design would not be ideal for a microsensor. Microscale angular rate sensors, on the other hand, are vibratory in nature, including Coriolis-type phenomena rather than the angular momentum-based gyroscopic mechanics of conventional-scale devices. A Coriolis acceleration is caused by linear translation inside a rotating coordinate frame with regard to an inertial reference frame. If the particle moves with a velocity, v inside the frame xyz, and the frame xyz rotates with an angular speed of with respect towards the inertial reference frame XYZ, then a Coriolis acceleration equal to ac= 2 x v will ensue. If the object has mass m, the Coriolis inertial force will be Fc = -2m x v. (minus sign because direction is opposite ac). This phenomenon is used by vibratory gyroscopes, An electrostatic comb drive is used to vibrate an inertial mass hung by a flexure in the x direction. An angular velocity around the z-axis causes a Coriolis acceleration and, consequently, force in the y-direction. If the "external" angular velocity is constant and the x-direction velocity is sinusoidal, the resultant Coriolis force is sinusoidal, and the suspended inertial mass vibrates in the y-direction with amplitude proportionate to the angular velocity. The angular rate is therefore detected via motion in the ydirection, which is normally sensed capacitively. Although vibration is an important component of these instruments, they are not strictly resonant sensors since they monitor amplitude rather than frequency.

Micromachining technique has enabled the development of extremely compact, low-cost angular rotation sensors. The accelerometer is manufactured on a silicon substrate using the same surface micromachining processes as this device. Three layers of polysilicon are also utilised in this situation, with the first and third layers fixed and the second layer free to vibrate around its centre. As depicted, four spring arms coupled to four fastening posts hold the centre in place.

This gadget can detect rotation around two axes the x- and y-axes as well as acceleration along the z-axis. The electrostatic forces created by voltages placed between the fixed comb fingers and the comb fingers of the second polysilicon cause the central layer of polysilicon to oscillate around the z-axis. Capacitor plates are created as illustrated between the first and third layers of polysilicon on the x and y axes and the second layer of polysilicon. To detect any movement of the vibrating disc produced by angular rotation, differential capacitive sensing methods are utilised. For example, if the disc is rotated about the x-axis, Eddy currents forces cause it to deflect about the y-axis. The capacitor plates on the x-axis can then detect this deflection. The three functions are sensed via a shared sensing circuit that alternately detects x-rotation, una, and acceleration. The gyroscope is meant to provide an angular rate resolution of 1°/s and an acceleration resolution of 20 mg.

Acceleration Sensors

A simple accelerometer is made out of a mass that may move freely along a sensitive axis inside a container. The technology is mostly based on this fundamental accelerometer, which may be classed into mechanical or electrical, active or passive, deflection or null-balance accelerometers, and so on. The vast majority of industrial accelerometers are either deflection or null-balance in nature. Accelerometers used in vibration / shock measurements are typically deflection kinds, although those used to measure car, aeroplane, and other movements for navigation reasons may be either deflection or null-balance types.

Accelerometers detect acceleration by suspending a mass on a force sensor, when the sensor accelerates, the mass's inertial resistance causes the force sensor to deflect. The acceleration may be calculated by measuring the deflection. The mass is cantilevered mostly on force sensor in this scenario. The sensor is surrounded by a base and a housing. The accelerometer is mounted using a tiny mounting stud (a threaded shaft).

Quadrature encoders are another sort of incremental encoder. A two-channel quadrature encoder detects position and orientation using two light detectors. The photo detectors are 90 degrees apart relative to one line pair on the code track. Because the two output signals, A and B, are 90 degrees out of phase, one will lead the other as the disc spins. If A is ahead of B, the disc is revolving clockwise, as illustrated If B is ahead of A, the disc rotates anticlockwise, as illustrated in Figure four distinct pulse edges occuring throughout each cycle. With quadrature decoding, each rising and falling edge generates a new encoder count, essentially quadrupling the encoder resolution.To increase noise immunity, the electrical complements of channels A and B may be incorporated as differential signals. This is particularly significant in situations with extensive wire lengths between the encoder and the motion controller or electrical drive.

Typically, the force sensor is a tiny piece of piezoelectric effect (discussed later in this chapter). The piezoelectic material may be used to monitor shear or compression force. Piezoelectric accelerometers are often equipped with characteristics like as, Operating temperature range: -100 to 250°C From 1mV/g to 30V/g Sensitivity operates at a fraction of the normal frequency. Figure 5.43 shows the accelerometer installed on the vibration source. The accelerometer is electrically insulated from the source of vibration, allowing the sensor to be grounded at the amplifier (to reduce electrical noise). Cables are attached to the surface of the vibration source near the accelerometer as frequently as feasible to avoid noise from the cable contacting the surface. Control electrodes attached to non-vibrating surfaces may detect background vibrations. Each accelerometer is unique, however some basic application principles are as follows: For the error to be less than 12%, the control vibrations should be below 1/3 of the signal.

- The accelerometers' mass should be less than one-tenth of the measurement mass.
- Shakers may be used to calibrate these devices; for example, a 1g shaker will provide a peak velocity of 9.81 m/s*2.

Contact Sensors

Force is a vector quantity that may be described as an action that causes acceleration or a specific response in a subject. This chapter will go through the techniques for determining the magnitude of these forces. The following factors must be taken into account when determining or measuring forces: If the forces operating on a body do not create any acceleration, they must form an equilibrium system of forces. After then, the system is said to be in static equilibrium. A body's forces may be classed into two types: internal, where the atoms of the body operate on each other, and external, where they do not. When a body is supported by other bodies while under the influence of forces, deformations and/or displacements occur at the sites of support or contact. Internal forces are spread throughout the body until equilibrium is reached, at which point the body is considered to be in a state of tension, compression, or shear. When looking at a body at a specific segment, it is clear that all internal forces work in pairs, with the two forces being equal and opposing, while exterior forces act singly.

Basic Force Measurement Methods

The following methods may be used to measure an unknown force:

1. Balancing an unknown force against a standard mass using a lever system;
2. Measuring the acceleration of a known mass;
3. Equalising it to a magnetic force generated by the interaction of a current-carrying coil and a magnet;
4. Distributing the force on a specific area to generate pressure and then measuring the pressure; and
5. Converting the applied force into the deformation of an elastic element.

The aforementioned techniques for measuring forces result in a range of measuring equipment designs.The difficulty in measuring force is mostly due to sensor design.The fundamentals of sensor design may be divided into two problems:

1. The fundamental geometric or physical limits imposed by the force sensor device's application; 2. The method by which the force may be transformed into a usable signal form (such as electrical signals or graded displacements).

The following sections will go through the various devices used for force-to-signal conversion and then provide some instances of how these devices may be used to measure forces.

Force sensors are essential for a fundamental knowledge of a system's reaction. Cutting forces generated by a machining process, for example, may be monitored to identify a tool failure or to analyse the reasons of this failure in managing process parameters and assessing surface quality.

In the automobile sector, force sensors are used to detect impact forces. The detection of forces produced at the end effector is used to manage robotic handling and assembly operations. Direct force measurement is helpful in regulating various mechanical systems.

Some force sensors work by sensing the deflection induced by the force. For this technology to work, rather large deflections (usually several micrometres) would be required. Helical springs' superior elastic qualities allow them to be effectively used as force sensors, converting the load to be measured into a tilt. Hooke's law demonstrates the relationship between force and deformation in the elastic region. Force sensors with built-in microelectronics that use strain gauge components or piezoelectric (quartz) crystals are widespread. These sensors can detect both impulsive and gradually increasing forces.

Piezoresistive Sensor and Capacitive Tactile Sensors

The magnitude of a mechanical displacement is sensed in a piezoresistive sensor by the amount of stress it causes in a mechanical component. A piezoresistor (a stress-sensitive resistor) strategically positioned on the mechanical part changes resistance as a function of the applied stress.

Many materials, such as metals, alloys, and tinted silicon, have piezoresistive properties. The application of stress causes the structure of a material to distort, resulting in changes in resistance and resistor size. The resistance (R) change as a function of applied strain is

Where R0 is the resistor's unstressed value and G is the piezo - resistive gauge factor. The entire footprint of the sensor may be made fairly tiny while yet having a decent value, i.e., 1 k, by using doped silicon as a piezoresistive sensor. The piezoresistive sensor technique is more area efficient than the capacitive sensor approach, which needs a large plate area to attain a substantial capacitance value. As a consequence, piezoresistive sensing is more often utilised for sensors with characteristic lengths less than 10 m. The capacitive measuring approach, on the other hand, is more widely applicable, but the best piezoresistive sensors include silicon with the right doping concentration.

Capacitive Tactile Sensor

Force may be measured using a capacitance variation transducer. The force is applied to a membrane, and the elastic deflection is sensed by a capacitance change. Because capacitive transducers reliably detect extremely tiny deflections, a very sensitive force transducer may be built.The capacitance fluctuations are converted into DC-voltage variations using an electronic circuit.A capacitance sensor is made up of two metal plates that are separated by either an air gap. The capacitance C between terminals may be calculated as follows:

Where C = capacitance in farads (F), = dielectric constant of open space, = relative dielectric constant of the insulator, A = overlapping area for the two plates, and h = gap thickness.Capacitance-type sensors have a poor sensitivity by design. In theory, narrowing the gap h should enhance sensitivity; nevertheless, there are practical electrical and mechanical constraints that prevent high sensitivities from being realised. One of the capacitive transducer's key benefits is that shifting one of its plates relative to the other needs an incredibly tiny force to be applied. A second benefit is that the sensor's sensitivity is not affected by environmental pressure or temperature.

It is better to employ a high permittivity dielectric in a helix capacitor design to maximise the change in capacitance when force is applied. The absolute capacitance of this sort of sensor decreases when the size is lowered to enhance the spatial resolution. There is an effective limit on the resolution of a capacitive array due to the restrictions imposed by the sensitivity of the measuring methods and the rising dominance of stray capacitance. The illustration depicts a cross section of a capacitive touch transducer in which the displacement and therefore applied force are resolved by moving one set of capacitor plates. The changing capacitance is maximised by using a highly dielectric polymer such as polyvinylidene fluoride. In terms of application, the coaxial design is superior since its capacitance provides a bigger rise for an applied force than the parallel plate design (Figure 6.7).

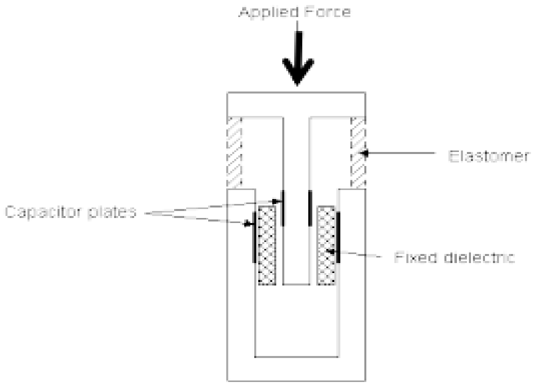

Figure 6.7 Capacitive Tactile Sensor

Force Sensing Resistors

Force sensing resistors (FSRs) take use of the fact that some polymer thick-film devices display diminishing resistance as the applied force increases. A force detecting resistor consists of two sections. The first is a resistive substance that has been applied to a film. The second is a set of digitising contacts that have been put to another film.

The electrical circuit between the two sets of conductors on the other sheet is completed by the resistive substance. When a force is applied to this sensor, a better connection is formed between the contacts, increasing conductivity. It turns out that conductivity is roughly a linear function of force throughout a broad range of forces. Figure 5.48 depicts the sensor's resistance as a function of force. It is vital to note that the sensor may work in three different zones.

The first dramatic change happens somewhere about 10 g of force. Resistance varies extremely quickly in this location. This characteristic comes in handy when building switches with force sensing resistors.

FSRs should not be utilised for precise force measurements since the resistance of sensor components might vary by 15- 25%. FSRs, on the other hand, have less hysteresis and are significantly less expensive than other sensing devices. The FSR is significantly less susceptible to vibration and heat than piezofilm.

Tactile Sensors

Tactile sensors are often thought of as a touch sensing technology. Tactile sensors are not the same as basic touch sensors, which take just a few discrete force readings. A force "distribution" is measured that used a closely spaced array of force sensors in tactile sensing.

Tactile sensitivity is vital in both grabbing and identifying items. Grasping an item must be done in a steady way so that it does not slide or get damaged. Object identification entails recognising a product's form, placement, and orientation, as well as detecting surface features and faults. These activities would ideally need two forms of sensing:

1. Continuous sensing of contact forces,
2. Sensing of the surface deformation profile.

It achieves virtually continuous changeable sensing of tactile forces (sensing of the tactile deflection profile).

Tactile Sensor Prerequisites

In the field of robotics, significant breakthroughs in tactile sensing are being made. Automated surface profile inspection, material handling or part transfer, part assembly, component identification and gauging in manufacturing applications, and fine-manipulation jobs are examples of uses. Some of these applications may just need basic touch (force-torque) sensing provided the pieces being grabbed are suitably positioned and enough process information is already available. Naturally, the primary goal of tactile sensing device design has been to emulate the capabilities of human fingertips.

1. A spatial resolution of roughly 2 mm is typical for an industrial tactile sensor.
2. A force resolution (sensitivity) of about 2 g
3. A maximum touch force of about 1 kilogramme
4. Quick reaction time of 5 milliseconds
5. A lack of hysteresis
6. Longevity in the face of harsh working circumstances
7. Unresponsiveness to changes in environmental circumstances (temperature, dust, humidity, vibration, etc.)
8. The ability to check slippage

Tactile Sensor Array

Tactile array sensors use a regular arrangement of sensing components to monitor pressure distribution throughout a robot's fingertip. The 8 x 8 array of elements, spaced at 2 mm in each direction, produces 64 force sensitive elements. Table 5.2 summarises some of the early tactile array sensor features. The sensor is made up of two crossed layers of copper strips surrounded by thin silicone rubber strips. The sensor creates a thin, compliant coating that may be readily adhered to a wide range of fingertip shapes and sizes. The computer samples the whole array.

A typical tactile sensor array may have many sensing components. Each element, or taxe is responsible for sensing the forces present. Because tactile sensors are used in applications where sensitivity like human touch is sought, an elastomer is used to approximate human skin. In general, an elastomer is a conductive substance whose electrical conductivity varies locally when pressure is applied. The sensor is made up of three layers: an important advantages, a conductive elastomer sheet, and a printed circuit board. The printed circuit board is made up of two rows of two "bullseyes," each with conductive inner and outer rings that interfere with the sensor's taxels.

The outer rings are linked together, as well as to a column-select transistor. The inner rings are wired to diodes. Because the applied pressure creates a local deformation in nearby taxels. This is known as crosstalk, and it is removed by the diodes. Tactile array sensor signals are utilised to give contact kinematics information. Several feature parameters may be collected, including contact location, object form, and pressure distribution. A touch and force detecting finger is an example of this. This tactile finger contains four touch sensors on the surface of fingertip constructed of piezoelectric polymer strips that offer dynamic contact information. A strain gauge force sensor measures static grip force.

Optical tactile sensors

In recent years, the fast advancement of optical technology has resulted in the creation of a diverse spectrum of touch sensors. The functioning principles of optical-based sensors are widely understood and classified into two types:

Intrinsic, in which the optical phase, intensity, or polarisation of transmitted light is altered without interfering with the optical channel.Extrinsic, in which the physical stimulus interacts with light that is not in the principal light path.

Touch, torque, and force detection may be accomplished using both intrinsic and extrinsic optical sensors. The best suited for industrial applications will be those that need the least amount of optical processing.

For robotic touch and force sensors, for example, detecting phase shift via interferometry is not a viable choice. The extrinsic sensor based on intensity measurement is the most extensively utilised for robotic touch and force sensing applications owing to its ease of manufacture and subsequent information processing. The following are some of the possible advantages of employing optical sensors:

External electromagnetic interference immunity, which is common in robotic applications:

The use of optical fibre enables the sensor to be situated some distance from the light source and receiver, making it intrinsically safe.

Low volume and weight.

A variety of optical technologies have been used to build touch and tactile optical sensors:

Modulating light intensity by inserting an impediment into the light path.

A spring or elastomer determines the force sensitivity. The sensor may be built around a deformable tube to eliminate cross-talk from external sources, resulting in an extremely compact sensor.

Photoelasticity

The phenomenon of photoelasticity occurs when stress or strain generates birefringence in optically transparent materials. The photoelastic material allows light to travel through it. The photoelastic medium effectively spins the plane of polarisation as the medium is strained, and so the intensity of the light reaching the detector varies as a response to the applied force. This sort of sensor is very important in slip measuring.

Strain Gage Load Cell

When exposed to a force, the strain gauge load cell deforms elastically, and a strain gauge network creates an electrical signal proportionate to this deformation. Load cells of the beam and ring kinds are examples of this.

Strain Gages

Strain gauges use a length of gauge wire to provide the appropriate resistance (often 120) in the shape of a flat coil. The coil is then cement (bonded) between two thin insulating paper and plastic sheets. A gauge of this kind cannot directly measure deflection. It must first be securely fastened to the stressed part. They are baked at about 195°F (90°C) to eliminate moisture after glueing the gauge to the part. A wax or resin coating on the device will give some mechanical protection.

The resistance between the test part and the gauge must be at least 50 M. The overall area of all conductors must remain modest so that the force required to distort the wire may be readily transmitted through the cement. When a member is strained, the resultant strain flexes the strain gauge and reduces the cross-sectional area. This results in an increase in gauge resistivity that is readily detected. To quantify extremely tiny stresses, modest variations in resistance per unit resistance (R/R) must be measured. A bonded strain gage's resistance normally changes by less than 0.5%. There are several gauge sizes and grid shapes to choose from.

The use of strain gauges to measure force necessitates meticulous consideration of stiffness and surroundings. Strain gauges with shorter lengths have greater response frequencies due to their design (examples: 660 kHz for a gauge of 0.2 mm and 20 kHz for a gauge of 60 mm in length). The temperature of the gauge is the most important environmental factor. Resistance is widely known to be a function of temperature, and so strain gauges are subject to temperature fluctuations.

As a result, if the temperature of the gauge is known to change owing to any impact, temperature correction is essential to guarantee that the force measurement is accurate. This tiny order of magnitude is often measured using a Wheatstone bridge. If the four resistances meet a given condition, no current will flow through the galvanometer (G). A voltage scale has been created at positions C and D of Fig. 5.56 to explain how a Wheatstone bridge works. Consider R1 to be a bonded gauge. If R1 is now stretched to raise its resistance by one unit (+ R), the voltage at point D will increase from zero to one unit (+ V), and there will be a voltage differential of one unit between C and D, resulting in a current through C. If R4 is likewise a bonded gauge, and R1 changes by + R while R4 moves by R, the voltage at D will rise to +2 V. Also, if R2 is changed by R4 and R3 is changed by + R at the same time, the voltage at point C will be -2 V and the voltage differential between C and D will be 4 V. It follows that, although a single gauge may be utilised, the sensitivity can be improved fourfold by using two gauges in tension and two others in compression.

CHAPTER 7

Sensors for Measuring Distance

Mr. Ravi Prakash Upadhyai, Assistant Professor,
Department of Mechanical Engineering, School of Engineering & Technology,
Jaipur National University, Jaipur, India
Email Id- ravi.prakash@jnujaipur.ac.in

Range sensors are applied to calculate the distance between two points. These sensors have been developed using a variety of technologies, the most notable of which being light/optics, computer vision, microwave, and ultrasonic. Range sensors may be either touch or noncontact.

Sensors for Noncontact Ranging

Noncontact range sensors are sensors that measure the actual distance to an object of interest without making direct physical contact. In various implementations of such distance measurement devices, at least seven distinct kinds of ranging methods are used (Everett et al., 1992):

1. Triangulation
2. Time of flight (pulsed)
3. Phase-shift measurement (CW)
4. Frequency modulation (CW)
5. Interferometry
6. Swept focus

Noncontact ranging sensors are either active (emitting some type of energy into the field of view) or passive (relying on energy emitted by the various objects in the scene under surveillance).Radar (radio direction and ranging), sonar (sound navigation and ranging), and lidar (light direction and ranging) are words that refer to active approaches that may be based on any of the aforementioned ranging techniques.

Radar, for example, is often accomplished using time of flight, phase-shift measurement, or frequency modulation.Because the speed of sound is slow sufficiently to be detected with relatively simple equipment, sonar is often based on time-of-flight range. Lidar refers to laser-based methods that use time-of-flight or phase-shift measurement.

The effective detection range of any such active (reflective) sensor is determined not only by radiated power levels, but also by the following target characteristics:

1. Cross-sectional area —determines how much of the emitted energy reaches the target.
2. Reflectivity- the amount of incoming energy that is reflected as opposed to absorbed or passed through.
3. Directivity- governs how reflected energy is dispersed (i.e., scattered versus focused).

Many noncontact sensors are based on wave propagation physics. The range of a wave is calculated by measuring either the propagation time from reference to target or the drop in intensity as the wave travels to the target and returns to the reference. Time-of-flight or frequency modulation techniques are used to calculate propagation time.

Sensors that measure proximity

They are used to detect the closeness of one item to another. They typically provide a on or off signal to indicate the presence or absence of an item. As proximity sensors, inductance, capacitance, photoelectric, and Hall Effect are often utilized. A coil coiled around a soft iron core is used in inductance proximity sensors. When a ferrous item is nearby, the sensor's inductance changes.

This modification is transformed into a voltage-triggered switch. Capacitance is analogous to inductance in that the proximity of an item alters the gap and hence influences the capacitance. Normally, photoelectric sensors are aligned with an infrared light source. When a moving item comes into contact with the light beam, the voltagelevel changes. When a current-carrying wire is subjected to a transverse magnetic field, a Hall Effect voltage is created. The voltage is proportional to the transverse distance between both the Hall Effect sensor and a nearby object.Proximity sensors, which are used to assess the presence (rather than the actual range) of close objects, were designed to expand the sensing range beyond that of direct-contact tactile or haptic sensors.

Recent advancements in electrical technology have substantially increased performance and reliability, expanding the number of potential applications. As a consequence, many industrial installations that previously relied on mechanical limit switches may now choose from a wide range of noncontact devices for their near (between a fraction of an inch and a few inches) sensing requirements. These proximity sensors are categorised into numerous sorts based on the particular qualities that are employed to activate a switching action:

These sensors' strong dependability makes them ideally suited for use in severe or otherwise unfavorable conditions, while still delivering fast response and extended service lifetimes. Instruments may be built to resist high shock and vibration, with some capable of managing forces exceeding 30,000 Gs and pressures approaching 20,000 psi (Hall, 1984). Burreson (1989) and Peale (1992) examine the benefits and disadvantages of detector selection for applications in difficult and harsh situations. Furthermore, proximity devices are useful for identifying things moving at fast speeds, when direct touch may cause harm, or for distinguishing between nonmetallic and metallic items. Ball (1986), Johnson (1987), and Wojcik (1994) give broad overviews of several proximity sensor types as well as selection advice.

Optical Triangulation

Optical triangulation sensors detect the location of objects by combining a light emitter, such as a laser or an LED, with a light receiver. The emitter and receiver are housed in the same housing. Light waves are directed toward a target by the transmitter. These are reflected off the target and sent to the receiver through a lens. The position of the target in reference to the sensor face is determined by the location of the incident light on the receiver. A description detector (PSD) or a pixelized array device, such as a charge coupled device, may be utilised as a receiver (CCD). Because less post-processing is needed, the PSD receiver provides a single analogue output and has a quicker reaction time than the output pixelized array device. It is also often smaller, resulting in a reduced total sensor size. Pixelized array devices, on the other hand, are beneficial when the target's surface is uneven or transparent.

Triangulation is a basic traditional method used to measure distances ranging from 1 cm to 100 m. There are various methods for measuring distance using triangulation. A basic triangulation sensing system may be built by combining a light-emitting diode as a light source with a linear photo-detector (PD) array. For getting distant pictures, image-detector and light-beam scanning may also be utilised.The operating range and standoff distance are critical characteristics for this sort of sensor. The standoff distance is the distance between the sensor face and the operating range's centre. This sort of sensor is available in both diffuse and specular forms. A diffuse design is helpful for targets with light-scattering surfaces, such as anodized metal. A specular design is beneficial for targets with light-reflective surfaces, such as mirrors. Furthermore, while researching this sort of sensor, the target colour and transparency should be taken into account since these features impact light absorption by the target.Optical triangulation sensors have a high resolution and ranges of up to a half metre. Higher ranges are possible, but at a substantially higher cost.

Triangulation Ranging

Triangulation range is based on a fundamental principle of plane trigonometry, which asserts that given the length of a side and two angles of a triangle, the length of the other sides and the remaining angle may be calculated. The fundamental Law of Sines may be adjusted to express the length of side B as a function of side A and the angles and as illustrated below.

For given sensor separation baseline A, length B would be the required distance to the item of interest at point P3 in ranging applications. Triangulation ranging methods are either passive (just utilise ambient light in the scene) or active (use an energy source to illuminate the target).

Passive stereoscopic ranging systems place directional detector (video cameras, solid-state imaging arrays, or position sensitive detectors) at P1 and P2 places. Both image sensors are positioned in an imaginary triangle to see the same object point, P3. The measurement of angles, together with the cameras' known orientation and lateral spacing, enables the range to the item of interest to be calculated.In contrast, active triangulation systems place a controlled light source (such as a laser) at either point P1 or P2, aimed at the observed point P3. A directional imaging sensor is likewise focused at P3 and is situated at the remaining triangle vertex. The source's illumination will be returned by the target, with a part of the returned energy landing on the detector. The lateral location of the detected spot offers a quantitative value of the unknown angle, allowing range calculation using the Law of Sines.

The performance characteristics of triangulation systems vary depending on whether they are active or passive. Passive triangulation systems employing ordinary video cameras need certain ambient illumination conditions, which must be given artificially if the scene is too dark.Furthermore, because to the difficulty in matching locations observed by one image sensor with those viewed by the other, these systems suffer from a correspondence issue. Active triangulation approaches, on the other hand, that use just a single detector, do not need particular ambient illumination and do not suffer from the correspondence issue. Active systems, on the other hand, may experience situations of no recorded strike due to specular reflection or light surface absorption.

Reduced accuracy with increasing range, angular measurement errors, and a missing portions (also known as shadowing) issue are all limitations shared by all triangulation sensors. The term "missing pieces" refers to the situation in which only one viewing point can see certain sections of a scene (P1 or P2).The offset distance between P1 and P2 causes partial blockage of the target in this circumstance (i.e., a point of interest is seen in one view but otherwise occluded or not present in the other). A tradeoff analysis of offset must be included in the design of triangulation systems: The range accuracy improves as this baseline measurement improves, while issues related to directional occlusion deteriorate.

Optical Time-Of-Flight

Optical time-of-flight sensors determine the location of things by measuring the time it takes light to travel to and from the item. Time-of-flight sensors, like optical triangulation sensors, have an emitter and a receiver. A laser or LED serves as the emitter, while a photodiode serves as the receiver. The emitter fires one or more light pulses at a target. Some light is reflected from the target and is collected by the photodiode. When it receives light, the photodiode emits a pulse, and the sensor electronics determine the time difference between the generated and received pulses. The target's distance is then computed using the speed of the light and the time difference.

The measuring ranges of most time-of-flight sensors are several metres. However, if a sequence of pulses from the emitter is employed, laser-based time off light sensors may have a range of many kilometres. These sensors' precision is lower than that of optical triangulation sensors, but their range is often higher.

Ranging by Time-of-Flight (TOF)

A gated wave (a few-cycle burst) is produced, bounced back off the target, or detected at a receiver near the emitter. The emitter and receiver may be the same sensor. The receiver may alternatively be attached to the target. The TOF is the time elapsed between the start of the burst and the start of the return signal. When the emitter and receiver are in the same place, the distance is specified as d = c. TOF/2, or d = c. TOF when the receiver is linked to the target. When detecting the return signal, the accuracy is generally 1/4 of the wavelength when its magnitude exceeds a threshold limit. To ensure precision, gain is automatically increased with distance.

Detecting the highest amplitude, may enhance accuracy. This makes identifying the wave's arrival timing less reliant on signal amplitude. Ultrasonic, radio frequency, or optical energy sources are often used; hence, the key factors involved in range calculation include the speed of sound in air (approximately 0.305 m/ms) and the speed of light (0.305 m/ns). The following are examples of potential error causes for TOF systems:

1. Variations in propagation speed, notably in the case of acoustic systems
2. Uncertainties in establishing the precise arrival time of the reflected pulse (Figueroa &Lamancusa, 1992).
3. Errors in the timing circuitry used to calculate the round-trip duration of flight.

Propagation Speed —With the exception of satellite-based position-location systems, changes in the propagation speed of electromagnetic radiation are generally insignificant and may be disregarded. This is not the case with acoustically based systems, where temperature and, to a lesser degree, humidity have a significant impact on sound speed. (The speed of sound is really related to the square root of temperature in degrees Rankine; a 30° change in ambient temperature may generate a 1-ft inaccuracy at a measured distance of 35 ft.)

Uncertainties in Detection

The high dynamic range in returning signal intensity induced by (1) variable reflectivity of target surfaces and (2) signal attenuation to the fourth power of distance owing to spherical divergence causes so-called time-walk mistakes. These changes in returning signal strength affect the rising time of the detected pulse, causing less reflective objects to seem farther away in the case of fixed- threshold detection (Lang et al., 1989). As a result, constant fraction timing discriminators are often used to set the detector threshold at a predetermined fraction of the incoming pulse's peak value.

Considerations for Timing- Because of the comparatively slow speed of sound in air, TOF range is a viable candidate for low-cost acoustically based systems. In optical or RF systems, the propagation speed of electromagnetic radiation may impose significant demands on related control and measurement equipment. As a consequence, light-speed TOF sensors need sub-nanosecond timing circuitry to estimate distances with a precision of around a foot. A required resolution of 1 mm necessitates a timing precision of 3 ps. This feature is rather costly to actualize and may not be cost viable for some applications, notably those requiring high accuracies at close range.

Interaction at the Surface

Any observed echo represents just a tiny percentage of the original signal when light, sound, or radio waves impact an object. Depending on the surface properties and the angle of incidence of the beam, the leftover energy reflects in dispersed directions and may be absorbed by or pass through the target. Because to specular reflection at the object surface, no return signal is received in certain cases, notably in the ultrasonic area of the energy spectrum. If the transmission source approach angle equals or surpasses a specific critical value, the reflected energy is diverted beyond the receiver's detecting envelope. Scattered signals may also reflect from secondary objects, returning to the detector at different times to produce misleading signals that might result in dubious or otherwise noisy data.To compensate, repeated measurements are normally averaged to bring the signal-to-noise ratio within acceptable ranges, although this comes at the price of the extra time necessary to obtain a single range value.

Laser Range Radar

Laser Range Radar (Laser-based TOF ranging systems), often known as laser radar or lidar, was developed in the 1970s at the Jet Propulsion Laboratory in Pasadena, California (Lewis & Johnson, 1977). Laser energy is released in a quick succession of short bursts that are targeted directly at the item being ranged. Based on the speed of light, the TOF of a particular pulse reflecting off an object is used to compute the distance to the target.Early sensors of this sort may achieve accuracy of a few centimetres over a range of 1-5 m.

Schwartz Electro-Optics, Inc. (SEO), Orlando, FL, manufactures a variety of laser TOF range finding systems that use a unique time-to-amplitude-conversion method to meet the sub-nanosecond timing limitations imposed by the speed of light. As the laser fires, a precision film capacitor starts discharging at a steady rate from a known fixed point, with the quantity of discharge proportional to the round-trip time-of-flight (Gustavson& Davis, 1992). On the sampled capacitor voltage, an analog-to-digital conversion is done; when a return signal is received, the resultant digital representation is converted to range and time-walk adjusted using a look-up table.

The LRF-X series rangefinder has a small footprint, fast processing, and the capacity to obtain range information mostly from surfaces (minimum 10% Lambertian reflectance) out to 100 m. The basic system employs a pulsed InGaAs laser diode in combination with an avalanche photodiode detector and has analogue and digital (RS-232) outputs.RIEGL Laser Measurement Systems, Horn, Austria, sells a variety of commercial devices that use short-pulse TOF laser ranging, including laser binoculars, surveying systems, "speed guns," level sensors, profile measurement systems, and tracking laser scanners. Lidar altimeters, vehicle speed measurement for law enforcement, collision avoidance for cranes and vehicles, and level sensing in silos are examples of typical uses.

The RIEGL LD90-3 series laser rangefinder uses a near-infrared laser diode source and a photodiode detector to achieve TOF ranges of up to 500 m with diffuse surfaces and up to 1000 m with cooperative objects. A quartz-stabilized clock correctly measures round-trip propagation time, which is then translated to measured distance by an onboard CPU using one of two possible algorithms.

The clutter suppression method uses a mix of range measurement averaging and noise rejection techniques to filter out backscatter from airborne particles, making it advantageous while working in low-visibility situations. The conventional measurement algorithm, on the other hand, delivers quick range measurements with no consideration for noise suppression and may thus give a greater update rate under more favourable environmental circumstances.

Laser Interferometry distance meter

Laser interferometers are capable of sensing incremental linear movements with nanoscale precision. Collimated laser light flows through a beam splitter in an interferometer, splitting the light energy into two channels. One route is immediately reflected to the detector, such as an optical sensor array, resulting in a fixed-length flight path. The alternative approach consists of a retroreflector (mirror) mounted to the object to be measured reflecting back to the detector. At the detector, the two beams constructively or destructively interfere with each other, resulting in a pattern of light and dark fringes. The interference pattern may be used to determine the phase relationship between the two beams, which is determined by the relative lengths of the two routes and hence the distance to the moving target. The pattern repeats as the target moves because the length of the variable route varies with the wavelength of the laser. As a result, the laser interferometer is an incremental measuring instrument by definition. Laser interferometers are without a doubt the most costly sensors covered in this chapter. They have the greatest resolution as well. Mechanical misalignment and vibrations are very sensitive to laser interferometers.

For servosystems, laser interferometers give the most precise position feedback. They have a very high resolution (up to 5.72 nm), are noncontact, have a fast update rate, and inherent accuracies of up to 0.02 ppm. They may be employed as passive position readouts or as active feedback sensors in a position servo loop in servosystems. The laser beam path may be accurately aligned with the load or a particular location being measured, hence eliminating or significantly lowering Abbe error. A helium-neon laser, a polarising beam splitter with a fixed retroreflector, a moving retroreflector that may be installed on the object whose location is to be determined, and a photodetector, commonly a photodiode, make up the system.

The laser's light is directed toward the polarising beam splitter, which has a partly reflecting mirror. A portion of the laser beam passes directly through the polarising beam splitter, while the remainder is reflected. The portion that travels directly through the beam splitter reaches the moving reflectometer, which reflects it back to the beam splitter, which then sends it to the photodetector. The reflected portion of the beam reaches the stationary retroreflector, which is a set distance away. It is reflected back to the beam splitter by the retroreflector before being reflected into the photodetector.

As a consequence, the two reflected laser beams collide with the photodetector, which turns the two light beams' combination into an electrical signal. Because of the way laser light beams interact, the detector's output is determined by the difference in lengths travelled by the two laser beams. These lengths are ignored in position measurement since both light beams travel the same distance from the laser to the beam splitter and from the beam splitter to the photodetector. The difference in distance between the round trip laser beam travel from the beam splitter to the moving retroreflector and the fixed round trip distance of laser beam travel from the beam splitter to the stationary retroreflector is all that is required for the laser interferometer measurement.

If these two distances are identical, the two light beams will recombine in phase at the photodetector, resulting in a large electrical output. This incident may be seen as a brilliant light fringe on a video display. However, if the distance between the two points is less than one-quarter of the wavelength of the laser, the light beams will combine out of phase, interfering with each other, resulting in no electrical output from the photodetector and no video output on the display, a condition known as a dark fringe.

The laser beam path length increases as the moving retroreflector positioned on the load travels away from the beam splitter, and a pattern of light and dark fringes repeats consistently. This produces electrical impulses that may be counted and translated to a distance measurement to give an exact load location. The wavelength of the laser light determines the distance between the light and dark fringes and the consequent electrical pulse rate. For example, the wavelength of a helium-neon (He-Ne) laser's light beam, m, or about 0.000025 in. As a result, the accuracy of load position measurement is mostly determined by the laser beam's known stable wavelength. However, fluctuations in humidity and temperature, as well as airborne pollutants such as smoke or dust in the air between the beam splitter and the moving retroreflector, may reduce accuracy.

Lasser Doppler Velocimetric

Laser Doppler velocimetry (LDV), also known as laser Doppler anemometry (LDA), is the method of measuring the velocity in transparent or semi-transparent fluid flows, or the linear or vibratory motion of opaque, reflecting surfaces, using the Doppler shift in a laser beam.With the creation of the helium-neon laser (He-Ne) at Bell Telephone Laboratories in 1962, the optics community gained access to a source of continuous wave electromagnetic radiation with a wavelength of 632.8 nanometers (nm) in the visible red spectrum. It was quickly shown that fluid flow could be measured using the Doppler effect on a He-Ne beam dispersed by extremely tiny polystyrene spheres entrained in the fluid. This phenomenon was employed in the development of the first laser Doppler flowmeter employing heterodyne signal processing at Brown Engineering Company's Research Laboratories (later Teledyne Brown Engineering).

The equipment was quickly dubbed the Laser Doppler Velocimeter (LDV), and the method was dubbed Laser Doppler Velocimetry (LDV). Another term for this application is laser Doppler anemometry (LDA).Early LDV uses varied from detecting and mapping the exhaust from rocket engines travelling at speeds of up to 1000 m/s to determining flow in a blood artery near the surface. A number of comparable devices have been developed for solid-surface monitoring, with applications ranging from measuring product speeds in paper and steel mill production lines to detecting surface vibration frequency and amplitude.

LDV, in its most basic and widely used version, crosses two collimated, monochromatic, and coherent laser light beams in the flow of the fluid being measured. Typically, the two beams are created by dividing a single beam, guaranteeing coherence between the two. Lasers with visible wavelengths (390-750 nm) are often utilised (usually He-Ne, Argon ion, or laser diode), enabling the beam path to be watched. The beams are focused by a transmitting optics to collide at their waists (the focal point of a laser beam), where they interact and form a series of straight fringes. As particles entrained in the fluid (either naturally occurring or produced) travel through the fringes, they reflect light, which is collected by a receiving optics and focussed on a photodetector (typically an avalanche photodiode).

The intensity of reflected light varies with frequency, which is similar to the Doppler shift between incoming and dispersed light and hence proportional to the component of particle velocity that lies in the plane of two laser beams. If the sensor is oriented such that the fringes are perpendicular to the flow direction, the electrical output from the photodetector will be proportional to the total particle velocity. All three flow velocity components may be monitored concurrently by combining three instruments (e.g., He-Ne, Argon ion, and laser diode) with different wavelengths.Another kind of LDV, especially in early device development, takes an entirely different method, similar to an interferometer. The sensor also divides the laser beam into two pieces, one of which is directed inside the flow and the other of which is focused outside the flow.

A receiving optics channel intersects the measuring beam and forms a tiny volume. Particles travelling through this volume scatter light with a Doppler shift from the measuring beam; a part of this light is captured by the receiving optics and sent to the photodetector. The reference beam is also supplied to the photodetector, where optical heterodyne detection generates an electrical signal proportional to the Doppler shift, which may be used to calculate the particle velocity component perpendicular to the plane of the beams. Similar optical heterodyning configurations are employed in laser Doppler sensors for detecting the linear velocity of solids and the vibrations of surfaces; the latter sensor is often referred to as a laser Doppler vibrometer, frequently abbreviated LDV.

Because the equipment may be placed outside of the flow being monitored and so has no influence on the flow, laser Doppler velocimetry is often preferred over other kinds of flow monitoring. The following are some examples of typical applications:

Laser Doppler velocimetry measures surface vibrations by reflecting laser light from the vibrating surface. The technology, which has been modified to include a scanning capability (to provide vibration measurement over an array of points, as in the Polytec MSA-500 and Aries Laser Vibrometer, VELA), has been used to measure vibration generation and propagation for ultrasonic motors as well as acoustic and ultrasonic microfluidics. Surprisingly, a laser Doppler vibrometer may also be used to detect the deformation of capillary waves.

A laser Doppler velocimeter (LDV) may be set to measure any desired component velocity, perpendicular or parallel to the optical axis. A semiconductor laser and optical fibres and couplers were used to conduct optical power in an LDV system. To add an offset frequency, the semiconductor laser's frequency modulation (or, alternatively, an external fiber-optic frequency modulator) is employed. Commercial laser Doppler velocimeters with optical-fiber leads and tiny sensor heads are available. However, to introduce the offset frequency, many commercial systems continue to utilise bulk optical components such as acoustooptic modulators or spinning gratings.

The velocity may be measured with great accuracy in a short amount of time using an LDV system. This implies that the technology may be used to monitor and adjust the velocity of objects in real time, as well as measure their vibration. Because laser light can be concentrated to a very tiny area, the velocity of extremely small objects may be measured, or great spatial resolution can be accomplished using scanning methods. This strategy is employed in a variety of industries, including manufacturing, medical, and research. Each of these applications places various demands on system performance in terms of sensitivity, measurement range, and temporal resolution.

LDV systems, for example, are used in industrial processes to regulate continuous roll milling of metal, to manage the rolling speed of paper and films, and to monitor fluid velocity and turbulence in mixing operations. Vibration analysis is another industrial use. The vibration of machines, machine tools, and other structures may be examined with a noncontact vibrometer without disrupting the structure's vibrational behaviour. Surprisingly, the LDV method was effective in measuring arterial blood velocity giving vital medical information. The study of the mobility of the tympanic membrane in the ear is another application in medical research.

Automation Design and process specifications

An automated assembly system combines many components into a single entity by performing a series of automated assembly procedures. The single entity might be a finished product or a component of a bigger product. The constructed entity often consists of a basic portion to which additional components are connected. The components are normally linked one at a time, thus the assembly is finished in stages.

A typical automated assembly system is made up of three subsystems:

1. One or more workstations where the assembly stages are completed,
2. Parts feeding devices that transport the individual components to the workstations, and
3. A work handling system for the finished entity. The work handling system takes the base component into and out of the station in assembly systems with a single workstation.

The handling system transports the partly built base portion between stations in systems with several stations. The following control functions are necessary in automated assembly machines and automated processing lines:

1. Sequence control
2. Safety monitoring
3. Quality control

The distinction between memory control and instantaneous control is particularly important in multi-station automated assembly systems.

Physical configuration may be used to classify automated assembly systems:

1. In-line assembly machine
2. Dial-type assembly machine

Carousel assembly system, and single station assembly machine. It is the machining transfer line's assembly variant. In the in-line setup, synchronous and asynchronous transfer mechanisms are often used to convey base pans from station to station.In the usual dial-type machine applicationbase pieces are put into fixtures or nests connected to the circular dial. At the different workstations situated around the dial's circumference, components were added and/or attached to the base section. The dial indexing machine works in synchronous or intermittent motion, with the cycle consisting of service time + indexing time. Dial-type assembly machines are sometimes built with continuous motion rather than intermittent action. This is widespread in beverage bottling and canning factories, but not in mechanical or electrical assembly.

The functioning of dial-type and in-line assembly systems is identical to that of their processing equivalents, with the exception that assembly operations are conducted. The optimal cycle time for synchronous work transfer between stations is equal to the operating time at the slowest station plus the transfer time between stations. At 100% uptime, the output rate is the reciprocal of the optimal cycle time. The system runs at less than 100W uptime due to component clogs at the workstations and other issues. To move the work around the carousel, the carousel arrangement may be used with continuous, synchronous, or asynchronous transfer techniques. Asynchronous work transfer carousels are often employed in semi-automated assembly systems, such as the single station assembly machine. Assembly procedures are done on a base component at a single location. The standard operational cycle is placing the base part in a fixed position in the workstation, then adding components to the base, and lastly removing the entire assembly from the station.

The component insertion machine, which is commonly used in the electronics industry to fill components into printed circuit boards, is an essential application of single station assembly. For robotic assembly applications, the single station cell is sometimes used as the configuration for mechanical assemblies. Parts are supplied into a single station, where the robot assembles them and executes the fastening processes. The single station system is intrinsically slower than the other three system types since all assembly duties are done and only one constructed item is finished per cycle.

In each of the above-described configurations, a workstation performs one or both of the following tasks: (1) a part is delivered to the assembly workhead and added to the existing base part in front of the workhead (in the case of the first station in the system, the base part is frequently deposited into the work carrier), and (2) a fastening or joining operation is performed at the station in which parts added at the workstation or previous workstations are peeled These actions are performed several times at a single station in the event of a single station assembly system. A method of delivering the pieces to the assembly workhead must be devised for job (1). The following hardware is generally included in a parts delivery system:

1. Hopper is the container into which the components at the workstation are loaded. Each sort of component has its own hopper. Typically, the components are fed into the hopper in bulk. This implies that the pieces are originally arranged in the hopper at random.
2. A feeder for parts. This is a device that pulls individual components from the hopper for delivery to the assembly workhead. Hopper and parts feeder are often integrated into a single functioning mechanism. A vibratory bowl feeder, as shown in Figure 6.1, is a popular hopper-feeder combination.

3. Orientor and/or selector. These delivery system components determine the right alignment of the components for the assembly workhead. A selector is a device that acts as a filter, allowing only pieces that are oriented correctly to pass through. Correctly positioned components are rejected and returned to the hopper. An orientor is a device that permits correctly aligned components to pass through while reorienting parts that were not originally properly orientated.
4. The feed track. The previous parts of the delivery device are generally spaced apart from the assembly workhead. A feed track is utilised to transport components from the hopper and parts feeder to the assembly workhead while ensuring appropriate part orientation throughout the transfer. There are two types of feed tracks: gravity and motorised. The most prevalent are gravity feed rails. The hopper and parts feeder are elevated above the workhead in this configuration. The components are delivered to the workhead using gravity. The motorised feed track forces the pieces to go down the feed track toward the assembly workhead using vibratory action, air pressure, or other methods.
5. Device for escapement and installation. The escapement device's function is to remove components from the feed track at time intervals that correspond to the cycle time of the assembly workhead. The component is physically placed in the right area at the workstation for the assembly process by the placement device. These components are sometimes merged into a single functioning mechanism. In certain circumstances, they are two distinct devices.

The hardware pieces of the parts delivery device conceptually.A components selector is shown. Parts that are not correctly aligned are returned to the hopper. Parts that are incorrectly orientated are reoriented and sent to the feed track in the case of a parts orientor. A more extensive explanation of the many components of the delivery system may be found here.

The programmed parts feeder is a recent advancement in the technology of parts feeding and delivery systems. A programmable parts feeder can feed components of variable shapes in a matter of minutes by adjusting (changing the software) for the variances. Because of its versatility, this feeder may be utilised in batch production or when product design changes arise. The majority of parts feeders are built as stationary automated systems for high-volume assembly of consistent product designs.A broad range of goods and subassemblies are manufactured using automated assembly methods. It should be noted that certain assembly processes are more suited to automation than others. Threaded fasteners, although popular in hand assembly, are a difficult assembly technique to automate. This topic is covered in the next section, along with some principles for developing items for automated assembly.

Motion Sequence

Many conventional assembly methods arose when people were the only accessible means of constructing a product, which is one of the barriers to automated assembly. Many mechanical fasteners routinely utilised in industry today need human anatomy and sensory skills. Consider using a bolt, lock washer, and nut to secure two sheet metal sections on a partly built cabinet. This kind of procedure is often performed manually at a single assembly station or on an assembly line. The cabinet is placed at the workplace, with the two sheet metal elements to be attached in an inconvenient location for the operator. The operator takes the bolt, lock-washer, and nut and manipulates them into position on opposing sides of the two sections before placing the lock-washer and then the nut onto the bolt. As fate would have it, the nut threads first bind on the bolt threads, requiring the operator to unscrew slightly and resume the procedure, employing a well-developed sense of touch to verify that the threads match. After tightening the bolt and nut with their fingers, the operator uses the proper screwdriver there are multiple bolt sizes with different heads to tighten the fastener.

For many years, this kind of manual operation has been widely and effectively utilised in industry to build items. The hardware needed is affordable, the sheet metal is easily perforated to produce the corresponding clearance holes, and the approach lends itself to field service; but, the human labour necessary at the assembly workstation to complete the first attachment is becoming quite costly. Because of the high expense of human labour, assembly technology is being reexamined with an eye toward automation. However, automating the previously mentioned assembly method is quite challenging. For starters, the locations of the holes through which the bolt must be placed vary per fastener, and some of the places may be impossible for the operator to reach. Second, the holes in the two sheet metal sections may not exactly align, necessitating the operator repositioning the two parts for a better fit. Third, in order to accomplish the fastening action, the user must juggle three independent hardware objects (bolt, lock-wash, and nut). And the fastening component may have to be incorporated in the juggling act as well. Fourth, a sense of touch is needed to ensure that the nut is correctly begun onto the bolt thread. Each of these four issues makes operation automation challenging. All four issues together make it practically impossible.

As a result, efforts at assembly automation have resulted in none of the ways indicated by the designer to tie together the many components of a product being evaluated.The first and most general conclusion to be drawn from this final example is that conventional manual assembly procedures are not always the ideal approaches for automated assembly.Humans are the most dexterous and intelligent machines, capable of moving to different positions in the workstation, adapting to unexpected problems and new situations during the work cycle, manipulating and coordinating multiple objects at the same time, and using a wide range of senses to perform work. To accomplish assembly automation, fastening processes that do not need all of these human competencies must be designed and defined during product design. The following are some guidelines and concepts for product design that may be used to help automated assembly:

Cut down on the amount of assembly necessary. This idea may be fulfilled during design by merging functions that were previously handled by distinct components of the product into the same portion. The use of plastic moulded pieces to replace sheet metal parts might be one approach to put this theory into practise. Several metal pieces might be replaced with a more complicated shape moulded into a plastic item. Although the plastic component seems to be more expensive, the savings in assembly time will often justify the choice.

Make use of a modular design. The number of independent assembly processes completed by a single automated system decreases system dependability in automated assembly. Riley advises that the product's design be modular, with each module needing a maximum of 12 or so pieces to be installed on a single assembly system. In addition, the subassembly should be built around a basic component to which subsequent components are attached.Cut down on the amount of fasteners needed. Instead of utilising separate screws, nuts, and similar fasteners, include a tile fastening mechanism into the component design via the use of snap fits and equivalent characteristics.

Reduce the requirement to manage several components at once. In automated assembly machine design, it is preferable to split tasks at several stations rather than handling and fastening many components at the same workstation. In the case of a single station assembly system, this concept must be construed to indicate that the handling of many components in each assembly work clement must be reduced.Limit the needed access direction. This concept basically states that the number of directions in which new components may be added to an existing subassembly should be kept to a minimum. This is the optimum condition if all of the components can be inserted vertically from above. This is obviously determined by the design of the subassembly.

High component quality is necessary. For the automated assembly system to operate well, the components added at each workstation must be of consistently high quality. In an automated system, poor quality components generate blockages in the feeding and assembly systems, resulting in downtime. Portability. Riley defines this as the circumstance in which a specific component may be consistently fed and positioned for delivery from the parts hopper to the assembly workhead. The engineering effort required to invent the means of feeding the components in the right orientation for the assembly process is one of the key expenditures in the creation of an automated assembly system.The orientation characteristics and other geometric factors of the components that impact the ease of feeding and aligning the pieces are the responsibility of the product designer.

Maximum speed and speed range

As a general rule, the greater the base speed for a given power, the smaller the motor. In fact, motors with base speeds of less than a few hundred rev/min are only useful in a few applications, and it is typically preferable to achieve low speeds by the use of suitable mechanical speed reduction.

Except for tiny universal motors and particular inverter fed motors, speeds over 10,000 rev/min are uncommon. The vast majority of medium-size motors have base speeds ranging from 1500 to 3000 rev/min. Base speeds in this range are appealing in terms of motor design because they achieve acceptable power/weight ratios, and they are also suitable in terms of any mechanical transmission. The range across which the steady state speed must be regulated, as well as the precision of the speed holding, are important criteria in the selection process in controlled speed applications. In general, the broader the speed range, the more costly the drive: a range of 10:1 would be standard, but a range of 100:1 would be demanding.

Figures for speed holding accuracy might be confusing since they are frequently expressed as a percentage of the base speed. As a result, if a drive claims a reasonable speed with a 0.2% accuracy and a base speed of 2000 rev/min, the user should anticipate the real speed to be between 1996 and 2004 rev/min while the speed reference is 2000 rev/min. However, if the speed reference is set to 100 rev/min, the actual speed may range between 96 and 104 rev/min while being within the standard. The inverter-fed induction motor, the D.C. drive, and any of the self-synchronous drives are all options for constant torque loads that require operation at all speeds, but only the D.C. drive comes standard with a force-ventilated motor capable of continuous operation with full torque at low speeds.

Because torque is minimal at low speeds, fan-type loads (see below) with a large working speed range are a little simpler prospect. In the middle and low power levels, an inverter-fed induction motor (using a conventional motor) is enough and will most likely be less expensive than a d.c. drive. The basic voltage-controlled induction motor is likely to be the cheapest option for constrained speed ranges (say, from base speed to 75%), and especially for fan-type loads when precise speed control is unnecessary.

Load requirements –Torque – Speed Characteristics

The steady-state torque-speed characteristic and the effective inertia as viewed by the motor are the most critical things we need to know about the load. Furthermore, we certainly need to know what level of performance is expected. At one extreme, for example, in a steel-rolling mill, the speed may need to be set at any value within a large range, and the mill must respond extremely fast when a new target speed is requested. After reaching the desired speed, it may be necessary to maintain it accurately even when exposed to rapid load variations. At the opposite end of the spectrum, a big ventilating fan's set speed range may be relatively narrow (say from 80% to 100%); it may not be vital to retain the set speed very accurately; and the time needed to change speeds or run-up from rest is unlikely to be significant.

At full speed, each of these instances may need the same amount of power and, at first glance, may be fulfilled by the same drive system. However, the ventilating fan is clearly a simpler matter, and using the same mechanism for both would be overkill. The rolling mill would need a regenerative D.C. or A.C. drive with tacho or encoder feedback, but the fan could do with a less expensive open-loop inverter fed induction motor drive, or simply a simple voltage-controlled induction motor. Although loads may vary greatly, they are often classified into two primary kinds, known as 'constant-torque' or 'fan or pump' types. We will take the example of a constant-torque load to demonstrate in detail what has to be done to arrive at a torque-speed curve specification. A thorough treatment is required since this is often the point at which consumers get stuck.

Duty cycle and classification

This is a complicated issue that reflects the fact that, although all motors are limited by a thermal (temperature increase) constraint, various patterns of operation might result in the same final temperature rise.

In general, the technique is to choose the motor based on the r.m.s. of the power cycle, with the premise that losses (and hence temperature increase) fluctuate with the square of the load. This is a plausible estimate for most motors, particularly if the variation in power is due to fluctuations in load torque at an essentially constant speed, as is often the case, and the motor's thermal time-constant is lengthy in comparison to the loading cycle period. (The thermal time constant has the same meaning as it does in any first order linear system, such as an R/C circuit. If the motor is started at room temperature and driven at a constant load, it normally requires four or five time constants to attain its stable working temperature.) Thermal time constants range from more than an hour for the biggest motors (for example, in a steel mill) to tens of minutes for medium power machines and seconds for tiny stepping motors.

Cooling and enclosures

The severe environment experienced by a winch motor on the deck of an ocean-going ship and the relative luxury enjoyed by a motor moving the drum of an office photocopier are obviously worlds apart. The former must be shielded from rain and saltwater penetration, whilst the latter may depend on a dry, dust-free environment.

Classifying the enormously vast variety of habitats may be a challenge, but thankfully, this is one area where international standards have been agreed upon and are widely utilised. The International Electrotechnical Committee (IEC) standards for motor enclosures are now almost ubiquitous, and they take the form of a classification number preceded by the initials IP and followed by two numbers. The first number represents the amount of protection against solid particle intrusion ranging from 1 (solid bodies larger than 50 mm in diameter) to 5, while the second digit represents the level of protection against water ingress ranging from 1 (dripping water) to 5 (jets of water) to 8. A zero in either the first or second number indicates that no protection is provided.

Motor cooling methods have also been classified, and the more common arrangements are denoted by the letters IC followed by two digits, the first of which indicates the cooling arrangement (e.g., 4 indicates cooling through the surface of the motor's frame) and the second indicating how the cooling circuit power is supplied (e.g. 1 indicates motor-driven fan).

Dimensional norms

In this domain, standardisation is developing, although it is still far from general. Standardization is relatively poor there at low-power end because so many motors are tailor-made for specific applications. Shaft diameter, centre height, mounting arrangements, terminal box position, and overall dimensions are fairly closely defined for mainstream motors (induction, d.c.) over a wide size range.

Supply interaction and harmonics

Most converter-fed drives create mains voltage distortion, which may disrupt other sensitive equipment, especially in close proximity to the installation. Some drives include 'frontend' conditioning (in which the current taken from the mains is made to approach closely to a sinewave at dynamic amplification), although this raises the expense of the power-electronics and is restricted to small and medium-power drives. As more and bigger drives are installed, the issue of mains distortion grows, and supply authorities respond by establishing more severe regulatory limitations controlling what is permissible.

Encoder Selection

When choosing a sensor to measure the required physical parameter, a variety of static and dynamic aspects must be addressed. The following are some examples of typical factors:

Range —Difference between the maximum and minimum value of the sensed parameter, Resolution —The smallest change the sensor can differentiate, Accuracy —Difference between the measured value and the true value, Precision —Ability to reproduce repeatedly with a given accuracy, Sensitivity —Ratio of change in output to a unit change in input, Zero offset —A nonzero value output for no input

Choosing a sensor that meets all of the aforementioned requirements is tough at best. Finding a position sensor with micrometre resolution across a metre range, for example, eliminates the majority of the sensors. Often, the unavailability of a low-cost sensor forces the modification of the mechatronic system.When picking a sensor, it is thus best to use a system-level approach rather than selecting it in isolation. When the aforementioned functional parameters are met, a short list of sensors may be constructed.

The size, amount of signal conditioning, dependability, robustness, maintainability, and cost will then determine the ultimate choice.

Factors Affecting the Selection of Position Sensors

Several major criteria should be addressed when choosing a position sensor:

(a) Cost. The original purchase price as well as the life-cycle cost must be considered.
(b) Detecting distance. When measuring distances greater than 25 mm, photoelectric sensors are mostly the best choice. Photoelectric sensors may have detection ranges of up to 300,000 mm for outdoor or highly dusty applications, and as little as 25 mm for extremely tiny components or disregarding backdrop. Limit switches and inductive proximity sensors, on the other hand, have small detecting distances. The electromagnetic field distance limits inductive proximity sensors to less than 25 mm for most types, and limit switches can detect only as far as the lever operator reaches.
(c) Material kind. Only ferrous and nonferrous materials may be detected by inductive proximity sensors, but photoelectric and limit switches can detect the presence of any solid substance.

If the target's surface is glossy, photoelectric sensors may need a polarizer.

1. Speed. Electronic gadgets that use DC power are the quickest, with inductive proximity versions reaching speeds of up to 2000 cycles per second. The quickest limit switches can detect and reset in 4 m/s, or around 300 times per second.
2. The environment. Proximity sensors work best in muddy, gritty surroundings, but metal chips and other metallic debris may deceive them. If photoelectric sensors are fogged or obscured by debris, they will be tricked or rendered unusable.
3. The voltage types, connectors, and device requirements are housing. All three varieties may meet a variety of needs, but the right choice must be made in light of the power supply, wiring schemes, and surroundings.
4. Third-party validation. Underwriters Laboratories (UL), the National Electrical Manufacturers Association (NEMA), the International Electrotechnical Commission (IEC), Factory Mutual, the Canadian Standards Association (CSA), and other organisations impose safety standards, which are frequently based on the type of application. The certification ensures that the gadget has been tested and certified for certain applications.
5. Intangible assets. These might include the availability of application support and service, the supplier's reputation, local availability, and manufacturer quality testing assertions.

Formal process modeling

After the requirements have been determined, formal process modelling may begin. The informal language descriptions must be systematically verified for ambiguity, inconsistency, and incompleteness in this stage. The easiest way to do this is to translate language descriptions into formal process models.Initially, intermediary formats such as a list of processes, a flowchart, and so on may be used. Before building the control algorithms, they must eventually be transformed into mathematically clear and consistent descriptions using a formal modelling framework such as a Finite State Machine (FSM). Modeling paradigms that may be expressed pictorially, according to practical engineers, are especially suited to humans.

A process is often considered as a Discrete Event System in formal modelling (DES). There is a lot of formalism for designing timed or untimed DES models (e.g. Petri Nets). This class does not have time to go into depth about them. A reader who is interested in real-time systems is directed to literature on the subject. This course demonstrates how to simulate process dynamics using a Finite State Machine. The following facts are given that are highly significant in modelling.

A. An FSM is a basic DES formalism in which the system may exist in any one of a limited set of discrete states at any time.

B. A state is just a value assignment to the system's collection of variables. The process variables in a discrete event system are expected to have a limited set of values. Limit switches, for example, may only accept one of two values: ON or OFF.

C. Furthermore, the set of process variables must be chosen in such a way that the process's future behaviour is completely determined by the current values of the chosen set of variables. For the stamping press example, the collection of process variables would contain the Top and Bottom limit switch settings. However, based only on these, the process's behaviour cannot be predicted. This is because it is impossible to tell whether the piston is going up or down based on these. As a result, the state of the motion must be included as a state variable. This variable may have the following values: 'moving up,' 'going down,' and'stationary'. In this situation, another variable would have to be included, namely the value of the portion detect sensor output, in order to differentiate between the cases when it is ON and when it is OFF, when the piston is at the top position.

D. Some of the state variables may be physically monitored using sensors. Others might not.

E. The selection of state variables might be subjective, and various designers may prefer different ones. The decision is also influenced by the kind of control actions desired. As a result, the selection of states is unique to the machine and its functioning.

F. Throughout its life cycle, the process transitions from one stage to the next. As a result, it spends the majority of its time in the United States. It does, however, sometimes change from one condition to another. A transition's occurrence is fully dependent on the occurrence of distinct events. These are the names given to situations involving states, some of which may change owing to external variables such as operator inputs or internal causes such as the passage of time. When such an event occurs, processes that cause state transitions are activated. Because state transitions or events are often regarded instantaneous, the system spends all of its time in the different states. The occurrence of transitions modifies state variables. Indeed, the change in the values of the state variables is interpreted as a transition from one state to another.

G. All conceivable state variable combinations may not be legitimate state assignments for a system. In other words, the system can only contain a subset of all potential state variable combinations. These are the combinations that the system is supposed to be able to attain.

CHAPTER 8

Parts of Automobile

Aravindan M K, Assistant Professor
Department of Mechanical Engineering, Faculty of Engineering and Technology,
JAIN (Deemed-to-be University), Ramanagara District, Karnataka - 562112, India
Email Id- mk.aravindan@jainuniversity.ac.in

An automobile has several numbers of parts. But there are four essential components of automobile. These are:

The Chassis

The engine, axles, propeller shaft, gearbox, control system components including brakes , steering, and rear suspension of the vehicle are all significant assemblies that are included in the chassis of a car. It is the car without the body, to put it another way. The frame, suspension, axles, and wheels make up the majority of the chassis of a car. The frame may take the shape of a standard chassis or may employ unit construction. The frame serves as the primary structure of the vehicle in a traditional chassis frame. It supports the car's engine, gearbox, and body. The frame, suspension, axles, and wheels make up the majority of the chassis of a car. The frame may take the shape of a standard chassis or may employ unit construction. The frame serves as the primary structure of the vehicle in a traditional chassis frame. It supports the car's engine, gearbox, and body. The frame, suspension, axles, and wheels make up the majority of the chassis of a car. To isolate engine vibrations, the sub-frame is linked to the mainframe and supported by it using certain proper rubber connections.

The majority of automobiles now have integrated structure because spot welding and sheet crushing procedures have advanced. The body of the vehicles, which also serves as the frame, is where all of the assembly pieces are attached. The car becomes more lightweight and small, and its price is likewise decreased. There are also several intermediate versions in use that have a body made of pressed steel and a light chassis. Wheels, axles, and the suspension system make up the remainder of the chassis. The wheels' up-and-down action causes vibrations, which the suspension system dampens. This is accomplished via the springs & shock absorbers that link the frame to the axle. The springs might be torsion bars, coil springs, or leaf springs. Even air or rubber may be used to create springs.

The vehicle's wheels can be suspended separately on springtime or on axles that are spring-suspended. If power from of the engine is sent to the axle, it can be considered "live." It may be a "dead" axle if it receives no power and only carries the weight of the automobile. In "four-wheel drive," both axles are "live" since power is sent to each of them. The axle supports the vehicle's weight while also enduring pressures brought on by braking and drive torque.

The Engine

The source of an automobile's propulsion is its engine. It goes without saying that the engine is a crucial component of the car since without one, it could not be able to move at all, defeating the purpose of the vehicle, which is to transport people or cargo.

The functionality of the car is determined by the engine's power. The effectiveness of a car is similarly determined by the engine's efficiency. An automobile's engine provides its propulsion. Without an engine, the car might not move what so ever, which would negate its primary purpose of moving people or cargo. It follows that the engine is a highly crucial component of the car. The efficiency of the engine governs how the car operates. The economy of a car is determined in a similar way by the engine's efficiency.

Unwanted engine overheating is caused by a portion of it. This heat must be adequately dispersed. To dissipate this heat, a coolant such as air or water might well be utilized. Consequently, an engine can indeed be cooled by water or by air. These days, various compounds with cooling properties have been created, and they maintain their unaltered state for a longer duration] these substances are utilized as coolants and don't need to be changed too often. In addition to having a longer lifespan, they are also more productive.Similar to this, an engine's lubrication is another important consideration that has to be addressed on a regular basis by the user. To lessen unneeded friction, an engine's moving components require routine lubrication. Lubricant chemistry has advanced significantly in recent years. Lubricants are rated according to a standard, and there is a specialized lubricant for every use.

The Transmission System

The engine's power is transferred to the vehicle's wheels through the transmission system. The crankshaft's rotation serves as the engine's primary means of power generation. To make the road wheels rotate, this movement must be communicated to them. The vehicle may move because of their rotating motion. The transmission system is made up of many components. These components include the clutch, gearbox, driveshaft, differential, and axle—more specifically, the live axle. The axle's ends are where the road tyres are located. These components transfer the motion. Each component of the transmission line has a specific purpose.

Clutch

Next to the crankshaft is the clutch, which is a component of the transmission system. It is a device that allows one shaft's rotating motion to be "willingly" communicated to the second shaft. Road wheels shouldn't be attached to the engine when it begins, so they shouldn't begin to move right away. Second, this motion must be smoothly transmitted to avoid upsetting the car's occupants and damaging its mechanical components. In vehicles used to move products, a smooth transmission procedure is crucial since anything less might result in the contents being damaged.

Gearbox

Next to the clutch in the transmission system is the gearbox. It features a gear system that offers various gear ratios. These ratios control how quickly the gearbox's output shaft rotates. A providing direction or (tractive attempt) is generated between the wheels of the vehicle and the road as a result of the torque applied to the road wheels. There is a significant tractive effort needed when beginning from rest. This necessitates the addition of significant "leverage" between the engines and the tires so that the engine's nearly constant torque generates the significant tractive effort.The gearbox's various gear ratios may offer the tractive force necessary to help the car overcome any opposition it encounters depending on the situation. The output from gearbox is transferred to the axle through the propeller shaft. The output from gearbox may go to either the front or the rear axle, or in rare circumstances both.

Differential

The next part of the transmission system is the differential. The differential receives the propeller shaft's motion and spins it all through 90 degrees. Due to the axle's 90-degree angle with the propeller shaft, this is crucial. A pinion and a gear are used to carry out the task. The differential's ability to decrease the speed of the inner wheels while increasing the speed of the outer wheels by a similar amount is another crucial function. This is necessary if the car is travelling along a curving course. The outer wheels must travel a circle with a greater radius than that of the inner wheels on a curved path.

This indicates that the outer wheels must go a greater distance than the inner wheels. All four wheels of the car must move as a unit in order for it to move. As a result, the inner wheels should cover a shorter distance in same amount of time as the outer wheels. Therefore, it is necessary to vary the speed of the inner and outer wheels. The differential does this with the aid of the sun planet gear mechanism.

Axle

The next part of a transmission system is the axle. The phrase "live axle" refers to the axle that is getting power from the engine. It is split in two. Road wheels are attached to the axle's ends. These wheels are directly in contact with the pavement. The car's body is located above the axle. The axle also supports a variety of loads, including the car's weight. The road wheels receive motion from it as well.

The Body

With the exception of a few applications for commercial heavy-duty vehicles, the usage of a separate structure that the body structure is connected is now all but obsolete. The engine and transmission are now linked to ‘sub-frames' that are often used in big vehicles. To isolate engine vibrations, the sub-frame is linked to the mainframe and supported by it using certain proper rubber connections.

The majority of automobiles now have integrated structure because spot welding and sheet pressing procedures have advanced. The body of the vehicles, which also serves as the frame, is where all of the assembly pieces are attached. The car becomes more lightweight and small, and its price is likewise decreased. There are also several intermediate versions in use that have a body made of pressed steel and a light chassis. In such designs, the light chassis is reinforced by a platform composed of a plate of steel. Auxiliaries and control systems are included in the car in addition to the four fundamental parts mentioned above.

The control systems of a car are crucial since they are used to manage the vehicle's motion. These consist of;

1. The steering mechanism, and
2. Brakes or the braking system.

Steering system

It could be necessary for the moving car to travel in a circle. If the road is not straight, it must be twisted through an angle. There may be additional instances where a car needs to make a left or right turn as the road is going to the left or right. The steering system allows for the car to be turned to the left, right, or along a curved course. The steering mechanism must be extremely precise since the car must turn precisely along the course.

Braking system

The car slows down and, when required, comes to a stop. An automobile's stopping is just as crucial as its moving. Naturally, when we get at our destination, we want to halt, thus the car should come to a stop. Additionally, a vehicle may need to stop or slow down in order to respond to an emergency. Its mobility must also be regulated at that moment. Brakes are utilized to give this motion control.

The Auxiliaries

These are the parts of a car that might not be necessary, yet they might improve comfort when driving. The reality is that some auxiliaries end up becoming necessary over time. A few years ago, there was no need for indicators to show when a vehicle was turning. However, the government has recently made these requirements. Although air conditioning is only necessary to give comfort, it is now a standard feature in every car in industrialized nations, and as more people are embracing it. The study of car engineering entails a thorough examination of all the elements and components of an automobile.Internal combustion is the type of engine utilized in cars. The introduction of some of the components that make up the transmission system has previously been given. Wheels, tires, and suspension systems are additional crucial automotive equipment. As these components make up the vehicle's control system, studying the steering and braking systems is equally crucial.

Valve and Valve Gear mechanism

By opening, shutting, or partly blocking different passages, a valve regulates, directs, or regulates the movement of a fluid (flammable gasses, streams, fluidized solids, or slurries). Although technically a kind of fitting, valves are often considered separately. To input the air-fuel combination into the combustion chamber area and outputs the combustion gas outside, the valve mechanism open or shuts the intakes valve and exhaust valve so at right time. Pear-shaped cams on a revolving camshaft, powered by a ring or a belt, provide the operation. The engine block houses the camshaft. The camshaft has several tiny cams that are positioned correctly on the shaft. Through the use of the metal pushrod and cams, it exerts force on the valve. A rocker arm that is pushing on a valve stem is pushed by the top of a pushrod.

Valve gear

A steam engine's valve gear controls the intake and exhaust valves, allowing steam to enter the cylinder and exhaust steam to exit at the appropriate times during the cycle. Additionally, it may be used as a reverse gear. As with an internal combustion engine when the valves constantly close and open at the same positions, this might be a straightforward process in the simple case. However, this is not the ideal configuration for a steam engine because maximum power is obtained by maintaining the inlet valve expansive throughout the upstroke (thereby having full boiler pressure, subtracting transmission losses, against by the piston throughout the stroke), whereas maximum efficiency is obtained by only briefly leaving the inlet valve open before allowing the steam to broaden in the canister (expansive working).

The cutoff is the point in the cylinder when steam is no longer allowed, and the best location for this depends here on work being done and the intended trade-off between efficiency and power. Steam engines are equipped with regulators (or throttles in American vernacular) to adjust the limitation on steam flow, but since it maximizes the usage of boiler steam, regulating the horsepower via the shutdown setting is typically preferred. By allowing the steam to enter the cylinder a little bit before front or rear dead center, another advantage may be realized. This advanced admittance, often referred to as lead steam, helps to reduce the inertia of fast motion.

The restriction that intake and emission occurrences are fixed in respect to one another and cannot be separately optimised applies to both slide and piston valves. Although the valve stroke shortens as the cutoff is advanced, there is lap on the steam edges of the valves, ensuring that the valve is always completely opened for exhaust. But as cutoff gets shorter, exhaust events likewise get faster. Early in the power stroke is the exhaust release point, and early in the exhaust stroke is compression.

Early closure also costs energy by compressing an otherwise unnecessary huge amount of steam, and early release wastes energy in the steam itself. The widespread research with poppet valve gears and locomotives was sparked by these inefficiencies. It was possible to move and operate the intake & exhaust poppet valves separately, improving cycle management. Poppet valves were eventually installed in a very small number of locomotives, but they were popular on steam cars and trucks. For instance, almost all Sentinel Lorries, locomotives, and railcars had poppet valves. The SR Leader class, employed sleeve valves modified from combustion engines, however this class did not succeed.

Valve timing diagram

An engine's intake and exhaust valves are shown opening and shutting graphically in a valve timing diagram. The piston’s movement from TDC to BDC controls the opening and shutting of the engine's valves. To govern this relationship between the piston and the valves, a valve timing diagram is built up between the two. The valve timing diagram includes a 360-degree figure that depicts the piston's travel from TDC to BDC throughout each of the engine cycle's strokes. This movement is measured in degrees, and the valves' opening and shutting are controlled in accordance with these degrees.

Need of Valve Timing Diagram

The average internal combustion engine runs through around 100,000 cycles per minute. Because there are several processes involved in each cycle, from the intake of the air-fuel combination through the exhaust of combustion residue, it is vital to have an efficient system that can enable

1. Synchronization of the engine cycle's various phases, from air-fuel ratio intake through residual combustion exhaust.
2. Complete seizing of the combustion process at the precise moment the air-fuel combination burns because leaking might harm the engine and be dangerous.
3. When necessary (at the moment of suction), provide the engine a mixture of air and fuel, or air in the case of a diesel engine.
4. Provide a path for the combustion residue to leave so that the engine can go through its next cycle.
5. Optimal timing for the intake and exit valves' opening and shutting, which shields the engine against flaws like banging or explosion.
6. the maintenance of combustion quality and a reduction in internal wear and tear through engine cylinder cleaning
7. The investigation of the specifics of combustion is necessary for altering the engine's output.

8. For these reasons, whether a 2-stroke or 4-stroke engine is developed, the valve timing schematic is used to ensure that the exhaust and intake valves open and close at the proper times as the piston moves from TDC to BDC.

Valve Timing Diagram for 4-Stroke Engine (Petrol and Diesel)

4-stroke motor Suction, compression, expansion, and exhaust are the four strokes that make up the cycle's completion. The graph known as a valve timing diagram illustrates the relationship between the valves (inlet and outflow) and the piston's movement from TDC to BDC.

Suction Stroke

Inlet valve opens when the piston, which is at TDC, begins moving towards BDC, and air-fuel mixture for a gasoline engine or fresh air for a diesel engine start entering the cylinder until the piston travels to BDC, starting the engine cycle.

Stroke of Compression

The inlet valve closes throughout that procedure to provide epilepsy of the chamber for the compaction of the fuel. After the suction stroke, the piston begins moving from BDC to TDC again in order to compress the air-fuel (in a gasoline engine) and fresh air (in a diesel engine). This increases the pressure inside of the cylinder, which is necessary for the fuel to burn.

Increased or Epansion Stroke-

After the fuel is compressed, it is burned, which forces the piston, which is at top dead centre (TDC), toward bottom dead centre (BDC), where the pressure created by the combustion is released and the output is achieved.

1. In petrol engines, the spark created by the ignition system is what causes combustion.
2. In a gasoline engine, the suction stroke is when the fuel and air charge enters the cylinder.

In a diesel engine, combustion happens as a result of the high compression given by the compression stroke, which raises the temperature within the cylinder to the diesel and air charge's auto-ignition temperature.

Exhaust Stroke

After the expansion stroke, the piston at BDC begins to move towards TDC, and then the exhaust valve opens to allow the combustion residue to be released. After the piston hits TDC, the exhaust valve closes.

Actual or Practical Process

The inlet valve opens 10–20 degrees ahead of TDC during the suction stroke of a 4-stroke engine to allow for the correct intake of air-fuel (petrol) or air (diesel), as well as to sweep out any leftover combustion residues in the combustion process. The compression stroke begins when the piston hits BDC, and the piston then begins to move once again towards TDC. During the compression stage, the inlet valve shuts 25 to 30 degrees past the BDC, completely sealing the combustion for the compressed air, fuel (for a gasoline engine), and air (diesel engine).

Valve Timing Diagram for 2-Stroke Engine

A two-stroke gasoline engine runs through its whole cycle in two strokes, the expansion stroke and the compression stroke. During each of these two strokes, fuel is injected into the engine and combustion residue is expelled. Figure 8.1 Valve Timing diagram for 2-stroke Engine

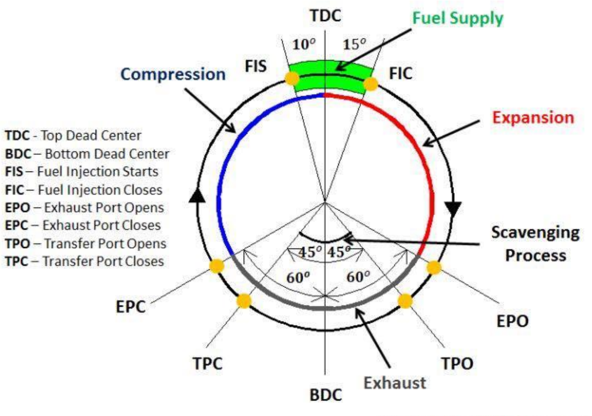

Figure 8.1Valve Timing diagram for 2-stroke Engine.

Expansion stroke

The combustion of compressed air-fuel (in a gasoline engine) or a diesel sprayed charge (in a diesel engine) during the compression stroke causes the piston, which is at TDC at the beginning of an expansion stroke, to move towards BDC, producing power.

1. During the expansion strokes, the piston travels from TDC to BDC, allowing the air-fuel (for a gasoline engine) and the air (for a diesel engine) to enter via the inlet port.
2. Up until the piston hits BDC, the expansion stroke continues.

Compression Stroke

Due to the piston's movement from BDC to TDC at the conclusion of the expansion stroke, the compression of the air-fuel (for gasoline engines) and diesel sprayed charged (for diesel engines) begins as well as the emission of combustion residue through the exhaust port. As the piston moves from BDC to TDC, it closes the intake and exhaust ports, increasing the pressure inside of the combustion chamber. Combustion of the mixture of air (in a gasoline engine) is sparked by the spark plug, whereas combustion of the diesel sprayed charge (in a diesel engine) is sprayed by the high pressure, and the cycle is repeated.

Actual or Practical Process

The inlet port opens 10 to 20 degrees prior to the expansion stroke, when the compression stroke is complete. This initiates the expansion stroke because of the combustion of air-fuel (in a gasoline engine) from the crankcase and air (in a diesel engine) entered through the inlet port, which in turn pushes the piston toward to BDC. The 2-stroke engine's intake port shuts 15-20 degrees after TDC during the adiabatic expansion.

Exhaust port opens 35 to 60 degrees first before piston reaches BDC as a result of the piston moving from TDC to BDC during in the expansion stroke, which in turn triggers the combustion residual's exhaust. The transfer port is opened for the scavenging procedure 30 to 45 degrees before BDC.

Exhaust valve closes 35 to 60 degrees after BDC as the piston moves from BDC to TDC, seizing the combustion chamber and causing the compression stroke to begin, which increases pressure inside the combustion chamber. And the cycle resumes. When the transfer port is opened, the fuel air mixture (for a diesel engine) and air are delivered to the cylinder.

For the engine to operate normally, the valves must open and close a few degrees between TDC and BDC. This degree gap ensures that each stroke is completed properly, shields the engine from flaws like knocking, and reduces emissions.

Automotive engine

A positive displacement internal-combustion engine with an intake, compression, combustion, and exhaust strokes is what is known as an automobile engine. An active internal combustion engine is a gas turbine. For autos and other vehicles, a broad range of propulsion technologies were now or possibly accessible. There were internal combustion engines powered by gasoline, gasoline, propane, or natural gas, as well as hybrid and plug-in hybrid vehicles, hydrogen-powered fuel cells, and all-electric vehicles. Due to their short range and expensive cost, fueled vehicles appear to be more advantageous. A network of refueling or charging stations was necessary for certain alternatives. Car manufacturers used a number of choices to follow parallel development tracks as no one option offered a clear advantage over the others. Vehicle weight reduction was one of the methods used.

Piston

Among other related systems, pistons are found in reciprocating engines, reciprocating pumps, gas compressor, hydraulic cylinders, and pneumatic cylinders. It is the moving part that is enclosed in a cylinder and sealed off from the gas by piston rings. Its function in an engine is to use a piston rod and/or connecting rod to transmit force from the expanding gas within the cylinder to the crankshaft.

For the goal of compressing or expelling the fluid in the cylinder, the function is reversed in a pump, and force is transmitted from the crank to the piston. By closing and opening apertures in the cylinder, the piston can also function as a valve in some engines.

Piston taper

The diameter difference between both the top and bottom of a piston ring's trip is known as a taper. Compare the readings at the top and bottom of the piston ring travel by taking measurements at each location. When the piston moves down and up the cylinder, taper causes the piston rings to move too much.

Camp Ground Piston

A piston for a reciprocating engine that is not spherical but has been machined such that its length perpendicular to the wrist pin is somewhat lower than its parallel diameter.

Special Alloy piston

Low carbon steel or aluminum alloys are used to make pistons. High temperatures, inertia, vibrations, and friction are all applied to the piston. The effects of the piston's and the cylinder's walls' differing rates of thermal expansion are reduced by carbon steels.

Parts of a piston

The piston's job is to transform this released fuel into mechanical work because it is the only moving component of the combustion chamber. The piston's fundamental form is a hollow cylinder that is closed on one side and is divided into the component parts piston crowns with ring belt, pins bosses, and tail. Major piston components and their roles are illustrated below:

Piston Ring

Gas compression between both the piston and cylinder wall is maintained by piston rings. In order to prevent combustion gas from leaking into the space between both the piston and the cylinder, piston rings cover the cylinder. A basic vehicle engine will typically have one of three types of piston rings:

Compression ring

It is located closest to the combustion chamber on the upper side of the ring stack. It is also known as the pressure or gas ring. The ring stops the leakage of combustion gases. Additionally, compression rings aid in transferring heat from piston to the cylinder walls.

Wiper ring

The piston ring with a tapering face that is situated in the groove between the piston ring as well as the oil ring is known as a wiper ring. The wiper ring is employed to better seal the combustor and to remove extra oil from the cylinder wall. The wiper ring stops combustion gases from passing by the compression ring.

Oil Ring

The piston ring in the ring groove nearest to the crankcase is known as an oil ring. During piston movement, the oil ring is utilised to remove extra oil from of the cylinder wall. Through ring apertures, extra oil is returned to the engine block's oil reservoir.

Piston Skirt

The cylindrical component positioned on the round portion of a piston is referred to as the skirting of a piston. Cast iron often makes the component because of its superior fatigue resistance and self-lubricating qualities. The grooves for installing the compression rings and piston oil rings are located in the skirt. Piston skirts come in a variety of styles to suit various purposes.Two main kinds of cylinder skirts are as follows:

Solid skirt

Solid skirt is another name for a full skirt. The whole skirt is shaped like a tube. It is frequently utilized in the engine of big cars.

Slipper skirt:

Motorcycle and certain car pistons are fitted with this style of skirt. Only the front and rear sides of the skirt are left on the engine cylinder after a portion of it has been removed. By doing so, the contact area here between piston and the cylinder wall is reduced and weight is also reduced.

Piston Pin/Gudgeon Pin

The pin used to attach the piston to the connecting rod is also known as a wrist pin or Gudgeon pin; it serves as a bearing for connecting rod to pivot upon as the piston travels. The gudgeon pin is found in a sliding headstock that is connected to the piston by a rod in many extremely large stationary and marine engines as well as many very early engine types, including those powered by steam. The gudgeon pin, which can be physically removed from the connecting rod, piston, or crosshead, is normally a short hollow rod composed of a steel alloy with high hardness and strength that has been forged.

Designing piston pins may be difficult, especially for compact, high-rpm vehicle engines. The piston pin must function at some of the engine's hottest temperatures, and because of where it is located, it is difficult to lubricate.

It must also be compact and light to fit inside the piston's diameter and avoid unnecessarily adding to the piston's mass. A tiny diameter rod with high bending and shear loads as well as some of the greatest compressive stresses of any gear in the whole engine is required to meet the criteria for lightweight and compactness. The piston pin is one of the most intricate mechanical parts found in combustion engines because of the manner it is built and the materials used to solve these issues. The following categories of pins result from these.

Fixed or stationary pin:

A screw secures the pin to a bosses of the piston. On the pin, the piston then pivots.

Semi-floating:

The pin has a center attachment to the rod and its ends are free to move inside the piston bearings and at the bosses.

Full-floating:

In this type of pin, neither the pin nor the piston connecting rod are connected to the pin. Instead, hooks, hooks, or snap rings fastened to the piston lobes hold it in place. The pin can thus move at the bosses and the rod simultaneously.

Piston Head/Crown

The head of a cylinder is its top, and it is sometimes referred to as a piston head or dome. This area is the one that makes touch with the combustion gases. It becomes incredibly hot as a result of this. Parts of piston heads are manufactured from specific alloys, such as steel alloys, to prevent melting.

Channels and cavities are typically used while building piston heads. This contributes to the swirl that enhances combustion. Different engines employ various types of piston heads. The differences' causes vary. Numerous variables, including the kind of engine and anticipated performance, affect the recommended piston head design.

Connecting Rod

The component of a petrol engine that joins a piston to the crankshaft is known as a connecting rod or con rod. The connecting rod, in conjunction with the crank, transforms the piston's reciprocating motion into the crankshaft's rotation.

Piston Bearings

At the locations where crucial rotation takes place, there are piston components called bearings. Typically, they are semi-circular metal pieces that slide into these points' holes.

The cups at the big end of the piston, where the rod is attached to the crankshaft, are the piston bearings. The tiny end, where the rod attaches to the piston, also has bearings.

Typically, composite metals like lead copper, silicon aluminum, and others are used to create piston bearings. To increase hardness and withstand the stress from the movement of the piston and connecting rod, the bearings are frequently coated.

Introduction of Two-stroke and Four-stroke Engine

The process through which the piston in the cylinder rises to the top and descends is known as the stroke inside a combustion engine. The cycle begins with the intake stroke, during which a brand-new combination of gasoline and air is forced into the engine's cylinder by the piston moving downward and expanding. The primary distinction between a 4-stroke engine as well as a 2-stroke engine is the number of stages or complete revolutions required to complete one power stroke. A 4-stroke engine requires four stages or two complete insurrections, whereas a 2-stroke engine only requires two stages or one complete revolution.

Two-Stroke Engine

To produce power, the two-stroke engine completes two piston rotations (one crankshaft revolution). The simultaneous ingestion of gas into the cylinder and exhaustion of the remaining gases allows the engine to produce power after just one cycle. A valve that controls the intake stroke opens and shuts in response to changing pressures is present. However, because it frequently comes into touch with moving elements, oil is added to the gasoline to offer lubrication, enabling smooth strokes.

CHAPTER 9

Four-Stroke Engine

Adarsha H, Associate Professor
Department of Mechanical Engineering, Faculty of Engineering and Technology,
JAIN (Deemed-to-be University), Ramanagara District, Karnataka - 562112, India
Email Id- h.adarsha@jainuniversity.ac.in

The four consecutive steps of a four-stroke engine are intake, compression, power, and exhaust. Each represents a whole piston stroke. As a result, it produces one power stroke per each two piston cycle (or four-piston stroke) cycles, and a cycle needs two crankshaft rotations to complete.

Working of a Four-stroke Engine

The four steps that make up the 4 stroke engine's operation are as follows:

Intake Stroke

The combustion chamber is drawn into with a combination of fuel and air. To empty this combustion chamber, the piston depresses within the cylinder bore. The air-fuel charge is forced into the evacuated tube when the inlet opens due to atmospheric pressure.

Combustion Stroke

The intake valve closes the mixture once the cylinder has been filled to its full capacity, and the piston rises. Between both the piston and also the crankcase is where the compression happens.

Power Stroke

After the completion of the compression stroke, the spark ignites the air-fuel mixture and forces the piston back down the cylinder bore to generate torque in the crankshaft. The pressure on the piston determines the amount of torque generated.

Exhaust Stroke

The combustion chamber's leftover gases are released into the atmosphere during the exhaust stroke. The last stroke occurs when the intake is closed and the outlet valve is open, and it is known as the exhaust stroke. Exhaust gases are released into the atmosphere by piston action.

Internal combustion engine

Internal combustion engines provide outstanding drivability and durability, with more than 250 million highway transportation vehicles in the United States relying on them. Along with gasoline or diesel, they can also utilize renewable or alternative fuels (e.g., natural gas, propane, biodiesel, or ethanol). They can also be combined with hybrid electric powertrains to increase fuel economy or plug-in hybrid electric systems to extend the range of hybrid electric vehicles.

Internal Combustion Engine Work

The fundamental chemical process of emitting radiation from a fuel and air combination is combustion, sometimes referred to as burning. In an internal combustion engine (ICE), the gasoline is ignited and burned inside the engine itself. The energy from the burn is then partially converted into work by the engine. A stationary cylinder as well as a moving piston make up the engine. The piston is propelled by the expanding combustion gases, which turns the crankshaft. This motion ultimately propels the wheels of the car through the powertrain's gearing system.

The spark ignition gasoline engine as well as the compression ignition diesel engine are the two types of internal combustion engines that are currently produced. The majority of these engines have a four-stroke cycle, which requires four piston strokes to complete a cycle. The intake, compressor, ignition and exhaust stroke, and exhaust are the four separate operations that make up the cycle. Diesel engines with compression ignition and spark ignition use different fuel delivery and igniting systems.

During the intake phase of a spark ignition engine, liquid fuel and air are combined before being inducted into the cylinder. The spark ignites the fuel-air combination after the piston crushes it, resulting in combustion. During the power stroke, the piston is propelled by the explosion of the combustion gases. Only air is sucked into a diesel engine, where it is compressed. The gasoline is then sprayed into the heated, compressed air by diesel engines at an appropriate, calibrated pace, setting it ablaze. To meet EPA emission limits, manufacturers have had to lower ICE emissions of pollutants including nitrogen oxides (NOx) and fine particles (PM) by more than 99% during the past 30 years thanks to research and development. Additionally, research has improved ICE efficiency and performance (hp and 0-60 mph increasing speed), assisting manufacturers in maintaining or improving fuel economy.

The combustion of a fuel takes place with the help of an oxidizer (often air) in a combustion chamber that is a crucial component of the working fluid flow circuit inside of an internal combustion engine (ICE or IC engine). In a combustion engine, a component is subjected to direct force as a result of the expanding of the high-temperature and rising gases generated during combustion. Typically, the force is applied to a rotor (Wankel engine), windmill blades (gas turbine), pistons (piston engine), or a nozzle (jet engine). The component is propelled across a distance by this force, which converts chemical into kinetic energy that is then utilised to move and power whichever the engine is connected to the engine. Understanding internal combustion engines requires thorough consideration of the ideal gas law. A gas's desire to expand is influenced by pressure, which rises as its temperature rises. A chamber of an internal combustion engine contains fuel that is introduced and ignites to raise the gas's temperature.

Gas inside the system is forced to expand when heat is supplied. This makes the piston rise in a piston engine. The engine is able to turn some of the energy input into productive work by coupling the piston to a crankshaft. In an irregular combustion engine, liquid gas is expelled in order to compress the piston. Then comes a heat sink.

Components of Internal Combustion Engine

The typical components of an internal combustion engine are listed below:

Cylinder

These car engine components are housed inside the engine block, sometimes referred to as the cylinder block. It has sleeves or a liner around it. When put to use, this lining becomes worn out but is simply replaceable. The combustion occurs because of the piston's ability to travel up and down in the cylinders. The bore and stroke of a cylinder define it. The upper and lower limits of the stroke are known as the bore and stroke, respectively. The bore is the inner diameter, while the stroke is the effective length along which the piston reciprocates, or the displacement of the cylinder from the TDC to the BDC. These hollow areas, known as jackets, are also present in the cylinder block surrounding and between the individual cylinders. In the case of liquid-cooled engines, it permits coolant to enter and circulate to facilitate effective heat dissipation.

Piston

The combustion cycle may be completed thanks to the piston, a cylindrical component that travels up and down in the cylinder (intake, compression, combustion, exhaust) .To prevent rapid wear of the piston surface, the diameter of the piston is slightly smaller than the bore of the cylinder. The round depressions on the piston surfaces are filled with three piston rings. These aluminum rings, which come in direct touch with the cylinder lining, reduce the likelihood of piston wear.The blowby effect is aided by the chamfered outer surface of the two initial rings, which are compression rings (prevention of waste gases inside the combustion chamber from entering into the crankcase.) The third ring, sometimes referred to as the oil ring, ensures that oil is distributed properly around the cylinder walls and keeps oil from into the combustion chamber.

Crankshaft

These engine components assist the connecting rod in turning the piston's sliding action into rotational motion. In a container known as the crankcase, it is housed beneath the cylinder block. The projections on the crankshaft are curved and spaced excluding the shaft axis. Each cylinder in a multi-cylinder engine has its own crankpin, which is used to secure the piston by the rod. The large end, which has a sliding bearing, is a component of the crankshaft known as the crankpin journal bearing. It also has counterbalance weights. It is offered to reduce the tensional vibrations that the crankshaft experiences as a result of the moving piston's reciprocating imbalance during combustion. Either the crank balancing is a component of the crank body or it is fastened to it.Either individual crankshafts or crankshafts in several pieces are created. The single-piece construction is ideal because it gives superior fiber flow, good stress-bearing capacities, and leaves no room for vibration.] Last but not least, crankshafts are often made of ductile steel by casting or steel by roll forging. Crankshafts built in one piece are constructed from heat-sensitive carbon steels. Due to the increased strength it may provide without undergoing heat treatment, several other steels, such as vanadium micro-alloyed steels, are also employed.

Connecting rod

The piston is connected to the crankshaft by means of these engine components. As was already established, it changes the piston's linear motion into the crank's rotating action. Through a piston pin, sometimes referred to as a gudgeon pin or wrist pin, one of its end components is fastened to the piston. The large end, which secures the lower and upper bearing caps, is connected to the crankshaft journal using bolts.

The large end connecting rod inserts the bearing, which is in the shape of two half-shells, into the crank journal. To rotate through an angle, neither end must be fixed firmly. As a result, both ends are constantly moving and much stressed due to the piston's pressure.

The connecting rod is typically constructed of forged steel, however where lightweight and high impact absorption capability are priorities, aluminum alloy may also be used. The connecting rod is a delicate component that is vulnerable to failure, thus it is produced with a high level of precision.

Cylinder head

These engine components act as a cover for the ignition coil, rocker arms, cylinder block, and valve. The head gasket sits between it and the cylinder block, which is fastened to it. Cast iron is used to make the cylinder head, however aluminum alloy is sometimes often used since it is more lightweight and transmits heat more efficiently than cast iron.

An overhead camshaft engine lacks a pushrod configuration for the valve mechanism and instead places the camshaft within the head. The cylinder is joined together with other components such as the combustion chamber, intake, and exhaust ports via the space beneath the cylinder.

Camshaft

This cam-equipped shaft is a part of an internal combustion engine. By sitting directly over the valves or via the rocker arm and piston mechanism, it controls the valves. The size of a camshaft affects the valve timing. In other words, the camshaft, which is placed on the shaft either immediately through a gear box or indirect through a sprocket and a timing belt, controls when the valves open and close.

A pushrod & tappet mechanism as well as rocker arms were necessary for the camshaft that was connected to the crankshaft by the gear. The camshaft is often composed of billet steel for high-quality ones and chilled iron castings for common ones. The cooled iron's aim is to provide more surface hardness and wear resistance.

Valves

Poppet valves are valves used in IC engines. It is composed of a flat circular disc called the valve head and a long, thin circular rod called the valve stem that is tapered along its length. The valve's purpose is to permit a fresh intake for fuel and air as well as the escape of combustion products (exhaust.)

The sliding action of the cam and related connections results in the opening and shutting of the valve.The capacity for heat transmission is increased by adding salt to the steel alloys used to make engine valves. The valves are divided into two pieces, the exhaust/outlet valve allowing exhaust gases to exit and the intake/inlet valve allowing a new charge to enter the chamber while it is open.

Rocker arm

This component of an internal combustion engine is crucial because it translates the rotating action of the cam or crankshaft through with a tappet or latch into a linear motion of the valves, which assists in depressing the valve head. For light and medium-duty engines, the rocker head is built of steel stampings, however the heavy-duty diesel engine's rocker head is composed of cast iron and forged carbon steel because it provides more strength and rigidity. The cylinder head's fixed pivot rod is the point around which the rocker arms oscillate.

Crankcase

These parts of an internal combustion engine are situated underneath the cylinder block, which also houses the crankshaft bearings. A sufficient amount of oil is contained in this main bearing, which is a sliding bearing. Diesel engines have five primary bearings, one at each end and two between each cylinder, whereas four-cylinder inline petrol engines have three bearings in the crankcase, each at each end and one in the center. Cast iron and aluminum, the same materials used to make the cylinder block, are utilized to create the crankcase. The engine's crankcase provides a variety of functions, including shielding the internal workings from debris like dirt and dust. In order to keep the oil and air within, it also functions as a casing for the crankshaft and connecting rod.

Oil pump and sump

The oil pump's job is to distribute oil to different engine components so they may be properly cleaned, lubricated, and cooled. The crankshaft gear drives the oil filter in the engine. The engine's components are pumped with oil, which aids in cleaning and cooling the unit. The oil sump acts as storage and has a chamber where the oil is kept. A wire mesh strainer that prevents dirt and debris from getting into the engine lifts the oil from the sump. Before the oil is sent to the engine components, it passes through the oil filter and oil cooler. After completing its task, the oil flows back into the oil sump.

Resistance offered in Automobile

This is the resistance that vehicle encounters when attempting to accelerate or leave a stall situation. The engine's powertrain must overcome this resistance in order to maintain motion. The vehicle will progressively slow down when the power generated is less than the resistance to motion. If we stop pedaling, we must have seen how bicycles slow down. When going uphill or when the wind is coming from the front, the bicycle likewise slows down. Additionally, a low tyre pressure causes the car to sputter and slow down. These are the resistors that, when present, cause the car to slow down.

Air resistance/ Aerodynamic drag

When a body moves through a thick material, the medium's molecules hit the moving item and absorb part of its energy. A resistance to the moving object is sensed as a result. The resistance increases with increasing medium density.

Gradient resistance

A portion of the vehicle's weight shifts in the direction of the motion when it is moving uphill. The vehicle would slow down, stall, and roll backwards if energy were not provided to resist this force. The weight of the vehicle, W, has two components if it is moving uphill at a slope of: one perpendicular to the roadways, and the other along the roadways (with a value of Win). The part that tries to stop the motion is the one that runs down the road surface.

Rolling resistance

The friction between both the wheels tyre and also the road surface is the major cause of rolling resistance. The weight on each roadway wheel, the kind of tread on the tyres, the inflation pressure of the wheels, and the type of road pavement all have a major role. In terms of math, rolling resistance.

Rolling-Resistance Tires

Imagine coasting while releasing the throttle pedal. Your automobile will slow down more quickly if it has a load carrier on the roof (air drag and extra weight). When moving downhill, you accelerate (gravity). You'll come to a halt more quickly if the ground is soft if your tires are short on air (more friction with the road). It eventually come to a stop as a result of rolling resistance.

Transmission system

The transmission system is one of the fundamental and critical components of a car. It is the process of transferring the engine's power to the wheels. The term "transmission" simply designates the gearbox, which generates speed and torque via gears and gear trains. One of your car's most intricate parts, it is made up of a number of gears (gearbox). It is largely in charge of ensuring that the wheels receive the proper amount of power to function at a specific speed. Car transmissions come in a variety of designs.

The most prevalent are automatic, although manual gearboxes in stick-shift automobiles need additional actions from the driver in order to operate the vehicle. Let's examine how a transmission system operates.

Working of Transmission System

Depending on the kind of transmission, the transmission system operates differently. Usually, the transmission system permits the engines and drive wheels' gear ratios. It may be altered when the automobile speeds up and slows down. The gearbox detaches the engine first from driving wheels when you start your automobile, arrive at your location, and need to halt so that the engine can run while the wheels are still. Additionally, the gearbox permits the engine to operate more slowly when the car is moving at a standard pace and can offer more rapid acceleration from a stop.

Types of Transmission

The transmission types found in automobiles are as follows:

Manual Transmission

A manual gearbox is a gear selection mechanism that calls for the driver to manually pick a gear by engaging a clutch and gear shift. A collection of gears (various sizes) and two shafts make up this transmission system. The output shaft, which has numerous gears, is constantly linked to the input gear and connected to the engine.

In this, the operator must manually change gears and depress or press the clutch pedal. The engine is engaged and disengaged from the transmission using a clutch, pressure plate, and flywheel in this transmission. The clutch is positioned between the pressure plate and flywheel, which are fastened to the engine. Pushing in the clutch is referred to as releasing the pressure plate, which every time you shift separates the clutch from of the engine.

Advantages of Manual Transmission

1. For off-road use, manual gearbox is thought to be preferable.
2. This kind of gearbox system can handle a lot of torque.
3. Compared to other varieties, they are significantly more dependable and simpler to maintain.

Disadvantages of Manual Transmissions

1. Some people cannot drive.
2. Increased learning curve
3. These make driving more challenging.

Intelligent Manual Transmission

The Intelligent Manual Transmission is a clutch less manual transmission, to put it succinctly. It features gears and a gear lever, making it similar to a manual gearbox. Since it just has a brake as well as an accelerator pedal instead of a clutch, the driver virtually has the impression of driving an automated vehicle.

It have total control over the transmission in circumstances like downhill driving or overtaking, and you don't have to deal with the hassle of using the clutch pedal. It is not necessary to elevate the accelerator when changing gears in this sort of transmission system, although doing so will make the process go more smoothly. It transmission system is unable to change gears on its own. In contrast, fuel economy and mileage in an IMT automobile vs a manual gearbox car are arbitrary and based on the driver's driving habits.

Advantages of Intelligent Manual Transmission

1. Person won't need to rely on software since IMT Car gives you total control over what gear that car is in.
2. An iMT is more expensive than a standard manual gearbox, on average.
3. IMT relieves the driver from having to use the clutch, especially in stop-and-go city traffic.
4. The iMT transmission system is unable to change gears on its own. In contrast, fuel economy and mileage in an IMT automobile vs a manual gearbox car are arbitrary and based on the driver's driving habits.

Automated Manual Transmission

An improved or modified form of a manual gearbox called an automated manual transmission does not require the clutch pedal to be depressed while changing gears. It resembles a manual gearbox nearly exactly, yet in this system the actuators and sensors serve as the clutch and change gears. Only the accelerator and braking pedals are present in a vehicle with an AMT; there is no clutch pedal.

When necessary, this transmission also supports manual shifting. The AMT gearbox makes use of hydraulics and a computer linked to the car's ECU (ECU). On this device, the pre-programmed gear change patterns mostly utilise the defined RPM range. The ECU activates the actuators that control the clutch the gearbox after the system has calculated the maximum RPMs. Tata Nexon, Hyundai Venue, Maruti Suzuki Alto, and more vehicles employ AMT.

Advantages of Automated Manual Transmission

1. Because controlling the clutch is not a chore that the diver must perform, the AMT is more convenient than the manual transmission, which lessens fatigue.
2. Since AMT is now more fuel-efficient than automatic gearbox, more power may be sent to the wheels.
3. May use it as you choose, thus the majority of vehicles with AMT also include a manual option.

Automatic Transmission

It is a multiple-speed gearbox used in cars that eliminates the need for the driver to shift into first gear when driving normally. It is made up of a torque converter, hydraulic controls, and a planetary gear set.The gearbox is linked to the engine by a torque converter, which is subsequently linked to a gear system. Some components inside the torque converter cooperate with one another. The flywheel that rotates the entire construction is housed in the outermost portion. The turbine spins as a result of the spinning pushing the fluid out of the pump quickly. The fluid keeps running through the stator and the two parts independently. Energy is delivered to the gear system once the shaft, which links to the remainder of the system, is linked to the turbine.

Advantages of AT

The primary benefit of automatic gearboxes is how convenient and user-friendly they are. Both the driver and the passengers enjoy comfortable driving thanks to them. The power of an AT is always greater than that of a comparable manual gearbox.They have a fixed gear ratio and are pulley-based gearboxes that are typically seen in compact cars with smaller engines. This contrasts with conventional transmissions, which only have a set number of gear ratios.

Continuously Variable Transmission

A steel belt travels between two pulleys that are used by the CVT. The CVT varies the diameter of both the "drive pulley" that transmits the engine's power and the "drive pulley" that transfers power to the wheels in order to continually vary its gear ratio.These pulleys have different widths depending on the amount of power needed; as one becomes wider, the other goes smaller. This enables the delivery of powerful and smooth acceleration. Currently, Toyota, Nissan, and Honda all employ CVTs in their automobiles.

Semi-automatic Transmission

A multi-speed gearbox that operates partially automatically but needs a driver's input to move the car from a stop and shift gears manually is known as a semi-automatic transmission. It combines an automatic and manual gearbox. There are both manual and automated choices, which might help you learn how to operate the gears. The engine's kinetic energy aids in the wheels' rotation, and gear ratios determine how quickly or slowly they turn. It's important to note that semi-automatics lack a clutch pedal. Semi-autos are actually simpler to drive since the car's CPU and sensors control the clutch so when driver shifts gears. Hyundai automobiles often come with a semi-automatic gearbox.

Dual-clutch Transmission

This transmission has two distinct clutches for odd or even gear sets, making changes very rapid. In that their individual clutches are contained within a housing and function as a single unit, the design is sometimes likened to two independent manual gearboxes. The DCT functions like an automatic gearbox and changes ratios without the driver's involvement. Typically, this sort of gearbox may be moved manually using the pedals just on steering wheel or in completely automated mode. These pricey gearboxes are currently mostly seen in race vehicles and high-end sports cars.

Advantages of Dual-clutch Transmission

1. DCTs outperform automatic gearboxes in terms of performance and fuel efficiency.

2. They are frequently used in the world of performance driving because they shift easily and precisely.

Sequential Transmission

Through electronic pedals positioned on the back of the steering wheel, a sequential manual gearbox enables you to choose the next gear (for example, moving from first gear to second gear) or perhaps the prior gear (for example, going from third gear to second gear). When moving up or down in a car with a sequence gearbox, you just press a lever or lever to advance through each gear.

In certain cars, the driver really uses a lever to shift down or up by pushing it forward or pulling it backward.In general, it is a kind of non-synchronous manual gearbox that is mostly employed in racing automobiles and motorbikes. They are sometimes referred to as sequential transmissions or sequential gearboxes.

Advantages of Sequential Transmission

1. In a sequential gearbox, gear shifting is simpler.
2. May change your speed up or down without pausing or feeling a loss of speed.
3. This mechanism's name refers to the fact that gear changes must be made sequentially.

Torque Converter Transmission

One of the earliest varieties of automated transmission is the torque converter gearbox. Performance or fuel economy were not factors in the design of the original torque converters. However, modern torque converters are quick and suited for driving on highways or in cities. Within the housing of the turbine, the casing is attached to the flywheel and rotates at the same rate as the crankshaft. Finally, the turbine fins spin or transmit torque to the gearbox by being driven by the impeller or centrifugal pump. The car equipped with an automatic transmission uses a torque converter.

Advantages of Torque Converter Transmission

1. In comparison to a car with a clutch, it produces the most torque.
2. By minimizing manual gear changes, it can make driving more comfortable for drivers.
3. They make driving simpler by taking away the clutch pedal.

Tiptronic Transmission

In that the driver may switch out of "automatic mode" and use the paddles to shift down or up like such a manual gearbox, the Tiptronic transmission system resembles an automatic transmission. Steptronic or Sportmatic are other names for the Tiptronic gearbox. It is an automated gearbox with manual gear-switching capability. Without the clutch, a Tiptronic transmission operates similarly to a manual gearbox. You now have more control gears at your disposal, which is great for negotiating steep slopes or improving control when passing on the highway.The Tiptronic gearbox has built-in safety features that will immediately shift if the driver forgets. These are frequently seen in vehicles like Volkswagen, Audi, Land Rover, Lamborghini, and other makes.

Advantages of Tiptronic Transmission

1. When changing gears, driving a car with a Tiptronic gearbox gives you more control.person
2. When changing gears, using a vehicle with either a Tiptronic gearbox gives you more control. Person may actively change gears to make the ride smoother and safer when going up or dow a steep hill.
3. By delaying the engine in the event of a failed downshift, automatic shifting in manual mode also helps the driver.

Clutch

The power transfer from the driving shaft towards the driven shaft can be engaged and disengaged mechanically using a clutch. The apparatus has two shafts, one of which is attached to the engines or power unit (the driving part) and the other of which generates the power output that moves the object.

Working principle of a clutch

The clutch's operating system is both fascinating and simple to comprehend. The fact that no torque or power is communicated until the friction surfaces come into contact with one another works just well. Two separate plates make up the clutch; one is fixed to the flywheel while the other slides over the crankshaft. The degree of axial load that's also given to the friction disc is determined by the amount of torque exerted. This means that the power transmission increases with increasing axial load and decreases with decreasing axial load.The clutch pedal is used to move the movable disc, which is connectors on the crankshaft, back and forth. The pressure plate, which is coupled to several helical springs or a single diaphragm spring, applies the load.

Parts of a clutch

The following are the basic components of a clutch, while there are other smaller components as well:

Flywheel

Mounted on the spindle, this clutch component continues to function as long as even the engine is on. The flywheel has a friction disc located on the outside.

Friction disc

Depending on its use, the friction disc may consist of one or many discs. It is constructed from a substance having a high frictional coefficient. On a driving shaft, the frictional disc is placed.

Pressure plate

This plate has a third friction disc attached to it. The splined hub is where this compression force is mounted.

Spring and release levers

The friction disc is moved back and forth by the springs' action. Levers are used in clutches to assist retract the diaphragm spring.

Different types of clutches

There are different types of clutches which are illustrated below

Single plate clutch

The friction clutch known as the single plate grip is primarily used to transmit the power of the driven and driving shafts. It may also be applied to devices that need to start and stop instantly.

Multi-plate clutch

The clutch is a tool used to assemble and disassemble engines with gearboxes. Multi-plate clutches are clutches that employ three or more clutch plates. To transfer the most torque feasible, the multi-plate clutch features numerous plates.

Cone clutch

The function of a disc or plate clutch is the same as that of a cone clutch. The cone clutch employs two conical edges to transmit torque through friction, as opposed to joining two spinning discs. Due to the wedging motion and larger surface area, the cone clutch transmits a higher torque that plate or disc clutches with the same size. Cone clutches were originally widely employed in cars and other combustion engine gearboxes, although they are mostly primarily utilized in low peripheral speed situations nowadays.

Centrifugal clutch

A centrifugal clutch is an automated clutch that functions by applying centrifugal force. At low rotational speeds, the drive shaft is disengaged; as speed rises, it becomes more engaged. It is frequently used during mobility scooters, underbones, farm equipment, go-karts, chainsaws, mini motorcycles, and some fast flowing and boats to reduce load while starting and idling and prevent engine failure when the output shaft is abruptly slowed or halted. The fluid connection and automated mechanical gearboxes have supplanted it for use in automobiles.

Electromagnetic clutch

Electromagnetic clutches transmit torque physically but work electrically. They were once known as electro-mechanical clutches for this reason. Over time, EM started to be referred to as electromagnetic rather than electro-mechanical, emphasizing their actuation strategy rather than physical functioning. Although there are now a vast array of uses and clutch types thanks to the popularity of clutches that began more than 60 years ago, the fundamental function has not changed.The best clutches for remote operation are electromagnetic ones since they can operate quickly and smoothly without the need for mechanical links to govern their engagement. However, there is a chance of overheating because when the clutch is engaged, the activation energy in the electromagnetic actuator dissipates as heat. As a result, the temperature grade of the insulating of the electromagnet regulates the maximum working temperature of the clutch. This is a significant drawback. Higher beginning costs are another drawback.

Hydraulic clutch

A hydraulic clutch is a mechanism used in cars that is operated by hydraulic fluid. Instead than using a cable to push the clutch plate, a hydraulic clutch instead moves the clutch plate using fluid that is kept in a reservoir. Because this clutch does not involve pedal height modifications and because it has clutch fluid, it automatically adjusts itself, it is favored in the current vehicle industry. They are made of significantly lighter materials, have a stronger clutch mechanism thanks to highly pressured fluid and cylinders, and demand the least amount of pedal exertion from the driver.

Clutch linkage

The clutch linkage is made up of many mechanical and occasionally hydraulic parts. The clutch pedal, a set of linkage poles and arms, or a cable are the typical components of a mechanical clutch linkage. There three types of clutch linkage which are illustrated below:

1. Shaft and lever linkage
2. Cable linkage
3. Hydraulic-operator clutch linkage

Overdrive

A car operating in overdrive cruises at a constant speed with fewer engine revolutions per minute (RPM), which improves fuel efficiency, reduces noise, and reduces wear. The phrase is vague. The simplest explanation is that there is an excessive gear ratio between the engine and the wheels, preventing the vehicle from reaching its peak speed. In other words, the vehicle might move more quickly in a lower gear with a higher RPM engine. An engine's power output rises with engine RPM to a peak and then declines. The engine's "redline" RPM, or absolute maximum RPM, is a little higher than the maximum point power. The power necessary to propel an automobile over air resistance, which rises with speed, limits the vehicle's top speed. When a car is moving at its top speed, the powertrain is operating at its point of highest output, or power peak, and it is moving at a speed where air density is equal to that peak output. Since the engine speed and travel speed must match, there is only one gear ratio at which the automobile may operate at its top speed. To get the highest possible fuel economy.

Questions for Revision

1. What is automation?
2. What is an automobile?
3. What is Advantages for Automation?
4. Define Fixed Automation.
5. Define Programmable Automation
6. Define Flexible Automation
7. Describe the Automation in Production System
8. Describe Basic Concept of Automation Terminology
9. Describe Basic Component of an Automation System
10. What is Program of Instructions?
11. Define CNC Machining and Turning Centers
12. Define Parts of a clutch

References for further study

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