# MODULE 2

**Machine Tool Operations:** Working Principle of lathe, Lathe operations: Turning, facing, knurling. Working principles of Drilling Machine, drilling operations: drilling, boring, reaming. Working of Milling Machine, Milling operations: plane milling and slot milling. (No sketches of machine tools, sketches to be used only for explaining the operations). **Introduction to Advanced Manufacturing Systems:** Introduction, components of CNC, advantages and applications of CNC, 3D printing.

**Introduction:**

Manufacturing process may be defined as a process of converting, the raw material into your finished product of required size and shape depending upon the various processes and methods.

Manufacturing process is broadly classified into two groups.

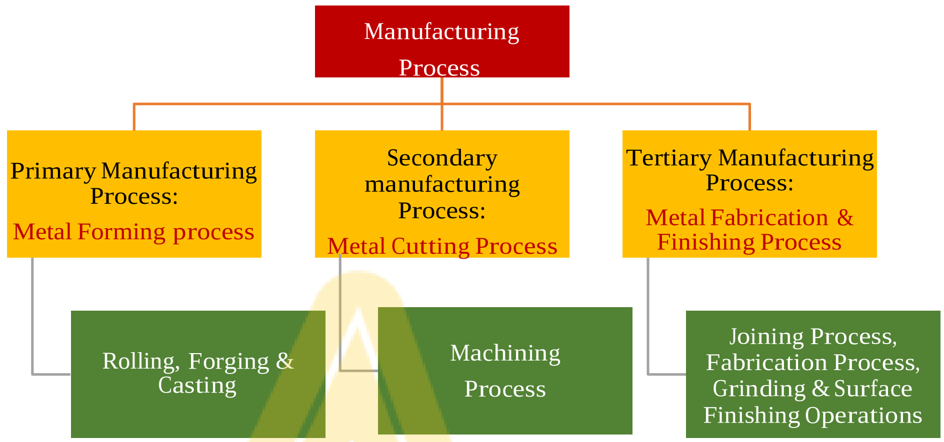



Figure: Block diagram of Classification of manufacturing Process

In metal cutting process, extra amount of material is removed from the workpiece in the form of chips. The material removed due to the relative motion between the cutting tool and the work-piece.

In metal forming process, no material is removed, but it is forced to change its size and shape by applying external pressure.

**Machine Tools:**

When machines perform the metal cutting operations by the cutting tools mounted on them, they are called "Machine tools". A machine tool may be defined as a power-driven machine which accomplishes the cutting or machining operations on it. The machine tools used for most of the machining processes are Lathe, Drilling, Planing, Milling and Grinding machines

**Lathe Machine Tool:**

The Lathe is one of the oldest machine tools used to produce cylindrical objects. The modern engine late are first developed in the year 1797 by an Englishman Henry Maudslay. The main function of the lathe is to removal of metal from a work piece of work to give it a required shape and size. This is accomplished by holding the work securely and rigidly on the machine and then turning it against a cutting tool which will remove the material from the work in the form of a chip. To cut the material properly, the tool should be harder than that of the material of the work piece.

**Principle working of a Lathe Machine Tool:**

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.

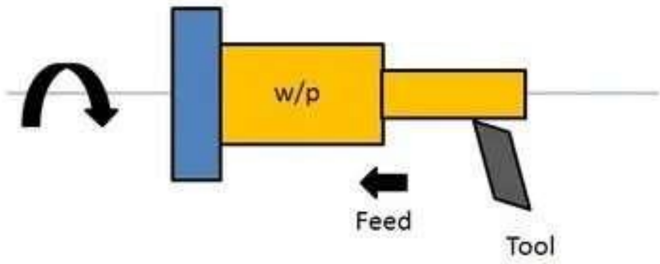



Figure: Principle of turning operation on Lathe

**Classification of Lathe Machine Tools:**

Lathes are classified based on their design, construction and application. Following are some of the important lathes used in industries.

1. Speed Lathe
2. Engine Lathe
3. Bench Lathe
4. Tool Room Lathe
5. Capstan & Turret Lathe
6. Special Purpose Lathe
7. Automatic Lathe
8. CNC Lathe (Turning Centres)

**Construction & Working Principle of Centre Lathe/ Engine Lathe:**

The schematic arrangement of the Centre or Engine Lathe is as shown in the following figure. The major parts of a centre lathes are:

1. Bed & Guideways
2. Headstock
3. Tailstock
4. Lathe bed
5. Carriage Assembly
6. Driving mechanism & Feeding mechanism

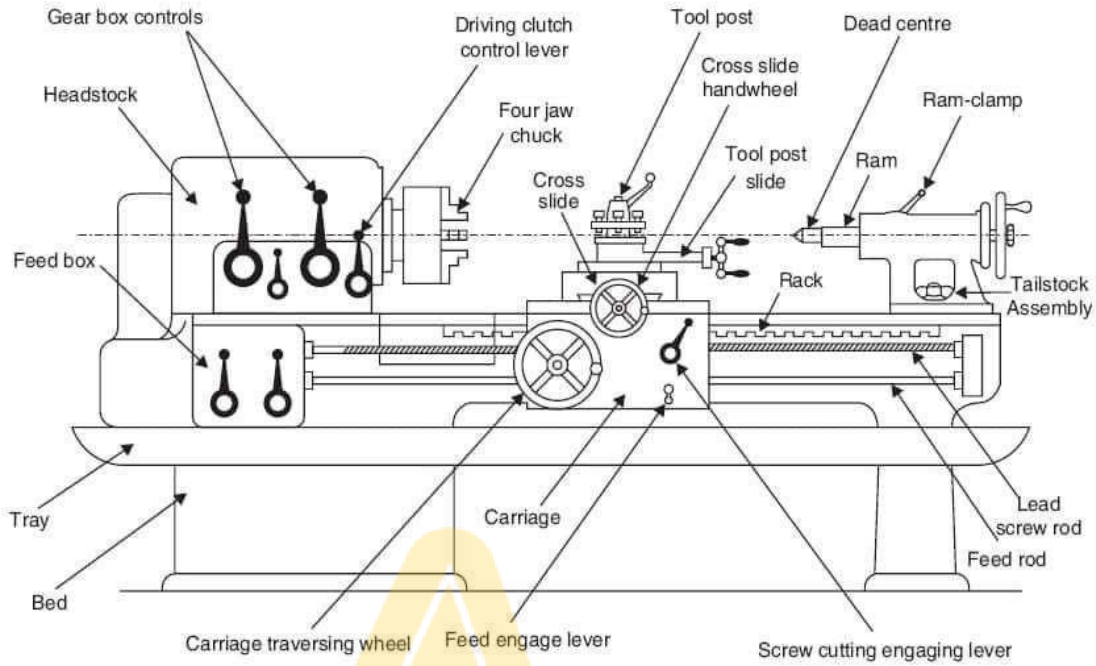



**Figure: Schematic arrangement of Centre Lathe.**

**Bed:** The bed forms, the base of the machine. The headstock and the tail stocks are located at either end of the bed and the carriage rest over the lathe bed and slides on it. The guide ways of the lathe bed may be flat and inverted V type having an include angle of 90 degree.

**Headstock:** The headstock is secured permanently on the inner waves, at the left end of the lathe bed and it provides mechanical means of rotating the work at multiple speeds, It contains a hallow spindle and mechanism for driving and altering this spindle speed. All the parts are housed within the headstock casting.

**Tailstock:** The tail stock is located on the inner waves at the right end and top of the bed ways. This has two main uses.

1. It supports the other end of the workpiece. When it is being machine between the centres.
2. It holds the tool for performing operations, such as drilling. Riming tapping etc., to accommodate different length of work.

The body of the Tailstock can be adjusted along the length of the bed-ways by sliding it to the desired position, and can be locked on a lathe bed-way.

**Carriage:** The carriage of a lathe has several parts that serves to support, move and control the cutting tool. It consists of the following parts saddle cross, slide, Compound slide, tool post and apron.

**Saddle:** The saddle is an H- shape casting that fits over the bed and slides along the base. It carries the cross slide and tool post.

**Cross slide:** It is mounted on the saddle and enables the movement of the cutting tool laterally, across the lathe bed by means of a cross feed handle. It also serves as the support for the compound rest.

**Compound rest:** The compound rest is mounted on top of the cross slide and has a circular base graduated in degrees. It is used for obtaining angular cuts and short tapers. As well as convenient positioning of the tool at the work.

**Tool post:** This is located on top of the compound slide to hold the tool and enable it to be adjusted to convenient Working position,

**Feed mechanism:** The movement of the tool related to the work is called as a feed. The feed can be given either by the hand, or by automatic or powered feed. To get the automatic feed, carriage is engaged to feed rod. while for cutting threads, carriage is engaged to screw rod.

## Lathe Operations:

Some of the operations carried out on a lathe machine are as listed below;

1. Facing
2. Turning
3. Step turning
4. Taper turning
5. Knurling
6. Thread cutting
7. Drilling
8. Counter sinking
9. Contour forming
10. Boring etc,

1. **Facing:** Is the operation of machining the ends of a piece of the work to produce a flat surface perpendicular with the axis. This is also used to cut the work to the required length. The operation involves feeding the tool perpendicular to the axis of rotation of the work piece. A regular cutting tool may be used for facing a large work piece. The cutting edge should be set at the same height as the centre of the work piece. A properly ground facing tool is mounted in a tool holder in the tool post to accomplish facing operation.

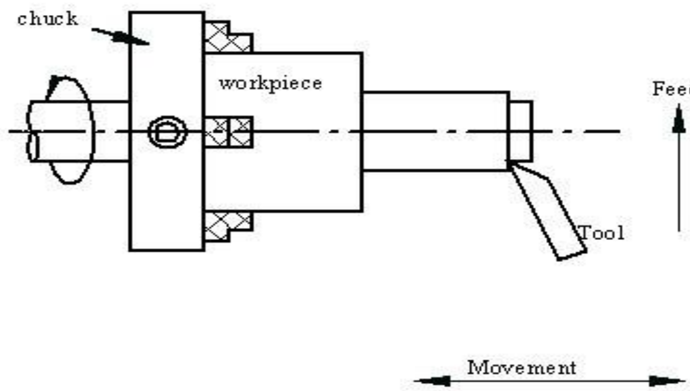



Figure: Facing Operation

## 2. Turning Operation:

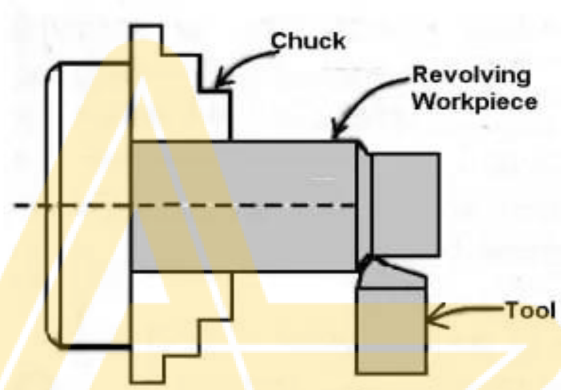



Figure: Turning Operation

The process of metal removal from the cylindrical jobs is called straight or plain turning. Cross-slide and the carriage are used to perform turning operation and make the operation faster and economical. Plain turning operations are generally performed in two steps-rough and finish turning.

Rough turning is usually done for rolled, cast or forged parts to remove the uneven or sandy or rough surface on the jobs. A roughing tool does roughing and used for excess stock removal. For finishing a tool with slightly round cutting edge is used. The depth of cut rate is at the range of 0.2 to 1 mm and the feed rate between 0.1 to 0.3 mm.

## 3. Knurling:

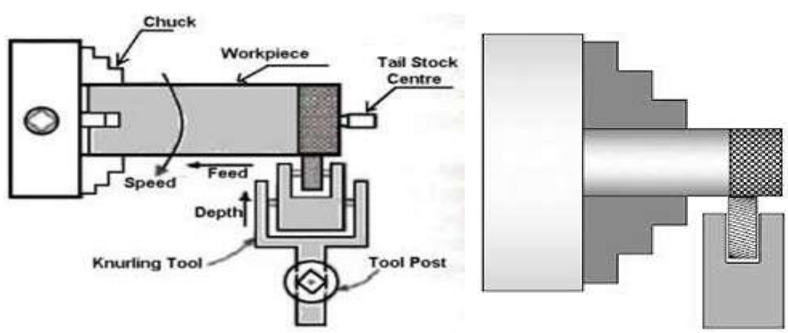



Figure: Knurling operations

Knurling is an operation performed on the lathe to generate serrated surface on the work piece. This is used to produce a rough surface for griping like the barrel of the micrometre or screw gauge. This is done by a special tool called knurling tool which has a set of hardened rollers with the desired serrations.

During knurling operation, the hardened rollers of the tool are pressed against the slowly rotating work pieces such that the impression of tool serrations are formed on the work pieces surface.

### 4. Taper turning:

Taper turning is an operation to produce conical surface on the work piece. This can be machined by either work piece inclined to the axis of the lathe or tool moving inclined to the axis of the lathe.

There are many methods for taper turning

a) By swivelling the compound rest. b) By offsetting the tail stock.

c) By taper turning attachment.

d) By using form tool/ Broad nose tool

e) Combination of Longitudinal and Transverse feed movement.

#### a) Taper Turning by Swiveling the compound Tool Rest

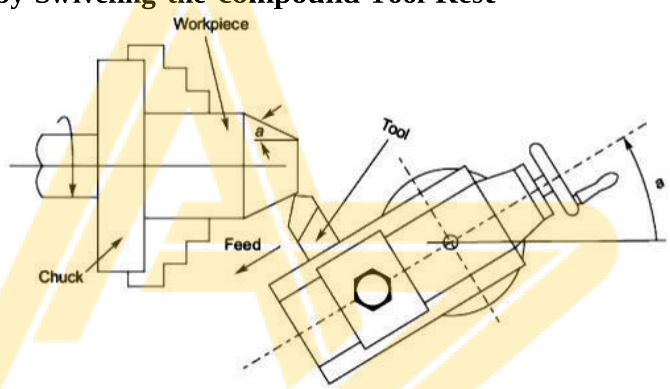



Figure: Taper turning by Swiveling the compound rest method

The work pieces which require steep taper for short lengths the taper turning was done by swiveling the compound rest method. In this method the compound tool rest is swiveled to the required taper angle and then locked in the angular position. The carriage is also locked at that position. For taper turning the compound rest is moved linearly at an angle so that the cutting tool produces the tapered surface on the work piece. This method is limited to short taper lengths due to the limited movement of the compound tool rest.

The taper angle is calculated by,

$$\tan\alpha = \frac{(D-d)}{2l}$$

Where,

D= bigger diameter of the taper (mm) d= smaller diameter of the taper (mm) L= Length of the taper (mm)

#### b) Taper Turning by Offsetting the Tailstock (or Tailstock set over method)

In this method the work piece is inclined with respect to the lathe axis and tool movement is in line with the lathe axis to produce the required taper. Here the tail stock body is shifted by small distance (offset) laterally. This makes the work piece is shifted at one end and hence there will be an inclination with respect to the lathe axis. The tool is moved parallel to the lathe axis and fed against the revolving work piece which produces the required taper.

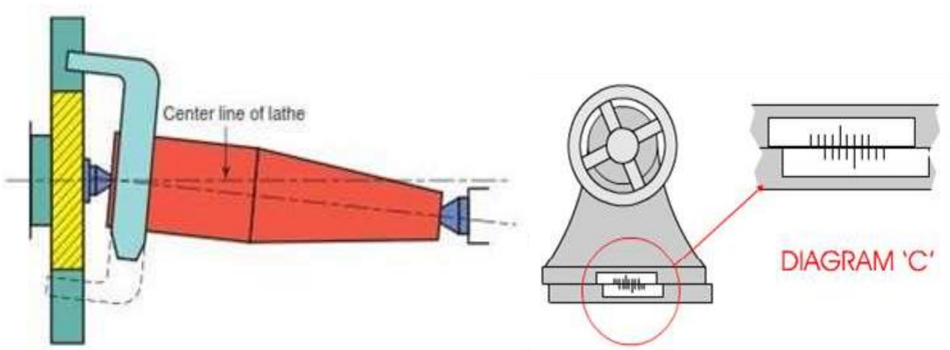
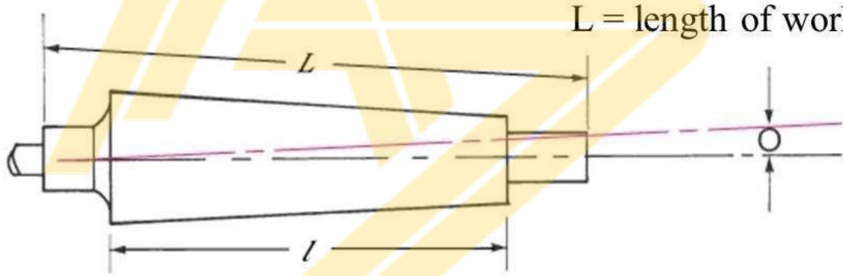



Figure: Taper turning by Setover method

The offset is calculated by,

$$\text{Offset} = \frac{D - d}{2 \times l} \times L$$

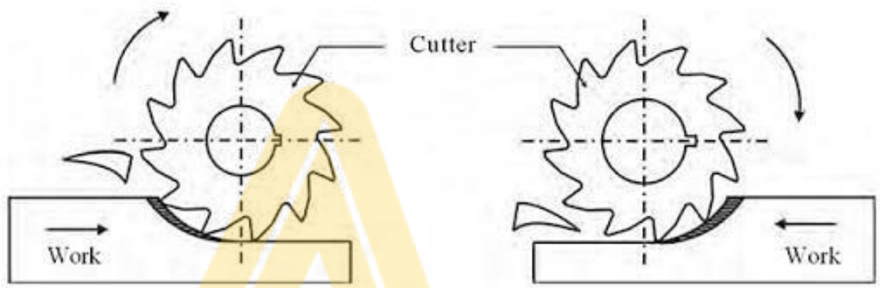
where D = large diameter
d = small diameter
$l$ = length of taper
L = length of work



# Milling Machine Tool

Milling is a metal cutting operation in which the cutting tool is a slow revolving cutter having cutting teeth formed on its periphery. The milling cutter is a multipoint cutting tool. The work piece is mounted on a movable worktable, which will be fed against the revolving milling cutter to perform the cutting operation.

## Principle of Milling




(a) (b)

Figure: (a) Up milling and (b) Down milling operation

Figure shown above is the principle of cutting action of a milling cutter. The milling cutter is mounted on a rotating shaft known as arbor. The work piece which is mounted on the table can be fed either in the direction opposite to that of the rotating cutter as shown in above fig (a) or in the same direction to that of the cutter as shown in above fig (b). When the work piece is fed in the opposite direction to the cutter tooth at the point of contact, the process is called as conventional or up-milling.

**Milling Machine Tool:** A Milling Machine is a machine tool in which a stationary work piece is fed against a rotating multi point cutter.

Various types of milling machines are

1) Plain or horizontal type of milling machine.
2) Vertical Milling Machine
3) Universal Milling machine
4) Planer type milling machine
5) Profile cutting milling machine.

**Horizontal Milling Machine**

The schematic arrangement of horizontal milling machine/ column and knee typr milling machine is as shown in the figure.

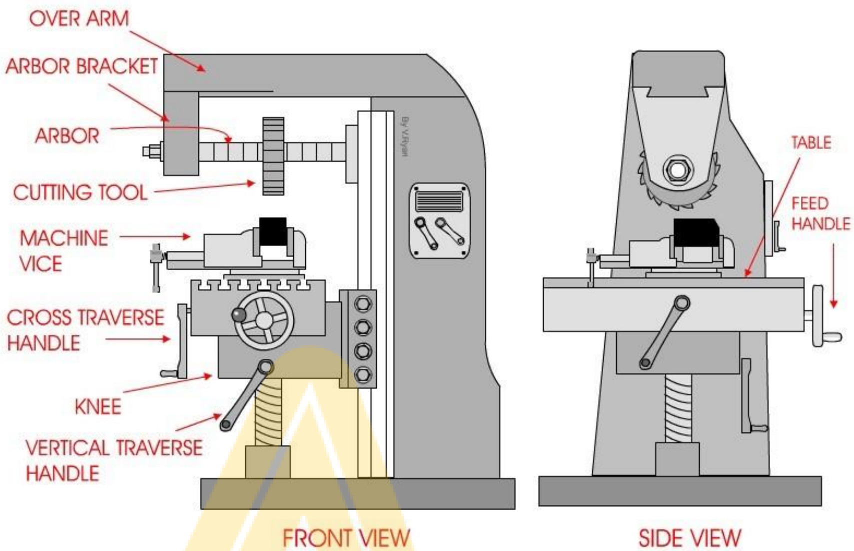



Figure: Horizontal / Column & Nee type milling machine

Milling machine has some principal parts. Their understanding would help us in understanding how the machine operates. The various parts are

1. Base
2. Column
3. Arbor
4. Knee
5. Saddle
6. Table
7. Overhanging arm
8. Driving and feeding Mechanism

**Base:** Base forms the foundation of the machine tool. It's a rectangular casting made up of Cast Iron. The one end of the base houses the Column and other end of the base contains a space for table elevating screw or knee supporting screw.

**Column:** The column is another rectangular casting mounted on one end of the base. The column is ribbed heavily in order to support the knee. The front vertical face of the column is provided with a vertical slide, which may be of square or dovetail type. The knee moves up and down on this slide. At the top of the column, an internal dovetail slide accommodates a cast overarm. The overarm supports the arbor. It also houses the driving mechanism to drive the spindle and feeding mechanism to feed the table.

**Arbor:** The arbor is a horizontal shaft provided with a straight body and tapered shank. On the straight portion of arbor, 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. The knee of the casting mounted on the front vertical slide of the column and is moved up or down by an elevating screw. The upper face of the knee is provided with guide ways so as to mount the saddle.

**Knee:** The Knee is a casting mounted on the front vertical slide of the column and is moved up or down by an elevating screw. The upper face of the knee is provided with guide ways so as to mount the saddle.

**Saddle:** The saddle is casting provided with two slides one at the top and the other at the bottom, which are exactly right angles to each other. The lower slide fits within the guideways 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 slide way on the top of the saddle. The top the table is machined with full length T-slots for mounting vices or other work holding fixtures.

**Overhanging Arm:** The overhanging arm extends from the column in order to support the arbor. The front brace attached to the overhanging arm supports the free end of the arbor and thus provides rigidity to the rotating cutter.

## Milling machine Operations/ Applications:

A variety of milling operations are performed on a milling machine to produce a horizontal, vertical, inclined surfaces, keyways, slots, gear teeth etc., A few of the most commonly used milling operations are described here.

### 1. Slab Milling

This method is also called as plain milling. The plain milling is the most common types of milling machine operations.

- Slab milling is performed to produce a plain, flat, horizontal surface parallel to the axis of rotation of a plain milling cutter.
- The operation is also known as slab milling.
- To perform the operation, the work and the cutter are secured properly on the machine.
- The depth of cut is set by rotating the vertical feed screw of the table. And the machine is started after selecting the right speed and feed.

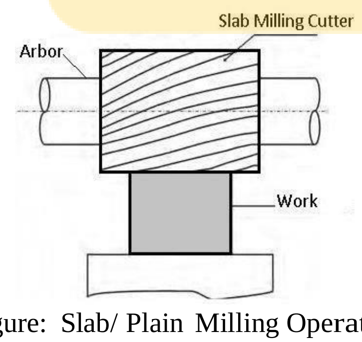



Figure: Slab/ Plain Milling Operation

### 2. Slot Milling

The slot milling, also called as groove or keyway cutting is done on a horizontal milling cutter or using an end milling cutter.

- The operation of producing of keyways, grooves and slots of varying shapes and sizes can be performed in a milling machine.
- It is done by using a plain milling cutter, a metal slitting saw, an end mill or by a side milling cutter.

- The open slots can be cut by a plain milling cutter, a metal slitting saw, or by a side milling cutter. The closed slots are produced by using end mills.

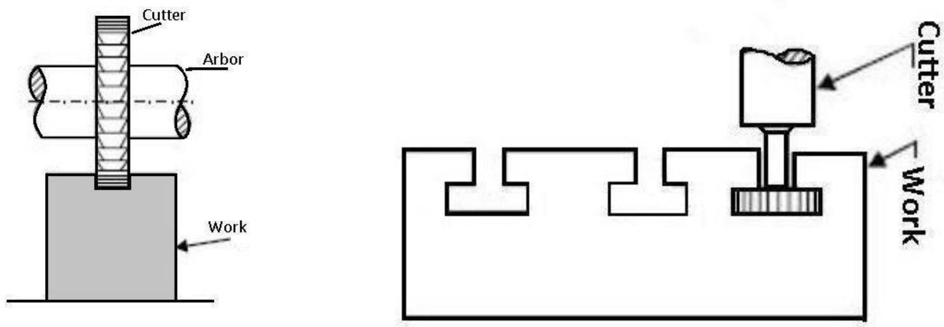



Figure: Slot Milling/ Grooving operation

**3. Face Milling**

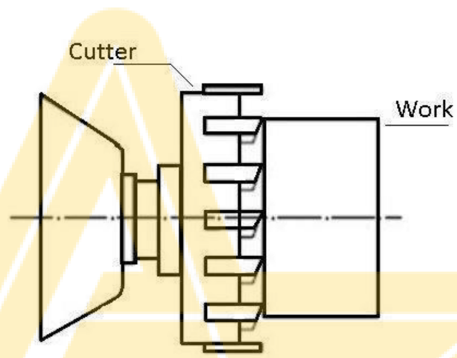



Figure: Face Milling operation

In this method, the flat surfaces are milled by the cutters, which are mounted with their axes perpendicular to the milled surfaces.

- The face milling is the simplest milling machine operations.
- This operation is performed by a face milling cutter rotated about an axis perpendicular to the work surface.
- The operation is carried in plain milling, and the cutter is mounted on a stub arbor to design a flat surface.
- The depth of cut is adjusted by rotating the cross-feed screw of the table.

**4. Angular Milling**

In this method, inclined surfaces are produces by milling cutters having their teeth inclined to their axes. Dovetail grooves and V-guides are machined by this method.

- The angular milling is the operation of producing an angular surface on a workpiece other than at right angles of the axis of the milling machine spindle.
- The angular groove may be single or double angle and may be of varying included angle according to the type and contour of the angular cutter used.
- One simple example of angular milling is the production of V-blocks.

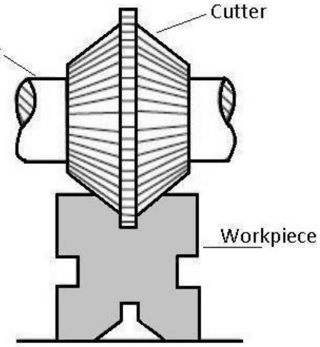



Figure: Angular Milling

**5. Form Milling**

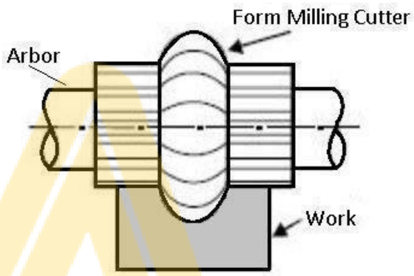
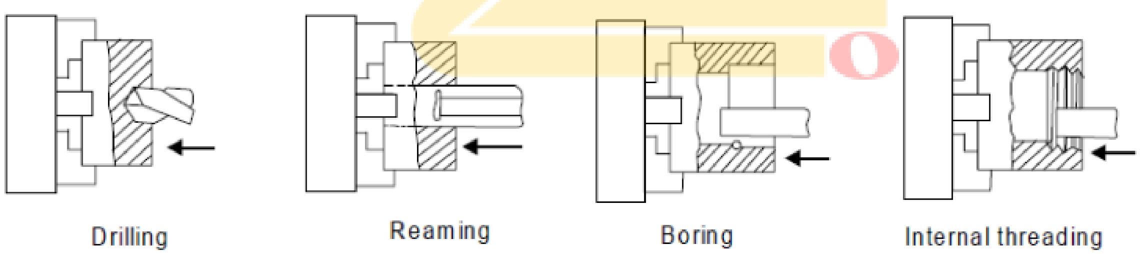



Figure:Form Milling

In this method, surfaces having irregular profile are milled by suitable cutters.

- The form milling is the operation of producing the irregular contour by using form cutters.
- The irregular shape may be convex, concave, or of any other shape. After machining, the formed surface is inspected by a template gauge.
- Cutting rate for form milling is 20% to 30% less than that of the plain milling.

**<u>Other Lathe Operations:</u>**




Lathe operations

# Drilling Machine Tool

## Introduction

Drilling machine is one of the most important machine tools in a workshop. It was designed to produce a cylindrical hole of required diameter and depth on metal workpieces. Though holes can be made by different machine tools in a shop, drilling machine is designed specifically to perform the operation of drilling and similar operations. Drilling can be done easily at a low cost in a shorter period of time in a drilling machine.

Drilling can be called as the operation of producing a cylindrical hole of required diameter and depth by removing metal by the rotating edges of a drill. The cutting tool known as drill is fitted into the spindle of the drilling machine. A mark of indentation is made at the required location with a centre punch. The rotating drill is pressed at the location and is fed into the work. The hole can be made up to a required depth.

## Types of drilling machines

Drilling machines are manufactured in different types and sizes according to the type of operation, amount of feed, depth of cut, spindle speeds, method of spindle movement and the required accuracy.

The different types of drilling machines are:

1. Portable drilling machine (or) Hand drilling machine
2. Sensitive drilling machine (or) Bench drilling machine
3. Upright drilling machine
4. Radial drilling machine
5. Gang drilling machine
6. Multiple spindle drilling machine
7. Deep hole drilling machine

## Upright drilling machine

The upright drilling machine is designed for handling medium sized workpieces. Though it looks like a sensitive drilling machine, it is larger and heavier than a sensitive drilling machine. Holes of diameter up to 50mm can be made with this type of machine. Besides, it is supplied with power feed arrangement. For drilling different types of work, the machine is provided with a number of spindle speeds and feed.

### Base

The base is a rectangular casting made of cast iron and so can withstand vibrations. It is mounted on a on the floor. It supports all the other parts of the machine on it.

### Column

The column stands vertically on the base at one end. It supports the work table and the drill head. The drill head has drill spindle and the driving motor on either side of the column

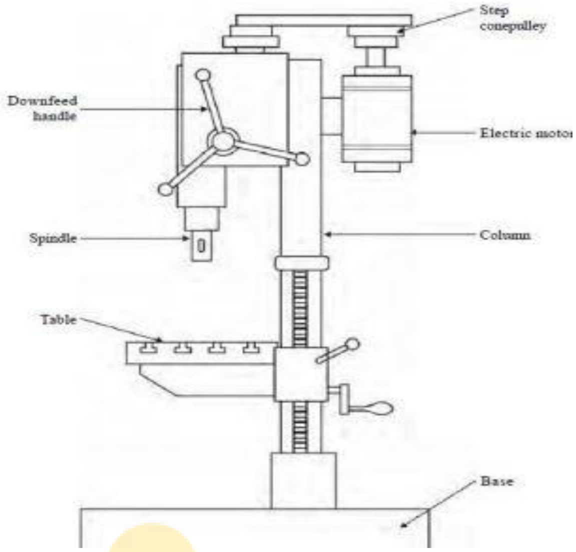



Figure: Upright Drilling Machine

**Table**

The table is mounted on the vertical column and can be adjusted up and down on it. The table has 'T'-slots on it for holding the workpieces or to hold any other work holding device. The table can be adjusted vertically to accommodate workpieces of different heights and can be clamped at the required position.

**Drill head**

Drill head is mounted on the top side of the column. The drill spindle and the driving motor are connected by means of a V-belt and cone pulleys. The motion is transmitted to the spindle from the motor by the belt. The pinion attached to the handle meshes with the rack on the sleeve of the spindle for providing the drill the required down feed.

## Radial drilling machine

The radial drilling machine is intended for drilling on medium to large and heavy workpieces. It has a heavy round column mounted on a large base. The column supports a radial arm, hich can be raised or lowered to enable the table to accommodate workpieces of different heights. The arm, which has the drill head on it, can be swung around to any position. The drill head can be made to slide on the radial arm. The machine is named so because of this reason. It consists of parts like base, column, radial arm, drill head and driving mechanism. A radial drilling machine is illustrated in Figure.

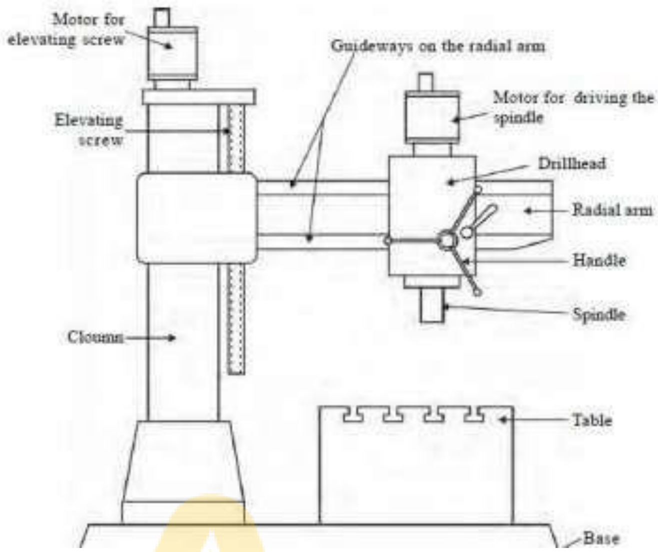



Figure: Radial drilling Machine

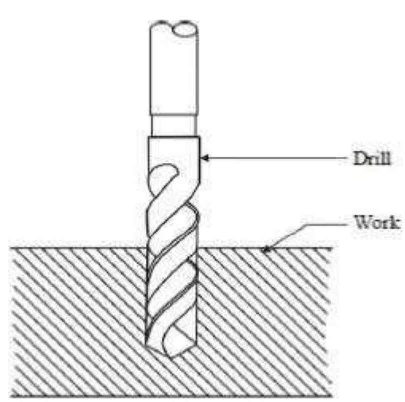
## Drilling machine operations

Though drilling is the primary operation performed in a drilling machine, a number of similar operations are also performed on holes using different tools. The different operations that can be performed in a drilling machine are:

1. Drilling
2. Reaming
3. Boring
4. Counter boring
5. Countersinking
6. Spot facing
7. Tapping
8. Trepanning

### 1. Drilling:

Drilling can be called as the operation of producing a cylindrical hole of required diameter and depth by removing metal by the rotating edges of a drill. The cutting tool known as drill is fitted into the spindle of the drilling machine. A mark of indentation is made at the required location with a centre punch. The rotating drill is pressed at the location and is fed into the work. The hole can be made up to a required depth.



**2. Reaming:**

Reaming shown in Figure, is an accurate way of sizing and finishing a hole which has been previously drilled. In order to finish a hole and to bring it to the accurate size, the hole is drilled slightly undersize. The speed of the spindle is made half that of drilling and automatic feed may be employed. The tool used for reaming is known as the reamer which has multiple cutting edges. Reamer cannot be used to drill a hole. It simply. follows the path which has been previously drilled and removes a very small amount of metal

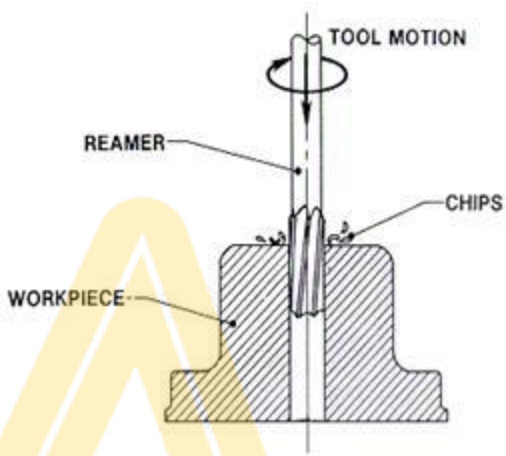



Figure: Reaming operation

**3. Boring**

Boring is the operation of enlarging the size of the previously drilled hole. For this purpose a special purpose cutting tool is used. Boring operation is also carried out to finish a hole accurately and to bring it to the required size.

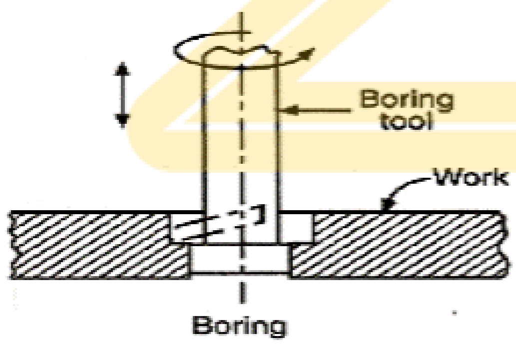



Figure: Boring operation

# Introduction to Advanced Manufacturing Systems

**Computer Numeric Control [CNC] Machine:**

Introduction: Computer Numeric Control (CNC) is the automation of machine tools that are operated by precisely programmed commands encoded on a storage medium (computer command module, usually located on the device. Most NC today is computer (or computerized) numerical control (CNC), in which computers play an integral part of the control.

**Definition**

Computer Numerical Control (CNC) is one in which the functions and motions of a machine tool are controlled by means of a prepared program containing coded alphanumeric data. CNC can control the motions of the work piece or tool, the input parameters such as feed, depth of cut, speed, and the functions such as turning spindle on/off, turning coolant on/off etc,.

**Components of CNC:**

A CNC machine tool following units in its construction,

1) Input device
2) MCU or machine control unit
3) Machine tool
4) Driving System
5) Feedback devices
6) Display Unit

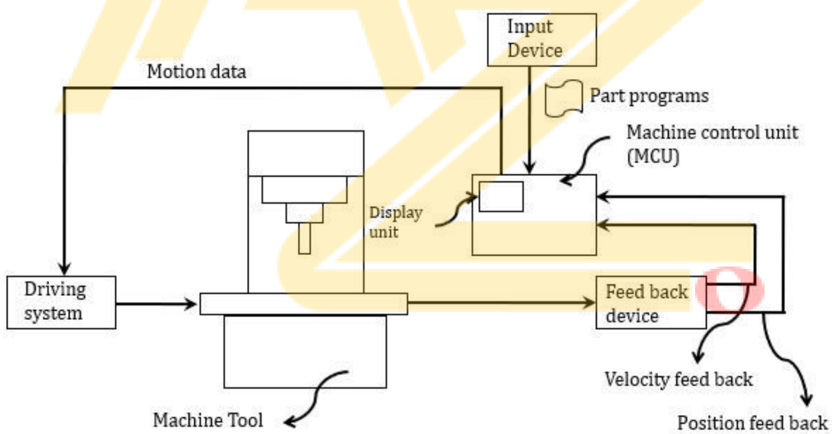



Figure: Block diagram showing Components of CNC machine tool

1. **Input Devices:** Input devises are the devises used to enter the part program into the machine tool. Universal Serial Bus (USB), ethernet communication, Tapes and recording devices can be used as input devices.
2. **Machine Control Unit:** The machine control unit (MCU) is a microcomputer that stores the program and executes the commands into actions by the machine tool. The MCU consists of two main units: the data processing unit (DPU) and the control loops

unit (CLU). The DPU processes the data from the part program and provides it to the CLU which operates the drives attached to the machine leadscrews and receives feedback signals on the actual position and velocity of each one of the axes. A driver (dc motor) and a feedback device are attached to the leadscrew. The CLU consists of the circuits for position and velocity control loops, deceleration and backlash take up, function controls such as spindle on/off.

3. **Machine Tool:** The machine tool could be one of the following: lathe, milling machine, laser, plasma, Coordinate measuring machine etc. Machine tool actuated as per the program through various mechanical driving and feeding mechanisms. Machine tool perform the intended task over the work piece.
4. **Driving system:** A drive system essentially is made up of amplifier circuits, drive motors and ball lead screws. Commonly used types of electrical motors include DC Servo motors, AC servo motors, Stepping motors and Linear motors
5. **Feed back devices:** For accurate operation of a CNC machine, the positional values and speed of the axes need to continuously updated. Inorder to perform this task Positional feed back devices and velocity feed back devices are used.
   The positional feedback systems gives the position of the tool/ workpice with respect to the reference point. Velocity feed back system gives the state of the velocity of the sped of the spindle, cutting tool and the movement of the table etc.,
6. **Display Unit:** Device that ensures interaction between the machine operator and the machine is called as a display unit. It displays the current status of the operation such as the spindle RPM, running part program, feed rate, position of the machine slide etc. it also shows the graphic simulation of the path taken by the tool and that the operator can verify the part program before actual machining and any malfunction of the CNC system is also displayed as warnings.

**Advantages of the CNC Machine Tool:**

- Accuracy and repeatability obtained is high. Most aircraft parts are produced today on CNC machines
- Complex shaped contours can be machined. Turbine blades, impellers etc.
- Can be easily programmed to handle variety of product styles
- High volume of production compared to conventional machines
- Lesser skilled or trained people can operate CNC machines unlike conventional ones where high skilled people are required
- CNC machines can be used uninterruptedly without turning them off provided regular maintenance is done
- Avoids errors that were otherwise committed by humans operating conventional machines
- Since CNC machines can be programmed, one person may well take care of a number of CNC machines. Reduces employees and hence costs are reduced
- Using CNC machines results in a safer work environment

- Can be upgraded to a newer technologies by replacing the existing CNC controller with advanced one

### Disadvantages of the CNC Machine:

- Thorough programming knowledge is required by the operators or programmers.
- Skilled programmers required, cost of the labour can be high
- Cost of the CNC machine is high compared to the conventional machine tools
- Spares of CNC machines are relatively costlier than conventional machines
- CNC machines require air conditioned environment and /or a chiller unit. Thus extra costs are involved.

### CNC Machining Centres:

- The term “machining centers” describes almost any CNC milling and drilling machine that includes an automatic tool changer and a table that clamps the workpiece in place.
- CNC machine center is a advance manufacturing machine tool which performs wide range of machining operation with accuracy and good quality surface finish.
- The orientation of the spindle is the most fundamental defining characteristic of a CNC machining centers.
- CNC machining centers can further be classified based on the rotation of either the work piece Or the rotation of the tool as:

  1. CNC turning machines
  2. CNC Milling machines

### CNC Turning Centres:

- The primary function of a CNC Turning Center is that it rotates (or “turns”) your workpiece.
- CNC Turning Machines are one of the oldest and simplest forms of machining parts, called “lathes,” .
- Can be either horizontal or vertical depending on the weight and tolerance of the workpiece.
- Work-peices for this process are usually round, but can be other shapes — like squares or hexagons.
- The work-piece is held in place by an instrument known as the “chuck.” The chuck then spins at various RPMs (depending on the capability of your machine).
- When this occurs, the machine’s tool moves into the rotating workpiece and begins to shave away material to create the desired shape.


Figure: CNC Turning centre and machining centre

**CNC Milling Centres/ Machining Centres:**

- The primary function of a CNC Milling Machine is that your tool will be doing the rotating and moving while your workpiece stays in one spot (generally).
- Milling is a more specific process that is similar to drilling and cutting.
- These machines can also be either horizontal or vertical, again depending on the tolerance and weight of your workpiece.
- This process has many axes that allow for a variety of shapes, holes, and slots to be cut into the workpiece at many angles.
- These axes provide many different maneuvers, either by the spindle or the bed, to cut the part desired to the exact specifications.

# 3D Printing

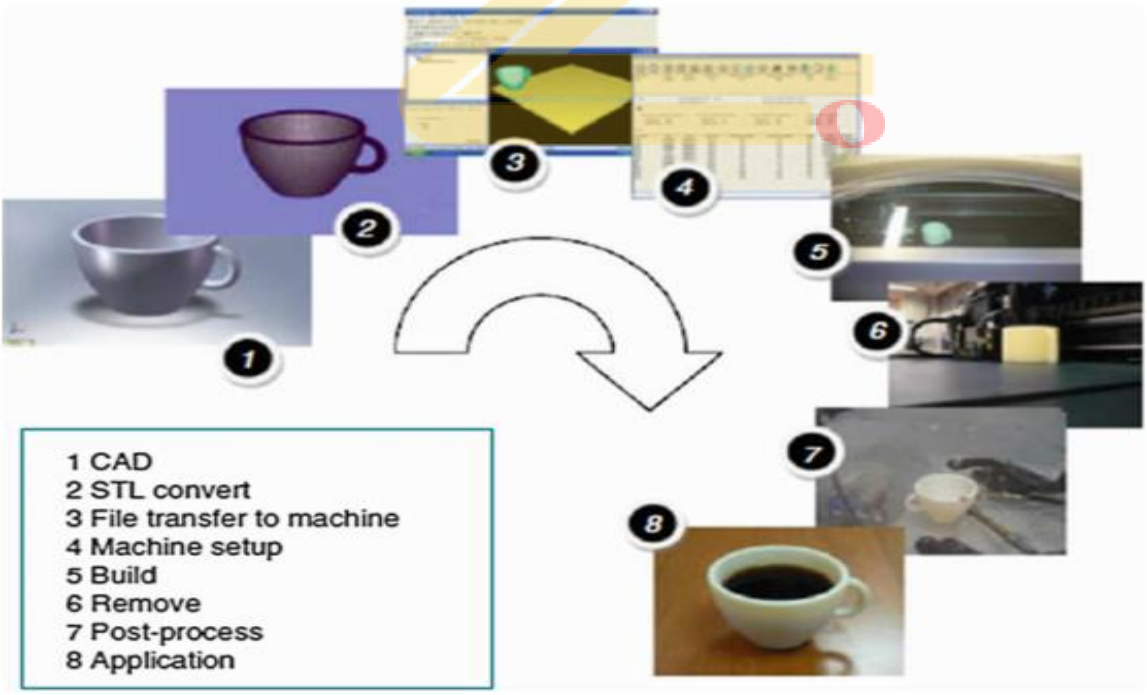
A method of manufacturing known as 'Additive manufacturing', due to the fact that instead of removing material to create a part, the process adds material in successive patterns to create the desired shape.

Main areas of use:

- Prototyping
- Specialized parts – aerospace, military, biomedical engineering, dental
- Hobbies and home use
- Future applications– medical (body parts), buildings and cars

3D Printing uses software that slices the 3D model into layers (0.01mm thick or less in most cases). Each layer is then traced onto the build plate by the printer, once the pattern is completed, the build plate is lowered and the next layer is added on top of the previous one.
Typical manufacturing techniques are known as 'Subtractive Manufacturing' because the process is one of removing material from a preformed block. Processes such as Milling and Cutting are subtractive manufacturing techniques. This type of process creates a lot of waste since; the material that is cut off generally cannot be used for anything else and is simply sent out as scrap. 3D Printing eliminates such waste since the material is placed in the location that it is needed only, the rest will be left out as empty space.

**Basic Principles of Additive Manufacturing: (Steps of AM process)**




AM involves 8 steps that move from the virtual CAD description to the physical resultant part

**Step 1: CAD**

All AM parts must start from a software model that fully describes the external geometry. This can involve the use of almost any professional CAD solid modeling software, but the output must be a 3D solid or surface representation. Reverse engineering equipment (e.g., laser scanning) can also be used to create this representation.

**Step 2: Conversion to STL**

Nearly every AM machine accepts the STL file format, which has become a de facto standard, and nearly every CAD system can output such a file format. This file describes the external closed surfaces of the original CAD model and forms the basis for calculation of the slices.

**Step 3: Transfer to AM Machine and STL File Manipulation**

The STL file describing the part must be transferred to the AM machine. Here, there may be some general manipulation of the file so that it is the correct size, position, and orientation for building.

**Step 4: Machine Setup**

The AM machine must be properly set up prior to the build process. Such settings would relate to the build parameters like the material constraints, energy source, layer thickness, timings, etc.

**Step 5: Build**

Building the part is mainly an automated process and the machine can largely carry on without supervision. Only superficial monitoring of the machine needs to take place at this time to ensure no errors have taken place like running out of material, power or software glitches, etc.

**Step 6: Removal**

Once the AM machine has completed the build, the parts must be removed. This may require interaction with the machine, which may have safety interlocks to ensure for example that the operating temperatures are sufficiently low or that there are no actively moving parts.

**Step 7: Post processing**

Once removed from the machine, parts may require an amount of additional cleaning up before they are ready for use. Parts may be weak at this stage or they may have supporting features that must be removed. This therefore often requires time and careful, experienced manual

**Step 8: Application**

Parts may now be ready to be used. However, they may also require additional treatment before they are acceptable for use. For example, they may require priming and painting to give an acceptable surface texture and finish. Treatments may be laborious and lengthy if the finishing requirements are very demanding.

## Advantages of Additive Manufacturing Technologies:

1. **Variety is free –** Changing a part is simple and can be made easily in the original CAD file and the new print can be taken easily.
2. **Complexity is free –** Printing of a complex part costs less than simple cubes of the same size The less solid or more complex object, it can be fastly and cheaply made through additiv manufacturing.
3. **No need for assembly –** Hinges and bicycle chains are some of the moving parts which can be printed in metal directly into the product and thus reduce the part numbers.
4. **Little-skill manufacturing –** Professionals take care of the complicated parts with specific parameters and high-tech applications, children in the elementary school have created their on figures by use of 3D printing processes.
5. **Few Constraints –** In the CAD software one can dream anything and design the same and create it with additive manufacturing.
6. **Various shades of materials –** In the CAD files, the engineers can program parts to have specific colors and printers can use materials of any color to print them.
7. **Lower energy consumption:** AM saves energy by eliminating production steps, using substantially less material, enabling reuse of by-products, and producing lighter products
8. **Less Waste:** Building objects up layer by layer, instead of traditional machining processes that cut away material can reduce materi al needs and costs by up to 90%. AM can also reduce the "cradle-to-gate" environmental footprints of component manufacturing through avoidance of the tools, dies, and materials scrap associated with CM processes. Additionally, AM reduces waste by lowering human error in production.
9. **Reduced time to market:** Items can be fabricated as soon as the 3-D digital description of the part has been created, eliminating the need for expensive and time-consuming part tooling and prototype fabrication.
10. **Innovation:** AM enables designs with novel geometries that would be difficult or impossible to achieve using CM processes, which can improve a component's engineering performance. Novel geometries enabled by AM technologies can also lead to performance and environmental benefit s in a component's product application.
11. **Part Consolidation:** The ability to design products with fewer, more complex parts, rather than a large number of simpler parts – is the most important of these benefits. Reducing the number of parts in an assembly immediately cuts the overhead associated with documentation and production planning and control. Also, fewer parts mean less time and labor is required for

assembling the product, again contributing to a reduction in overall manufacturing costs. The "footprint" of the assembly line may also become smaller, further cutting costs

12. **Lightweight:** With the elimination of tooling and the ability to create complex shapes, AM enables the design of parts that can often be made to the same functional specifications as conventional parts, but with less material.

13. **Agility to manufacturing operations:** Additive techniques enable rapid response to markets and create new production options outside of factories, such as mobile units that can be placed near the source of local materials. Spare parts can be produced on demand, reducing or eliminating the need for stockpiles and complex supply chains.

## Disadvantages of Additive Manufacturing Technologies:

1. **Production cost is high** – With the use of techniques other than additive manufacturing, parts can be made faster and hence the extra time can lead to higher costs. Besides, high-quality of additive manufacturing machines may cost high.
2. **Discontinuous production process –** To prevent economies of scale, parts can only be printed one at a time.
3. **Requires post-processing –** The surface finish and dimensional accuracy are of low quality than other manufacturing methods.
4. **Slow build rates –** Some of the printers lay down material at speed of one to five cubic inches per hour. Depending on the part needed the other manufacturing processes may be higher.
5. **Considerable effort in application design and setting process parameters –** Material design needs vast knowledge and additive manufacturing machine is needed to make quality parts.
6. **Poor mechanical properties** – Layering and multiple interfaces can cause defects in the product.
7. **Post-processing is needed –** Surface finish and dimensional accuracy may be of low quality than other manufacturing methods.

## Applications of Additive Manufacturing Technologies:

- Automotive applications
- Aerospace applications
- Biomedical applications
- Consumer goods applications
- Space applications
- Health care applications

- Artistic Industry
- Architectural Industry

## Additive Manufacturing Processes:

Additive manufacturing processes are classified into seven areas on the basis of

- Type of materials used
- Deposition technique, and
- The way the material is fused or solidified

These classifications have been developed by the ASTM International Technical Committee F42 on additive manufacturing technologies.

**The seven major additive manufacturing processes classified as per ASTM F42 are:**

1. Photopolymerization
2. Material jetting
3. Binder jetting
4. Material extrusion
5. Powder Bed Fusion
6. Sheet Lamination
7. Direct Energy Deposition

### Photopolymerisation:

Photopolymerization processes make use of liquid, radiation curable resins, or photopolymers as their primary materials. Most photopolymers react to radiation in the ultraviolet (UV) range of wavelengths, but some visible light systems are used as well. Upon irradiation, these materials undergo a chemical reaction to become solid. This reaction is called photopolymerization. Related Additive manufacturing technology which uses Photopolymerization is **Steriolithography (SLA).**

Vat polymerisation uses a vat of liquid photopolymer resin, out of which the model is constructed layer by layer. An ultraviolet (UV) light is used to cure or harden the resin where required, whilst a platform moves the object being made downwards after each new layer is cured.

As the process uses liquid to form objects, there is no structural support from the material during the build phase., unlike powder based methods, where support is given from the unbound material.

In this case, support structures will often need to be added. Resins are cured using a process of photo polymerisation or UV light, where the light is directed across the surface of the resin with the use of motor controlled mirrors. Where the resin comes in contact with the light, it cures or hardens.

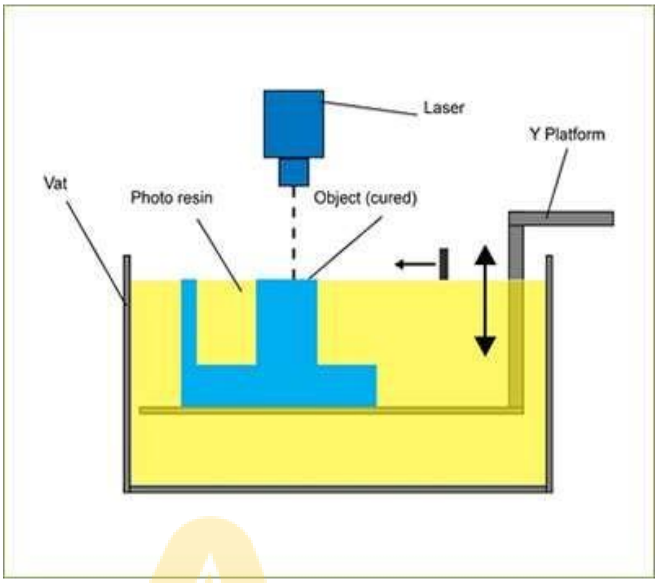



Figure: Photopolymerization Process

**Photopolymerisation –**
**Step by Step procedure**

1. The build platform is lowered from the top of the resin vat downwards by the layer thickness
2. A UV light cures the resin layer by layer. The platform continues to move downwards and additional layers are built on top of the previous.
3. Some machines use a blade which moves between layers in order to provide a smooth resin bas to build the next layer on.
4. After completion, the vat is drained of resin and the object removed.

**The SLA process** has a high level of accuracy and good finishbut often requires support structures and post curing for the part to be strong enough for structural use. The process of photo polymerisation can be achieved using a single laser and optics. Blades or recoating blades pass over previous layers to ensure that there are no defects in the resin for the construction of the next layer The photo-polymerisation process and support material may have likely caused defects

**Advantages:**

- High level of accuracy and good finish
- Relatively quick process
- Typically large build areas: objet 1000: 1000 x 800 x 500 and max model weight of 200 kg

**Disadvantages:**

- Relatively expensive
- Lengthily post processing time and removal from resin
- Limited material use of photo-resins
- Often requires support structures and post curing for parts to be strong enough for structural use

Complexity and in their methods of controlling the deposition of material. The material layers are then cured or hardened using ultraviolet (UV) light.

As material must be deposited in drops, the number of materials available to use is limited. Polymers and waxes are suitable and commonly used materials, due to their viscous nature and ability to form drops.