MODULE 1

MATERIAL SCIENCE

Powder metallurgy

Methods to produce metal powder

1. Atomization

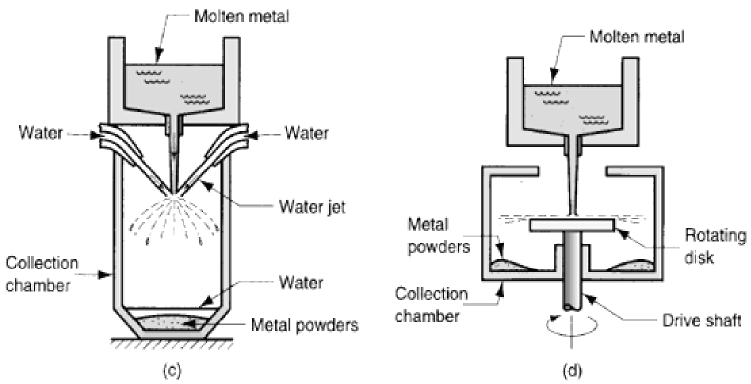
2. Machining

3. Reduction

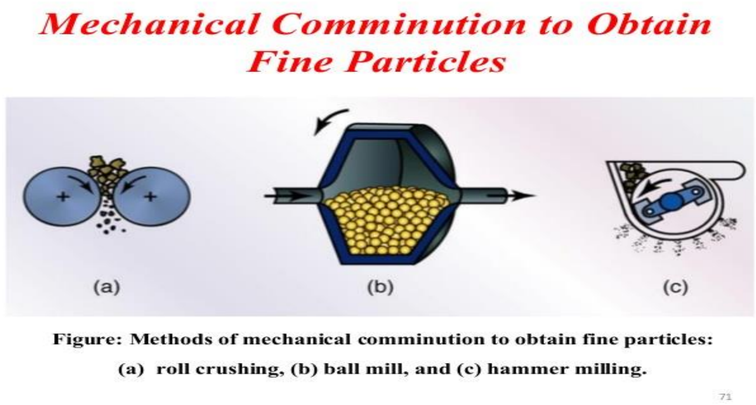
4. Crushing

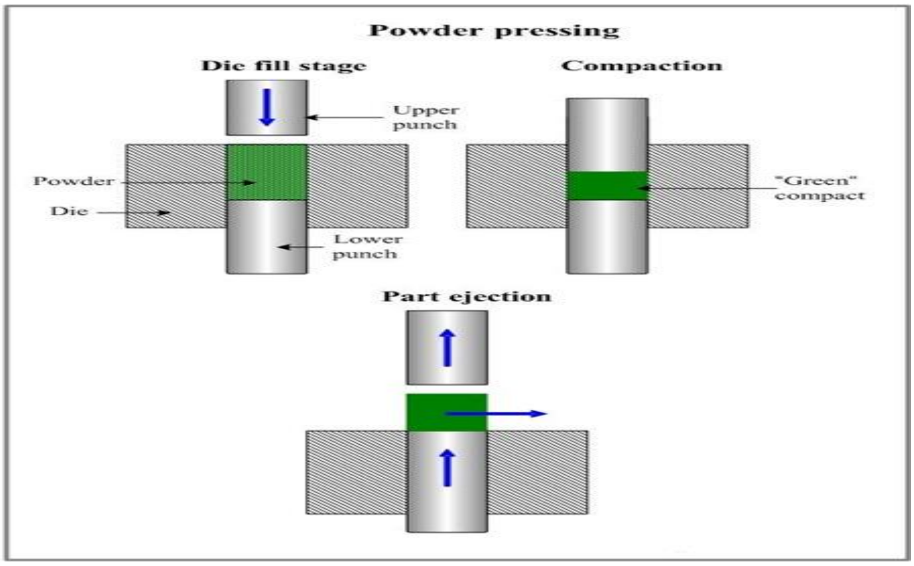
5. Electrolytic decomposition

1. Atomization:-

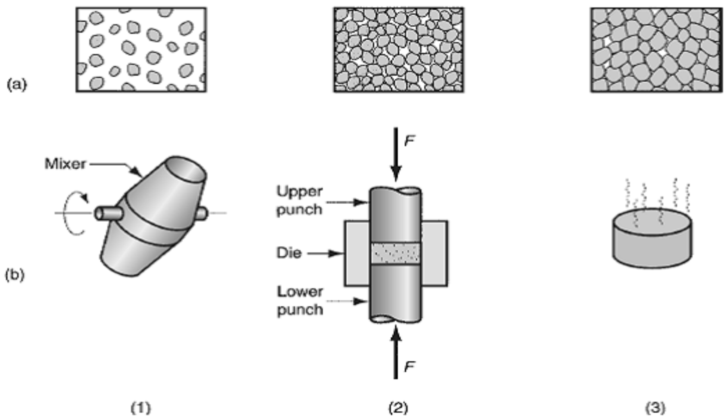


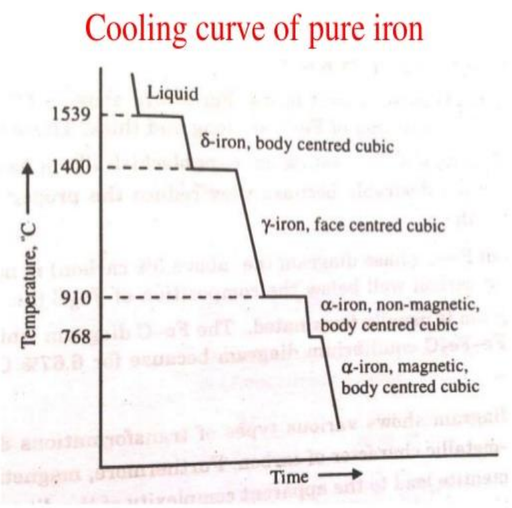
2. Machining





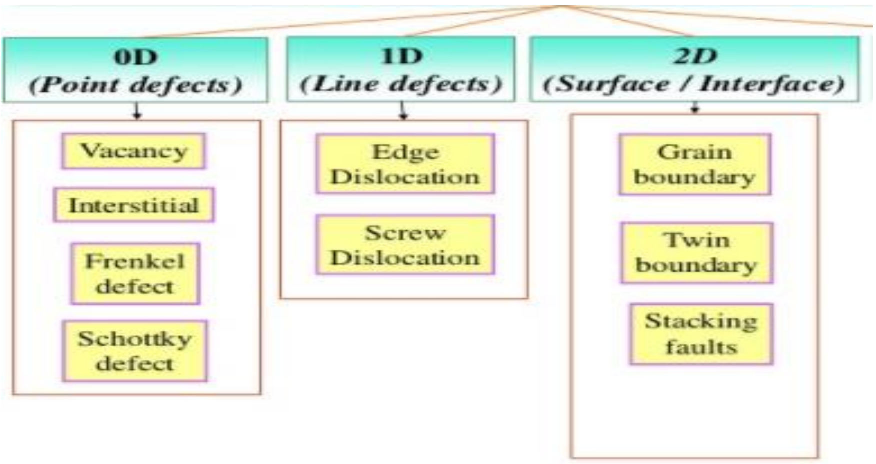
Steps in powder metallurgy



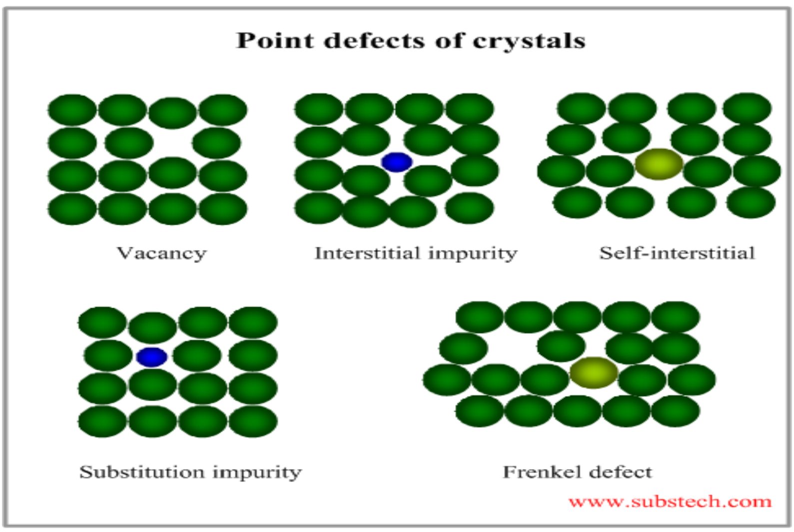


Cooling curve of pure iron [Source: V.D. Kodgire, S.V. Kodgire, 2010]

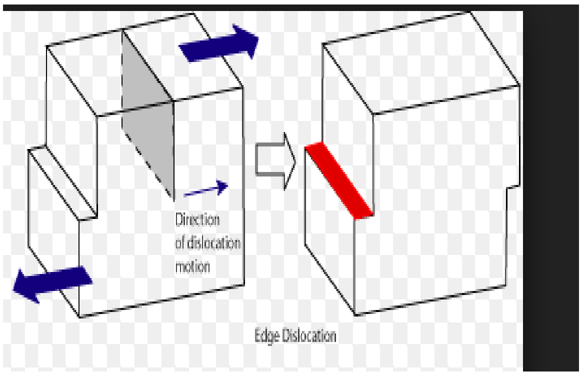
Classification crystal defects



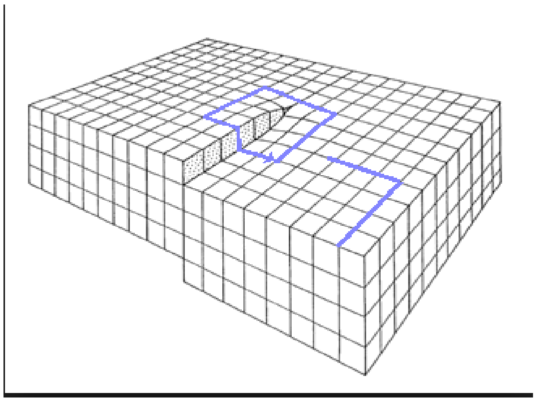
Point defects: -



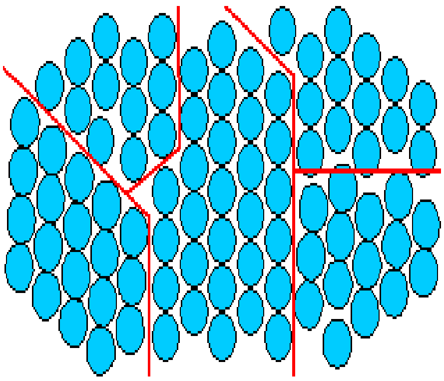
Edge dislocation

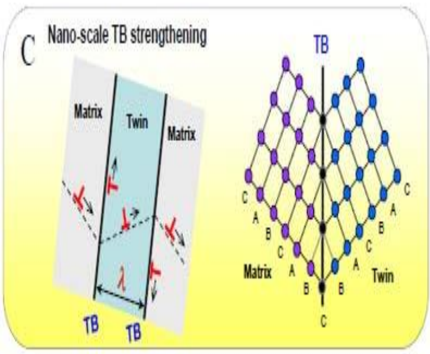


Screw dislocation. :



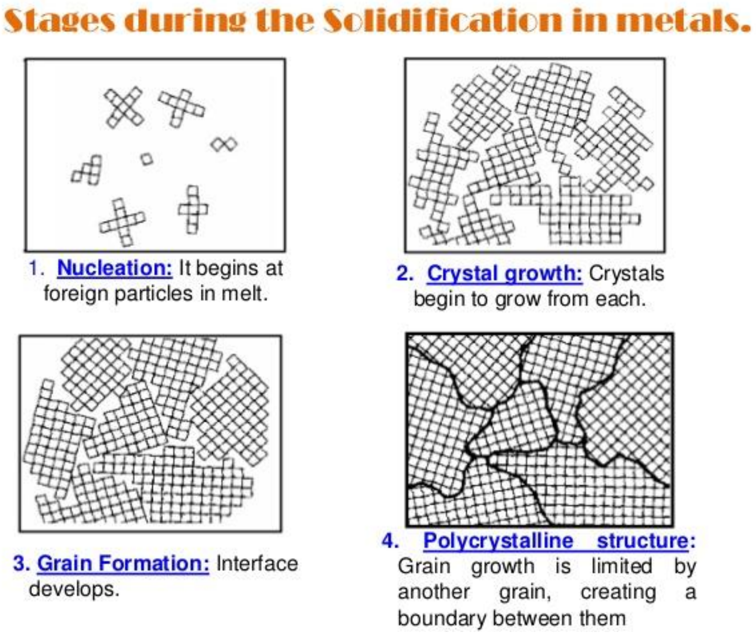
<u>Surface defects</u>



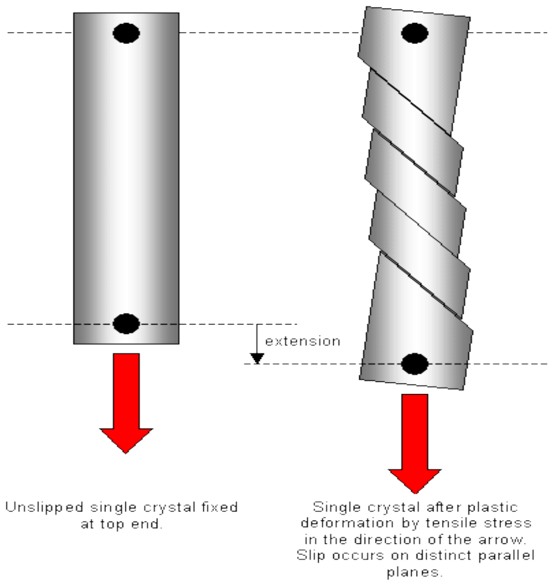


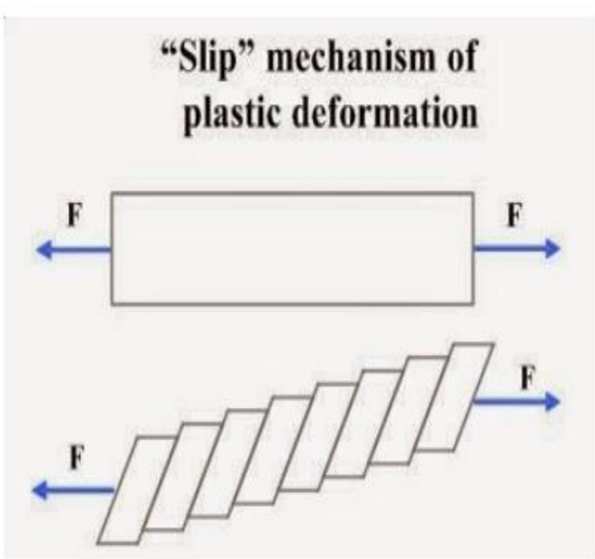
Grain boundary Twin boundary

Crystal growth and grain formation.

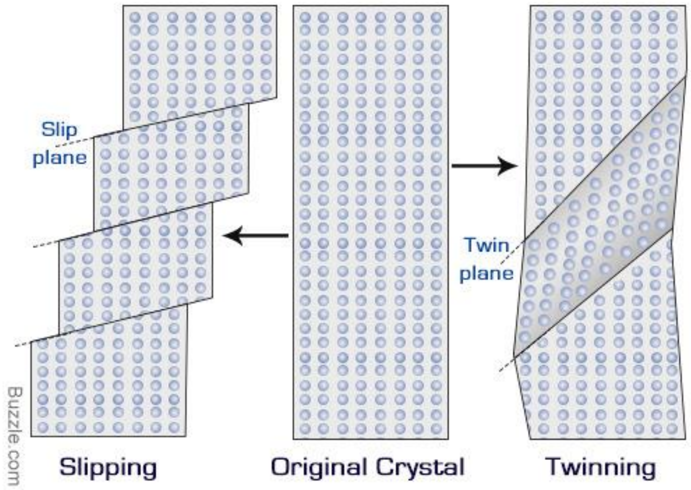


Plastic deformations of metals by slip





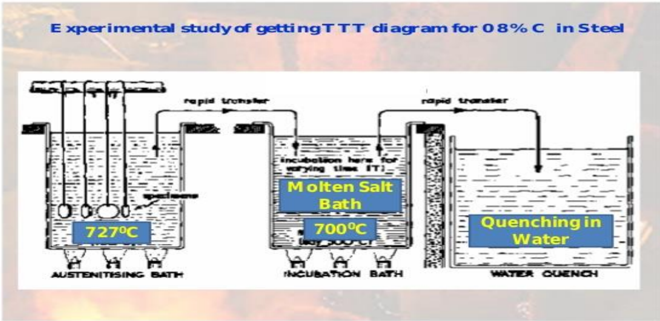
Plastic deformations of metals by slip



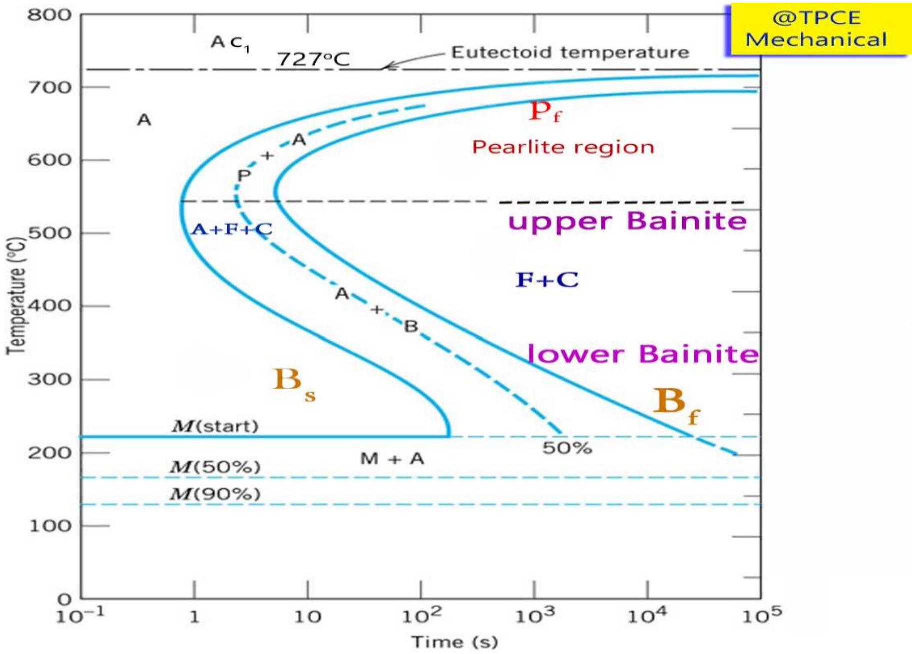
Iron-carbon equilibrium diagram

TTT diagram / C curve/ S curve.

- Also known as time-temperature-transformation (TTT) diagrams) are plots of temperature versus time
- Also known as Isothermal transformation diagrams
- An isothermal transformation diagram is only valid for one specific composition of material, and only if the temperature is held constant during the transformation, and strictly with rapid cooling to that temperature.



The TTT curve will be like



Continuous Cooling Transformation diagram (CCT diagram).

- A continuous cooling transformation (CCT) phase diagram is often used when heat treating steel.
- These diagrams are used to represent which types of phase changes will occur in a material as it is cooled at different rates.

These diagrams are often more useful than time-temperature-transformation diagrams because it is more convenient to cool materials at a certain rate than to cool quickly and hold at a certain temperature.

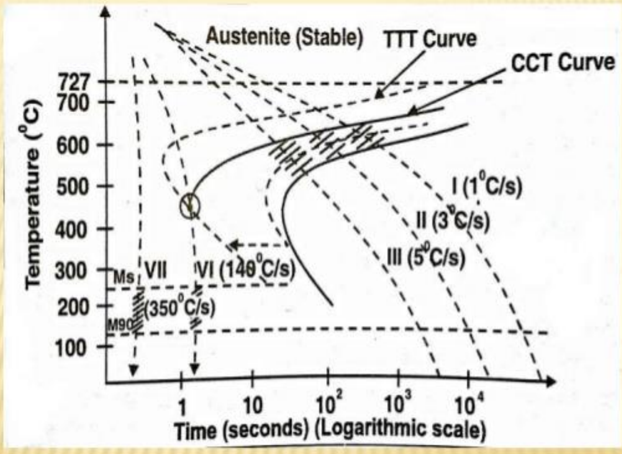


Fig. Continuous cooling transformation (CCT)

<u>Heat treatment processes.</u>

Process in which a metal is heated to a certain temperature and the cooled in a particular manner to alter its internal structure for obtaining desired degree of physical and mechanical properties such as brittleness, hardness, and softness. It is used to alter the physical, and sometimes chemical, properties of a material

<u>Various heat treatment processes.</u>

Annealing, normalizing,hardening, tempering,mar tempering,austempering, case hardening (cyaniding, nitriding and carburizing).

Annealing is a process of heating the steel slightly above the critical temperature of steel (723 degrees Centigrade) and allowing it to cool down very slowly.

- increase its ductility and reduce its hardness, making it more workable
- Cooling in still air or water

Normalizing is a heat treatment process for making material softer but does not produce the uniform material properties of annealing.

- A material can be normalized by heating it to a specific temperature and then letting the material cool to room temperature outside of the oven.
- Normalizing temperatures are said to range from 810 C to 930 C.

- Relieves stress on steel; this improves ductility and toughness in steels that may harden after the cold working process.
- Air cooling.

Hardening is a metallurgical metalworking process used to increase the hardness of a metal.

- Hardening involves heating of steel, keeping it at an appropriate temperature until all pearlite is transformed into austenite, and then quenching it rapidly in water or oil.

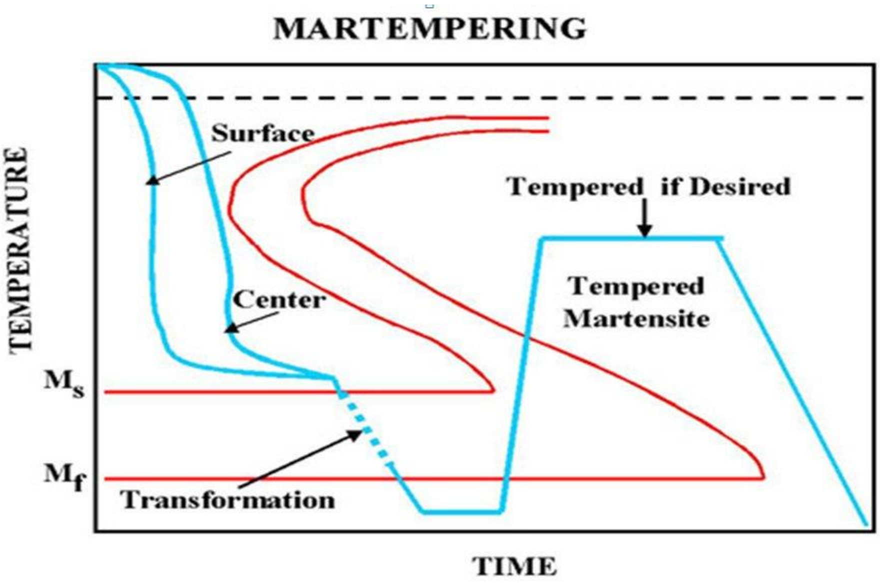
Tempering is a process of heat treating, which is used to increase the toughness of iron-based alloys.

- Tempering is usually performed after hardening, to reduce some of the excess hardness, and is done by heating the metal to some temperature below the critical point for a certain period of time, then allowing it to cool in still air

Mar tempering is a heat treatment for steel involving austenitisation followed by step quenching; at a rate fast enough to avoid the formation of ferrite, pearlite or bainite to a temperature slightly above the martensite start (Ms) point

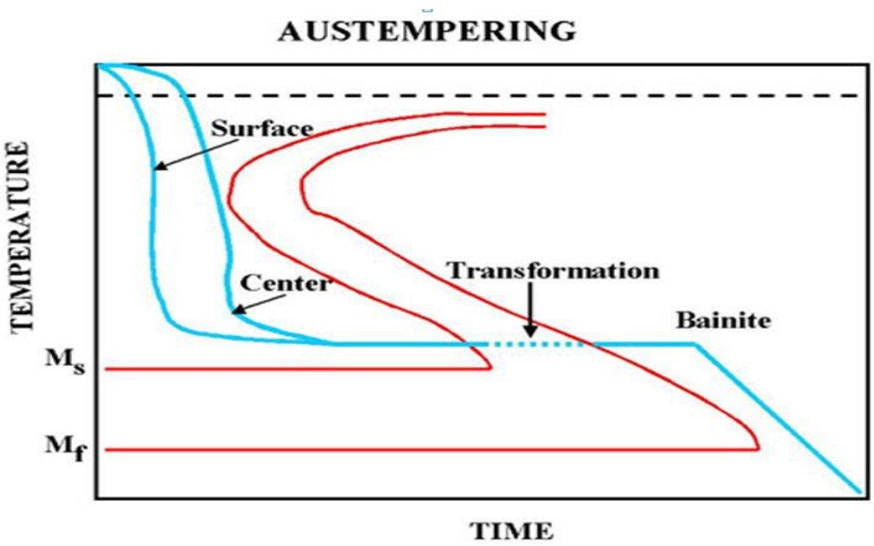
It involves

- Quenching from the austenitising temperature into a hot fluid medium at a temperature usually above the martensitic range;
- Holding in the quenching medium until the temperature throughout the steel is substantially uniform;
- Cooling at a moderate rate to prevent large differences between the outside and the centre of the section; and
- Tempering in conventional fashion.



Austempering is an isothermal heat treatment that, when applied to ferrous materials, produces a structure that is stronger and tougher than comparable structures produced with conventional heat treatments

- The parts are heated to "red heat" in a controlled atmosphere (so they don't scale) but then are quenched in a bath of molten salt at 450°F (232°C) to 750°F (399°C).



Case-hardening or surface hardening is the process of hardening the surface of a metal object while allowing the metal deeper underneath to remain soft, thus forming a thin layer of harder metal (called the "case") at the surface.

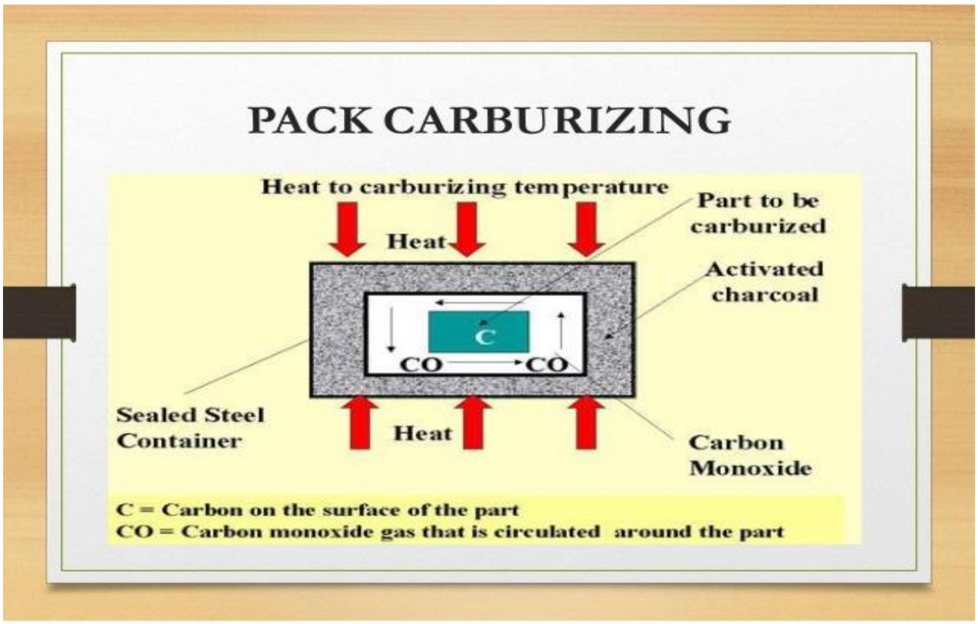
Cyaniding, nitriding and carburizing are various surface hardening processes used

Carburizing is a heat treatment **process** in which iron or steel absorbs carbon while the metal is heated in the presence of a carbon-bearing material, such as charcoal or carbon monoxide. The intent is to make the metal harder.

- Different types of carburizing methods are pack carburizing, liquid carburizing, gas carburizing and vacuum carburizing.

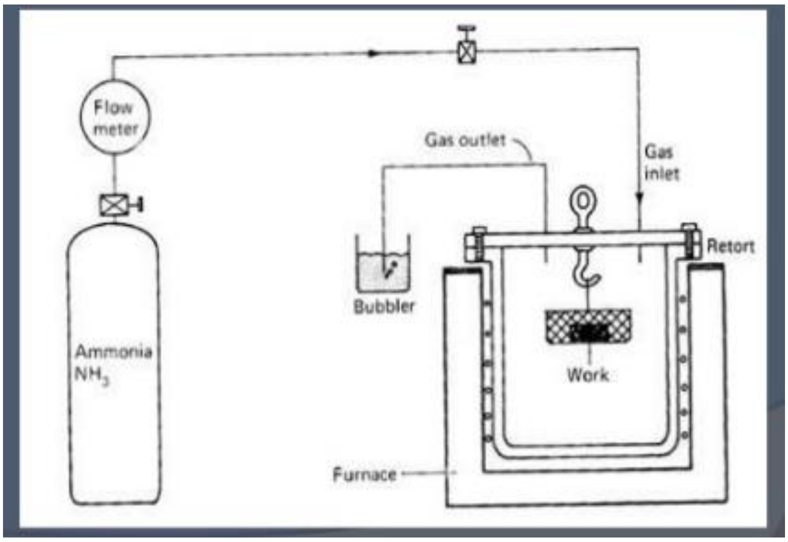
Pack carburizing

PACK CARBURIZING is a process in which carbon monoxide derived from a solid compound decomposes at the metal surface into nascent carbon and carbon dioxide. The nascent carbon is absorbed into the metal, and the carbon dioxide immediately reacts with carbonaceous material present in the solid carburizing compound to produce fresh carbon monoxide**.**



Gas carburizing is a surface-hardening process which is carried out at a high temperature - usually above 925°C. The process is usually conducted in a sealed quench furnace in which a **carburizing gas** is introduced. Atomic carbon is generated by the reaction between the gaseous furnace atmosphere and the steel.

Nitriding is a heat treating process that diffuses nitrogen into the surface of a metal to create a case-hardened surface.



In **Cyaniding heat treatment** process in which an iron-base alloys is heated in contact with a **cyanide** salt so that the surface absorbs carbon and nitrogen.

Residual stress due to heat treatment.

- Residual stresses are stresses that remain in a solid material after the original cause of the stresses has been removed.
- Residual stress is the internal stress distribution locked into a material. These stresses are present even after all external loading forces have been removed.

Heat treatment of aluminum- age hardening

Precipitation hardening, also called age hardening or particle hardening, is a heat treatment technique used to increase the yield strength of malleable materials, including most structural alloys of aluminum, magnesium, nickel, titanium, and some steels and stainless steels. In superalloys, it is known to cause yield strength anomaly providing excellent high-temperature strength.

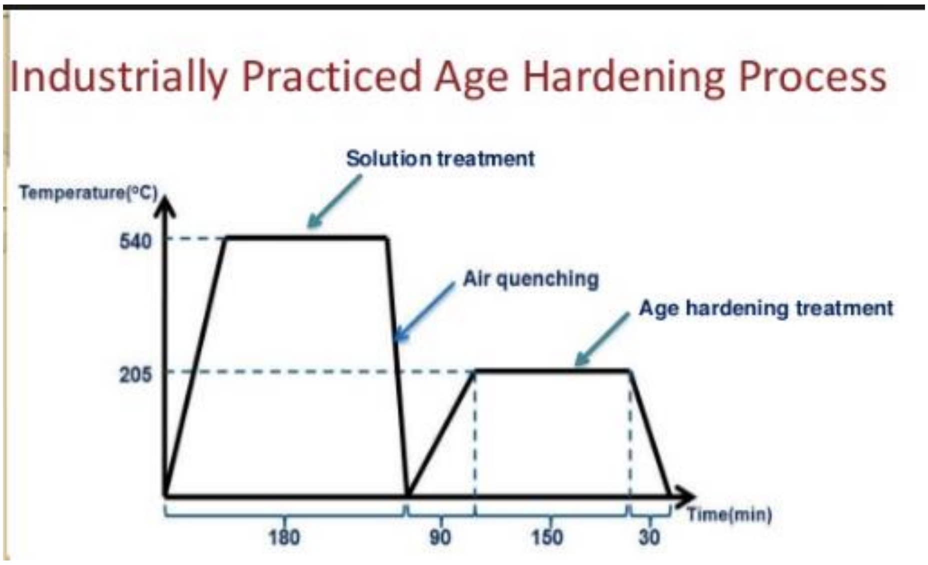
Precipitation hardening relies on changes in solid solubility with temperature to produce fine particles of an impurity phase, which impede the movement of dislocations, or defects in a crystal's lattice. Since dislocations are often the dominant carriers of plasticity, this serves to harden the material.

Important steps involved in the process of age hardening are

Solution treatment

Air quenching

Age hardening process



MODULE NO 2

Chapter 1

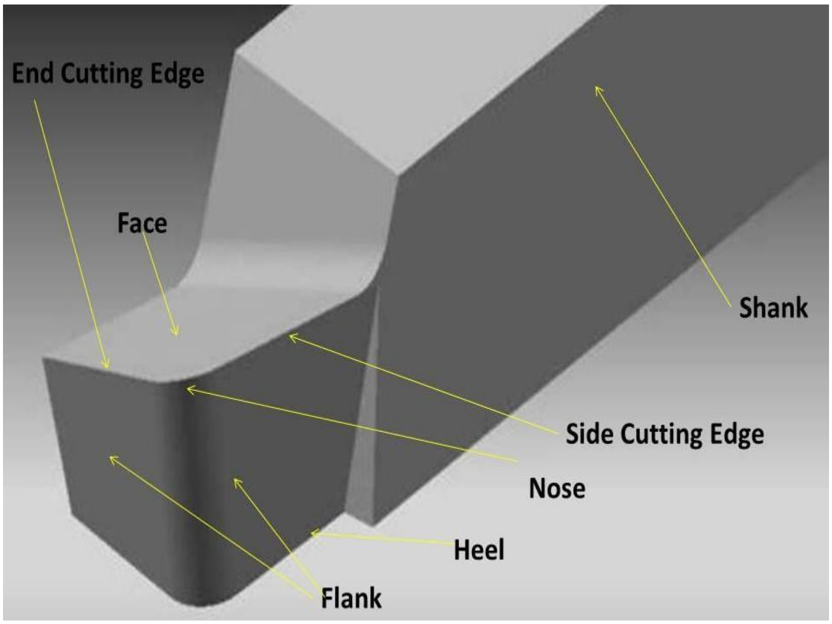
METAL CUTTING

Single point cutting tool geometry

Metal-**cutting tools** are classified as **single point** or multiple **point**. A **single-point cutting tool** can be used for increasing the size of holes, or boring. Turning and boring are performed on lathes and boring mills.

Terminology of single point cutting tool

Shank – It is main body of tool. The shank used to grippesd in tool holder.
Flank – The surface or surface below the adjacent of the cutting edge is called flank of the tool.
Face – It is top surface of the tool along which the chips slides.
Base – It is actually a bearing surface of the tool when it is held in tool holder or clamped directly in a tool post.



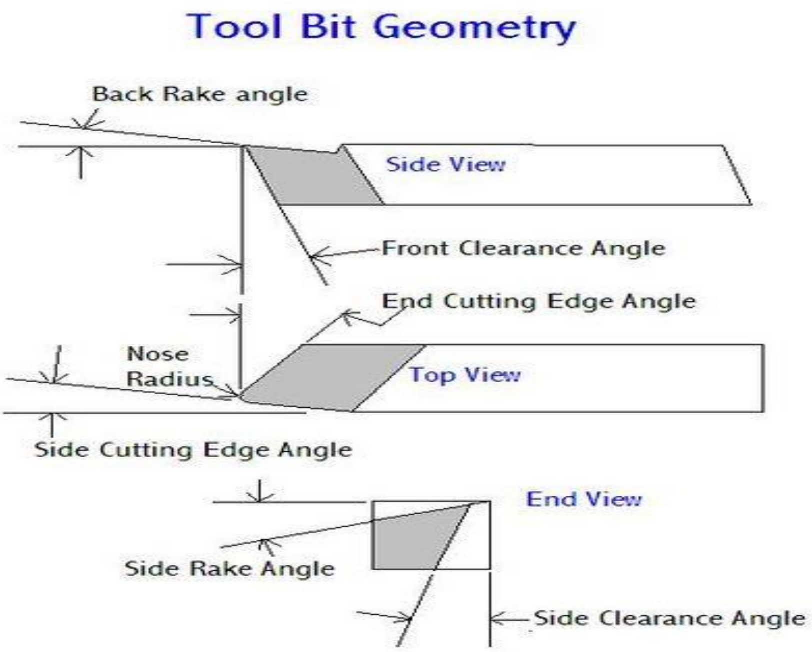
Heel – It is the intersection of the flank & base of the tool. It is curved portion at the bottom of the tool.
Nose – It is the point where side cutting edge & base cutting edge intersect.
Cutting edge – It is the edge on face of the tool which removes the material from workpiece. The cutting edges are side cutting edge (major cutting edge) & end cutting edge (minor cutting edge)
Tool angles-Tool angles have great importance. The tool with proper angle, reduce breaking of tool, cut metal more efficiently, generate less heat.
Noise radius –It provide long life & good surface finish sharp point on nose is highly stressed, & leaves grooves in the path of cut. Longer nose radius produce chatter.

Angles of Single point cutting tool:

1: Side Cutting Edge Angle:
The angle between side cutting edge and the side of the tool shank is called side cutting edge angle. It is often referred to as the lead angle.
2: End Cutting Edge Angle:
The angle between the end cutting edge and a line perpendicular to the shank of the tool shank is called end cutting edge angle.
3: Side Relief Angle:
The angle between the portion of the side flank immediately below the side cutting edge and a line perpendicular to the base of the tool.
4: End Relief Angle:
The angle between the end flank and the line perpendicular to the base of the tool is called end relief angle.
5: Back Rake Angle:
The angle between the face of the tool and line perpendicular to the base of the tool measures on perpendicular plane through the side cutting edge. It is the angle which measures the slope of the face of the tool from the nose, towards the rack. If the slope is downward the nose it is negative back rake.

6: Side Rake Angle:
The angle between the face of the tool and a line parallel to the base of the tool measured on plane perpendicular to the base and the side edge. It is the angle that measure the slope of the tool face from

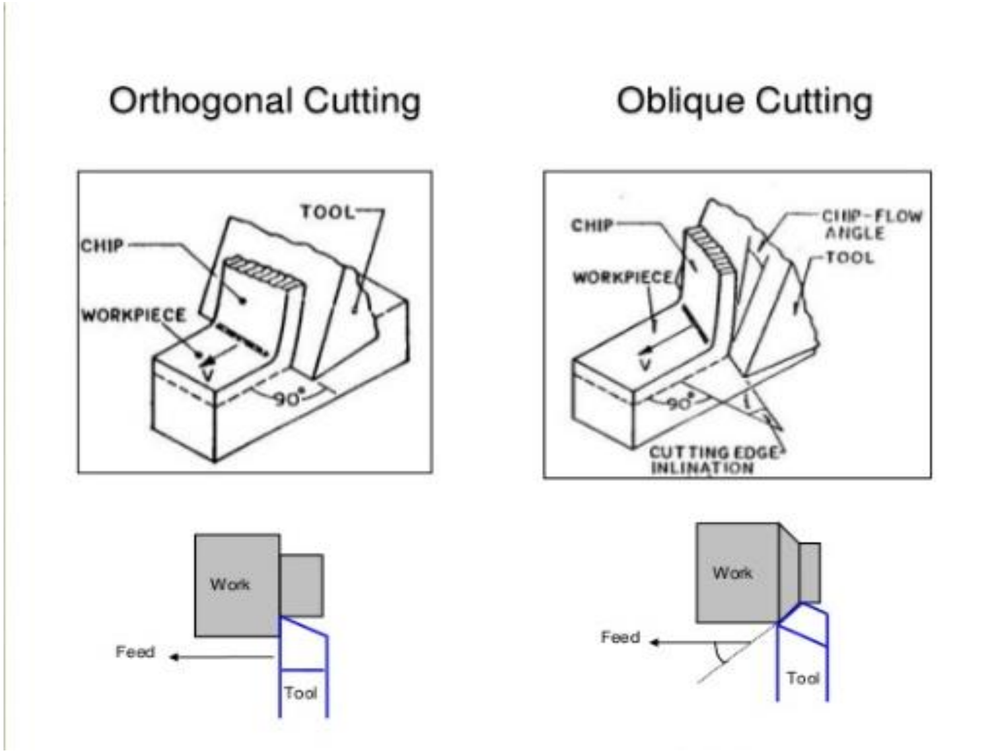
the cutting edge, if the slope is towards the cutting edge it is negative side rake angle and if the slope is away from the cutting edge, it is positive side rake angle. If there is no slope the side rake angle is zero.



Orthogonal cutting and oblique cutting.

Orthogonal cutting is a type of metal cutting in which the cutting edge of wedge shape cutting tool is perpendicular to the direction of tool motion. In this cutting the cutting edge is wider than width of cut. This cutting is also known as 2D cutting because the force develop during cutting can be plot on a plane or can be represent by 2D coordinate.

Oblique cutting is another type of cutting in which the cutting edge of wedge shape cutting tool make a angle except right angle to the direction of tool motion. This will affect the cutting conditions. It is also known as 3D cutting because the cutting force develop during cutting cannot be represent by 2D coordinate or used 3D coordinate to represent.



Difference between orthogonal cutting and oblique cutting

S. No.	Orthogonal Cutting	Oblique Cutting
1.	The cutting angle of tool make right angle to the direction of motion.	The cutting angle of tool foes not make right angle to the direction of motion.
2	The chip flow in the direction normal to the cutting edge.	The chips make an angle with the normal to the cutting edge.
3.	In orthogonal cutting only two components of force considered cutting force and thrust force which can be represent by 2D coordinate system.	In oblique cutting three component of force are considered, cutting force, thrust force and radial force which cannot represent by 2D coordinate. It used 3D coordinate to represent the forces acting during cutting, so it is known as 3D cutting.
4.	This tool has lesser cutting life compare to oblique cutting.	This tool has higher cutting life.

5.	The shear force act per unit area is high which increase the heat developed per unit area.	The shear force per unit area is low, which decreases heat develop per unit area hence increases tool life.
6.	The chips flow over the tool.	The chips flow along the sideways.

Chip formation in metal cutting

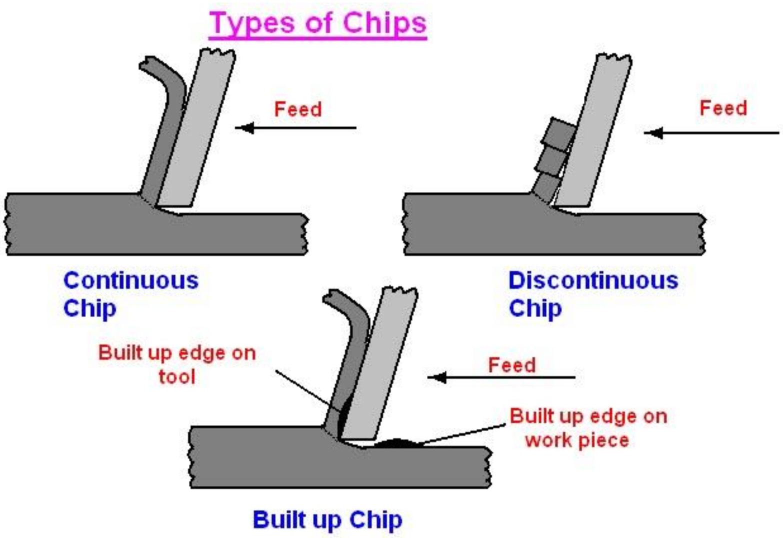
Every Machining operation involves the formation of chips. The nature of which differs from operation to operation, properties of work piece material and the cutting condition. Chips are formed due to cutting tool, which is harder and more wearer-resistant than the work piece and the force and power to overcome the resistance of work material. The chip is formed by the deformation of the metal lying ahead of the cutting edge by a process of shear.

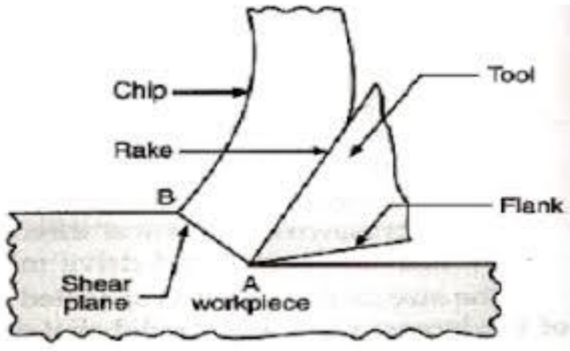
Main types of chips are:

Continuous or Ribbon Type Chips

Discontinuous Chips

Continuous Chip Built-up-Edge (BUE)





When we move the tool against the work piece, the metal will deformed through the shear plane and metal cutting will takes place.

Various cutting tool materials

Basic properties that cutting must posses are:

- Tool material must be at least 30 to 50% harder than the work piece material.
- Tool material must have high hot hardness temperature.
- High toughness
- High wear resistance
- High thermal conductivity
- Lower coefficient of friction
- Easiness in fabrication and cheap

Different cutting tool materials used for cutting operations in practice are high carbon steel, high speed steel, non -ferrous cast alloys, cemented carbides, ceramics and sintered oxides, ceremets, diamond, cubic boron nitride, UCON and sialon.

1. High Carbon Steel tools

- Its composition is C = 0.8 to 1.3%, Si = 0.1 to 0.4% and Mn = 0.1 to 0.4%.
- It is used for machining soft metals like free cutting steels and brass and used as chisels etc.
- This tool loose hardness above 250°C.
- Hardness of tool is about Rc = 65.
- Used at cutting speed of 5m/min.

2. High speed steel (H.S.S)
General use of HSS is 18-4-1.
18- Tungsten is used to increase hot hardness and stability.
4 – Chromium is used to increase strength.
1- Vanadium is used to maintain keenness of cutting edge.
In addition to these 2.5% to 10% cobalt is used to increase red hot hardness.
Rest iron

- H.S.S is used for drills, milling cutters, single point cutting tools, dies, reamers etc.
- It looses hardness above 600°C.
- Some times tungsten is completely replaced by Molybdenum.
- Molybdenum based H.S.S is cheaper than Tungsten based H.S.S and also slightly greater toughness but less water resistance.

3. Non – ferrous cast alloys

It is an alloy of
Cobalt – 40 to 50%,
Chromium – 27 to 32%,
Tungsten – 14 to 29%,
Carbon – 2 to 4%

- It cannot heat treated and are used as cast form.
- It loses its hardness above 800°C
- It will give better tool life than H.S.S and can be used at slightly higher cutting speeds.
- They are weak in tension and like all cast materials tend to shatter when subjected to shock load or when not properly supported.

4. Cemented carbides

- Produced by powder metallurgy technique with sintering at 1000°C.
- Speed can be used 6 to 8 times that of H.S.S.
- Can withstand up to 1000°C.
- High compressive strength is more than tensile strength.
- They are very stiff and their young's modulus is about 3 times that of the steel.
- High wear resistance.
- High modulus of elasticity.
- Low coefficient of thermal expansion.
- High thermal conductivity, low specific heat, low thermal expansion.

The advantages of carbide tools are

- They have high productivity capacity.
- They produce surface finish of high quality.
- They can machine hardened steel.
- Their use leads to reduction in machining costs.

5. Ceramics and sintered oxides

- Ceramics and sintered oxides are basically made of Al_2O_3, These are made by powder metallurgy technique.
- Used for very high speed (500m/min).
- Used for continuous cutting only.
- Can withstand up to 1200°C.
- Have very abrasion resistance.
- Used for machining CI and plastics.
- Have fewer tendencies to weld metals during machining.
- Generally used ceramic is sintered carbides.
- Another ceramic tool material is silicon nitride which is mainly used for CI.

6. Cermets

- Cermets are the combination of ceramics and metals and produced by Powder Metallurgy process.
- When they combine ceramics will give high refractoriness and metals will give high toughness and thermal shock resistance.
- For cutting tools usual combination as Al_2O3 + W + Mo + boron + Ti etc.

- Usual combination 90% ceramic, 10% metals.
- Increase in % of metals reduces brittleness some extent and also reduces wear resistance.

7. Diamond

- Diamond has
    1. Extreme hardness
    2. Low thermal expansion.
    3. High thermal conductivity.
    4. Very low coefficient of friction.
- Cutting tool material made of diamond can withstand speeds ranging from 1500 to 2000m/min.
- On ferrous metals diamond are not suitable because of the diffusion of carbon atoms from diamond to work-piece.
- Can withstand above 1500°C.
- A synthetic (man made) diamond with polycrystalline structure is recently introduced and made by powder metallurgy process.

8. Cubic Boron Nitride (CBN)

- The trade name is Borazon.
- Consists of atoms of Nitrogen and Boron and produced by power metallurgy process.
- Used as a substitute for diamond during machining of steel.
- Used as a grinding wheel on H.S.S tools.
- Excellent surface finish is obtained.

9. UCON

- UCON is developed by union carbide in USA.
- It consists of Columbium 50%, Titanium 30 % and Tungsten 20%.
- This is refractory metal alloy which is cast, rolled into sheets and slit into blanks. though its hardness is only 200 BHN, it bis hardened by diffusing nitrogen into surface producing very hard surface with soft core. It is not used because of its higher costs.

10. Sialon (Si-Al-O-N)

- Sialon is made by powder metallurgy with milled powders of Silicon, Nitrogen, Aluminum and oxygen by sintering at 1800°C.
- This is tougher than ceramics and so it can be successfully used in interrupted cuts. Cutting speeds are 2 to 3 times compared to ceramics.
- At present this is used for machining of aerospace alloys, nickel based gas turbine blades with a cutting speed of 3 to 5 m/sec.

Factors affecting the life of cutting tools

The **life of cutting tool** is affected by the various factors mentioned below:

1. Properties of Work Piece Material:

- With the increase in hardness of work piece, forces and power consumption increases and tool wear increases. So tool life decreases.
- When ductility of work piece increases, forces and power consumption decreases, tool wear decreases. So tool life increases.

- But there is no quantitative relationship available between properties of work and tool life.

2. Tool Geometry:

As the tool geometry changes, like when rake angle increases, the tool life will increase. But there is no quantitative relationship between tool geometry and tool life.

3. Use of Cutting Fluid:

- When the cutting fluid is used during machining it is acting as a lubricant in friction zone and carrying away the heat during machining.
- So forces in machining with the use of cutting fluid. It increases by 25 to 40 %.

4. Process Parameters:

1. Cutting speed
2. Feed
3. Depth of cut

- Because of uniqueness of process parameters, the researchers tried to establish relationship between process parameters and tool life.
- Taylor has assumed that cutting velocity is the major parameter influencing the tool life.

Machinability

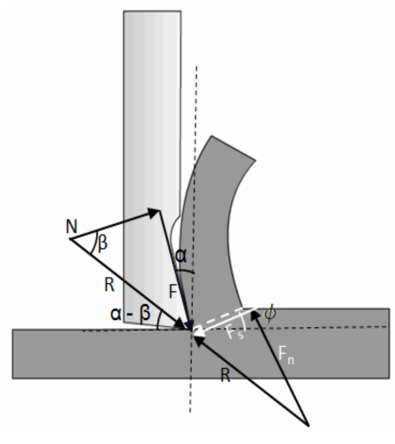
The term **machinability** refers to the ease with which a metal can be cut (machined) permitting the removal of the material with a satisfactory finish at low cost.

Energy efficiency in metal cutting

Forces experienced by a tool during cutting are detrimental in design of mechanical structure of cutting machine, predicting power consumption, determining the tool life and increasing the productivity.

Forces acting on the chip

If you make a free body analysis of the chip, forces acting on the chip would be as follows.



At cutting tool side due to motion of chip against tool there will be a frictional force and a normal force to support that. At material side thickness of the metal increases while it flows from uncut to cut portion. This thickness increase is due to inter planar slip between different metal layers. There should be a shear force (Fs) to support this phenomenon.

Shear force on shear plane can be determined using shear strain rate and properties of material. A normal force (Fn) is also present perpendicular to shear plane. The resultant force (R) at cutting tool side and metal side should balance each other in order to make the chip in equilibrium. Direction of resultant force, R is determined as shown in Figure.

Chapter 2

CUTTING FLUIDS

Functions of cutting fluids

Cutting fluids are used in metal machining for a variety of reasons such as improving tool life, reducing work piece thermal deformation, improving surface finish and flushing away chips from the cutting zone. Practically all cutting fluids presently in use fall into one of four categories:

- Straight oils
- Soluble oils
- Semi synthetic fluids
- Synthetic fluids

The primary functions of cutting fluids in machining are :

- Lubricating the cutting process primarily at low cutting speeds
- Cooling the work piece primarily at high cutting speeds
- Flushing chips away from the cutting zone

Secondary functions include:

- Corrosion protection of the machined surface
- enabling part handling by cooling the hot surface

Process effects of using cutting fluids in machining include:

- Longer Tool Life
- Reduced Thermal Deformation of Work piece
- Better Surface Finish (in some applications)
- Ease of Chip and Swarf handling

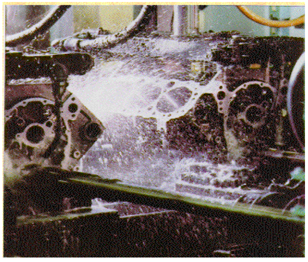
Desirable properties of cutting fluids

Properties to be possessed by the cutting fluids are

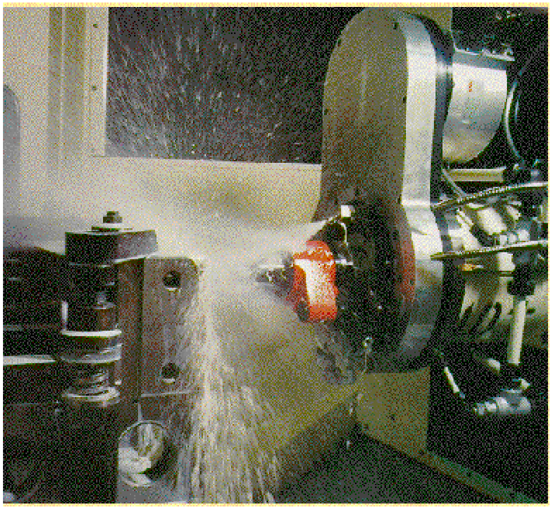
1. Cutting fluids should have low viscosity to permit free flow of the liquid.
2. It should posses good lubricating properties.
3. It should have high specific heat, high heat conductivity and high heat transfer coefficient.
4. It should be non-corrosive to work and machine.
5. It should be non-toxic to operating person.
6. It should be odorless.
7. It should stable in use and storage.
8. It should be safe.
9. It should permit clear view of the work operation.

Method of application of lubrication - minimum quantity lubrication (mql)

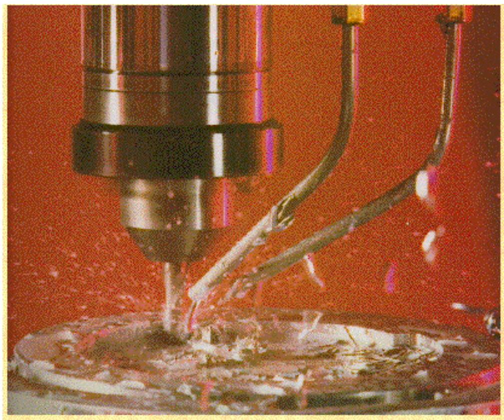
The principal methods of cutting fluid application include: Flood Application of Fluid: **A flood** of cutting fluid is applied on the **work piece**



Jet Application of Fluid: a jet of cutting fluid is applied on the work piece directed at the cutting zone



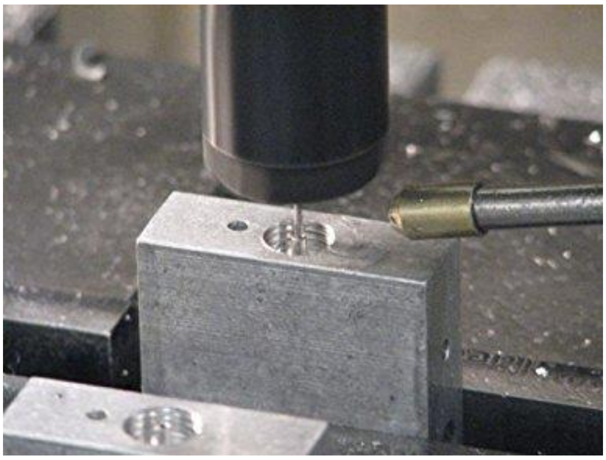
Mist Application of Fluid: cutting fluid is atomized by a jet of air and the mist is directed at the cutting zone



Minimum quantity lubrication (mql)

The concept of MQL is fundamentally different than that of flood coolant and this can be a large stumbling block to machinists who are new to MQL. The use of flood coolant is incredibly basic. As long as relatively clean coolant 'floods' the interface of the cutting tool and work piece, the heat generated by machining operations is kept at bay. This process works (another reason it is widely accepted!), but has some significant consequences.

- One of the main downsides to the use of coolant is that it adds extra equipment into the equation. Equipment to recalculate, filter, test, and treat coolant to keep it viable is required.
- Another consequence of coolant is that it's messy.
- Machines, floors, and finished parts are often left wet from coolant, causing potential slip hazards and often requiring part cleaning before secondary operations can take place.
- Repeated exposure too many coolants can have real consequences for the humans involved as well.
- Some coolants have been shown to cause dermatitis and to be carcinogenic with long-term exposure to coolant vapor.
- Studies have shown that the cumulative cost of coolants/MWFs can equal as high as 15% of the total cost to produce a part.



The cost and negative effects of flood coolant set the stage beautifully for MQL. When presented with an alternative which saves money, eliminates the mess, disposal, and negative aspects of coolant. In a nutshell, MQL makes us of a lubricant, not a coolant, and does so in 'minimum quantities' (like its name!). Where coolants flood the interface in an attempt to cool things down, MQL coats the interface with a thin film of lubricant and prevents heat build up through friction reduction. The excellent lubricity of a good MQL lubricant means that the majority of the heat from friction is transmitted to the chip and exits the interface as chips are expelled. This lubrication and transfer of heat keeps the cutting tool much cooler and reduces tool wear.

Various types of cutting fluids and their selection for an application

Cutting fluids are an instrumental part of metal machining due to their improvement of the tool life, reduction of the work piece thermal radiation, flushing away chips from the cutting area, and improving the surface finish. There are four main categories of cutting fluids:

1. **Straight oils**
   these oils are non-emulsifiable and very useful in machining operations where they function in undiluted form. Their composition is a base mineral or even petroleum oil. Often they contain polar lubricants like vegetable oils, fats and esters.
   They may also contain extreme pressure additives including sulphur, chlorine, and phosphorus. To achieve the best lubrication use straight oils however they may have poor cooling characteristics.
2. **Synthetic fluids**
   They do not contain mineral oil base or petroleum. Instead, they're formulated from the alkaline organic and inorganic compounds alongside additives to prevent corrosion. They function well in their diluted form. Of all the varieties of cutting fluids, synthetic fluids offer the best cooling performance.
3. **Soluble oils**
   Soluble Oils usually form an emulsion after mixing them with water. The resulting concentrate contains emulsions and a base mineral oil to produce a stable emulsion. They function well in their diluted form and offer a great lubrication in addition to heat transfer performance. They are the least expensive and are the most widely used fluids in the industry.
4. **Semi-synthetic fluids**
   these fluids are basically a combination of the soluble oils and synthetic fluids. Besides, the heat transfer performance and cost of the semi-synthetic fluids falls between those of the soluble and synthetic fluids.

The following factors should be considered when selecting a fluid:

- Cost and life expectancy
- A Fluid compatibility with work materials and machine components
- A Speed, feed and depth of the cutting operation
- A Type, hardness and microstructure of the metal being machined
- A Ease of fluid maintenance and quality control
- Ability to separate fluid from the work and cuttings
- A The products applicable temperature operating range
- A Optimal concentration and pH ranges
- A Storage practices
- A Ease of fluid recycling or disposal

Chapter 3

LATHES

Type of lathes

Lathe is considered as one of the oldest machine tools and is widely used in industries. It is called as mother of machine tools. It is said that the first screw cutting lathe was developed by an Englishman named Henry Maudslay in the year 1797. Modern high speed, heavy duty lathes are developed based on this machine.

Various designs and constructions of lathe have been developed to suit different machining conditions and usage. The following are the different types of lathe

1. Speed lathe
a. Woodworking lathe
b. Centering lathe
c. Polishing lathe
d. Metal spinning lathe

2. Engine lathe
a. Belt driven lathe
b. Individual motor driven lathe
c. Gear head lathe

3. Bench lathe
4. Tool room lathe

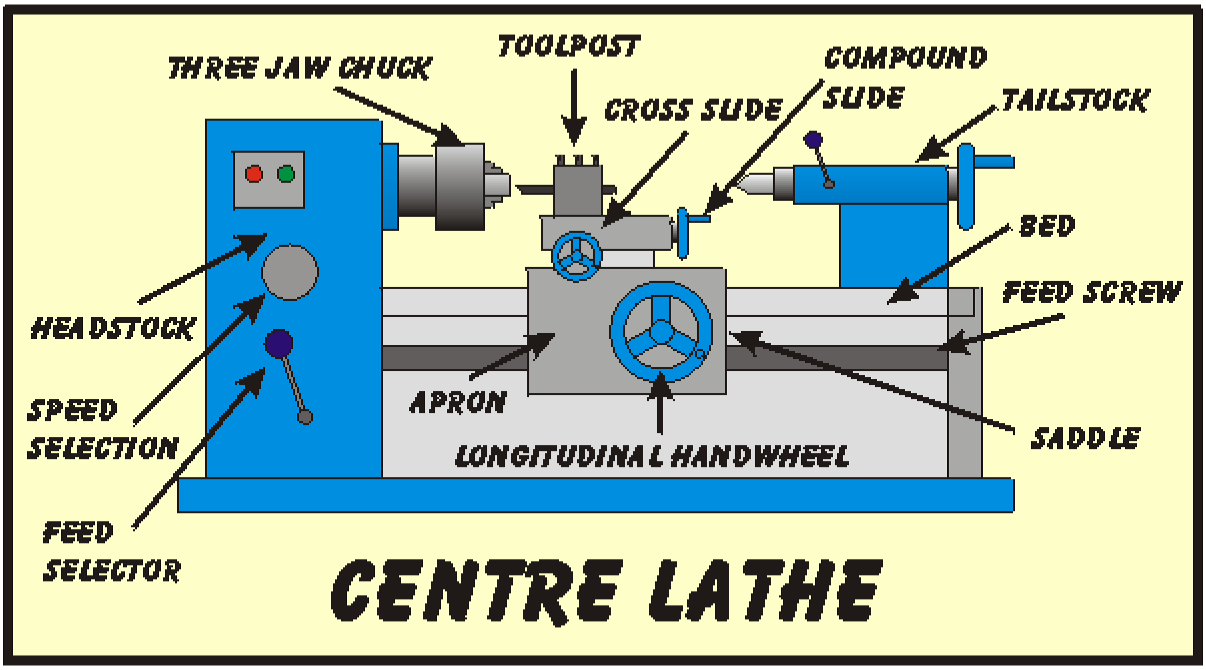
5. Semi automatic lathe
a. Capstan lathe
b. Turret lathe

6. Automatic lathe

7. Special purpose lathe
a. Wheel lathe
b. Gap bed lathe
c. 'T' lathe

d. Duplicating lathe

Centre lathe



Main parts of a lathe

Every individual part performs an important task in a lathe. Some important parts of a Lathe are listed below

1. Bed
2. Headstock
3. Spindle
4. Tailstock
5. Carriage
a. Saddle
b. Apron
c. Cross-slide
d. Compound rest
e. Compound slide
f. Tool post
6. Feed mechanism
7. Lead screw
8. Feed rod
9. Thread cutting mechanism

Bed

Bed is mounted on the legs of the lathe which are bolted to the floor. It forms the base Of the machine. It is made of cast iron and its top surface is machined accurately and precisely.

Headstock

Headstock is mounted permanently on the inner guide ways at the left hand side of the leg bed. The headstock houses a hollow spindle and the mechanism for driving the spindle at multiple speeds. The headstock will have any of the following arrangements for driving and altering the spindle speeds

(i) Stepped cone pulley drive
(ii) Back gear drive
(iii) All gear drive

Spindle

The spindle rotates on two large bearings housed on the headstock casting. A holeextends through the spindle so that a long bar stock may be passed through the hole. The front end of the spindle is threaded on which chucks, faceplate, driving plate and catch plate are screwed.

Tailstock

Tailstock is located on the inner guide ways at the right side of the bed opposite to the headstock. The body of the tailstock is bored and houses the tailstock spindle or ram. The spindle moves front and back inside the hole. The spindle has a taper hole to receive the dead centre or shanks of tools like drill or reamer. If the tailstock hand wheel is rotated in the clockwise direction, the spindle advances. The spindle will be withdrawn inside the hole, if the hand wheel is rotated in anti-clockwise direction.

Carriage

Carriage is located between the headstock and tailstock on the lathe bed guide ways. It can be moved along the bed either towards or away from the headstock. It has several parts to support, move and control the cutting tool. The parts of the carriage are:
a) Saddle
b) Apron
c) cross-slide
d) Compound rest
e) Compound slide
f) Tool post

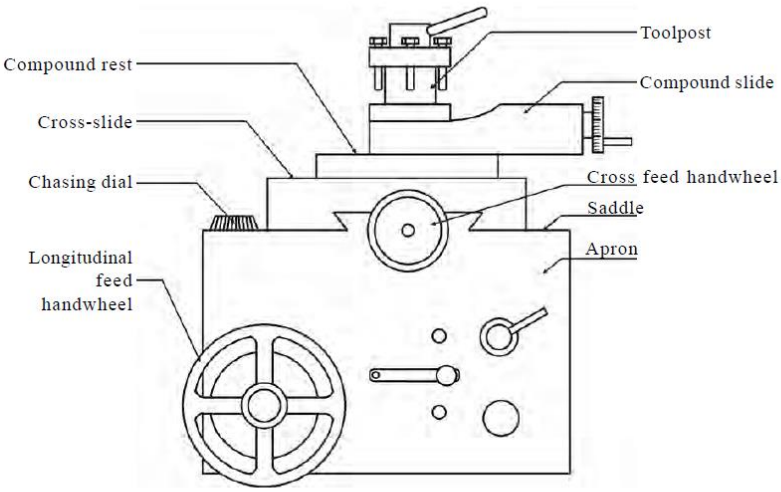


Fig 1.5 Carriage

Saddle:
It is an "H" shaped casting. It connects the pair of bed guide ways like a bridge. It fits over the bed and slides along the bed between headstock and tailstock. The saddle or the entire carriage can be moved by providing hand feed or automatic feed.

Cross slide:
Cross-slide is situated on the saddle and slides on the dovetail guide ways at right angles to the bed guide ways. It carries compound rest, compound slide and tool post.
Compound rest:
Compound rest is a part which connects cross slide and compound slide. It is mounted on the cross-slide by tongue and groove joint. It has a circular base on which angular graduations are marked. The compound rest can be swiveled to the required angle while
Turning tapers.
Tool post:
This is located on top of the compound slide. It is used to hold the tools rigidly. Tools are selected according to the type of operation and mounted on the tool post and adjusted to a convenient working position. There are different types of tool posts and they are:
1. Single screw tool post
2. Four bolt tool post
3. Four way tool post
4. Open side tool post

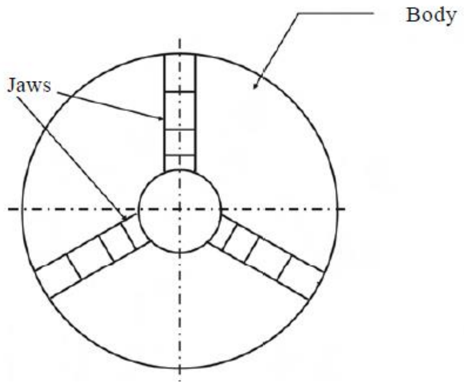
Lead screw
The lead screw is a long threaded shaft used as master screw. It is brought in to operation during thread cutting to move the carriage to a calculated distance. Mostly Lead screws are Acme threaded.

Various work holding devices in lathe

The work holding devices are used to hold and rotate the work pieces along with the spindle. Different work holding devices are used according to the shape, length, diameter and weight of the work piece and the location of turning on the work. They are
1. Chucks
2. Face plate
3. Driving plate
4. Catch plate
5. Carriers
6. Mandrels
7. Centers
8. Rests

Chucks

Work pieces of short length, large diameter and irregular shapes, which cannot be mounted between centers, are held quickly and rigidly in chuck. There are different types of chucks namely, three jaw universal chuck, Four jaw independent chuck, Magnetic chuck, Collet chuck and Combination chuck.
Three jaw self-centering chuck
The three jaws fitted in the three slots may be made to slide at the same time by an equal amount by rotating any one of the three pinions by a chuck key. This type of chuck is suitable for holding and rotating regular shaped work pieces like round or hexagonal rods about the axis of the lathe. Work pieces of irregular shapes cannot be held by this chuck.



Four jaw independent chuck

There are four jaws in this chuck. Each jaw is moved independently by rotating a screw with the help of a chuck key. A particular jaw may be moved according to the shape of the work. Hence this type of chuck can hold woks of irregular shapes

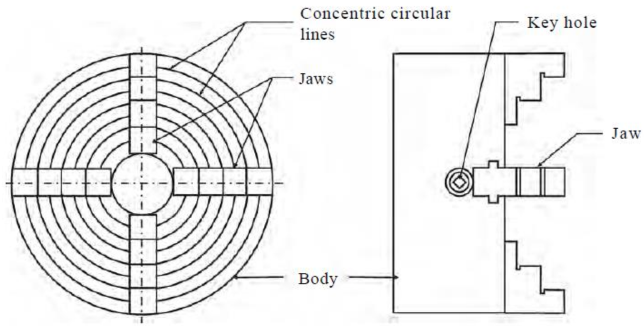


Fig 1.15 Four jaw chuck

Magnetic chuck

The holding power of this chuck is obtained by the magnetic flux radiating from the electromagnet placed inside the chuck

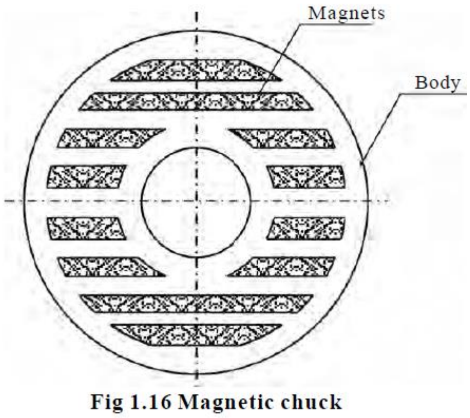


Fig 1.16 Magnetic chuck

Collet chuck

Collet chuck has a cylindrical bushing known as collet. It is made of spring steel and has slots cut lengthwise on its circumference. So, it holds the work with more grip.Collet chucks are used in capstan lathes and automatic lathes for holding bar stock in production work.

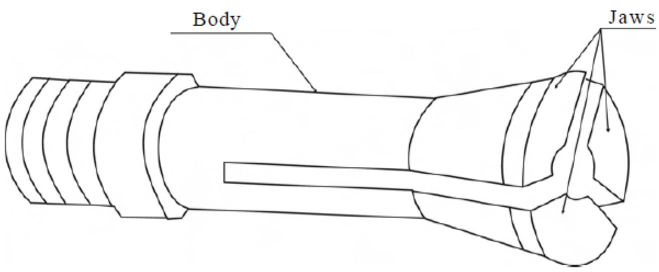


Fig 1.17 Collet chuck

Face plate

Faceplate is used to hold large, heavy and irregular shaped work pieces which cannot be conveniently held between centres. It is a circular disc bored out and threaded to fit on the nose of the lathe spindle. It is provided with radial plain and 'T' – slots for holding the work by bolts and clamps.

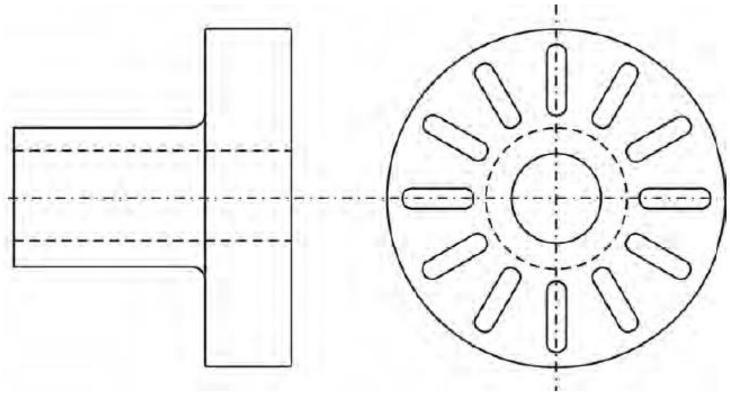


Fig 1.18 Face plate

Driving plate

The driving plate is used to drive a work piece when it is held between centers. It is a circular disc screwed to the nose of the lathe spindle. It is provided with small bolts or pins on its face. Work pieces fitted inside straight tail carriers are held and rotated by driving plates.

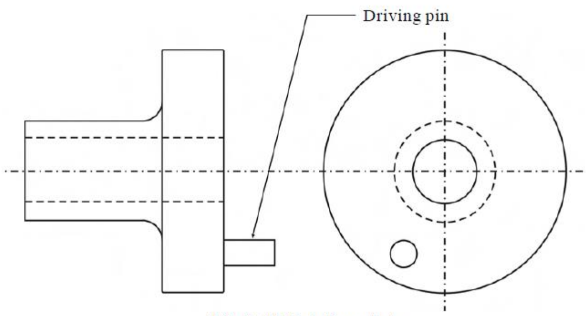


Fig 1.19 Driving plate

Catch plate

When a work piece is held between centers, the catch plate is used to drive it. It is a circular disc bored and threaded at the centre. Catch plates are designed with 'U' – slots or elliptical slots to receive the bent tail of the carrier. Positive drive between the lathe spindle and the work piece is effected when the work piece fitted with the carrier fits into the slot of the catch plate.

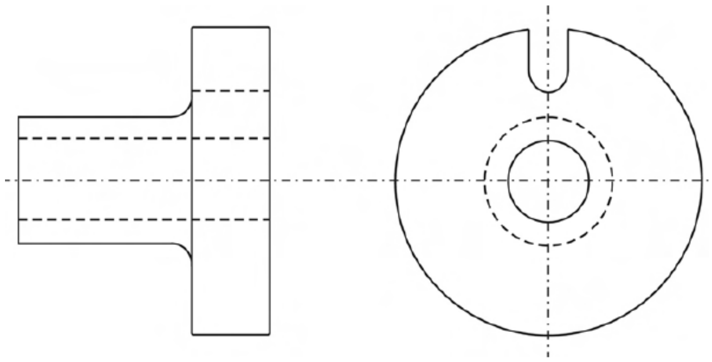


Fig 1.20 Catch plate

Carrier

When a work piece is held and machined between centers, carriers are useful in transmitting the driving force of the spindle to the work by means of driving plates and catch plates. The work is held inside the eye of the carrier and tightened by a screw. Carriers are of two types and they are

1. Straight tail carrier 2. Bent tail carrier

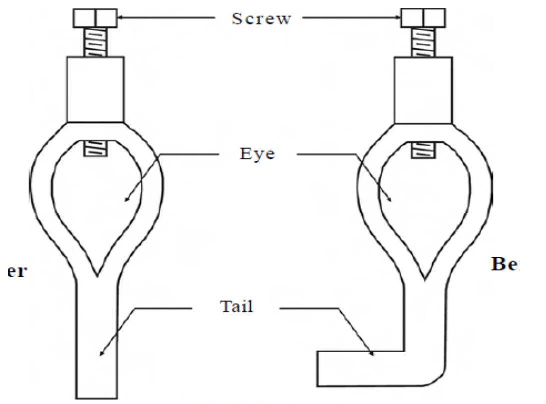


Fig 1.21 Carriers

Mandrel

A previously drilled or bored work piece is held on a mandrel to be driven in a lathe and machined. There are centre holes provided on both faces of the mandrel. The live centre and the dead centre fit into the centre holes. A carrier is attached at the left side of the mandrel. The mandrel gets the drive either through a catch plate or a driving plate. The work piece rotates along with the mandrel. There are several types of mandrels and they are:

1. Plain mandrel 5. Collar mandrel
2. Step mandrel 6. Cone mandrel
3. Gang mandrel 7. Expansion mandrel

Plain mandrel

The body of the plain mandrel is slightly tapered to provide proper gripping of thework piece. The taper will be around 1 to 2mm for a length of 100mm. It is also known as solid mandrel. It is the type mostly commonly used and has wide application.

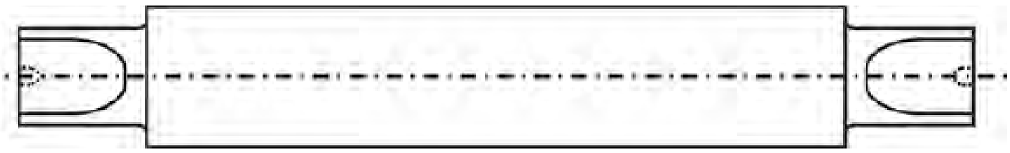


Fig 1.22 Plain mandrel

Gang mandrel

It has a fixed collar at one end and a movable collar at the threaded end. This mandrel is used to hold a set of hollow work pieces between the two collars by tightening the nut.

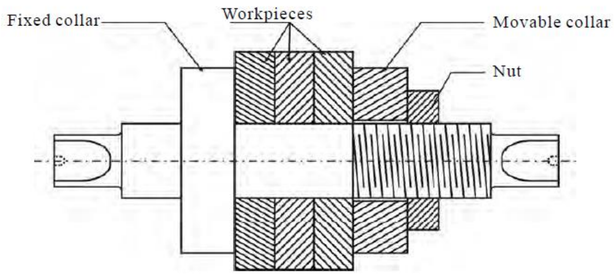


Fig 1.23 Gang mandrel

Screwed mandrel

It is threaded at one end and a collar is attached to it. Work pieces having internal threads are screwed on to it against the collar for machining.

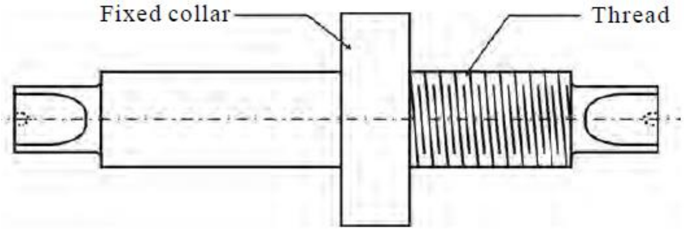


Fig 1.24 Threaded mandrel

Centers

Centers are useful in holding the work in a lathe between centers. The shank of a centre has Morse taper on it and the face is conical in shape. There are two types of centers namely

(i) Live centre
(ii) Dead centre

The live centre is fitted on the headstock spindle and rotates with the work. The centre fitted on the tailstock spindle is called dead centre.

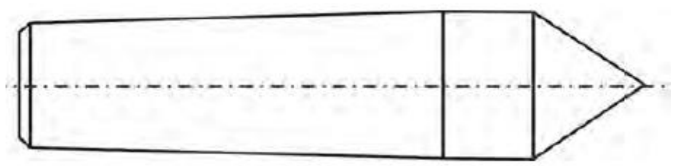


Fig 1.26 Centre

Rests

A rest is a mechanical device to support a long slender work piece when it is turned between centers or by a chuck. It is placed at some intermediate point to prevent the Work piece from bending due to its own weight and vibrations setup due to the cutting force.

There are two different types of rests

1. Steady rest
2. Follower rest

Steady rest

Steady rest is made of cast iron. It may be made to slide on the lathe bed ways and clamped at any desired position where the work piece needs support. It has three jaws. These jaws can be adjusted according to the diameter of the work. Machining is done upon the distance starting from the headstock to the point of support of the rest.

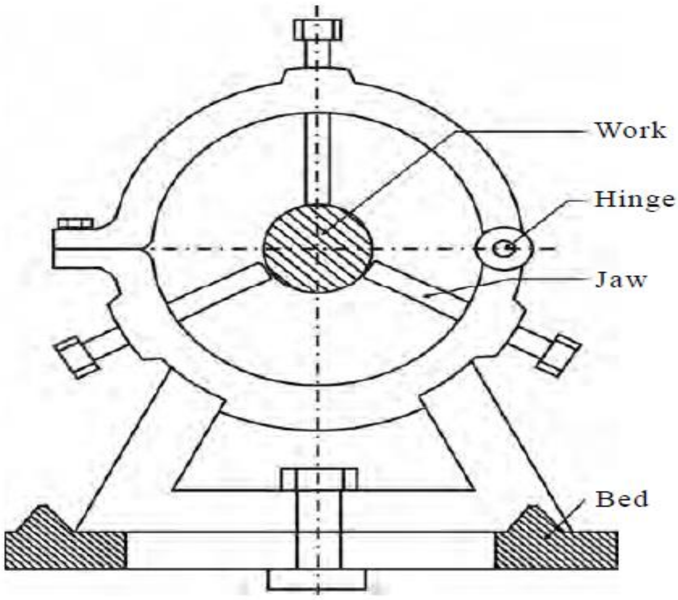


Fig 1.28 Steady rest

Follower rest

It consists of a 'C' like casting having two adjustable jaws to support the work piece. The rest is bolted to the back end of the carriage. During machining, it supports the work and moves with the carriage. So, it follows the tool to give continuous support to the work to be ableto machine along the entire length of the work.

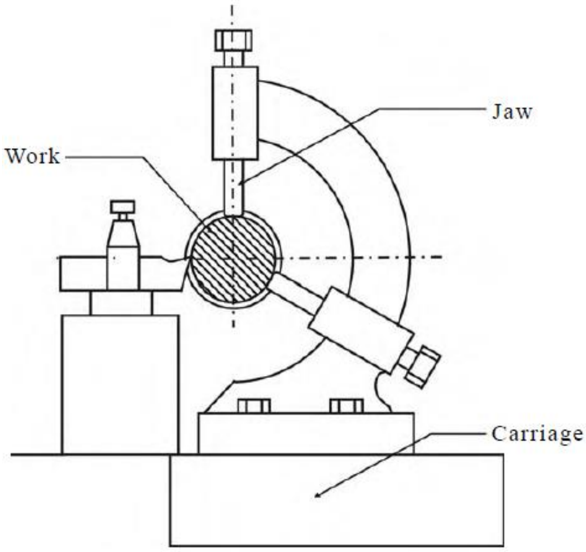


Fig 1.29 Follower rest

Operations performed in a lathe

Various operations are performed in a lathe other than plain turning. They are

1. Facing
2. Turning
a. Straight turning
b. Step turning
3. Chamfering
4. Grooving
5. Forming
6. Knurling
7. Undercutting
8. Eccentric turning
9. Taper turning
10. Thread cutting
11. Drilling
12. Reaming
13. Boring
14. Tapping

Facing

Facing is the operation of machining the ends of a piece of work to produce flat Surface Square with the axis. The operation involves feeding the tool perpendicular to the axis of rotation of the work.

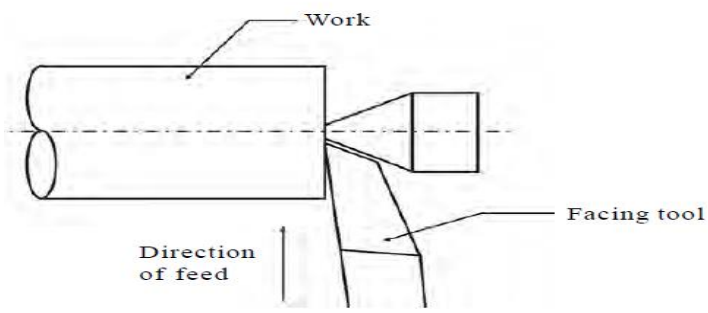


Fig 1.31 Facing

Turning

Turning in a lathe is to remove excess material from the work piece to produce a cylindrical surface of required shape and size

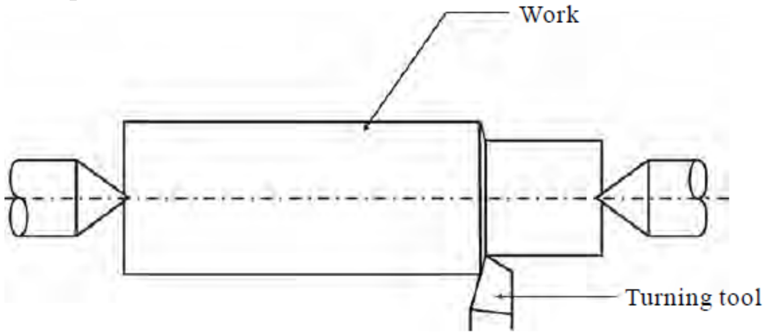


Fig 1.32 Straight turning

Chamfering

Chamfering is the operation of bevelling the extreme end of the work piece. The form tool used for taper turning may be used for this purpose. Chamfering is an essential operation after thread cutting so that the nut may pass freely on the threaded work piece.

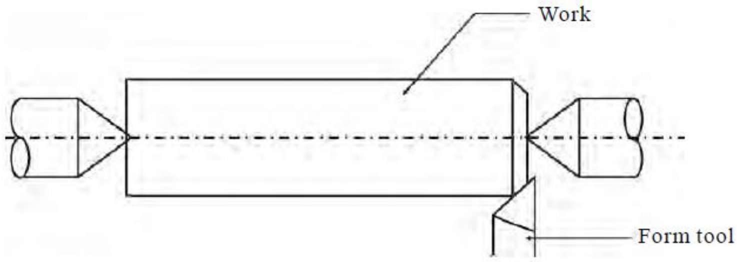
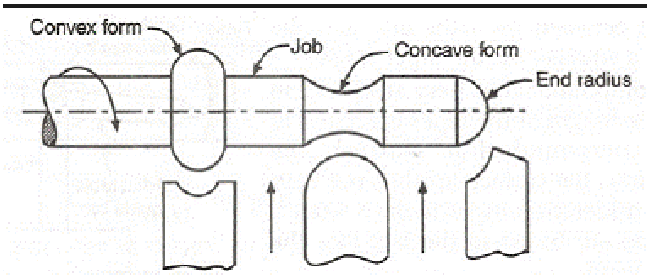


Fig 1.33 Chamfering

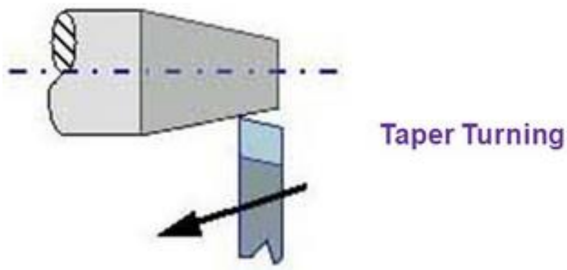
Forming

Forming is a process of turning a convex, concave or any irregular shape. For turning a small length formed surface, a forming tool having cutting edges conforming to the shape required is fed straight into the work



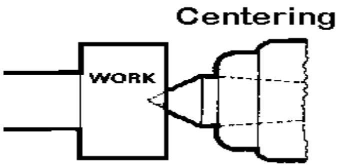
Taper turning

A taper may be defined as a uniform increase or decrease in diameter of a piece of work measured along its length



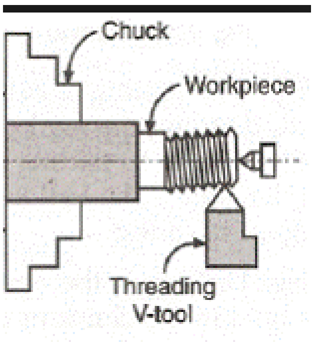
Centering

It is the process of making small conical holes at the end of the work piece for the easy supporting of the centers.



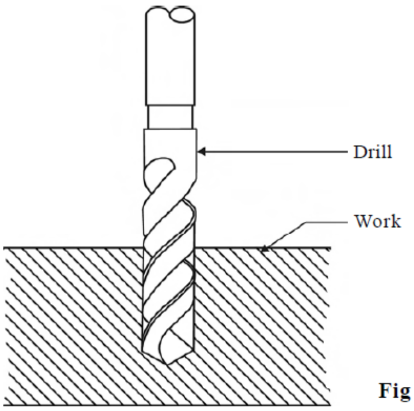
Thread cutting

Thread cutting is one of the most important operations performed in a lathe. The process of thread cutting is to produce a helical groove on a cylindrical surface by feeding the tool longitudinally.



Drilling

Drilling is the operation of producing a cylindrical hole of required diameter and depth by removing metal by the rotating edge of a cutting tool called drill. Drilling is one of the simplest methods of producing a hole. Drilling does not produce an accurate hole in a work piece.



Fig

Boring

Boring is the operation enlarging the diameter of the previously made hole.

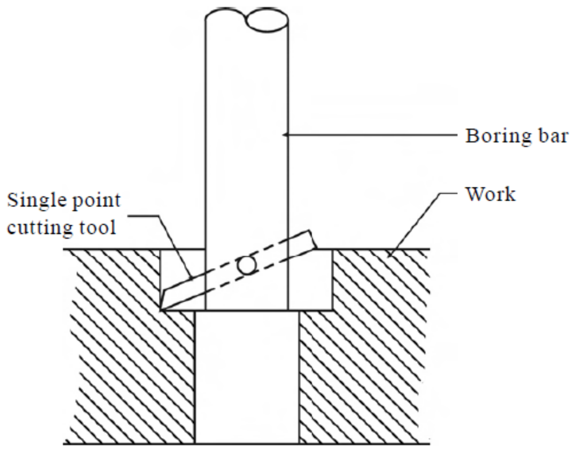


Fig 2.19 Boring

Taper turning methods

Different taper turning methods are

(1)Compound rest method (2) Tailstock set over method

Compound rest method

The compound rest of the lathe is attached to a circular base graduated in degrees, which may be swiveled and clamped at any desired angle. The angle of taper is calculated using the formula.

$$\tan \text{Ø} = \frac{D - d}{2\,l}$$

Where D – Larger diameter

d – Smaller diameter
l – Length of the taper
Ø - Half taper angle

The compound rest is swiveled to the angle calculated as above and clamped. Feed is given to the compund slide to generate the required taper. *Taper turning by compound rest method is illustrated in Fig.*

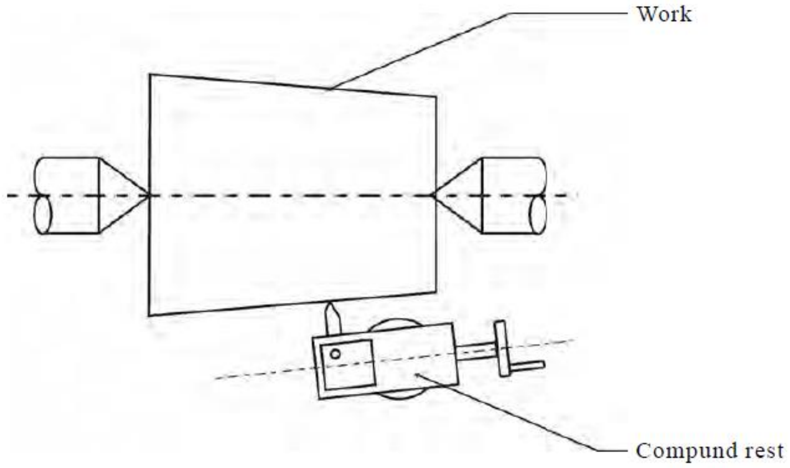


Fig 1.39 Taper turning by compound rest method

Tailstock set over method

Turning taper by the set over method is done by shifting the axis of rotation of the Work piece at an angle to the lathe axis and feeding the tool parallel to the lathe axis. The construction of tailstock is designed to have two parts namely the base and the body. The base is fitted on the bed guide ways and the body having the dead centre can be moved at cross to shift the lathe axis.
The amount of set over - s, can be calculated as follows

$$s = L \times \frac{D - d}{2\,l}$$

Where
s - Amount of set over D – Larger diameter
d – Smaller diameter L - Length of the work
l – Length of the taper

The dead centre is suitably shifted from its original position to the calculated distance. The work is held between centers and longitudinal feed is given by the carriage to generate the taper.
The advantage of this method is that the taper can be turned to the entire length of the work. Taper threads can also be cut by this method. The amount of set over being limited, this method is suitable for turning small tapers (approx. up to 8°). Internal tapers cannot be done by this method.

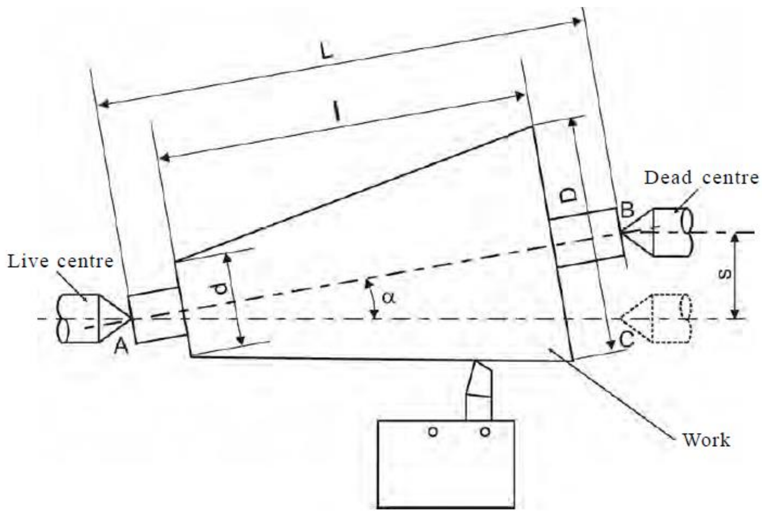


Fig 1.40 Taper turning by tailstock setover method

Thread cutting

Thread cutting is one of the most important operations performed in a lathe. The process of thread cutting is to produce a helical groove on a cylindrical surface by feeding thetool longitudinally.

1. The job is revolved between centers or by a chuck. The longitudinal feed should be equal to the pitch of the thread to be cut per revolution of the work piece.
2. The carriage should be moved longitudinally obtaining feed through the lead screw of the lathe.
3. A definite ratio between the longitudinal feed and rotation of the headstock spindle should be found out. Suitable gears with required number of teeth should be mounted on the spindle and the lead screw.
4. A proper thread cutting tool is selected according to the shape of the thread. It is mounted on the tool post with its cutting edge at the lathe axis and perpendicular to the axis of the work.
5. The position of the tumbler gears are adjusted according to the type of the thread (Right hand or left hand).
6. Suitable spindle speed is selected and it is obtained through back gears.
7. Half nut lever is engaged at the right point as indicated by the thread chasing dial.
8. Depth of cut is set suitably to allow the tool to make a light cut on the work
9. When the cut is made for the required length, the half nut lever is disengaged. The carriage is brought back to its original position and the above procedure is repeated until the required depth of the thread is achieved.
10. After the process of thread cutting is over, the thread is checked by suitable gauges.

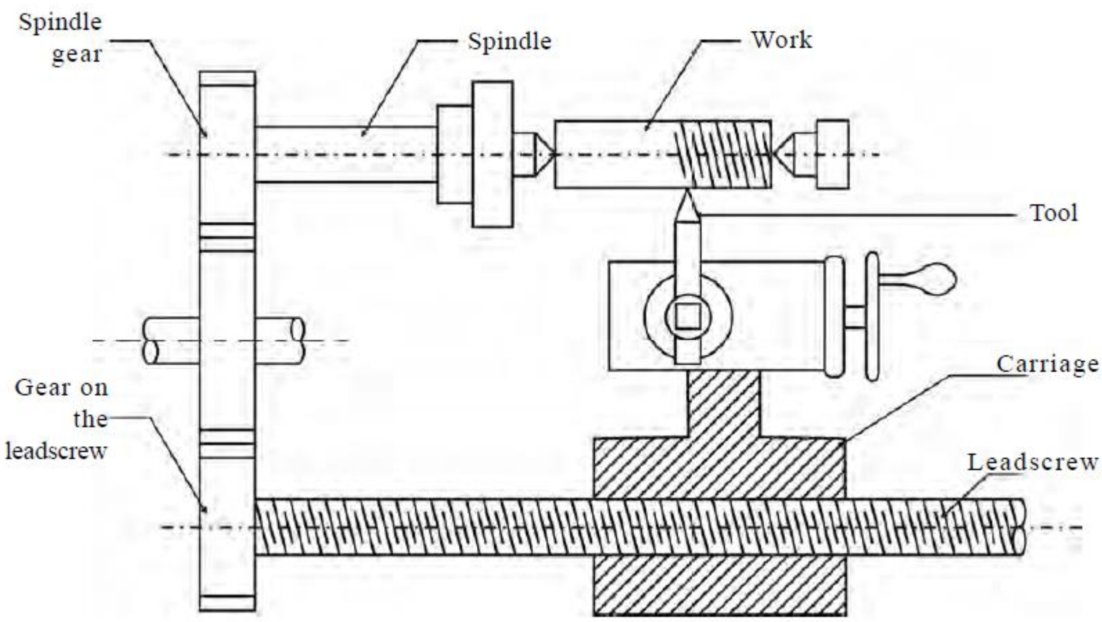


Fig 1.42 Thread cutting

Feed

The feed of a cutting tool in a lathe work is the distance the tool advances for each revolution of the work. Feed is expressed in millimeters per revolution.

Depth of cut

The depth of cut is the perpendicular distance measured from the machined surface to the uncut surface of the work piece. It is expressed in millimeters. In a lathe, the depth of cut is expressed as follows

$$\text{Depth of cut} = \frac{d_1 - d_2}{2}$$

'd_1' - diameter of the work surface before machining
'd_2' - diameter of the machined surface