Elements of Mechanical Engineering [18ME15/25]

Revised: 2020-21

Student Hand Notes

A T M E
College of Engineering

Vision of the Institute

Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

Mission of the Institute

- To keep pace with advancements in knowledge and make the students competitive and capable at the global level.
- To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as torch bearers of tomorrow's society.
- To strive to attain ever-higher benchmarks of educational excellence.

COURSE MODULE

Course Coordinator: **Prof. Thejkumar J**				Academic Year:**2020-21**			
Department: **Mechanical Engineering**							
Course Code	Course Title	Core/Elective	Prerequisite	Contact Hours			Total Hrs/ Sessions
				L	T	P	
18ME15/25	**Elements of Mechanical Engineering**	**Core**	**BASIC SCIENCE**	**4**	**-**	**-**	**50**

Course objectives: This course (18ME15/25) will enable students to:

CLO1: Learn the fundamental concepts of energy, its sources and conversion.
CLO2: Comprehend the basic concepts of thermodynamics.
CLO3: Understand the concepts of boilers, turbines, pumps, internal combustion engines and refrigeration.
CLO4: To understand the properties of various engineering material and their applications.
CLO5: Distinguish different metal joining techniques and understand the concepts of power transmission elements.
CLO6: Enumerate the knowledge of working with conventional machine tools, their specifications

Topics Covered as per Syllabus

MODULE-I

Sources of Energy: Introduction and application of energy sources like fossil fuels, Hydel, Solar, Wind, Nuclear fuels and Bio-fuels. Environmental issues like Global Warming and Ozone Depletion

Basic Concepts of Thermodynamics: Introduction, States, Concepts of work, Heat, Temperature, Zeroth law, 1st Law, 2nd Law and 3rd Laws of thermodynamics. Concept of Internal energy, Enthalpy and entropy (Simple Numericals)

Steam: Formation of Steam and Thermodynamic properties of steam (Simple Numericals)

(RBT: L1, L2 and L3)

MODULE-2

Boilers: Introduction to Boilers, Classification, Lancashire boiler, Babcock and Wilcox Boiler, Introduction to Boiler mounting and accessories (No sketches).

Turbines: Hydraulic Turbines- Classification and specification, Principles and operation of Pelton Wheel Turbine, Francis Turbine and Kaplan Turbine (Elementary Treatment only)

Hydraulic Pumps: Pumps, Introduction, Classification and specification of Pumps, Reciprocating pump and Centrifugal Pump, Concept of Cavitation and Priming.

(RBT: L1, L2)

MODULE - 3

Internal Combustion Engines

Classification, IC engines parts, 2 and 4 stroke petrol and 4 stroke diesel engines. P-V diagrams of Otto and Diesel cycles. Simple problems on indicated power, brake power, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and specific fuel consumption.

Refrigeration and Air conditioning

Refrigeration – Definitions – Refrigerating effect, Ton of Refrigeration, Ice making capacity, COP, relative COP and Unit of refrigeration. Refrigerants, Properties of refrigerants, List of commonly used refrigerants, Principle and working of vapor compression refrigeration and vapor absorption refrigeration. Domestic refrigerator, Principles and applications of air conditioners, window and split air conditioners.

(RBT: L1, L2 and L3)

MODULE-4

PROPERTIES, COMPOSITION AND INDUSTRAIL APPLICATIONS OF ENGINEERING MATERIALS:

Metals- Ferrous: Cast Iron, Tool steels and stainless steels. **Non-Ferrous**: Aluminum, brass, bronze, **Polymers**: Thermoplastics and thermo setting polymers. **Ceramics**: Glass, optical fiber glass, cements, **Composites**- Fiber reinforced composites, Metal Matrix composites. **Smart Materials**: Piezoelectric materials, Shape memory alloys, Semiconductors and insulators.

JOINING PROCESSES: SOLDERING, BRAZING AND WELDING

Definitions, Classification and Methods of soldering, Brazing and welding, Brief description of arc welding, Oxy-acetylene welding, TIG welding and MIG welding

BELT DRIVES

Open & crossed belt drives, Definitions- slip, creep, velocity ratio, derivations for length of belt in open and crossed belt drive, ratio of tension in flat belt drives, advantages and disadvantages of V belts and timing belts, simple numerical problems.

GEAR DRIVES:

Types- Spur, helical, bevel, worm and rack and pinion, Velocity ratio, advantages and disadvantages over belt drives, simple numerical problems on velocity ratio

(RBT: L1, L2 and L3)

MODULE-5

Lathe: Principle of Working of a Center Lathe, Parts of a Lathe. Operations on Lathe- Turning, Facing, Knurling, Thread Cutting, Drilling, Taper Turning by Tailstock Offset Method and Compound Slide Swiveling Method. Specification of Lathe

Milling Machine: Principle of Milling, Types of Milling Machines, Working Of Horizontal and Vertical Milling Machines. Milling Processes -P lane Milling, End Milling, Slot Milling, Angular Milling, Form Milling, Straddle Milling, and Gang Milling

(Layout of sketches of the above machines needs to be dealt. Sketches need to be used only for explaining the operations performed on the machines)

Introduction to Advanced Manufacturing Systems

Computer Numerical Control (CNC): Introduction, Components of CNC, Open Loop and Closed Loop Systems, advantages of CNC, CNC Machining centers and Turning Centers.

Robots: Robot Anatomy, Joints and Links, Common Robot Configurations, Applications of Robots in material handling, Processing and assembly and inspection.

(RBT: L1, L2)

List of Text Books

1. **Elements of Mechanical Engineering**, K R Gopal Krishna, Subhash Publication, Bangalore 2008
2. **Work Shop Technology, Vol1 & 2,** Hajara Chowdary, Media Promoters, New Delhi 2001
3. **A Text Book of Elements of Mechanical Engineering**, S.TrymbakaMurthy, 3rd revised edition 2006, I. K International Publishing House Pvt Ltd , New Delhi

List of Reference Books

1. **Elements of Mechanical Engineering**, R K Rajput, Firewall media, 2005
2. **Elements of Mechanical Engineering**, A S Ravindra, Best Publications, 7th edition 2009
3. **CAD/CAM/CIM**, Dr. P Radhakrishnan, 3rd edition, New age International Publisher, New Delhi
4. **Introduction to Robotics: Mechanics & Control**, Craig J J, 2nd edition, Addison-Wesley publishing company, 1989
5. **Introduction to engineering Materials**, B K Agarwal, Tata McGraw Hill Publication, New Delhi.
6. **Thermal Science and Engineering**, Dr. D S kumar, S K Kataria & Sons Publications, New Delhi

List of URLs, Text Books, Notes, Multimedia Content, etc

Video Demonstration of Different types of automation and Mechanisms:

https://web.microsoftstream.com/channel/eb803232-ea0b-44c6-9d3b-2b16a67d1046 **(Tech Videos)**

https://web.microsoftstream.com/channel/39a40d8b-3f4b-41f3-a027-a9002be969b3 **(Lecture Videos)**

Copy of Notes (Soft Copy): Available

Course Outcomes: Students will be able to

CO1: Identify different sources of energy, their conversion process and also describe the basic concepts thermodynamics and solving simple numerical problems on steam.	**L3**
CO2: Explain the working principle of boilers, Turbines, Pumps, IC Engines and Refrigeration.	**L2**
CO3: Demonstrate the working principles of an I.C Engine, Refrigeration, air conditioning and also calculate the performance parameters of an I. C engine.	**L3**
CO4: Recognize & Classify the various engineering materials, metal joining processes and power transmission elements. Also solve simple numerical on power transmission elements.	**L3**
CO5: Describe the working of conventional machine Tools, Machining processes and the advanced manufacturing system.	**L2**

Internal Assessment Marks: 40 (30 Marks three Session tests are conducted during the semester and marks allotted based on the average of three performances and additional 10 Marks for Assignments /Unit tests/ written quizzes).

The Correlation of Course Outcomes (CO's) and Program Outcomes (PO's)

Subject Code: 18ME15/25				TITLE: Elements of Mechanical Engineering						Faculty: Thejkumar J		
List of Course Outcomes	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12
CO-1	2	-	-	-	-	-	2	-	-	-	-	2
CO-2	3	2	-	-	-	-	-	-	-	-	-	-
CO-3	3	2	-	-	-	-	-	-	-	-	-	-
CO-4	2	-	-	-	-	-	-	-	-	-	-	-
CO-5	2	-	-	-	3	-	-	-	-	-	-	2

Note: 3 = Strong Contribution 2 = Average Contribution 1 = Weak Contribution - = No Contribution

MODULE-5

Lathe: Principle Of Working of a Center Lathe, Parts of a Lathe. Operations on Lathe-Turning, Facing, Knurling, Thread Cutting, Drilling, Taper Turning by Tailstock Offset Method and Compound Slide Swiveling Method. Specification of Lathe

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(RBT: L1, L2 and L3)

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5. Machine Tools Operations

5.1 Introduction:

Production or manufacturing can be simply defined as value addition processes by which raw materials of low utility and value due to its inadequate material properties and poor or irregular size, shape and finish are converted into high utility and valued products with definite dimensions, forms and finish imparting some functional ability. The products are made by a combination of manual labor, machinery, tools and energy.

The word manufacturing is derived from the Latin word "manufactus" meaning made by hand; the word manufacture first appeared in AD 1567 and the word manufacturing in 1683. The word production and manufacturing is used interchangeably.

The conversion of resources into raw materials is normally taken care of by two sub disciplines of engineering – mining and metallurgy. The real conversion starts from the stage where the material is obtained in the raw form. There are many process involved in converting an available raw material into final product. These processes of conversation are known as manufacturing process.

5.2 Manufacturing Processes

This refers to science and technology of manufacturing products effectively, efficiently, economically and environment-friendly through

1. Application of any existing manufacturing process and system
2. Proper selection of input materials, tools, machines and environments.
3. Improvement of the existing materials and processes Development of new
4. materials, systems, processes and techniques

It is extremely difficult to tell the exact number of various manufacturing processes existing and is being practiced presently because a spectacularly large number of processes have been developed till now and the number is still increasing exponentially with the growing demands and rapid progress in science and technology.

5.2.1 Purpose of Machining

Most of the engineering components such as gears, bearings, clutches, tools, screws and nuts etc. need dimensional and form accuracy and good surface finish for serving their purposes. Pre – forming like casting, forging etc. generally cannot provide the desired accuracy and finish. For that such preformed parts, called blanks, need semi-finishing and finishing and it is done by machining and grinding. Grinding is also basically a machining process.

Machining to high accuracy and finish essentially enables a product to

1. Fulfill its functional requirements
2. Improve its performance
3. Prolong its service

The general processes that a component undergoes before being converted into final product are;

a) Casting
b) Primary and Secondary forming
c) Machining
d) Joining, assembly and finishing.

5.3 LATHE

Lathe: The lathe is one of the oldest machine tools and also known as the father of the machine tool. The first basic lathe was designed by Henry Maudslay, in the year 1797.

Definition: Lathe is a machine tool used to remove metal from the work piece, to a required shape and size.

Working Principle: The work is held in a work holding device known as chuck. Work is rotated about its axis, against a single point cutting tool. The tool moves parallel to the axis of rotation of the work piece to produce a cylindrical surface. The tool should be harder than the material of the work piece, should be rigidly held on tool post of the machine and should be fed in a definite way relative to the work. The cutting tool may also be fed at an angle relative to the axis of work for machining tapers and angles.

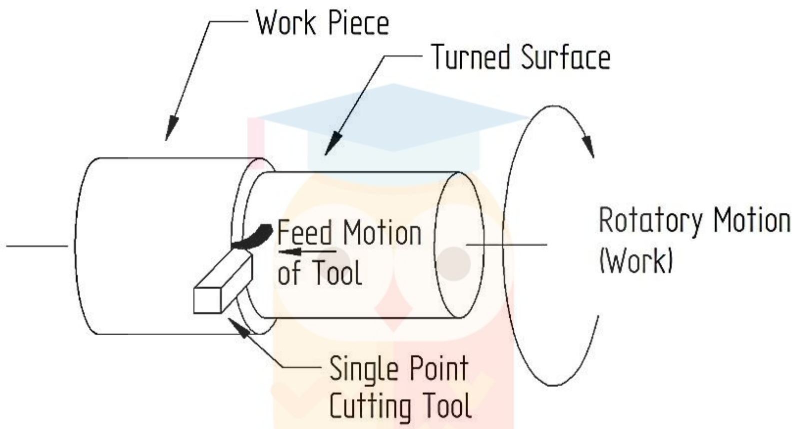


Figure.5.3 working principals of lathe

Figure: 5.3(a). Centre Lathe

5.3.1 Parts of a Centre Lathe

1. **Bed:** The bed is the main component of a lathe. All the major components are mounted on the lathe bed, like tail stock, headstock, carriage, etc. Tailstock and carriage move over the guide ways provided on top face of the bed. The bed material should have high compressive strength and high wear resistance. Cast iron alloyed with nickel chromium forms a good material for bed.
2. **Headstock:** Headstock is mounted on the left hand side of the lathe bed. The head stock is hollow accommodates gear box, which helps to vary the spindle speed. The gear box also transmits the power to other parts like feed rod and lead screw. The chuck or face plate is attached to the spindle which provides mechanical means clutching and rotating the work piece. The headstock

contains speed and feed changing levers. Head stock is also known as live center

3. **Tailstock:** The tailstock is mounted on the right hand side of the lathe bed. The function of the tailstock is to support the work piece, and to accommodate different tools like drill, reaming, boring and tapping, etc. The tailstock moves on the guide ways over the bed, to accommodate for different length of work piece. Tailstock is known as dead center.
4. **Carriage:** The carriage is mounted on the lathe bed, which slides on the guide ways of the bed. The carriage has various other parts like, saddle, cross slide, compound rest, tool post and apron. **i) Saddle**

   The saddle is mounted on the bed and slides along the ways. The cross slide and tool post are mounted on the saddle. The movement of the saddle is parallel along the axis of the lathe, it is also known as feed. **ii) Cross slide**

   The cross slide is mounted on the top of the saddle. This moves the tool at perpendicular to the work piece or machine axis. The cross slide can be moved either by rotating the cross slide hand wheel or engaged with the apron mechanism (Automatic movement). The perpendicular distance moved by the cross slide is proportional to the amount of metal removed and it is known as depth of cut.

   iii) Compound slide

   The compound slide (compound rest) is mounted on the top of the cross slide. The rest part of the compound slide has graduations in degree. Compound slide is used to obtain taper on the work piece, even this helps to fix the tool right angle to machine axis.

   iv) Tool post

   The tool post is mounted on top of the compound slide. The tool post holds the tool rigidly.

   v) Apron

   The apron is fastened to the saddle and hangs over the front of the bed. It apron is fitted with mechanism for both manual and powered movement of the saddle and the carriage. Split nut engages the Apron with lead screw, which is used to cut internal or external threads. **vi) Feed rod**

   Feed rod is a long shaft extending from the feed box. The power is transmitted from a set of gears from headstock. The feed rod is used to move the carriage or cross slide for turning, boring and facing operations. **vii) Lead screw**

The lead screw is a long threaded shaft connected to the headstock. The lead screw is used only when thread cutting operation is to be carried out on the work piece. For normal turning operations the lead screw is disengaged.

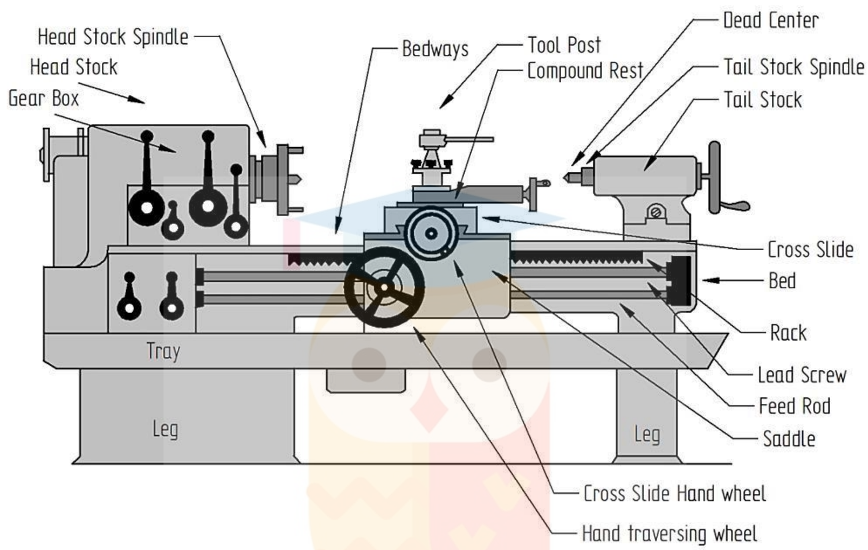


Figure.5.3.1. Centre Lathe

5.4 Operations on Lathe:

Different types of operations that can be carried out

1. Turning
2. Facing
3. Knurling
4. Thread cutting
5. Drilling
6. Taper turning

Turning processes (typically are carried on a lathe) are shown in figure 5.4

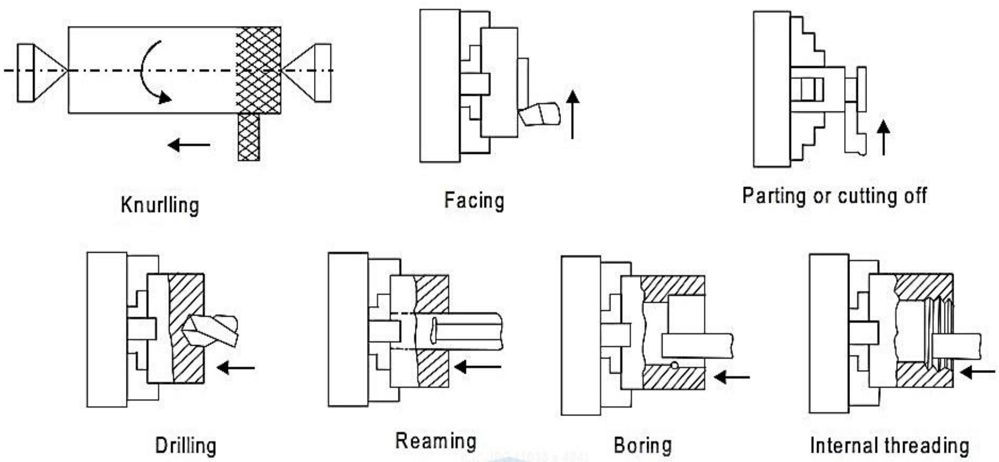


Figure 5.4 Lathe operations

5.4.1 Turning

Straight Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters. Turning operation shows in figure 5.4.1

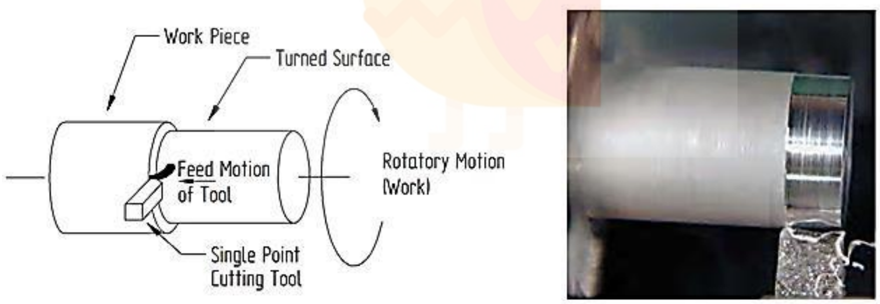


Figure 5.4.1 Turning operation

5.4.2 Facing

Facing is the process of removing metal from the end of a work piece to produce a flat surface. It is some time called squaring. The facing tool used is of round edge; if the tool is pointed then the work piece will not have good finishing. The work piece rotates about its axis and the facing tool is fed perpendicular to the axis of lathe. Most often, the work piece is cylindrical, but using a 4-jaw chuck you can face rectangular or odd-shaped work to form cubes and other non-cylindrical shapes.

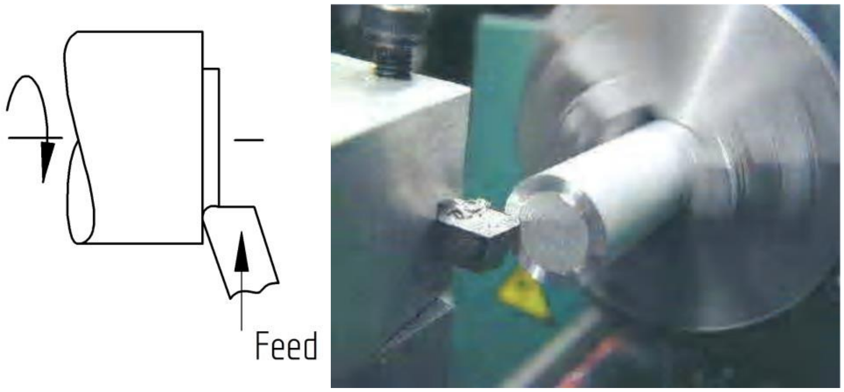


Fig.5.4.2 facing operation

5.4.3 Knurling

Knurling is the process of embossing a required shaped pattern on the surface of the work piece. This diagram shows the knurling tool pressed against a piece of circular work piece. The lathe is set so that the chuck revolves at a low speed. The knurling tool is then pressed against the rotating work piece and pressure is slowly increased until the tool produces a pattern on the work piece.

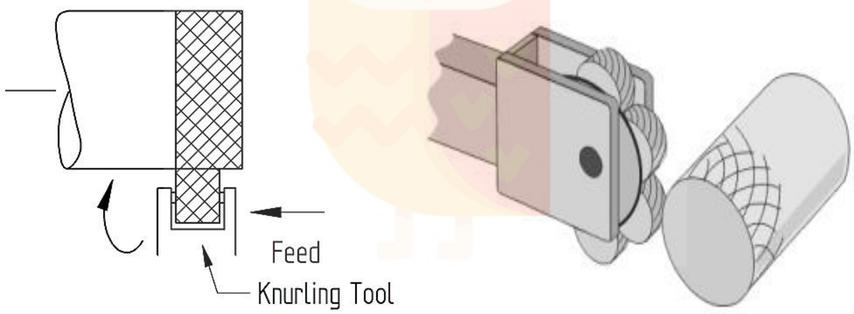


Fig.5.4.3 knurling operation

5.4. 4 Thread cutting

Thread cutting on the lathe is a process that produces a helical ridge of uniform section on the work piece. This is performed by taking successive cuts with a threading tool bit the same shape as the thread form required.

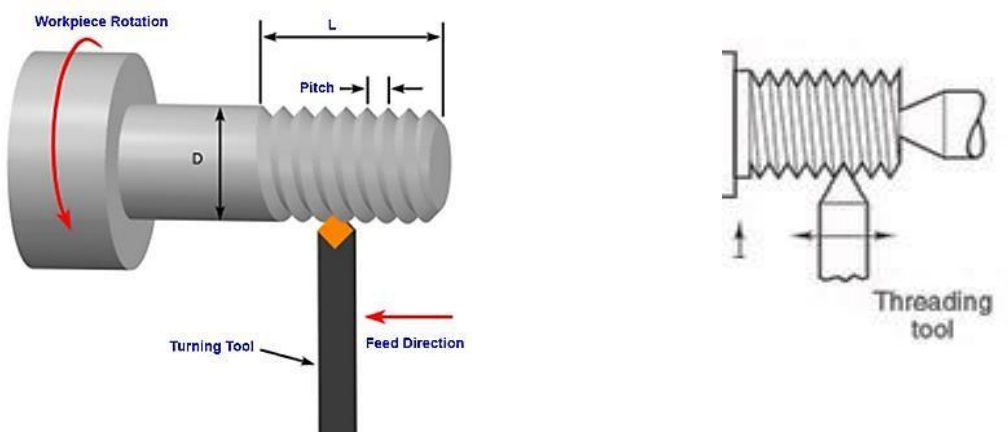


Fig.5.4. 4 Thread cutting operation

5.4.5 Drilling

Drilling is the operation of producing a cylindrical hole in a work piece using a drill. The work piece is held in the chuck and the drill is held in the tailstock. The feed is provided by means of moving the sleeve of the tailstock. The figure shows the drilling operation.

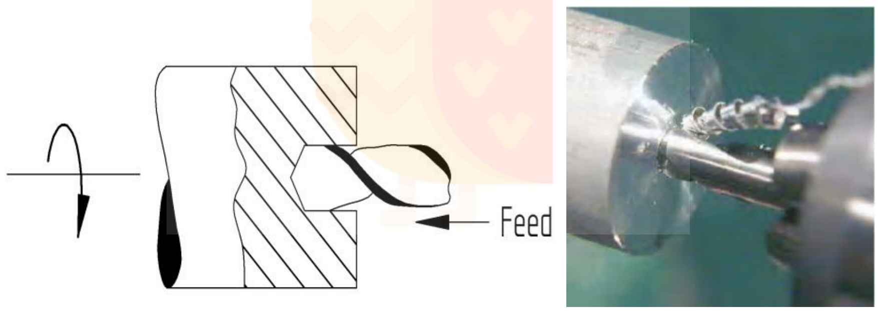


Fig.5.4.5 Drilling operation

5.4.6 Taper turning

A taper may be defined as a uniform increase or decrease in diameter of work piece measured along its length. Taper surface is generated on a cylindrical work piece. The amount of taper in a work piece is usually specified by the difference in diameters of the taper to its length.

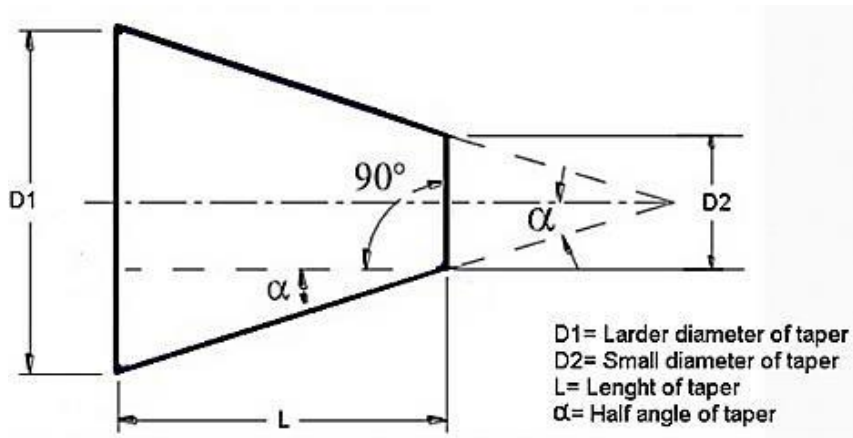


Figure 5.4.6 Taper Turning Methods

The taper turning is done on a lathe by different methods. The selection of method depends on length of taper to be generated on the work piece. The different methods of taper turning are

1. Taper turning by form tool method
2. Taper turning by swiveling the compound rest.
3. Taper turning by offsetting the tail stock
4. Taper turning by taper turning attachment.

5.4.6(A) Taper Turning by Swiveling Compound Rest

In this method of taper the half taper angle is calculated. The compound rest has rotating base graduated in degrees, which can be rotated to any angle (according to the taper angle). In this method the tool is advanced by rotating the compound rest and hand wheel so that the tool moves according to set taper angle. This method produces taper length larger than form tool method.

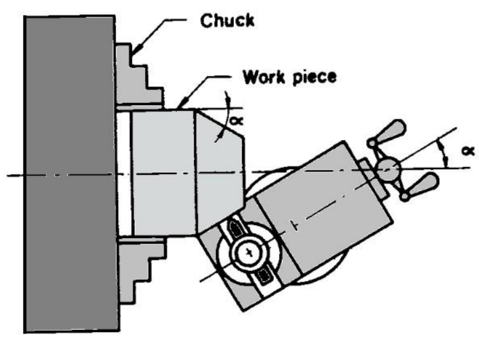


Figure 5.4.6(A) Taper Turning by Swiveling Compound Rest

Formula which is used to calculate taper angle is tan $\boldsymbol{\alpha}$ = D – d

2L **α** = Half taper angle D= Large diameter d= Small diameter L= Length of taper

5.4.6(B) Taper turning by tailstock offset method

In a lathe the live center and dead center both lies on the same axis. The work is held between the live and dead center. The dead center (tailstock) axis is shifted (towards or away from the operator) to the required length on the lathe bed to get taper on the work piece.

In this method amount of set over is limited to a maximum of 8^{o}. In tail stock off set method small taper angle is obtained for longer length work piece.

The tailstock off set method is as shown in figure. The work piece is held between the centers and the carriage is moved on the bed. The tool traces the lathe axis, but the work piece is offset by an angle. Hence taper is generated on the work piece.

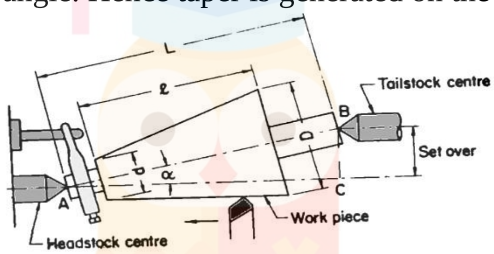


Figure 5.4.6(B) Taper turning by tailstock offset method

Off set, $X = \frac{(D - d)L}{2l}$

X = Set over D= Large diameter d= Small diameter L= Length of work piece l = Length of taper

5.5 SPECIFICATION OF LATHE MACHINE TOOL

A lathe machine is specified by the following

1. The height of the centers measured from the lathe bed.
2. Swing diameter over bed. This is the largest diameter of the work piece which will revolve without touching the bed. It is equal twice the height of centers from the bed.

3. Swing diameter over carriage. It is the largest diameter that can revolve over the cross-slide. This will always be less than the swing diameter over the bed.
4. Maximum bar diameter. This is the maximum diameter that will pass through the headstock spindle.
5. Length of the bed.

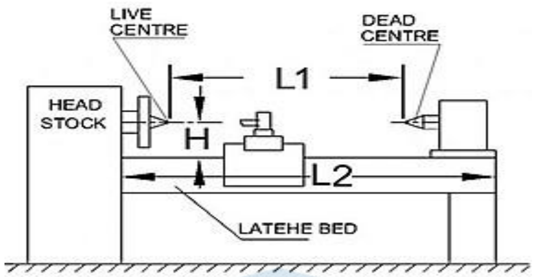


Figure 5. Specification of Lathe

5.6 Milling Machine

5.6.1 Introduction

Milling is one of the most versatile machining processes or a metal cutting process for removing excess material from a work piece with a rotating multiple cutting tools. Each tooth removes a small amount of metal in each revolution; hence metal removal rate is high. Milling can be used to produce a very large variety of intricate shapes and size.

5.6.2 Working principle of milling machine

Milling machine is a machine tool that removes metal as the work is fed against a rotating multipoint cutter (Milling cutter). The milling cutter is a multiple – point tool, which has equally spaced peripheral teeth. The cutter rotates at a speed and because of the multiple cutting edges on the cutter it removes metal at a very fast rate. The machine can also hold one or more number of cutters at a time. This is why a milling machine finds wide application in production work. This is superior to other machines as regards accuracy and better surface finish.

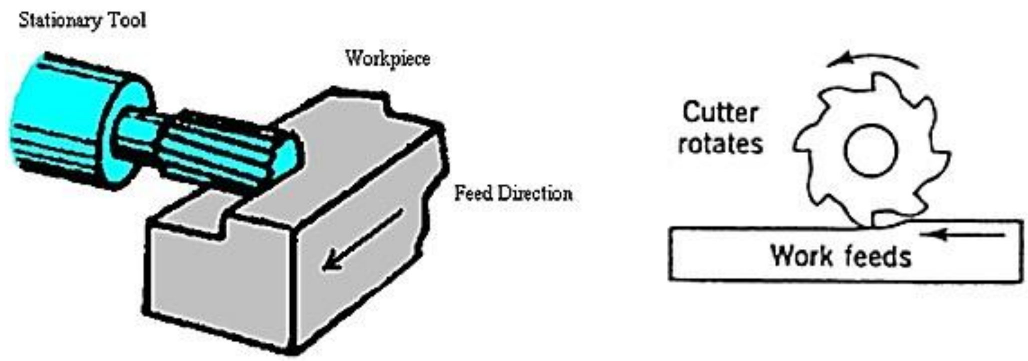


Figure 5.6.2 working principle of milling operation

5.6.3 Types of Milling Machines:

Milling machines are generally classified into two types. This classification is done based on the orientation of the axis of rotation of the spindle or the cutter. The two types are

a) Horizontal Milling Machine b) Vertical Milling Machine

In horizontal milling machine the spindle is horizontal and in the same plain as the table and in vertical milling machine the spindle is vertical to the table.

5.6.3 (a) Milling Processes

- **Up – Milling**

It is known as a conventional milling. Metal is removed when the cutter moves upwards. The cutter rotates opposite direction of feed of work piece. At the beginning of the cutting process the chip thickness is at minimum as the process of cutting proceeds the thickness of the chip increases. Thickness of the chip would be maximum at the end of the cut. Similarly in case of stress, minimum at the initial stage, increases and reaches maximum at the end of the cut. The cutting force is directed upwards and this tends to lift the work from the table, therefore greater need for good clamping device.

- **Down Milling**

This type of milling is also known as climb milling. The metal removed by the cutter is in the downward direction. The cutter and feed are in the same direction. In this type of milling the chip thickness is maximum at the beginning of the cut and decreases as the cutting process progress. Thickness of the chip is least at the end of the cut. The cutting force is maximum when the tooth begins its cut and it reduces to minimum when the tooth leaves the work piece. The cutting action of the teeth press the work piece downwards, this tends to seat the work firmly on the table. Hence, lesser clamping force is required for the work piece.

5.6.4 Difference between up milling and down milling

Figure 5.6.3a: Up Milling

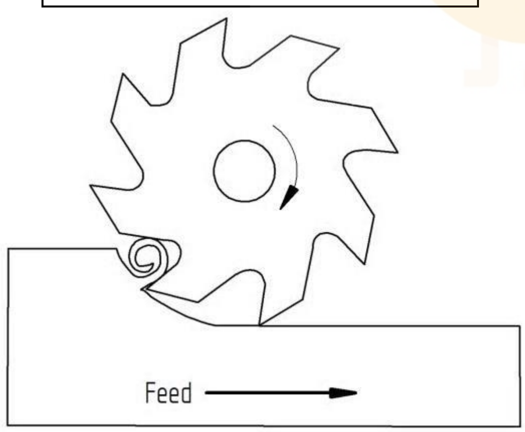
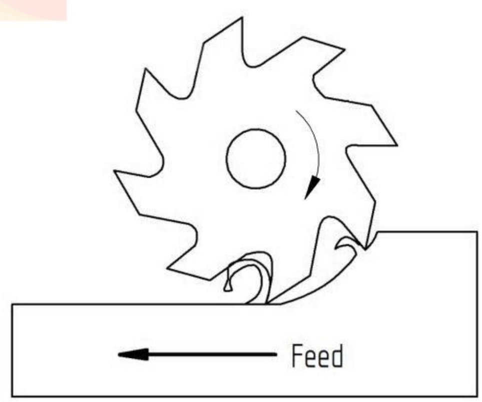


Figure 5.6.3b: Down Milling



Sl. No	UPMILLING	DOWNMILLING

1	The direction of rotation of the cutter and the work piece travel are in the opposite direction.	The direction of rotation of the cutter and work piece travel are in the same direction.
2	The material removed by the milling cutter starts with a minimum thickness and ends with a maximum thickness.	The material removed by the milling cutter starts with a maximum thickness and ends with a minimum thickness.
3	The cutting force of the milling cutter acts upwards tends to lift the work piece from the table, results in greater clamping force.	The cutting force of the milling cutter acts down wards, push the work piece in down direction results in lesser clamping force.
4	The chips accumulate at the cutting zone and interfere with cutting tool.	Chips are disposed off easily and do not interfere with cutting tool.
5	It is difficult to pour the coolant directly at the cutting zone.	The coolant can be poured directly at the cutting zone.
6	In up milling greater speeds and feeds are not possible.	In down milling greater speeds and feeds are possible.
7	In up milling good surface finish can be obtained.	In down milling good surface finish can be obtained.

Column and Knee Type Milling Machine:

Knee and column milling machines are designed for general-purpose work and can perform not only the straight milling of plane and curved surfaces but also gear and thread cutting drilling boring and slotting.

5.6.5 Working principle of Horizontal milling machine

The horizontal mill is also the similar cutter but their cutters are placed on a horizontal arbor. A lot of horizontal mills have got rotary tables that help in milling in various angles. These tables are called the universal tables. Apart from this all the tools that are used in a vertical mill can also be used in the horizontal mill.

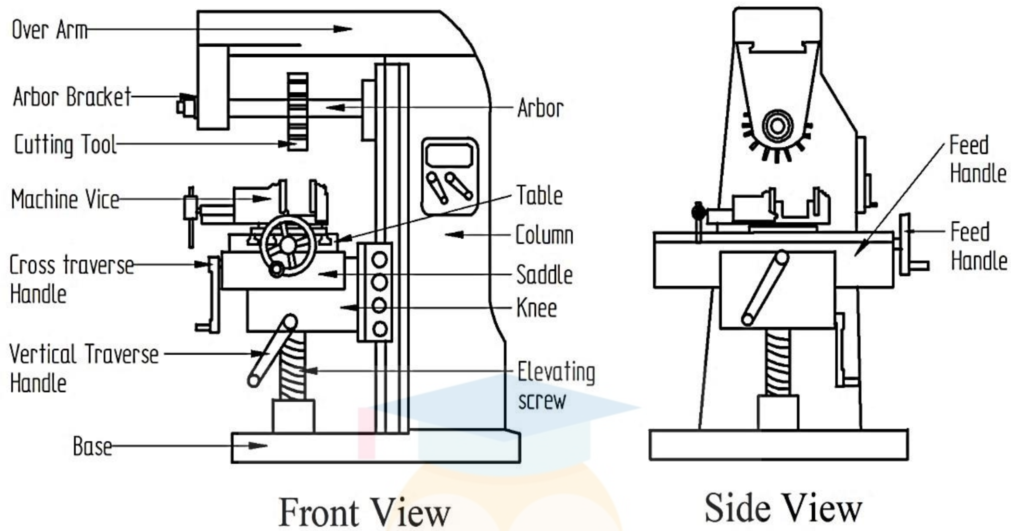


Figure 5.6.5.Horizontal milling machine

The basic components of a knee and column type milling machines are **1.** The **base**, which supports the other components.

2. The **column**, which contains the spindle and its driving mechanism

3. The **over arm**, which provides support for arbor – mounted cutters

4. The **knee**, a separate section attached to the column and can move vertically over the column

5. The **saddle**, which is supported by and moves horizontally on the knee

6. The **table**, which supports the work piece and can move horizontally at right angles to the saddle movement.

5.6.6 Working principle of Vertical Milling Machine

The base, column, knee, saddle and table of a vertical milling machine are very similar to that of the Horizontal Milling machine. The difference is the positioning of the spindle. The spindle axis is vertical or normal to the machining surface of the work piece. The over – arm and the arbor are not present in vertical type. The milling cutter is directly mounted on to the spindle with spindle attachment.

The spindle head or Machine head is supported by the column, which is mounted on the base of the milling machine. Spindle shaft one end is connected to a motor through a gearbox for, varying speed of the spindle. The other end of the spindle shaft is connected to the milling cutter. The spindle can move up and down relative to work piece. In some vertical milling machines the spindle head can swivel, allowing the milling cutter to machine angular surfaces.

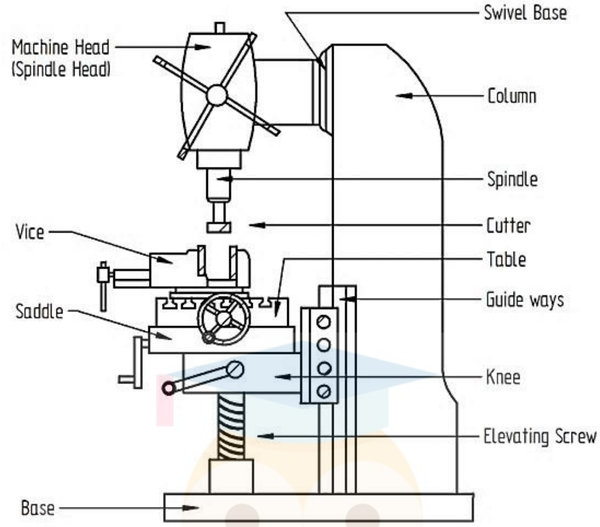


Figure5.6.6 Vertical milling machine

The basic components of a knee and column type Vertical milling machines are:

1. The **base**, which supports the other components.
2. The **column**, which contains the spindle and its driving mechanism
3. The **knee**, a separate section attached to the column and can move vertically over the column
4. The **saddle**, which is supported by and moves horizontally on the knee
5. The **table**, which supports the work piece and can move horizontally at right angles to the saddle movement.
6. The **spindle head**, this hold the spindle which is normal to the machining surface or the table

Vertical milling machines are used for machining grooves, slots and flat surfaces. The usual tools that are mounted on to the spindle are end mill and face mill.

5.6.7 Milling Operations

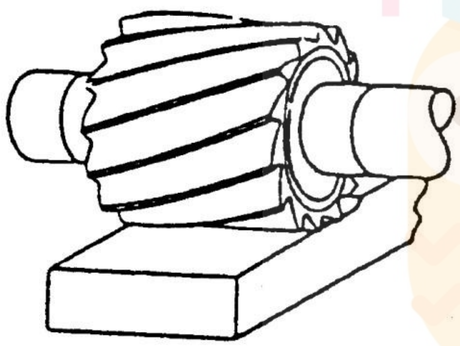
The different types of milling operations that can be carried out on a milling machine are-

1) Plain or Slab milling
2) End milling

3) Slot milling
4) Angular milling
5) Form milling
6) Straddle milling
7) Gang milling

5.6.7 Plain or Slab milling

The slab milling is the operation of producing flat, horizontal surface parallel to the axis of rotation of a slab-milling cutter. Slab milling is done to remove the material from the upper surface of the work piece. The slab milling cutters is held in the arbor and it may have straight or helical teethes. Both cutters can be used to generate flat surfaces. The require depth of cut can be adjusted by raising the table or the knee and the feed is given by moving the saddle.



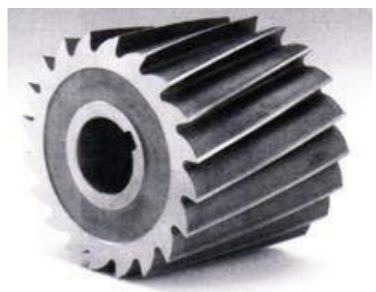


Figure 5.6.7 a slab or plain m

Figure 5.6.7 b Helical teeth mill cutter

5.6.8 End milling or Face Milling

Face milling is the operation of milling flat surface on the face of the work piece. The difference between the plain milling and the face milling is the axis of the milling cutter. The operation is performed by a face-milling cutter rotated about an **axis perpendicular** to the surface machined. The face-milling cutter is mounted on a vertical milling machine. The cutter is directly mounted on to the spindle head. The depth of cut is adjusted by raising or lowering the spindle head.

Figure 5.6.8 End milling or Face Milling operation

5.6.9 Slot milling

The process of producing keyways grooves and slots of varying shapes and sizes is known as slotting. The side milling cutter is mounted on to the arbor of a horizontal milling machine when slotting had to be done on Horizontal milling machine. T – Slots and dovetail slots are carried out on a veridical milling machine

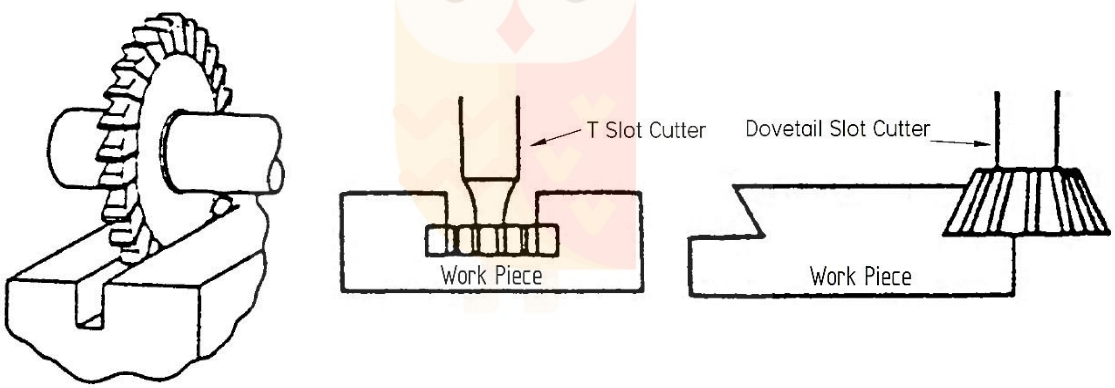
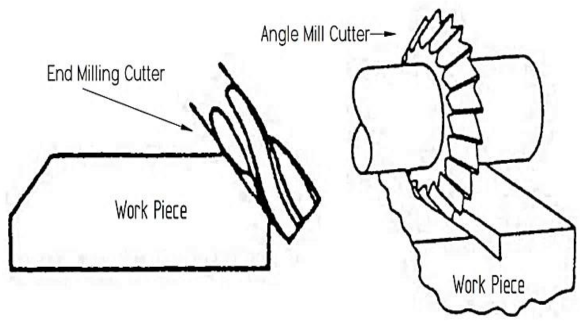


Figure 5.6.9 Simple Slotting of key way using side milling cutter

5.6.10 Angular milling

The angular milling is a process of generation of angular surface on a work piece. The angular groove may be single or double angle depends on the shape of groove required. One simple example of angular milling is a v-block.



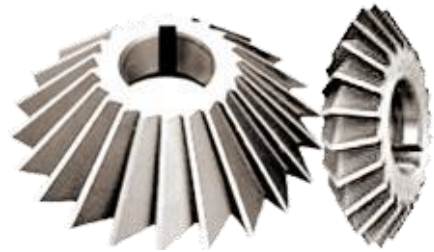


Figure 5.6.10 Angular Milling operation

5.6.11 Form Milling

It is a process of producing a required profile on the work piece. This process is carried out on horizontal milling machine. The number of parallel and angular relationships that can be machined by horizontal (peripheral) milling is limited almost solely by cutter design. Form cutters are expensive, but it is the only way of obtaining complex profiles.

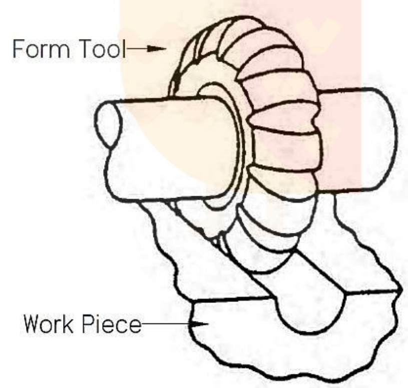


Figure 5.6.11 Form milling

5.6.11 Straddle Milling

The straddle milling is the operation of generating two flat vertical surfaces on either sides of work piece at the same time. The side milling cutters are mounted on the arbor of the horizontal milling machine. The space between the two side mills depends of the width of the vertical surface and the distance is obtained by the spacing collars.

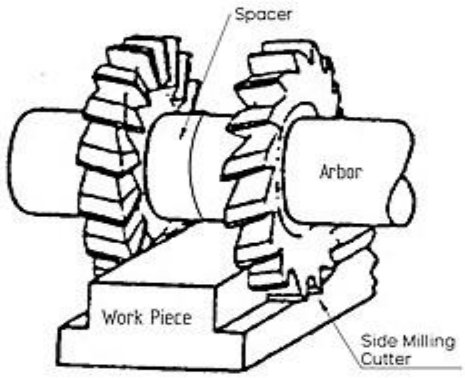


Figure 5.6.11 Straddle Milling

5.6.12 Gang Milling

It is a process of milling a work piece with two or more cutter mounted on the same arbor. There is no space collars provided. The size of the cutter can be same or different depending up on the profile of the end product required. Gang milling is commonly used to produce several different steps simultaneously in a work piece or to produce sections of the same thickness from bars or extrusions.

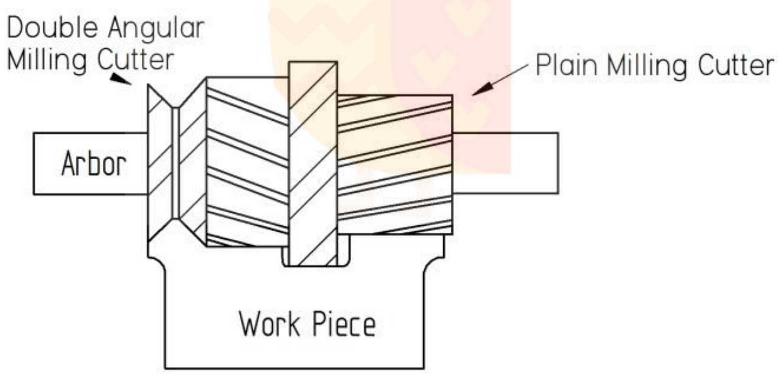


Figure 5.6.12 Gang milling

5.7 ADVANCED MANUFACTURING SYSTEMS

Advanced manufacturing involves the use of technology to improve products and/or processes, with the relevant technology being described as advanced, innovative or cutting edge. Advanced Manufacturing systems include drafting principles, manufacturing programming, CAD/CAM and CNC technologies, automation and robotics, and careers in advanced manufacturing. Hands-on projects and team activities will allow students to apply learning on the latest industry technologies.

The Advanced Manufacturing entity makes extensive use of computer, high precision, and information technologies integrated with a high performance workforce in a production system capable of furnishing a heterogeneous mix of products in small or large volumes with both the efficiency of mass production and the flexibility of custom manufacturing in order to respond quickly to customer demands.

The development of Computer Numerically Controlled (CNC) machines is a tremendous contribution to the manufacturing industry. Simply put, a CNC system receives and interprets the data and then controls certain actions accordingly. The CNC systems, a versatile form of soft automation, are mostly used in the lathe machine, milling machine, laser machine, sheet metal process, etc. The concept was originally developed to control operation and motion of machine tools

5.7.1 COMPUTER NUMERICAL CONTROL (CNC)

Computer Numerical Control (CNC) is a specialized and versatile form of Soft Automation and its applications cover many kinds, although it was initially developed to control the motion and operation of machine tools.

The CNC is computer-based electronic equipment, as mentioned earlier, which receives information in digital form from input devices, as well as positional information of certain elements of the machine. Then it interprets the digital data as requirements for new positions of the machine elements and gives appropriate commands of direction.

Figure 5.7 CNC Machine

5.7.2 Components of CNC Machine

Numerical control is described as a technique to control various functions of a machine tool with an input. CNC is a microprocessor-based system, the heart and brain of a CNC machine. Following are some of the components of a CNC system:

- **a)** Central processing unit (CPU)
- **b)** Input devices
- **c)** Machine control panel
- **d)** Programmable logic controller (PLC)
- **e)** Servo-control unit
- **f)** Display unit

A serial communication port is often utilized to transfer data from a computer to a CNC machine. There are international standards established for serial communications. The CPU is where a CNC system is controlled. It receives the data stored in the memory as part program. The data is then decoded and modified into position control and velocity control signals. It oversees the movement of the spindle or control axis. An action is rectified if it does not match with the programmed data.

Speed control unit works in a harmonious way with the CPU for the movement of the machine axes.

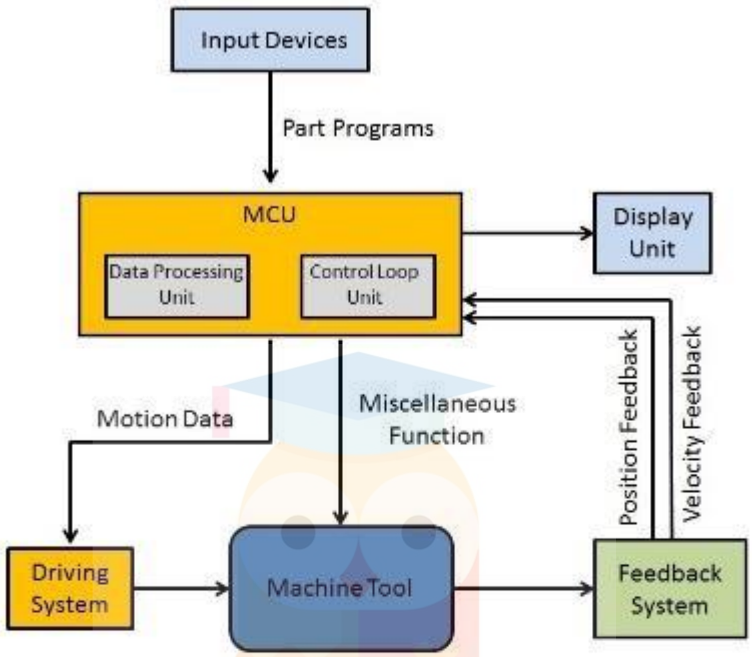


Figure 5.7.1 Components of CNC Machine

5.7.3 CONTROL SYSTEM

- **Open loop and closed loop systems**

CNC systems require motor drives to control both the position and the velocity of the machine axes. Each axis must be driven separately and follow the command signal generated by the NC control. There are two ways to activate the servo drives: the open-loop system and the closed-loop system

- **Open loop systems**

Programmed instructions are fed into the controller through an input device. These instructions are then converted to electrical pulses (signals) by the controller and sent to the servo amplifier to energize the servo motors. The cumulative number of electrical pulses determines the distance each servo drive will move, and the pulse frequency determines the velocity.

The primary drawback of the open-loop system is that there is no feedback system to check whether the program position and velocity has been achieved. If the system performance is affected by load, temperature, humidity, or lubrication then the actual output could deviate from the desired output

Open loop systems have no access to the real time data about the performance of the system and therefore no immediate corrective action can be taken in case of system disturbance.

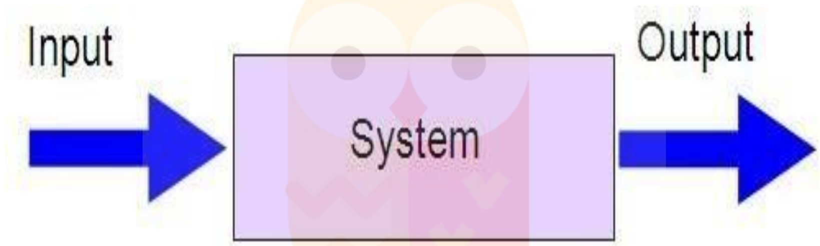


Figure 5.7.3a open loop system

Closed loop system

The closed-loop system has a feedback subsystem to monitor the actual output and correct any discrepancy from the programmed input. The feedback system could be either analog or digital. The analog systems measure the variation of physical variables such as position and velocity in terms of voltage levels. Digital systems monitor output variations by means of electrical pulses

Closed-loop systems are very powerful and accurate because they are capable of monitoring operating conditions through feedback subsystems and automatically compensating for any variations in real-time. In a close loop system, feedback devices closely monitor the output and any disturbance will be corrected in the first instance. Therefore high system accuracy is achievable.

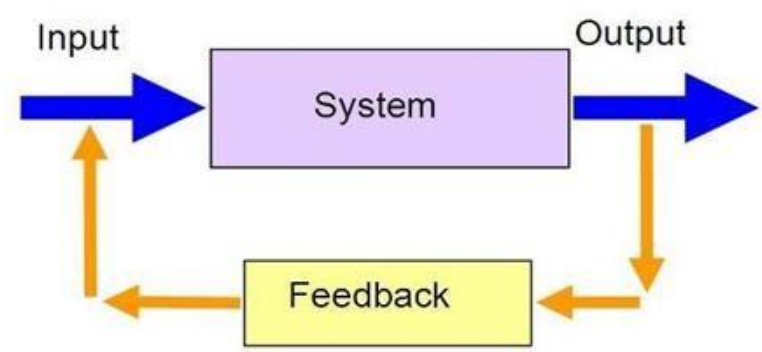


Figure 5.7.3b closed loop system

5.7.4 Advantages of CNC machining

The manufacturing industry relies heavily on CNC machining. Following are some of the advantages of CNC machining:

- **a)** Higher flexibility and repeatability
- **b)** Reduced indirect costs
- **c)** Increased productivity
- **d)** Consistent quantity
- **e)** Reliable operation
- **f)** Reduced non-productive time
- **g)** Higher accuracy
- **h)** Reduced lead time
- **i)** Automatic material handling

5.7.5 Disadvantages

- **a)** High initial investment
- **b)** Specialized maintenance required
- **c)** Does not eliminate the human errors completely.
- **d)** Requires more specialized operators.
- **e)** Not so relevant the advantages on the production of small or very small series.

5.7.6 Applications of CNC Machines

CNC machines are widely used in the metal cutting industry and are best used to produce the following types of product:

- **a)** Parts with complicated contours.
- **b)** Parts requiring close tolerance and/or good repeatability.

c) Parts requiring expensive jigs and fixtures if produced on conventional machines
d) Parts that may have several engineering changes, such as during the development stage of a prototype.
e) In cases where human errors could be extremely costly.
f) Parts that are needed in a hurry.
g) Small batch lots or short production runs.

5.7.7 CNC MACHINING CENTERS

The machining center, developed in the late 50's is a machine tool capable of multiple machining operations on a work part in one setup under NC program control.

Machining Center: A computer-controlled machine tool is capable of performing many types of cutting operations on multiple surfaces and directions on a workpiece. Machining centers are classified as vertical, horizontal, or universal. The designation refers to the orientation of the machine spindle.

A vertical machining Centre has its spindle on a vertical axis relative to the work table. A vertical machining Centre (VMC) is typically used for flat work that requires tool access from top. E.g. mould and die cavities, large components of aircraft.

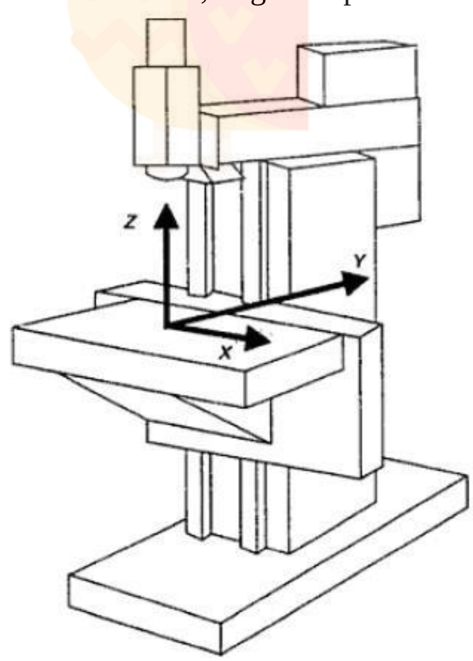


Figure 5.7.7a vertical machining Centre

A horizontal machining Centre (HMC) is used for cube shaped parts where tool access can be best achieved on the sides of the cube.

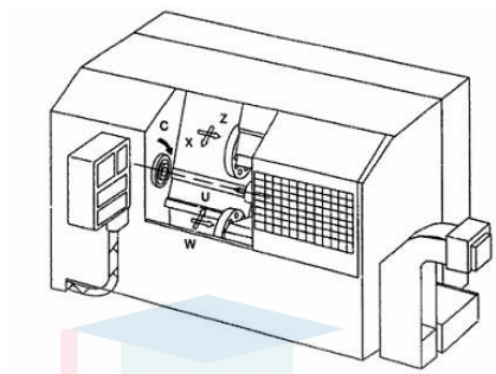


Figure 5.7.7b Horizontal machining Centre

1. CNC turning centers come in either horizontal or vertical configurations. There are also inverted vertical turning centers, which reverse the position of the spindle and the chuck. All three machine types generally consist of the same basic components (i.e., headstock, carriage, etc.), but differ in their orientation. A turning or universal machining Centre (UMC) has a work head that swivels its spindle axis to any angle between horizontal and vertical making this a very flexible machine tool.E.g.: Aerofoil shapes, curvilinear geometries

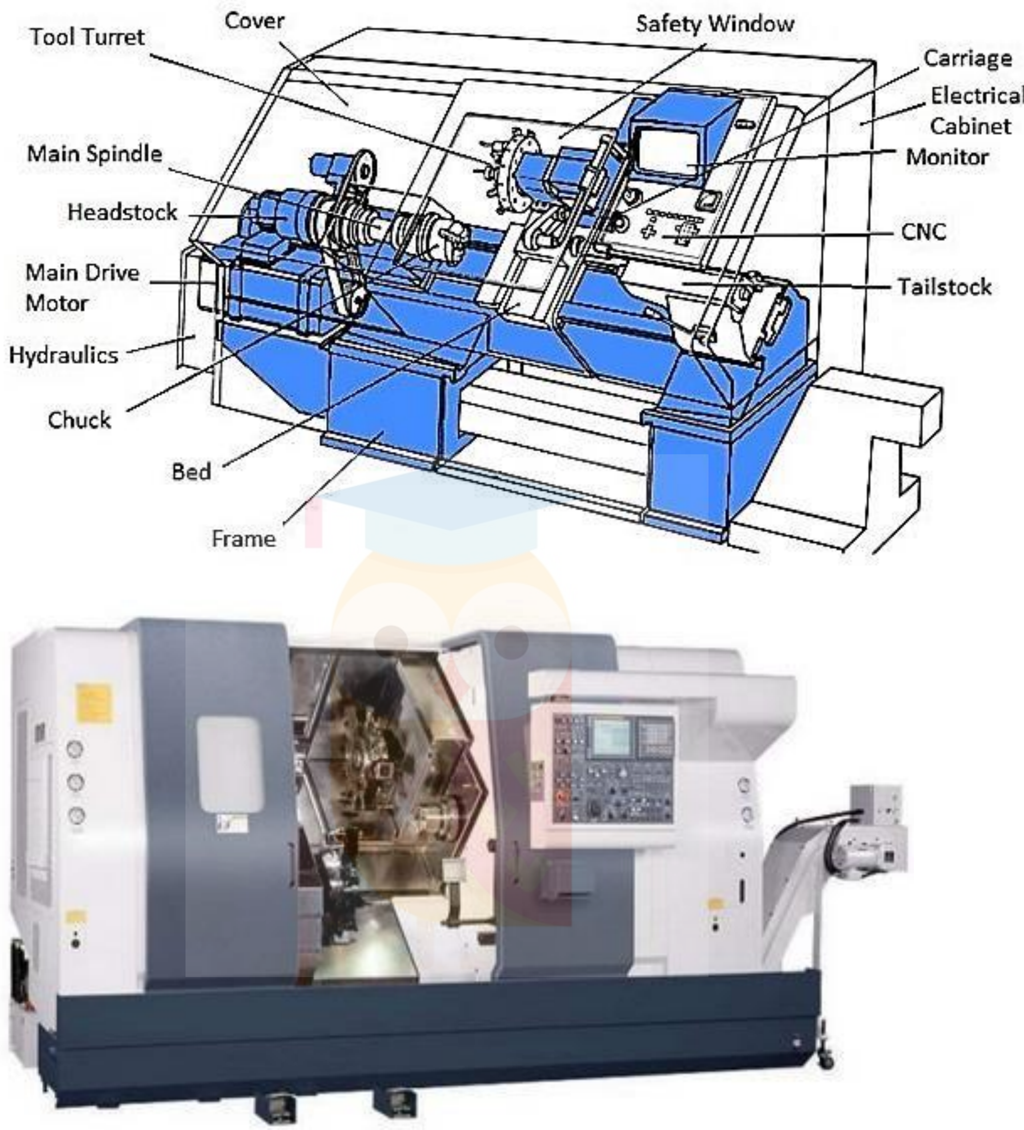


Figure 5.7.7c Turning machining Centre

5.8 ROBOTICS

5.8.1 Introduction to Robotics

Robotics is the art, knowledge base, and the know-how of designing, applying, and using robots in human endeavors. Robotics is an interdisciplinary subject that benefits from mechanical engineering, electrical and electronic engineering, computer science, biology, and many other disciplines.

5.8.2 History of Robotics

- **a)** 1922 Czech author Karel Capek wrote a story called Rossum's Universal Robots and introduced the word "Rabota"(meaning worker)
- **b)** 1954 George Devol developed the first programmable Robot.
- **c)** 1955 Denavit and Hartenberg developed the homogenous transformation matrices
- **d)** 1962 Unimation was formed, first industrial Robots appeared.
- **e)** 1973 Cincinnati Milacron introduced the T3 model robot, which became very popular in industry.
- **f)** 1990 Cincinnati Milacron was acquired by ABB
- **g)** 21C: Walking Robots, Mobile Robots, Humanoid Robots

5.8.3 ROBOT DEFINITION "A re-programmable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motion for a variety of tasks" 5.8.4 ROBOT ANATOMY, JOINTS AND LINKS

The manipulator of an industrial robot consists of a series of joints and links. Robot anatomy deals with the study of different joints and links and other aspects of the manipulator's physical construction. A robotic joint provides relative motion between two links of the robot. Each joint, or axis, provides a certain degree-of-freedom (dof) of motion. In most of the cases, only one degree-of-freedom is associated with each joint. Therefore the robot's complexity can be classified according to the total number of degrees-of-freedom they possess

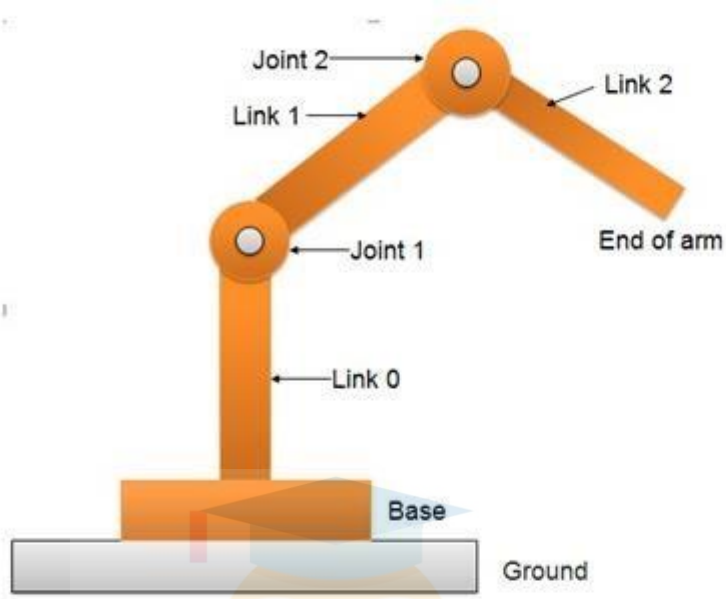


Figure 5.8.4 Robot Anatomy

Each joint is connected to two links, an input link and an output link. Joint provides controlled relative movement between the input link and output link. A robotic link is the rigid component of the robot manipulator. Most of the robots are mounted upon a stationary base, such as the floor. From this base, a joint-link numbering scheme may be recognized as shown in Figure the robotic base and its connection to the first joint are termed as link-0. The first joint in the sequence is joint-1. Link-0 is the input link for joint-1, while the output link from joint-1 is link-1—which leads to joint-2. Thus link 1 is, simultaneously, the output link for joint-1 and the input link for joint-2. This joint-link-numbering scheme is further followed for all joints and links in the robotic systems.

5.8.5 ROBOT JOINTS

Nearly all industrial robots have mechanical joints that can be classified into following five types as shown in Figure below.

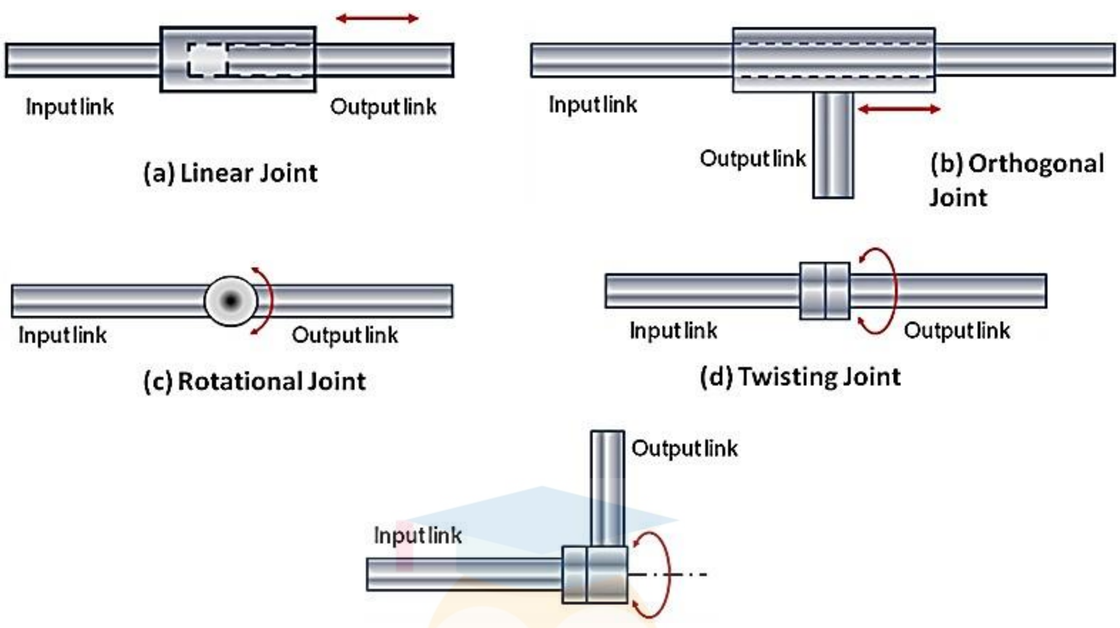


Figure 5.8.5 Robot joints

a) Linear joint (type L joint): The relative movement between the input link and the output link is a translational sliding motion, with the axes of the two links being parallel.

b) Orthogonal joint (type U joint)

This is also a translational sliding motion, but the input and output links are perpendicular to each other during the move.

c) Rotational joint (type R joint)

This type provides rotational relative motion, with the axis of rotation perpendicular to the axes of the input and output links.

d) Twisting joint (type T joint): This joint also involves rotary motion, but the axis or rotation is parallel to the axes of the two links.

e)Revolving joint (type V-joint, V from the "v" in revolving): In this type, axis of input link is parallel to the axis of rotation of the joint. However the axis of the output link is perpendicular to the axis of rotation.

5.8.6 COMMON ROBOT CONFIGURATIONS

Basically the robot manipulator has two parts viz. a body-and-arm assembly with three degrees-of-freedom; and a wrist assembly with two or three degrees-offreedom.

For body-and-arm configurations, different combinations of joint types are possible for a three-degree-of-freedom robot manipulator. Five common body-and-arm configurations are outlined in figure.

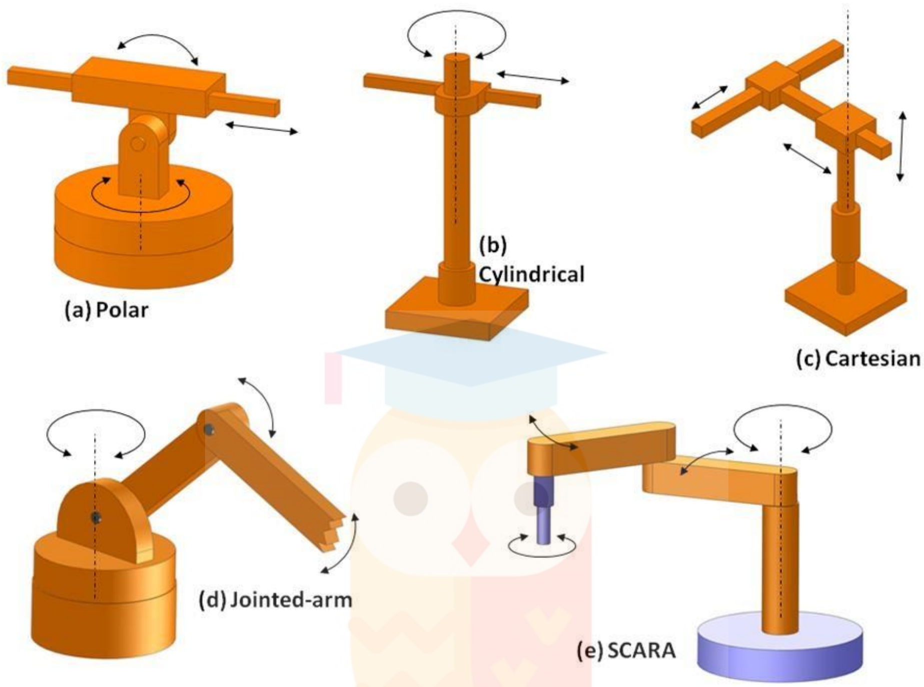


Figure 5.8.6 Common Robot configuration

a. Polar configuration

It consists of a sliding arm L-joint, actuated relative to the body, which rotates around both a vertical axis (T-joint), and horizontal axis (R-joint). **b. Cylindrical configuration**

It consists of a vertical column. An arm assembly is moved up or down relative to the vertical column. The arm can be moved in and out relative to the axis of the column. Common configuration is to use a T-joint to rotate the column about its axis. An L-joint is used to move the arm assembly vertically along the column, while an O-joint is used to achieve radial movement of the arm. **c. Cartesian co-ordinate robot**

It is also known as rectilinear robot and x-y-z robot. It consists of three sliding joints, two of which are orthogonal O-joints. **d. Jointed-arm robot**

It is similar to the configuration of a human arm. It consists of a vertical column that swivels about the base using a T-joint. Shoulder joint (R-joint) is located at the top of the column. The output link is an elbow joint (another R joint). **e. SCARA Configuration**

Its full form is 'Selective Compliance Assembly Robot Arm'. It is similar in construction to the jointer-arm robot, except the shoulder and elbow rotational axes are vertical. It means that the arm is very rigid in the vertical direction, but compliant in the horizontal direction.

5.8.7 Advantages of Robots

- **a)** Robots can work in hazardous environments without the need.
- **b)** Robots need no environmental comfort.
- **c)** Robots work continuously without experiencing fatigue of problem.
- **d)** Robots have repeatable precision at all times.
- **e)** Robots can be much more accurate than human.
- **f)** Robots replace human workers creating economic problems.
- **g)** Robots can process multiple stimuli or tasks simultaneously.
- **h)** Robots increase productivity, safety, efficiency, quality, and consistency of products.

5.8.8 Disadvantages

- **a)** Robots lack capability to respond in emergencies.
- **b)** Robots, although superior in certain senses, have limited capabilities in degree of freedom, Dexterity, Sensors, Vision system, real time response.
- **c)** Robots are costly, due to Initial cost of equipment, Installation costs, Need for Peripherals, Need for training, Need for programming.

5.8.9 Robot Applications

Robots are mainly used in three types of applications: material handling; processing operations; and assembly and inspection. In material handling, robots move parts between various locations by means of a gripper type end effector. Material handling activity can be sub divided into material transfer and machine loading and/or unloading.

Table 5.8.9: Material handling applications

Application	Description
Material transfer	• Main purpose is to pick up parts at one location and place them at a new location. Part re-orientation may be accomplished during the transfer. The most basic application is a pick-and-place procedure, by a low-technology robot (often pneumatic), using only up to 4 joints. • More complex is palletizing, where robots retrieve objects from one location, and deposit them on a pallet in a specific area of the pallet, thus the deposit location is slightly different for each object transferred. The robot must be able to compute the correct deposit location via powered lead-through method, or by dimensional analysis. • Other applications of material transfer include de-palletizing, stacking, and insertion operations.
Machine loading and/or unloading	• Primary aim is to transfer parts into or out-of a production machine. • There are three classes to consider: o machine loading—where the robot loads the machine o machine unloading—where the robot unloads the machine o machine loading and unloading—where the robot performs both actions • Used in die casting, plastic molding, metal machining operations, forging, press-working, and heat treating operations.

5.8.10 Processing Operations

In processing operations, the robot performs some processing activities such as grinding, milling, etc. on the work part. The end effector is equipped with the specialized tool required for the respective process. The tool is moved relative to the surface of the work part. Table5.8 outlines the examples of various processing operations that deploy robots.

Figure 5.8.10 Processing Operations

Table 5.8.10: Robotic process operation

Process	Description
Spot Welding	Metal joining process in which two sheet metal parts are fused together at localized points of contact by the deployment of two electrodes that squeeze the metal together and apply an electric current. The electrodes constitute the spot welding gun, which is the end effector tool of the welding robot.
Arc Welding	Metal joining process that utilizes a continuous rather than contact welding point process, in the same way as above. Again the end effector is the electrodes used to achieve the welding arc. The robot must use continuous path control, and a jointed arm robot consisting of six joints is frequently used.
Spray Coating	Spray coating directs a spray gun at the object to be coated. Paint or some other fluid flows through the nozzle of the spray gun, which is the end effector, and is dispersed and applied over the surface of the object. Again the robot must use continuous path control, and is typically programmed using manual lead-through. Jointed arm robots seem to be the most common anatomy for this application.
Other applications	Other applications include: drilling, routing, and other machining processes; grinding, wire brushing, and similar operations; waterjet cutting; and laser cutting.

5.9 ASSEMBLY AND INSPECTION

The use of robots in assembly is expected to increase because of the high cost of manual labor common in these operations. Since robots are programmable, one strategy in assembly work is to produce multiple product styles in batches, reprogramming the robots between batches. An alternative strategy is to produce a mixture of different product styles in the same assembly cell, requiring each robot in the cell to identify the product style as it arrives and then execute the appropriate task for that unit.

Inspection is another area of factory operations in which the utilization of robots is growing. In a typical inspection job, the robot positions a sensor with respect to the work part and determines whether the part is consistent with the quality specifications.

Figure 5.9a: Robot assembly in a typical automobile factory

Figure 5.9b: A robot inspecting for uniform diameter in a precision pipe