MODULE 5

Content:

Fundamentals of Machine Tools and Operations: Fundamentals of Machining and machine tools, Construction and Working Principle of Lathe, Various Lathe Operations: Turning, Facing, Taper Turning and Knurling. Construction and Working of Milling Machines and applications. Construction and working of simple Drilling Machines and applications. (Sketches of layout need not be dealt with for all machine tools)

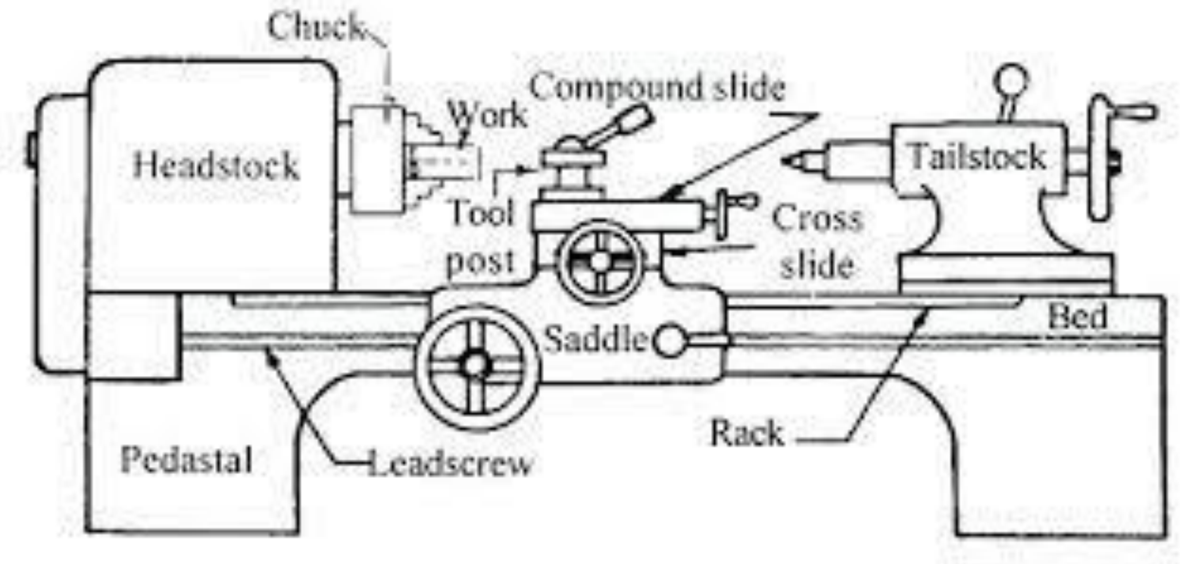
Introduction to Modern Manufacturing Tools and Techniques: CNC: Introduction, components of CNC, advantages and applications of CNC, CNC Machining centers and Turning Centers Concepts of Smart Manufacturing and Industrial IoT.

Introduction to Mechatronics: Concept of open-loop and closed-loop systems, Examples of Mechatronic systems, and their working principle.

Fundamentals of Machine Tools and Operations:

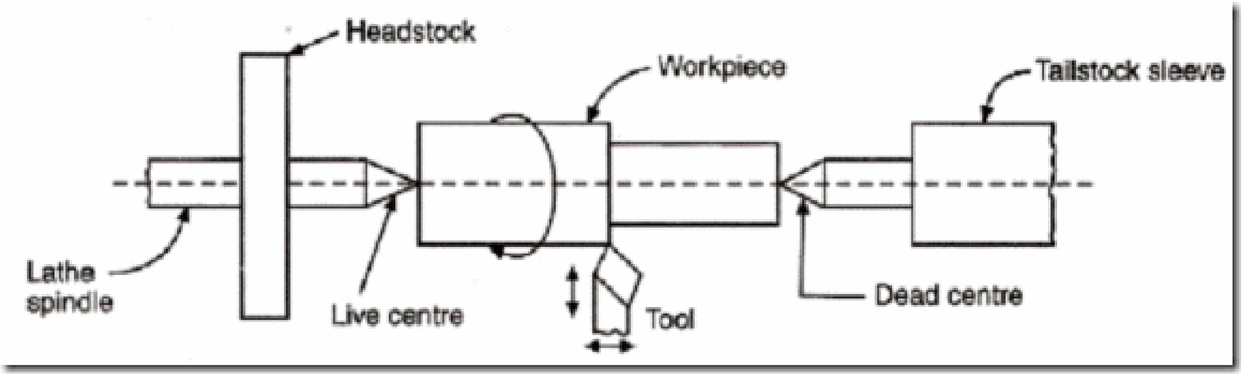
Machine Tool: A machine tool is a machine for handling or machining metal or other rigid materials, usually by cutting, boring, grinding, shearing, or other forms of operations. Machine tools employ some sort of tool that does the cutting or shaping.
The fundamental machine tools that are used for most of the machining processes are lathe, drilling, tapping, planning, milling, and grinding machines.
Machining: Machining is a process in which a material (often metal) is cut to a desired final shape and size by a controlled material-removal process.

Lathe: A lathe is a machine tool employed generally to produce circular objects. It is said to be the mother of all the machine tools, as it is versatile, that most of the machining operations which are performed on other machine tools like drilling, grinding, shaping, milling, etc., cane be performed on it.
Construction of a lathe:



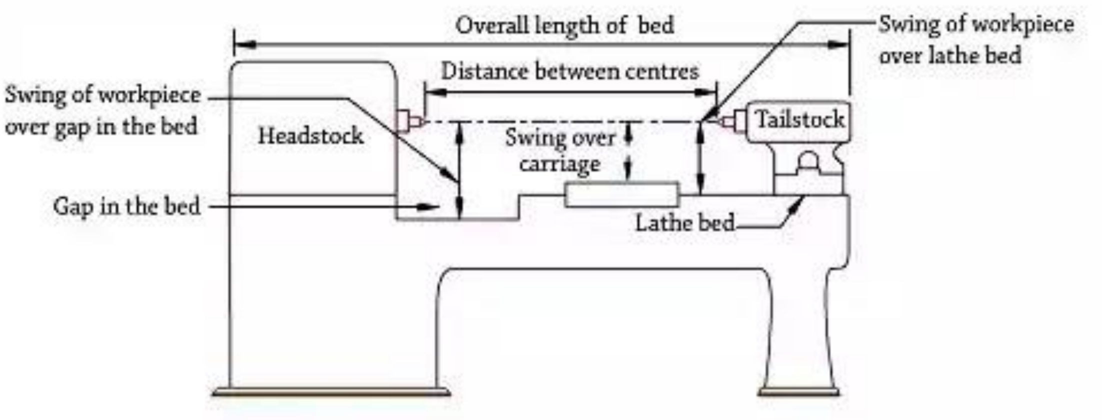
The bed is a robust base that connects to the headstock and permits the carriage and tailstock to be moved parallel with the axis of the spindle. Lathe bed is made of high-grade cast iron having approximately tensile strength of 30 kgf/mm² & with hardness of BHN 201.
The headstock is usually located on the left side of the lathe and is equipped with gears, spindles, chucks, gear speed control levers, and feed controllers.
Carriage is found nestled between the headstock and tailstock. The carriage is responsible for guiding the tool bit as it cuts or otherwise manipulates the workpiece. The main function of the carriage is to position the tool along the lathe bed.
Lathe tailstocks are used to support workpieces that feature a central hole. Sometimes called "foot stocks", lathe tailstocks help to prevent excessive bending of a workpiece. They're particularly suited to working with longer, slender workpieces.
The lathe has a gear box that controls the relative rate of the chuck and the lead screw that allows you to move the workpiece automatically using the power feed. Changing the gears allows you to change this relative speed.

Working principle of a lathe:



Lathe machine is one of the most important machine tools which is used in the metalworking industry. It operates on the principle of a rotating work piece and a fixed cutting tool. The cutting tool is feed into the work piece which rotates about its own axis causing the workpiece to form the desired shape. The work piece is held between the headstock and tailstock. It is rotated at high speed.

Lathe specifications:
The size of a lathe is specified by the following as shown in fig.
1. Maximum diameter of the workpiece that can be revolved over the lather bed. Or the height of the centres above the lathe bed.
2. Maximum diameter and the width of the workpiece.
3. Maximum length of the workpiece.
4. Overall length of the bed.

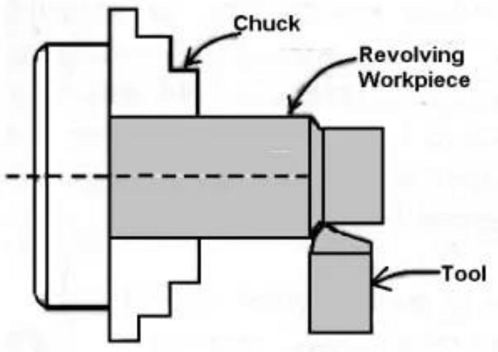


Lathe specification

Lathe Operations:

Turning:

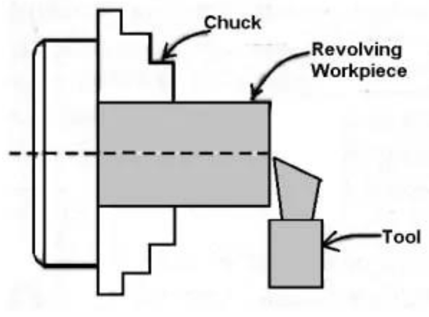
Turning is the most common lathe machining operation. During the turning process, a cutting tool removes material from the outer diameter of a rotating workpiece. The main objective of turning is to reduce the workpiece diameter to the desired dimension. There are two types of turning operations, rough and finish.



Turning Operation

Facing:

Facing is a common machining process that involves the use of a lathe or milling machine to remove material from the end and/or shoulder of a workpiece. After the workpiece is placed on the machine, a cutting tool is pressed against it at the end or shoulder.

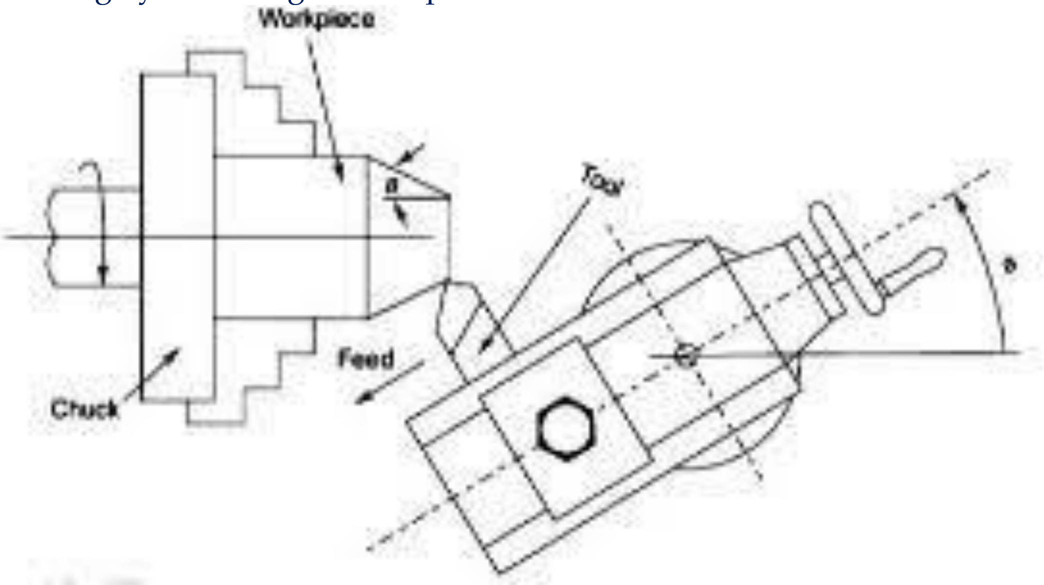


Facing Operation

Taper turning:

Taper turning is the turning process in which the cutting tool moves at an angle to the axis of the workpiece so that a tapered shape is obtained in the workpiece. In a tapered piece, the diameter of the workpiece changes uniformly from one end to another. The workpiece can be tapered from inside or outside.

Taper turning by Swiveling the compound rest:



In this method the compound tool rest is swiveled to the required taper angle and then locked on the angular position. The carriage is also locked at that position. For taper turning the compound tool rest is moved linearly at an angle so that the cutting tool produces the tapered surface on the workpiece. This method is limited to short-tapered lengths.

Knurling:

Knurling is a process of impressing a diamond shaped or straight-line pattern into the surface of a workpiece by using specially shaped hardened metal wheels to improve its appearance and to provide a better gripping surface. It consists of one upper roller and one lower rollers on which the desired impression patterns can be seen. The knurling tool is set in the tool post in such a way that the upper and lower rollers of the knurling head touch the surface of the workpiece to be knurled.

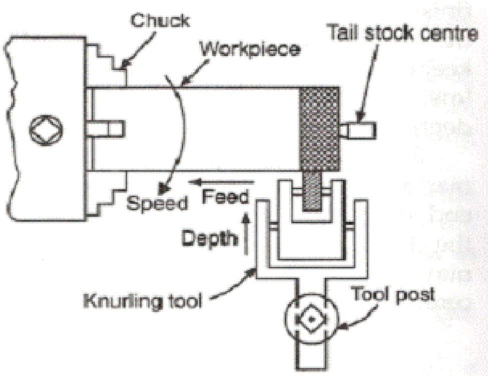
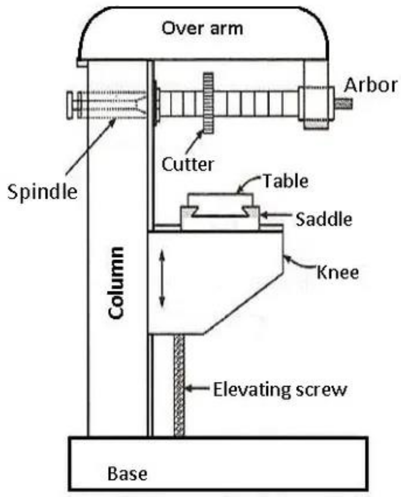


Fig. 7.17. Knurling

Milling machine:

The milling machine is used for making various types of gears. It is generally used to produce slot or groove in work pieces. The cutter revolves at a normal speed and the work fed slowly past the cutter. The work can be fed in a longitudinal, vertical, or cross direction. As the work progress further, the cutter teeth remove the metal from the work surface to produce the desired shape.

Construction of Horizontal Milling machine:



The main parts of horizontal milling machine are base, Column, Knee, Saddle, Table, Overarm, Arbor Support and Elevating Screw. In a horizontal milling machine, the cutter axis is horizontal. The cutting surfaces of a milling cutter are generally made of a hard and temperature-resistant material, so that they wear slowly. A low-cost cutter may have surfaces made of high-speed steel. More expensive but slower-wearing materials include cemented carbide.

The column houses the spindle, transmission systems from the electric motor to the spindle and it enables to mount the table control and lifting mechanisms.

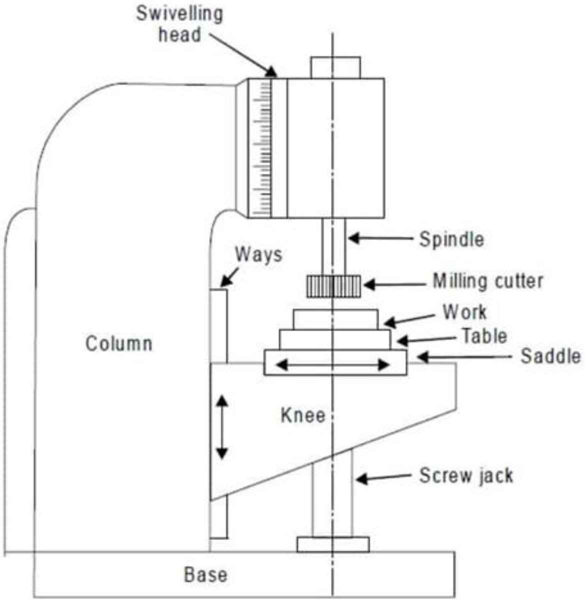
Arbor is the horizontal shaft provided with a straight body and tapered shank. On the straight portion of arbor, the rotary cutters are mounted. The tapered end of the arbor fits into the tapered hole of the spindle. The other end of the arbor is mounted in a bearing housed in the projecting overarm.

Knee: the knee is casting mounted on the front vertical side of the column and is moved up or down by an elevating screw. The upper face of the knee is provided with guideways to mount the saddle.

Saddle: The saddle is a casting provided with two slides one at the top and the other at the bottom which are exactly at 90^0 to each other. The lower slide fits within the guide ways on the top of the knee and the upper slide receives the dovetail guides provided on the bottom of the table.

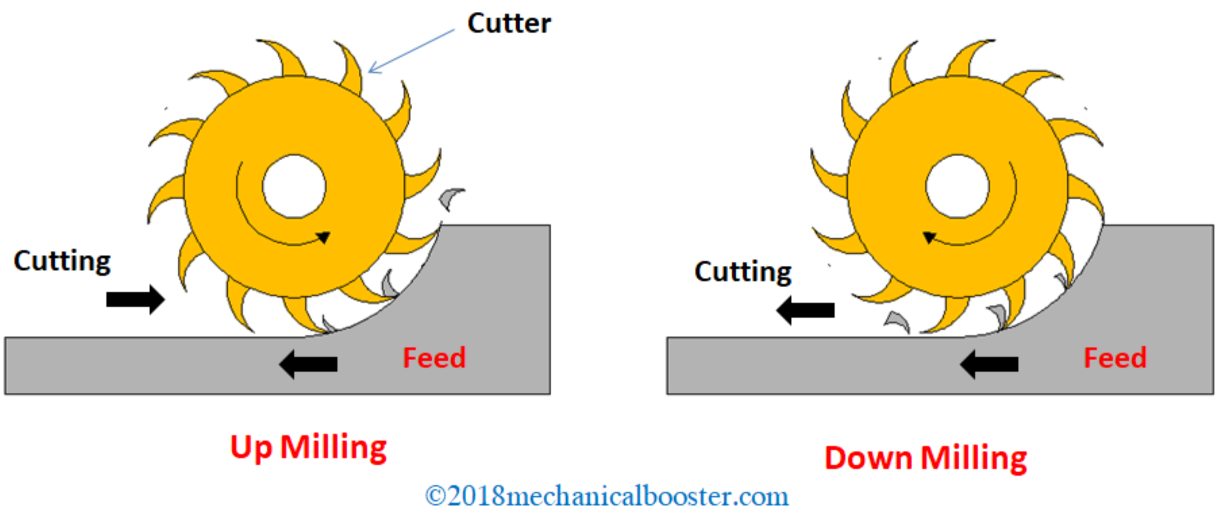
Table: the table is mounted on the top of the saddle. The bottom of the table has a dovetail slide which fits in the slideways on the top of the saddle. The top of the table is machined with several full-length T- slots for mounting vices or other work holding fixtures.

Construction of Vertical Milling machine:



In a vertical milling machine, the spindle is mounted with its axis vertical perpendicular to the worktable. The column and the base are formed into an integral casting.
The spindle head is fitted vertically in the guideways provided in the projecting end of the column. The spindle can be moved up and down over the guideways.
A saddle is mounted over the guideways provided at the top of the base. The saddle can be moved longitudinally.
In this milling machine the workpiece can be moved only in the horizontal plane both longitudinally and in the transverse direction, but not vertically.
The rotating cutter can be either raised or lowered to give the required depth of cut.

Working principle of Milling machine:
In a milling machine the milling cutter is mounted on a rotating shaft known as arbor. The workpiece which is mounted on the table can be fed either in the direction opposite to that of the rotating cutter or in the same direction of that of the cutter.

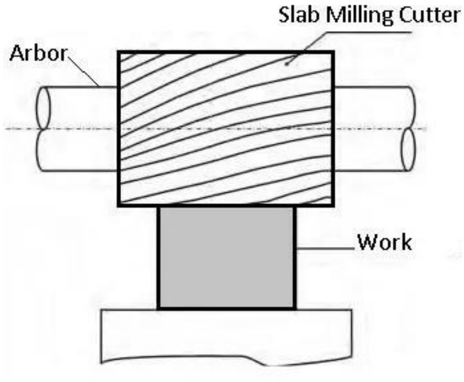


Up milling: When the workpiece is fed in the opposite direction to the cutter tooth at the point of contact, the process is called conventional or up milling. In this process, as the workpiece advances, against the rotating cutter, the chip that is removed gets progressively thicker. The action of the cutter forces the workpiece and the table against the direction of the table feed; thus, each cutter tooth enters a clean metal gradually thus the shock load on each tooth is minimized.

Down milling: When the workpiece is fed in the same direction to the cutter tooth at the point of contact, the process is called climb or down milling. In this process, the cutter enters the top of the workpiece and removes the chip that gets progressively thinner as the cutter tooth rotates. Generally, more metal can be removed for each cut than the conventional up milling.

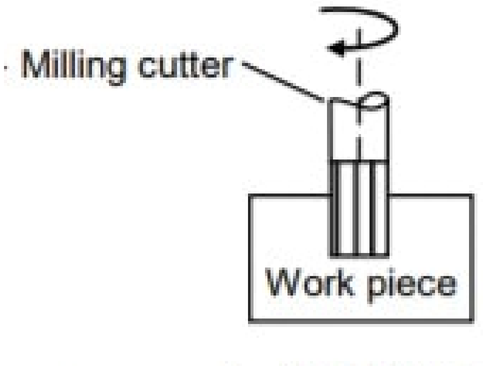
Milling Processes:

i. Plain milling: Plain milling, also known as slab milling or surface milling, the process of milling flat surface with the axis of cutting tool parallel to the surface being machined. The rotating milling cutter does not give a continuous cut but moves from one end of the workpiece to another end.



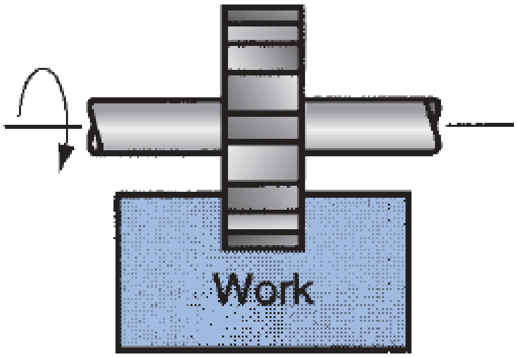
Plain Milling Operation

ii. End milling: An end milling process consists of a cylindrical cutter that has multiple cutting edges on both its periphery and its tip, permitting end-cutting and peripheral cutting. It is used to mill slots, pockets, and keyways.

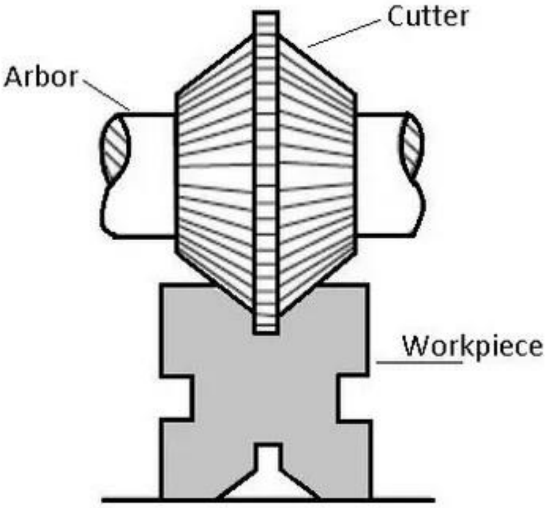


End Milling

iii. Slot milling: Slot milling is the process of milling slots using different types of cutters called "slot drill" which has the capacity to cut into solid material.

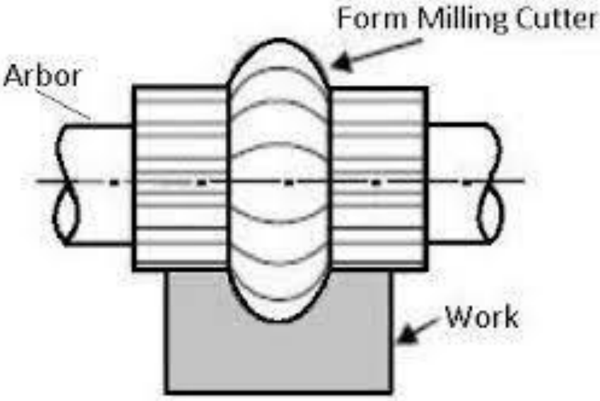


iv. Angular milling: Angular milling is the milling operation used to mill flat surfaces that are neither parallel nor perpendicular to the milling cutter axis. Angular surfaces like dovetail grooves, chamfers and serrations are done through this process.



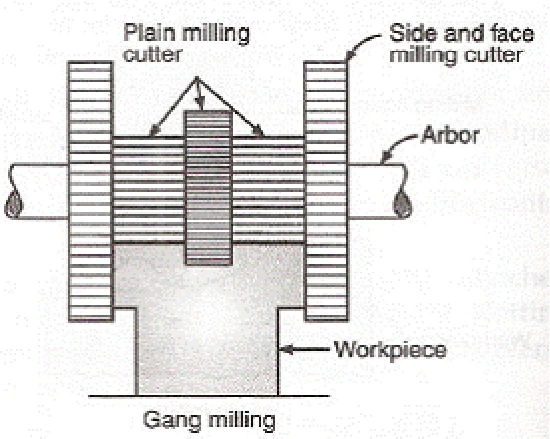
Angular Milling

v. Form milling: Form milling is a milling operation used to machine special forms/ contours consisting of curves and for straight lines by using a special "form mill cutter" which are shaped exactly to the contour that is to be form milled.



Form Milling Operation

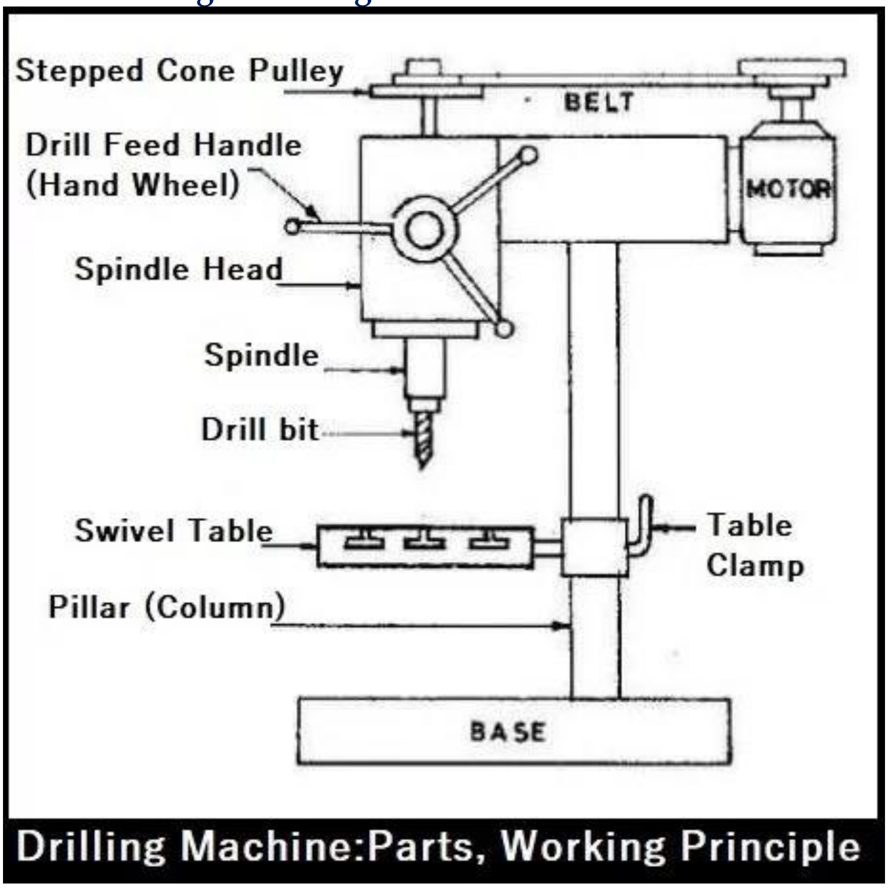
vi. Gang milling: Gang milling is a process of milling which is used to machine two or more parallel surfaces with several types of milling cutters according to the shape of the desired work surface.



Applications of Milling:

- The milling machine is used for making various types of gears.
- It is generally used to produce slot or groove in work pieces.
- It can machine flat surface and irregular surfaces too.
- It is used in industries to produce complex shapes.

Construction and Working of drilling machine:

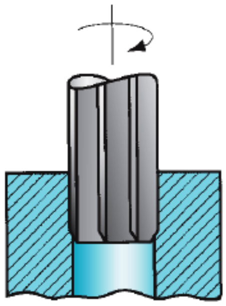


The basic parts of a drilling machine are a base, column, drill head and spindle. The base made of cast iron may rest on a bench, pedestal or floor depending upon the design. Larger and heavy-duty machines are grounded on the floor. The column is mounted vertically upon the base.

Working Principle of Drilling Machine: When the power is given to the motor, the spindle rotates and thereby the stepped pulley attached to it also rotates. On the other end, one more stepped pulley is attached and that is inverted to increase or decrease the speed of the rotational motion.

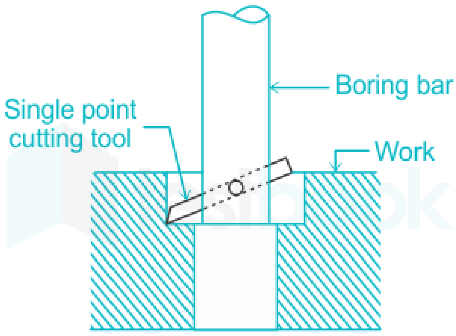
Drilling machine operations:

i. Reaming: Reaming is a finishing operation of high precision drilled holes performed with a multi-edge tool called reamer. Reamer is like twist drill but has straight flutes. After drilling the hole to a slightly smaller size, the reamer is mounted in place of twist drill and with reduced speed the reaming is done in the same way as drilling.



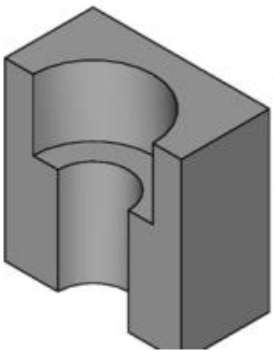
Reaming

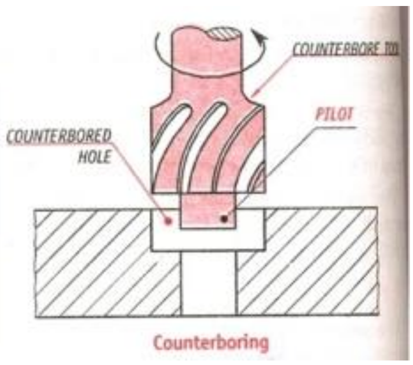
ii. Boring: Boring is done on a drilling machine to increase the size of the already drilled hole.



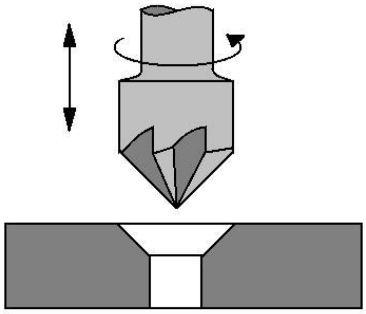
Boring Cutter

iii. Counterboring: Counterboring is to increase the size of a hole near the surface of the hole through a small depth as shown in Fig. The counterboring forms a larger sized recess or a shoulder to the existing hole.

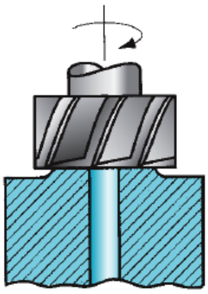




iv. Countersinking: Countersinking is a process that creates a V-shaped edge near the surface of a hole. It is often used to deburr a drilled or tapped hole, or to allow the head of a countersunk-head screw to sit flush or below a surface.

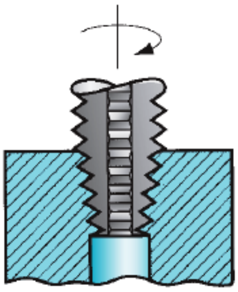


v. Spot Facing: Spot facing is a machining operation for producing a flat seat for bolt head, washer, or nut at the opening of a drilled hole. The tool is called a spot facer or a spot facing tool.

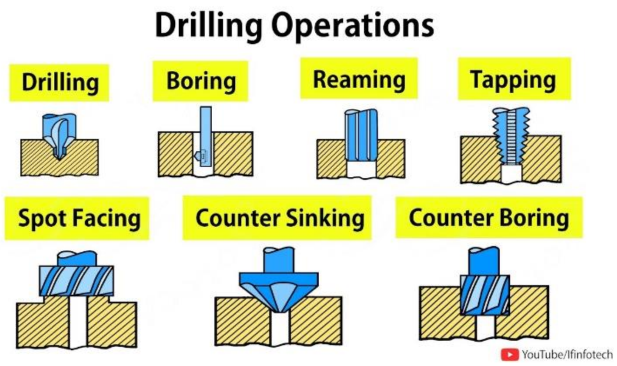


Spot facing

vi. Tapping: Tapping is the process of cutting a thread inside a hole so that a cap screw or bolt can be threaded into the hole. Also, it is used to make thread on nuts. Tapping can be done on the lathe by power feed or by hand.



Tapping



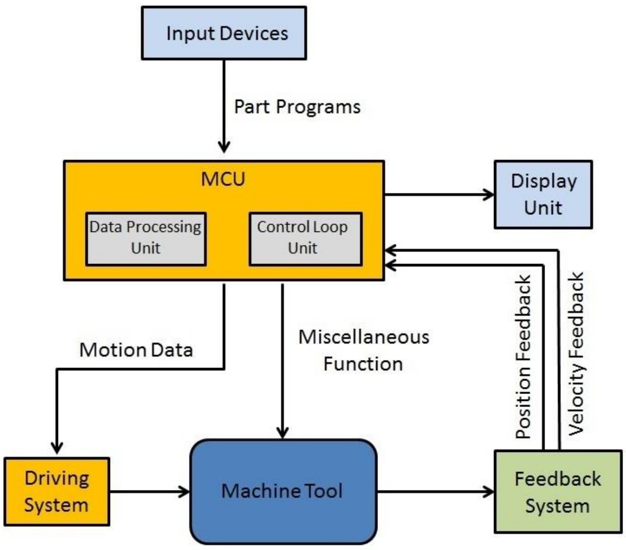
Drilling machine applications:

- Fuel Injector Bodies.
- Fuel Rails for Diesel Engines.
- Heat Exchanger Tube Sheet.
- Aircraft Landing Gear.
- Fluid Assembly Ends.
- Hydraulic Cylinder Inside Bore.
- Oilfield Exploration Equipment.
- Oilfield Downhole Exploration.

Introduction to Modern Manufacturing Tools and Techniques:

Components of CNC:

1. Input device
2. MCU or Machine Control Unit
3. Machine Tool
4. Driving System
5. Feedback devices
6. Display unit



1. Input device: The part program is entered into the MCU through the input device.
2. MCU or Machine Control Unit: MCU is the heart of the CNC system. It consists of

a. Central Processing Unit (CPU): it is the brain of the MCU, and it comprises of
   i. a control section that retrieves data from the memory and generates signal which in turn activates all MCU components.
   ii. An Arithmetic Logic Unit (ALU) to perform arithmetic operations.
   iii. Intermediate access store which holds data and programs temporarily that is required

b. CNC memory which is divided into Main memory and Secondary Memory. Main memory stores the operating system software and machine interface programs.

Secondary memory such as hard disks is used to store large programs which can be used by the main memory when required.

c. Input/ Output interface: The I/O interface establishes communication between the machine operator, the components of the CNC system and the other connected computers. The control panel is the interface through which the operator communicates with the CNC system.
d. Machine tool controls to control the spindle speed, feed rate etc.,
e. Sequence controls for auxiliary functions such as coolant control, emergency stop, tool changing functions etc.,

3. Machine Tool: This can be any type of machine tool such as a machining center, a turning center, a lathe, milling machine etc.,
4. Driving System: A driver system essentially is made up of amplifier circuits, drive motors and ball leadscrews. The control signals of each axis are fed by the MCU to amplifier circuits. The control signals are then augmented to actuate drive motors which in turn rotate the ball leadscrews to move the machine table.
5. Feedback devices: for the accurate operation of a CNC machine, the positional values and speed of the axes needs to be continuously updated. This is done by the feedback devices.

a. Positional Feedback devices: Here two types. i. Linear position measuring transducer to measure the linear distance travelled by the slide. ii. Rotary encoders is a device used to convert rotational position information into an electrical output signal. This is used to measure angular displacements.
b. Velocity feedback devices: in this a tachometer mounted at the end of the motor shaft measures the actual speed of the motor in terms of voltage generated. The output voltage from the tachometer is compared with the desired speed and the difference is fed back to monitor the motor speed.

6. Display unit: the display unit is the device that ensures interaction between the machine operator and the machine. It displays the status of operation such as the spindle RPM, the running part program, the feed rate, position of the machine slides etc.,

Advantages of CNC:

1. Accuracy and repeatability.
2. Complex shaped contours can be machined.
3. Can be easily programmed to handle variety of product styles.
4. High volume of production compared to conventional machines.
5. Lesser skilled/ trained people can operate CNC machine.
6. Can be operated continuously.
7. Less defective products.
8. One person can take care of number of CNC machines.
9. Safer work environment.
10. Can be upgraded to newer technologies by replacing the existing CNC control.
11. Many CNC machines can be linked together to a main computer.

Disadvantages of CNC:

1. A thorough programming knowledge is required by the operators or programmers. Hence cost of labour can be high.
2. Cost of CNC machine is high compared to conventional machines.
3. Spares of CNC are relatively costlier than conventional machines.
4. CNC machine requires air-conditioned environment which involves extra cost.

Applications of CNC:

1. Automotive industry
2. Aerospace industry
3. Machinery industry
4. Electrical industry
5. Instrumentation industry

CNC Machining Center:

Computer Numerical Control (CNC) Machining is the process through which computers control machine-based processes in manufacturing. A CNC machine tool center can perform drilling, milling and lathe operations. The manufacture of prismatic parts in the industry, such as gearboxes, partitions, frames, covers, etc., requires different types of operations such as milling, boring, drilling, tapping and many other related machining operations. A machining center is an CNC machine that can mill, drill, bore, tap, and perform various other work all without changing the attachment of the work piece. It can automatically bring several various tools to the work location.

CNC Turning Center:

A turning center is a lathe with a computer numerical control. Sophisticated turning centers can also perform a variety of milling and drilling operations.

CNC turning centers are advanced computer numerically controlled machines. They can have 3, 4, or even 5 axes, along with a multitude of cutting capabilities, including milling, drilling, tapping, and of course, turning.

CNC Turning is commonly used for cylindrical shaped workpieces, however, it can be used for square or hexagonal-shaped raw materials. The workpiece is held in place by a 'chuck'. The' chuck' spins at varying RPMs (rotations per minute). Unlike a traditional lathe, today's machines are numerically controlled.

Smart Manufacturing:

Smart manufacturing is the notion of orchestrating physical and digital processes within factories and across other supply chain functions to optimize current and future supply and demand requirements.

Smart Manufacturing means bringing the elements of smart technology – sensing inputs, computing power, always-on connectivity, artificial intelligence, and advanced data analytics – to the traditional production process.

Smart manufacturing utilizes big data analytics, to refine complicated processes and manage supply chains. Big data analytics refers to a method for gathering and understanding large data sets in terms of what are known as the three V's, velocity, variety, and volume.

Industrial IOT:

Industrial IoT (IIoT) is the use of network-connected sensors and other monitoring devices to improve the manufacturing and quality of an organization's products and product parts. IIoT devices are used primarily for insights on machine health, causes for defective parts, and general data collection.

What are the examples of IoT devices?

Answer: There are several top devices in the market. Smart Mobiles, smart refrigerators, smartwatches, smart fire alarms, smart door locks, smart bicycles, medical sensors, fitness trackers, smart security system, etc., are few examples of IoT products.

Introduction to Mechatronics:

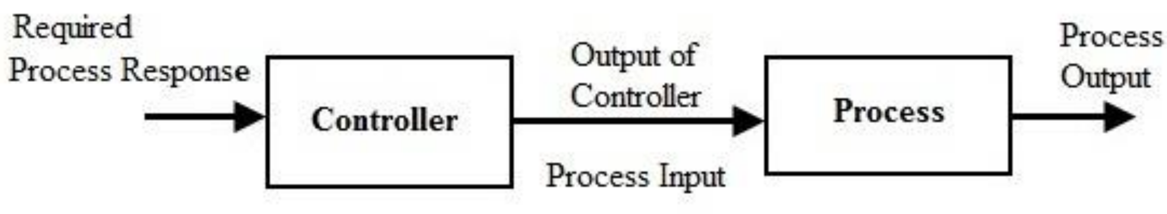
Mechatronics is defined as a multidisciplinary field of engineering that includes a combination of systems engineering: mechanical engineering, Electric/Electronic Engineering, control engineering, and computer engineering.

Mechatronics is a multidisciplinary field that refers to the skill sets needed in the contemporary, advanced automated manufacturing industry.

Mechatronics is a branch of engineering that brings together multiple disciplines—namely, mechanical, electrical, computer, and robotics engineering—to connect seemingly disparate stages of design and production processes into a single, streamlined system.

Open-loop system:

An open-loop system has no self-regulation or control action over the output value. Each input setting determines a fixed operating position for the controller. Changes or disturbances in external conditions does not result in a direct output change (unless the controller setting is altered manually).



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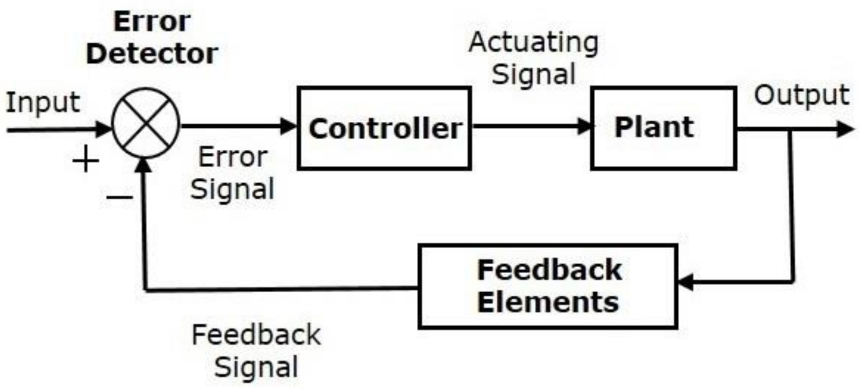
Closed-loop system:

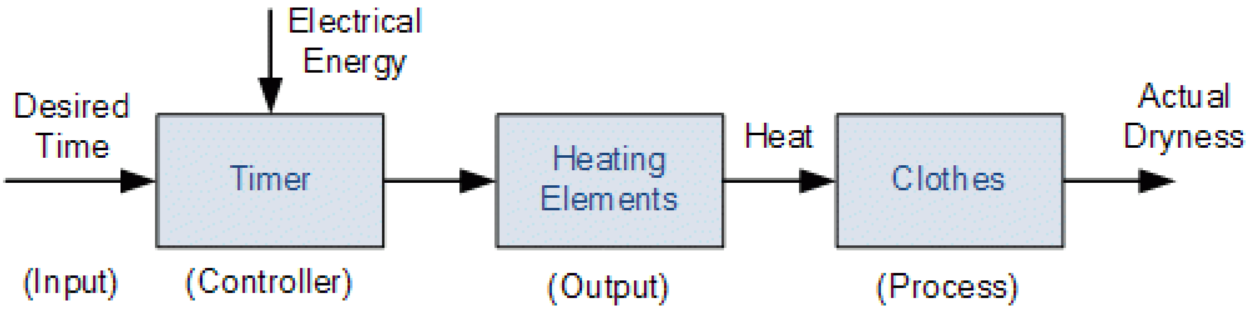
A closed loop control system is a mechanical or electronic device that automatically regulates a system to maintain a desired state or set point without human interaction. It uses a feedback system or sensor. The error signal generated by the error detector is sent to controller. Controller sends actuating signal based on the error signal to plant to control the process.



Examples of mechatronic system:

i) Clothe dryer:

In this system electrical energy is used to dry the clothes. The heating elements will convert electrical energy onto heat energy required for the drying. This is an open loop system where we don't have any control over the extent to which clothe is dried. The timer set in the beginning will ensure that electrical energy is supplied for that duration. Controller will switch off power supply when this time is reached irrespective whether clothe is dried or not.



ii) Air conditioning system:

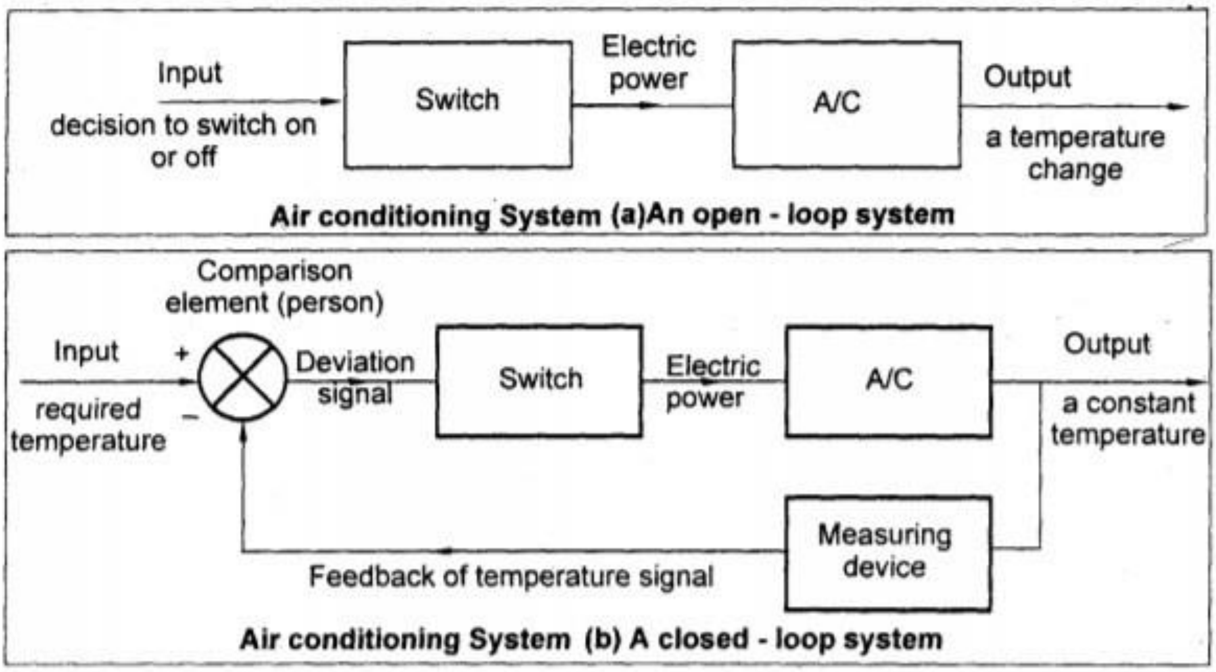


Figure shows both open-loop and closed-loop air conditioning systems.
In case of open loop AC system, the temperature of the space to be cooled cannot be controlled precisely as there is no feedback element in the form of temperature measuring device and send feedback signal.
In case of closed loop AC system, the temperature sensor will measure the actual temperature and send the feedback signal to the error detector. The error detector will compare the desired temperature and the actual temperature and generates error signal. This error signal will be used to operate the switch based on the requirement whether the AC system should be ON or OFF.