TOOL DESIGN

MECH-III YR

Prepared by

Mr. Ch. Sandeep

Assistant Professor

Department of Mechanical Engineering

Institute of Aeronautical Engineering

(Autonomous)

Dundigal, Hyderabad

UNIT-I

Tool Material

- Technically any steel used as a component part of a tool could be called a tool steel.
- As almost any steel could be used for certain part of a tool.
- A steel containing alloying elements that enable it to be heat-treated to obtain desirable characteristics such as strength, hardness, toughness and wear resistance could be referred to as a tool steel.

Classification of tool steels

1. According to the method of quenching, such as water-hardening steels, oil-hardening steels and air-hardening steels.
2. According to alloys such as carbon tool steels and alloy tool steels.
3. According to applications such as shock-resisting steels, cold-working steels, hot-work steels, die-casting die steels, drill steels, tools & die steels etc.

The American Iron & Steel (AISI) and the society of Automotive Engineers (SAE) has developed a system of classifying tool steels which groups grades of similar properties.

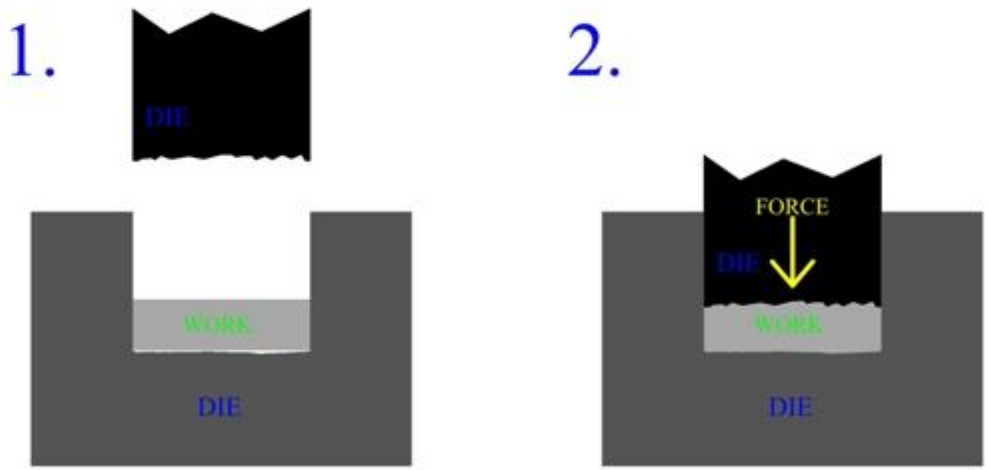
1. Water –Hardening tool steels: Group W

- The water hardening or carbon steels (group W) are one of the oldest types of tool steels. They depend primarily upon carbon content for their heat-treatable properties with additions of chromium & vanadium.
- Chromium is added to increase hardenability & wear resistance, while vanadium is added to refine the grain for added toughness.

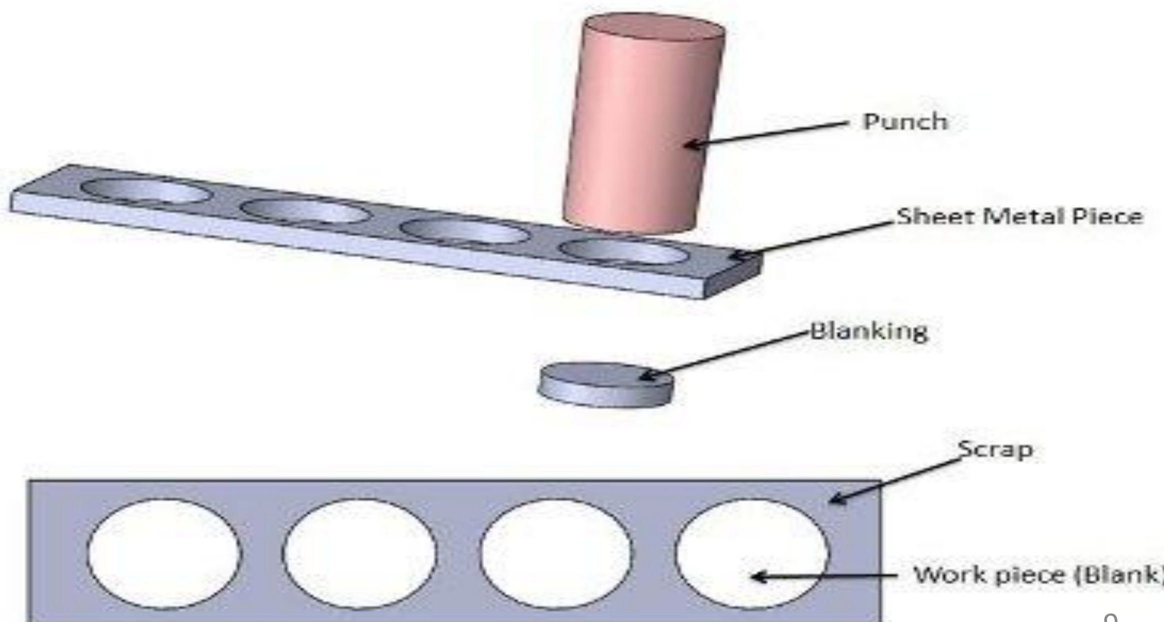
- Carbon content varies from 0.60 to 1.40 %, with approximately 1.0 % carbon being the most.
- They are easy to machine compared to other steels and require relatively simple heat-treating methods.
- They are suitable for light or medium cold impact operations such as coining, cold heading , punching, knurling, embossing and for wood & metal hand cutting tools.

- They are probably the best all-round tool steels under lower temperature working conditions.
- The water-hardening tool steels should not be used when the tool has drastic crack during heat treatment.
- The added expense of oil-or-air-hardening grades may pay in this situation.

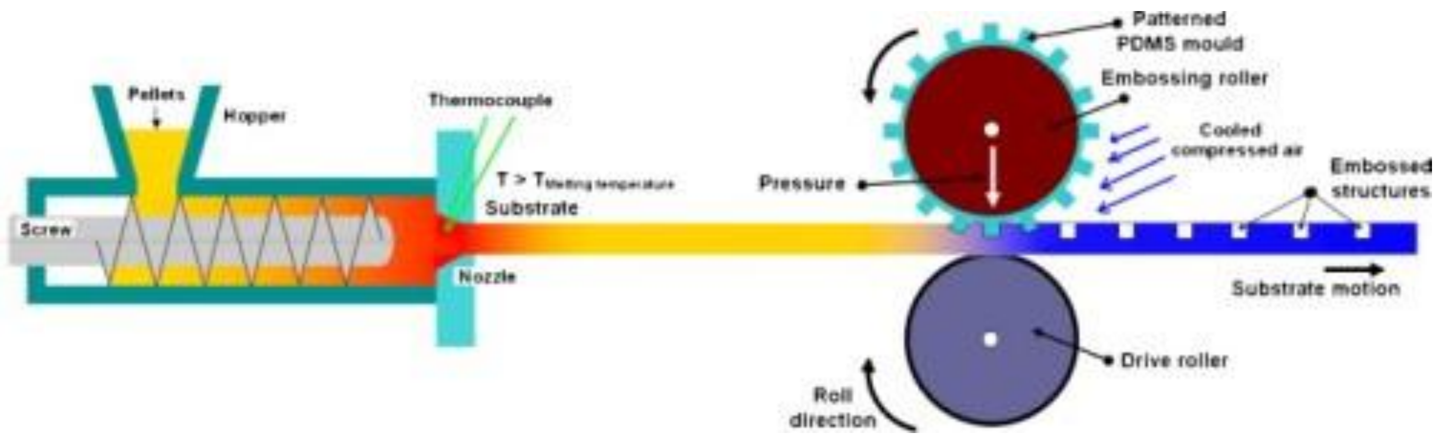
COINING PROCESS



PUNCHING




Knurling
Rotation of Work.
Work rotates very slowly for Knurling
Knurl,
Pattern produced
Direction of Knurling Tool
Wheels are pushed against surface to produce a pattern
Knurling Tool


Pellets
Hopper
Thermocouple
Screw
Substrate
Nozzle
Pressure
Patterned PDMS mould
Embossing roller
Cooled compressed air
Embossed structures
Substrate motion
Drive roller
Roll direction

EMBOSSING

2. Shock-Resisting tool steels: Group S

- These steels are used for shock operations at normal temperatures and where maximum abrasion resistance is not required.
- They contain less carbon and have higher toughness and hardness.
- The chief alloying elements are silicon, chromium, tungsten and molybdenum, these alloys increase hardenability and provide heat and wear resistance.

- The high tungsten types are characterized by higher heat resistance
- The applications of Group S tool steels include pneumatic chisel, heavy-duty shear blades, punches, rivet busters and similar tools for cold battering operations.
- They are also suitable for machine parts that require high shock resistance.

1

1. Pneumatic chisels
2. Heavy duty shear blades

2

3

4

5

3. Punches
4. Rivet Busters
5. Tool for cold battering operations

3. Oil-Hardening Cold-Work steels: Group O

- Group O tool steels are one of the more important groups in that they are able to overcome some of the difficulties encountered in the use of water hardening steels (i.e., Group W)
- They lend themselves to safer hardening and have less dimensional change during heat treatment.

- They are relatively inexpensive, readily available, have a good machinability, good resistance to decarburization and have a high enough carbon content to provide good wear resistance.
- The depth of hardening is greater than that of water-hard steels and as a result they are usually less tough.
- They do not have high red hardness and therefore must be used for tools that will operate near room temperatures.

- These steels have a wide range of applications: specific examples are blanking, bending, trimming, coining, shearing and shaping dies, thread rolling dies, broaches, knurling tools, gages and other applications beyond the scope of carbon grades.

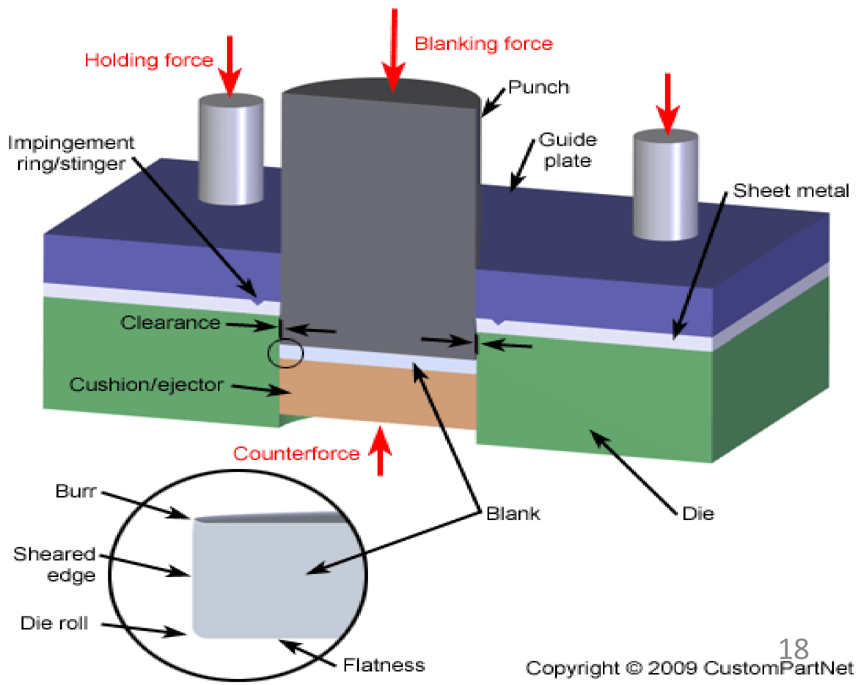
Blanking

•When a component is produced with one single punch and die where the entire outer profile is cut in a single stroke the tool is called a blanking tool.

•Blanking is the operation of cutting flat shapes from sheet metal.

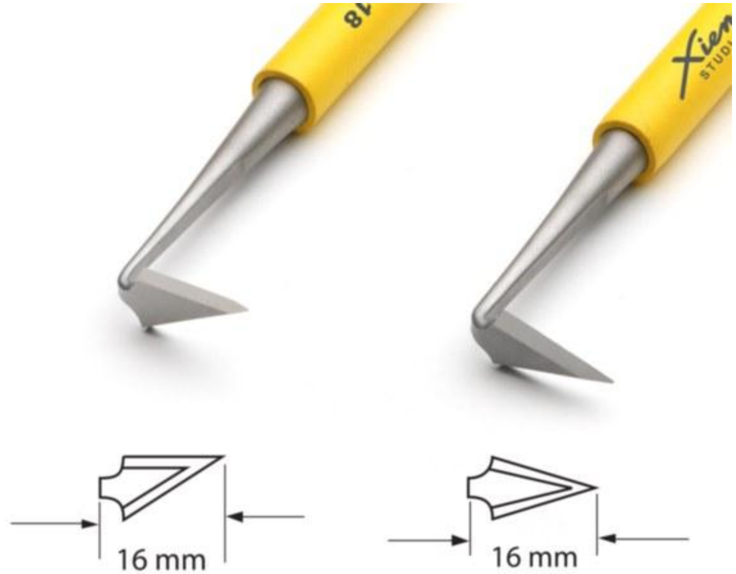
•The outer area of metal remaining after a blanking operation is generally discarded as waste.

•It is a metal cutting operation.



Trimming

When cups and shells are drawn from flat sheet metal the edge is left wavy and irregular, due to uneven flow of metal. Shown is flanged shell, as well as the trimmed ring removed from around the edge. While a small amount of Material is removed from the side of a component in trimming tool.



Broaching

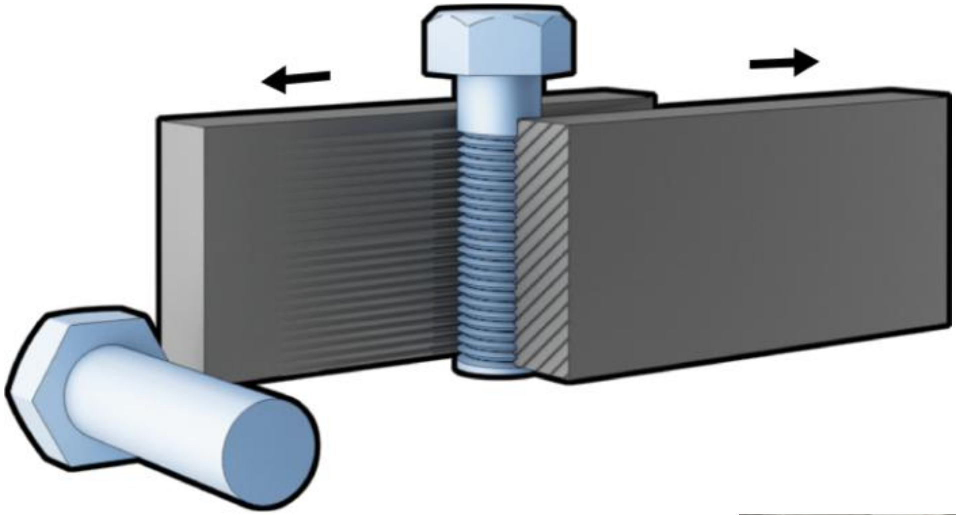
Broaching is a machining process that uses a toothed tool, called a **broach**, to remove material. There are two main types of broaching: linear and rotary.

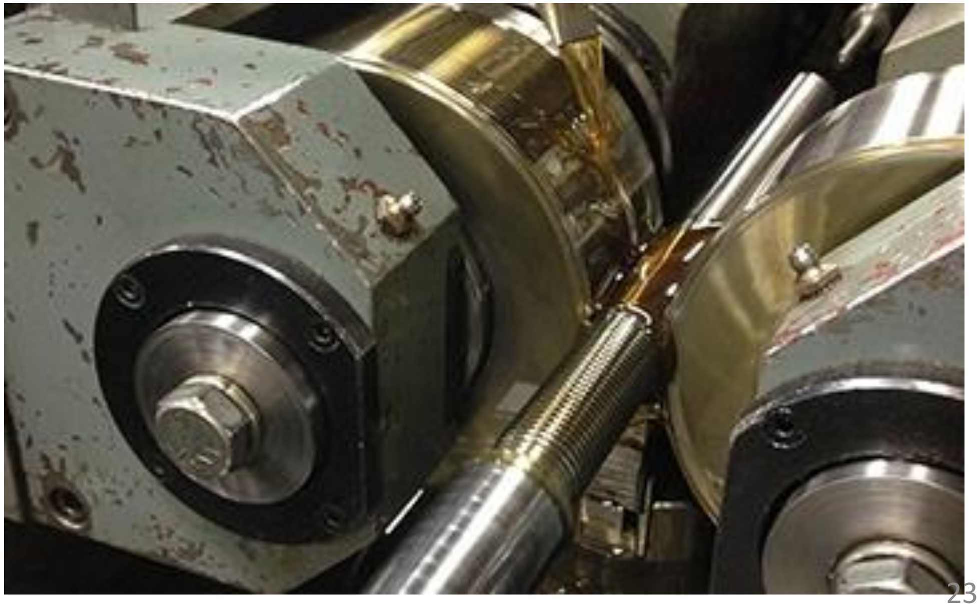
4. Air-Hardening Cold-Work steels: Group A

- Air-hardening tool steels have the advantages of oil-hardening tool steels but to a greater extent.
- Manganese, chromium, molybdenum and vanadium are the chief alloying elements and their main function is to promote air-hardening characteristics which result in excellent dimensional stability.

- The high carbon content provides good wear resistance, and the high-manganese grades may be hardened at lower temperatures, thus reducing scaling and further reducing dimensional change.
- The Air-hardening grades are applicable to intricate tool shapes such as thread-rolling dies, long slender broaches, dies with projections and other applications where resistance to distortion and abrasion is of prime importance.

Thread Rolling Dies





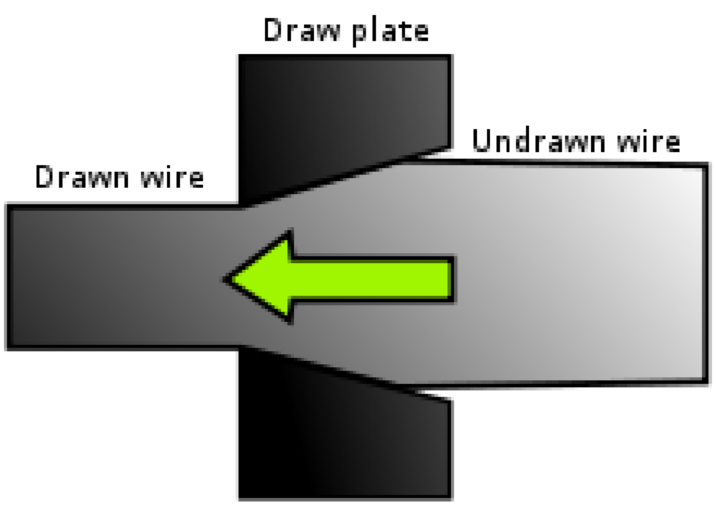
5.High-Carbon-High-Chromium Cold-Work Steels: Group D

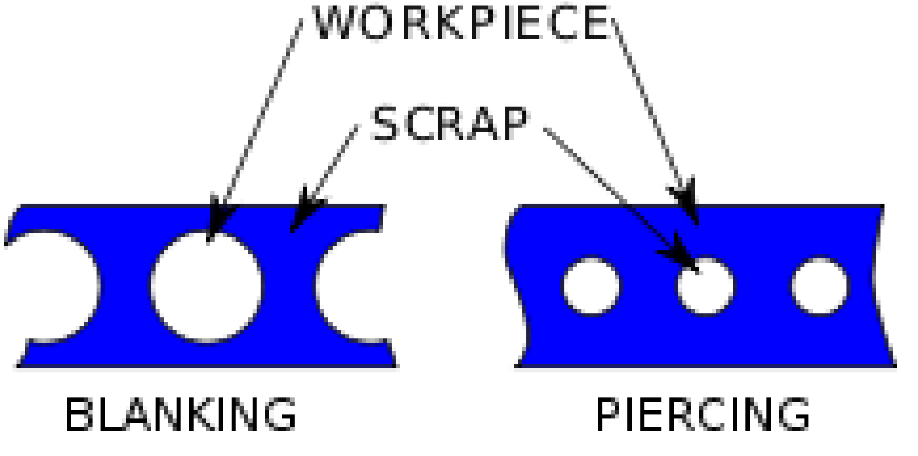
- Group D tool steels combine high wear resistance with deep hardening properties.
- These characteristics are caused by the high content of chromium and carbon.
- They have extremely low dimensional change during hardening & have a medium resistance to heat softening.

- They are susceptible to edge brittleness, which makes them unsuitable for edge-cutting tools.
- Specific applications for group D steels are wire-drawing dies, master gages, intricate blanking & piercing dies and other applications where dimensional stability and long-wear properties are important.

Wire drawing

Wire drawing is a metal working process used to reduce the cross-section of a wire by pulling the wire through a single, or series of, drawing dies

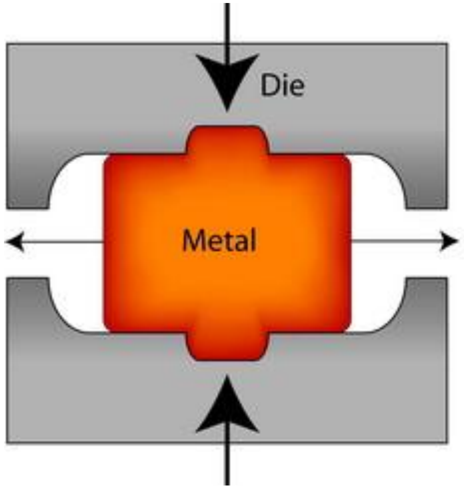


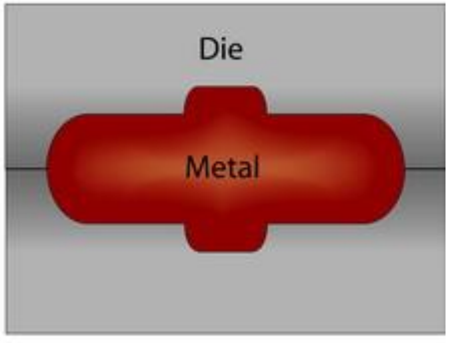


6. Hot-Work tool steels: Group H

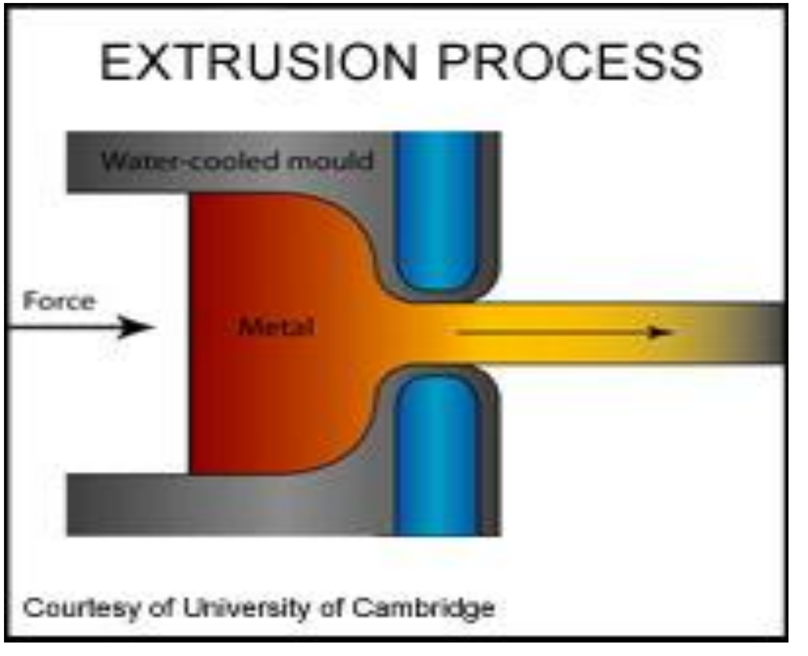
- The tool steels discussed to this point have from low to medium resistance to heat softening.
- Group H tool steels have been alloyed to withstand high working temperatures for such applications as hot-forging dies, hot-extrusion dies, hot shear, die-casting dies and plastic-molding dies.

Hot Forging





Hot extrusion die



6. Hot-Work tool steels: Group H

(i) Chromium hot-work tool steels (group H11 to H16)

(ii) Tungsten hot-work tool steels (group H20 to H26)

(iii) Molybdenum hot-work tool steels (group H41 to H43)

(i) Chromium hot-work tool steels (group H11 to H16)

- These contain from 5 to 7% chromium and smaller amounts of vanadium, tungsten and molybdenum.
- In addition to good red-hardening properties, they are extremely deep-hardening and have good dimensional stability during hardening.

(ii) Tungsten hot-work tool steels (group H20 to H26)

- These contain from 9 to 18% tungsten and 2 to 12% chromium these alloys increase in resistance to high-temperature softening & washing compared to grades H11 to H16.
- They are however more brittle at working hardness and generally cannot be successfully water-cooled during service.

(iii) Molybdenum hot-work tool steels (group H41 to H43)

- These contains 5 to 9.5% of molybdenum, 4% chromium, 1.5 to 6.5% tungsten and smaller amounts of vanadium.
- They have properties almost identical to those of the H20 to H26 steels, their main advantage being a lower initial cost.

Cast-Iron

- Gray cast iron is sometimes used as the main body of jigs & fixtures. It is sometimes easier to cast a shape than to build it up with pieces of steels.
- Metal may be placed to better advantage and as a result the weight of the fixture or jig may be reduced.
- The stability and compression strength of gray cast iron as well as its ease of casting make it suitable for this purpose.
- Cast Iron is also used in the construction of large forming and drawing dies as a material for die-set shoes.

Mild or Low- Carbon Steel

- Low-carbon steels are used extensively by the tool designer.
- Hot and cold-rolled flats, cut to size and properly machined are used as component parts of jigs & fixtures where wear resistance and maximum strength are not a necessity.
- Standard structural shapes are used in the construction of frame works for large jigs and fixtures.

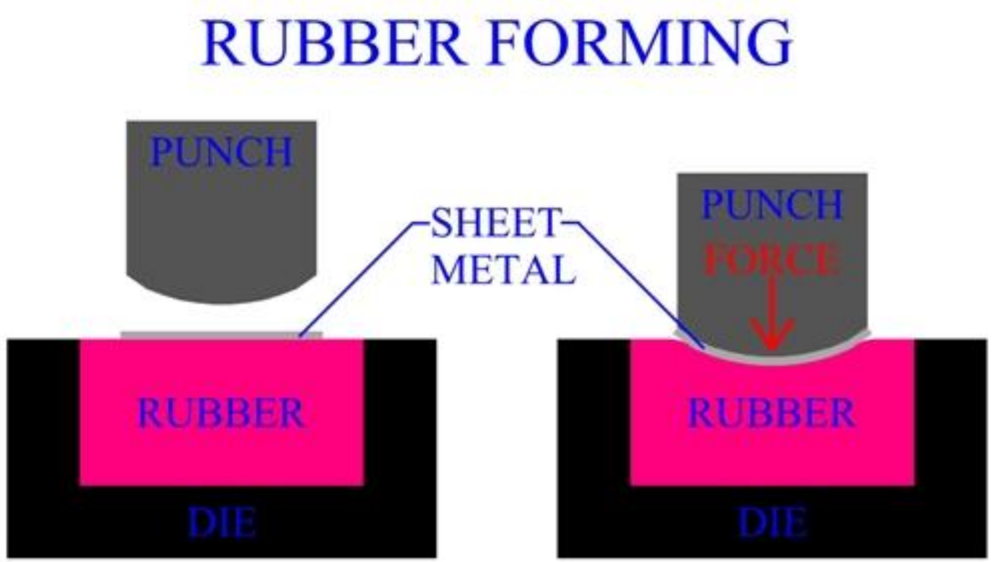
- Cold- rolled shapes are smoothly and accurately finished and are commonly used for component parts that require little or no machining.
- Hot-rolled shapes have an oxide scale and are not finished as accurately as cold-rolled but are lower in cost and therefore may be used when extensive machining is necessary.

- Hot-rolled shapes are also better suited when the tool is fabricated by welding, as cold-rolled steel has a greater tendency to wrap when heated or machined due to the extra stresses set up during the cold-rolling operation at the steel mill which are relieved during heating or machining.

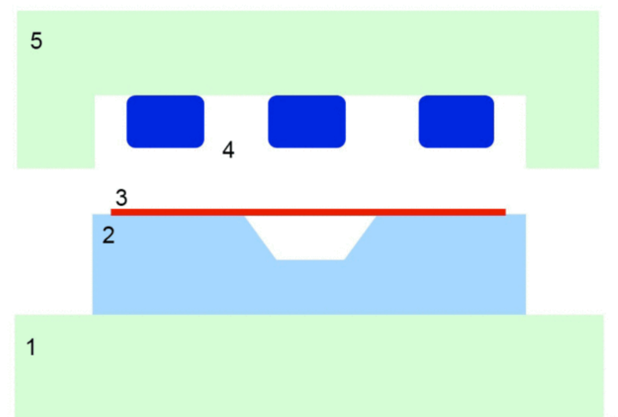
Non-Metallic Tooling Materials

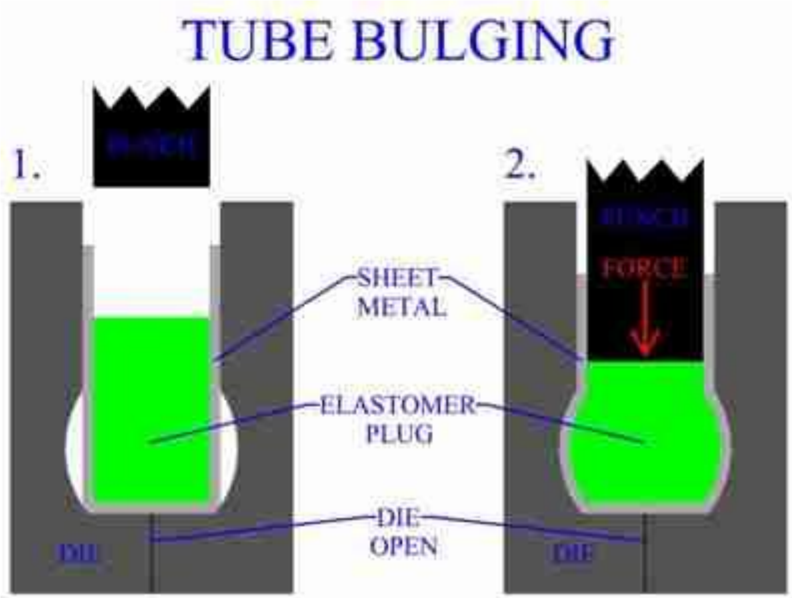
1. **<u>Rubber</u>**

- This material in the form of a rubber pad is used in various specialized forming, drawing, blanking and bulging operations.
- It is also used as stripper material with conventional punches and dies.



1. Bottom of the press
2. Lower Die
3. Sheet Metal
4. Rubber Pad
5. Top of the press





Rubber Strippers

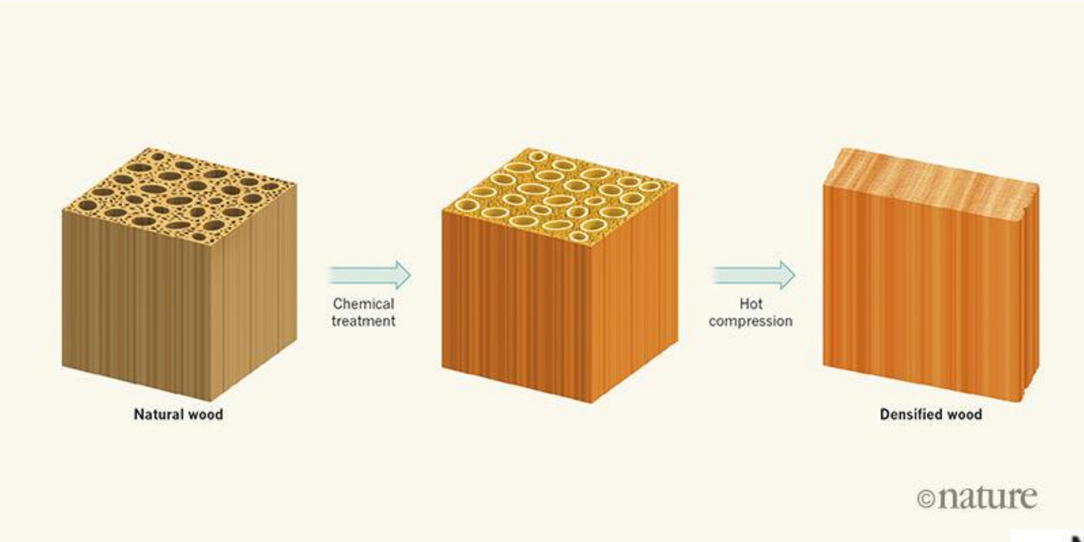
2. Masonite

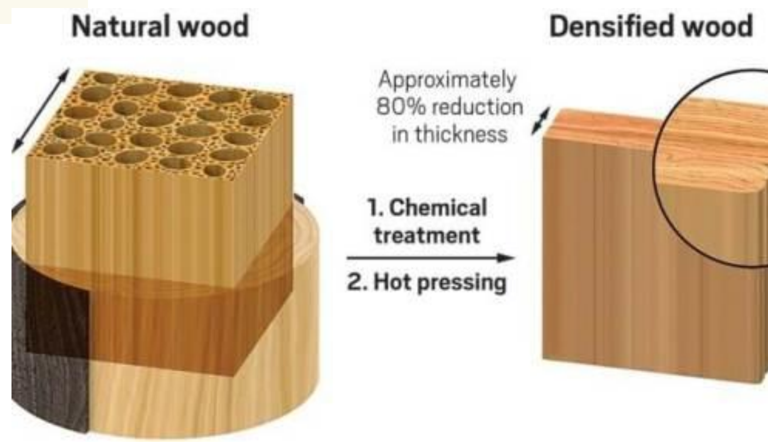
- This is a cellulose material that is sometimes used for the construction of punches and dies in drawing operations on this gages of metal.
- Typical examples would be form blocks in rubber forming & stretch dies.
- It can be used for blanking and punching operations providing steel inserts are used to provide cutting surfaces.
- Its advantages in its light weight, ease of working, ease of repair and the fact that it doest scratch the finished part.

Masonite is a type of hardboard, another kind of engineered wood, which is made of steam-cooked and pressure-molded wood fibers

3. Densified Wood

- Various woods are laminated and impregnated with phenolic resin and compressed to about 50% of the original thickness of the wood layers.
- Densified woods are used in the construction of forming and drawing dies for soft materials.
- They are also used for the die-board component of steel-rule dies.





- Densified wood is made by using a mechanical hot press to compress wood fibers and increase the density by a factor of three. This increase in density is expected to enhance the strength and stiffness of the wood by a proportional amount.

4. Plastics

- The aircraft industry is responsible for the major developments of plastic as tooling materials, because of short lead times and limited production runs of aircraft parts.
- The advantages of plastics as tooling materials are reduced labor cost, reduced lead time, ease of tool-design changes, easy revision and repair, inexpensive fabricating equipment, ease of duplication and resistance to moisture, temperature and chemicals.

- The choice between plastics & other conventional tooling materials generally depends upon the severity of operation & the length of the production run.
- The major plastics used in various types of tooling are phenolics, polyisters, urethanes and epoxies.

- They are suited for an unlimited number of applications, such as : stretch dies, hydraulic-press dies, draw die, mockups, prototypes, fixtures, drill jigs, assembly fixtures, press-brake dies and duplicator patterns.
- They can be laminated with other materials, surface-cast, mass-cast are used as paste plastic tooling.

5. Oxide cutting tool materials

- As a tooling material the application of oxides is generally limited to cutting tools. It is a relatively new cutting-tool material.
- Many improvements have been made since its introduction, and certain machining operations it has distinct advantages.
- It does however, have distinct limitations, as it is one of the newer cutting tools, requires improvements.

6. Diamonds

- Diamond powder is used for grinding & polishing, while whole diamonds are used as turning tools, grinding-wheel dressers & inserts for wire-drawing dies.
- Industrial diamonds are either natural or man-made. They are considered to be the hardest know substance.
- Other characteristics are high abrasion resistance, chemical inertness, high strength,

-high melting point, high modulus of elasticity and low compressibility.

- Diamonds are used in precision production turning of plastics, precious metals, light metals and difficult to machine materials.
- They are used in place of other cutting-tool materials because their hardness and lasting sharp cutting edges reduce deflection forces and cut through the grain structure of the material.

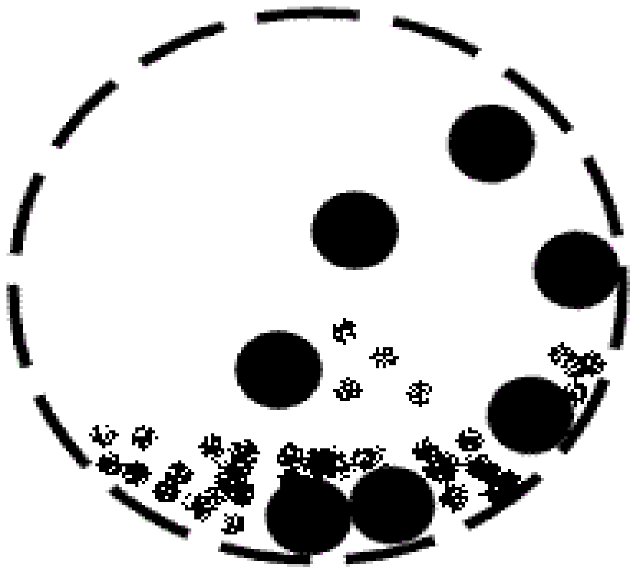
- This result in less surface smear, an excellent surface finish and extremely close tolerance work.
- They are generally used only as finishing tools with light cuts, fine feeds and high cutting speeds.
- Depths of cuts may be from 0.001 to 0.005 in., with tolerances of 0.005in., and closer being held.
- The machining speed is usually as high as the machine will operate without vibration.

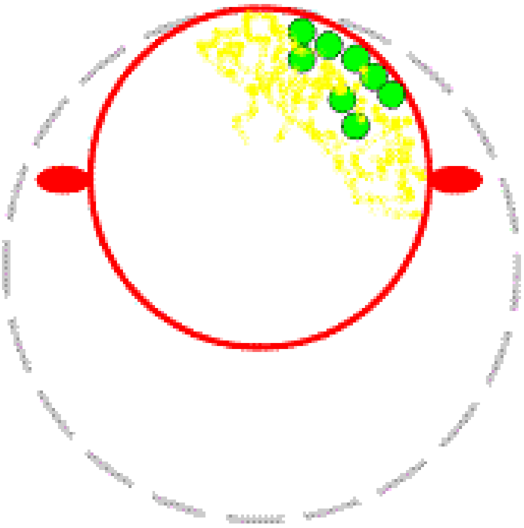
Non-ferrous tooling materials

A. <u>Sintered Carbides:</u>

- The sintered or cemented carbides are basically hard carbides of tungsten, titanium and tantalum held together with a cobalt binder.
- Other materials may be involved such as chromium and nickel.
- They are products of powder metallurgy, which fundamentally consists of mixing powder carbides with powder cobalt in a ball mill, followed by pressing or compacting the mixed powder into the desired shape

A **ball mill** is a type of grinder used to grind and blend materials for use in mineral dressing processes, paints, pyrotechnics, ceramics and selective laser sintering. It works on the principle of impact and attrition: size reduction is done by impact as the balls drop from near the top of the shell.





- The resulting blank is then presintered to increase the hardness so that it can easily be handled & formed.
- It is then formed by various machining methods and final-sintered to complete the process.
- Sintered carbides are characterized by high hardness, high compressive strength and high red hardness.
- They are used for metal cutting more than any other operation.

- Cutting speeds & feed are generally higher than those used with high-speed steel & cast-alloy cutting tool materials.
- SFM (Surface Feet per Minute)

Two types of classification:

1. The straight tungsten carbide grades:

- Contains tungsten carbide and cobalt along with small amounts of titanium and tantalum.
- Used for machining Cast Iron, Non-Ferrous & Non-Metallic materials.

2. The Steel-cutting grades:

- Contains larger amounts of titanium and tantalum carbides.
- Used for machining steels & steel alloys. The heavy additions of titanium and tantalum prevent the steel chip from causing cratering (washing out of carbide particles from behind the cutting edge).

B. **Cast Non-Ferrous Alloys:**

- It is also called cast alloys, these tools materials are chiefly composed of cobalt, chromium, tungsten & carbon.
- They are usually cast to the desired shape & size and thus are named cast alloys.
- High red hardness & abrasion resistance are characteristics of these alloys.
- They do not have to be heat-treated, as hardness in the range RC60 to 65

- The hard grades are primarily used as cutting tools and are able to withstand cutting speeds twice as high as employed with high-speed cutting tools.
- They are weaker and more brittle than high-speed tools but are able to withstand more shock than carbide cutting tools: as a result they serve as a cutting material with characteristics intermediate between high-speed steel and sintered carbides.

C. **Zinc-base Alloys:**

- These alloys may be used as materials for punches and dies for short-run production of aluminum sheet upto 0.064 in thick.
- The main advantage of this application is the ease and speed of fabrication.
- They may be used in the form of tooling plate or may be cast.

- Cast tools form well to the desired shape and require little machining.
- When used as punch & die materials, Zinc-base alloys tend to flow towards the cut and in this respect tend to be self- sharpening.

D. <u>Bismuth Alloys:</u>

- The bismuth or low-melting alloys are alloys of bismuth, lead, tin, cadmium & other metals.
- They are referred to as low-melting alloys because the melting points may be below the boiling point of water.
- High-bismuth alloys expand when they solidify which makes them excellent material for duplicating mold detail.

- Bismuth alloys are available commercially in a number of compositions, depending upon the characteristics desired.
- Specific applications are molds for duplicating plaster or plastic patterns, anchoring punches and dies for blanking, chucks for holding special or irregular contour parts, stretch press form blocks, tracer models for pantograph engraving & duplicating.

E. Magnesium:

- The important characteristics of magnesium compared to other materials is its light weight.
- For this reason it is used as structural material for large assembly fixtures in the aircraft industry.
- The main advantages is that fixtures are easier to handle.
- Another advantage is that it doesn't deflect under its own weight as many heavier materials do.

- It is also easily machined and welded.
- The thermal expansion is almost the same as aluminum, which makes it particularly well suited for the aircraft industry.
- Magnesium is also used as tooling plate & facing material for forming blocks.

Heat Treating

- Heat treatment or heat treating, is a process where by the physical properties of a metal are changed by subjecting it to a combination of heating & cooling.
- The purpose may be to harden, soften, toughen, stress-relieve, increase machinability, increase strength or a combination of these.
- The degree and rate oh heating and cooling will depend upon the properties desired.

1. **Normalizing:**

- The purpose of normalizing is to put a ferrous material back into a normal structure after forging, casting or improper heat treatment.
- The process results in grain refinement, homogeneity of the structure and in some cases increased machinability.

- These properties put a steel into a condition that enable it to respond correctly to further heat treatments.
- Normalizing is accomplished by heating the steel approximately 100°C above the usual hardening temperature and allowing it to cool in still air.

2. Annealing:

- The purpose of annealing is generally to soften, although the term is sometimes used when the purpose is to stress-relieve.
- A tool steel may be annealed in order that it may be machined .
- Annealing for the purpose of softening is accomplished by heating the steel to a temperature slightly above its hardening temperature and cooling slowly in the furnace or in a heat-insulating material such as Lime, ashes or powdered asbestos.

3. Spheroidizing:

- Carbon steels with a high percentage of carbon may be difficult to machine even though they have been annealed.
- A heat-treating process which will improve the machinability of a steel in this condition is known as Spheroidizing or spheroidize annealing.
- This process reduces the length of the carbides and produces a spheroidal form. This structure is easier to machine.

- Spheroidizing is accomplished by prolonged holding at a point just below the lower critical temperature or by heating and cooling alternatively between temperatures that are just above and below the lower critical temperature.

4. Critical temperature: various transformations occur

5. Critical cooling: cooling needed to harden a steel

6. Hardenability: cooling rapidly to get max hardness

7. Stress relieving: heating steel and holding to reduce stress

8. Stabilizing: In order to prevent dimensional change

9. Hardening: heating tool to get harden.

10. Pack hardening: prevent from scaling
11. Quenching: cooling heated piece metal.
12. Tempering: reheating the steel after hardening
13. Double tempering: Higher alloyed tools steel
14. Decarburization: loss of carbon on the surface
15. Microstructure: refers to structure revealed by a microscope.
16. Preheating: reduce thermal shock when cooled tool is placed directly into a very hot furnace.

Factors affecting heat treating

1. **Temperature**: If the hardening temperature is too low, the tool-steel will not harden properly or may harden only on the outer portions.

- If it is too high, excessive grain growth, scaling, decarburization and wraping may be result.

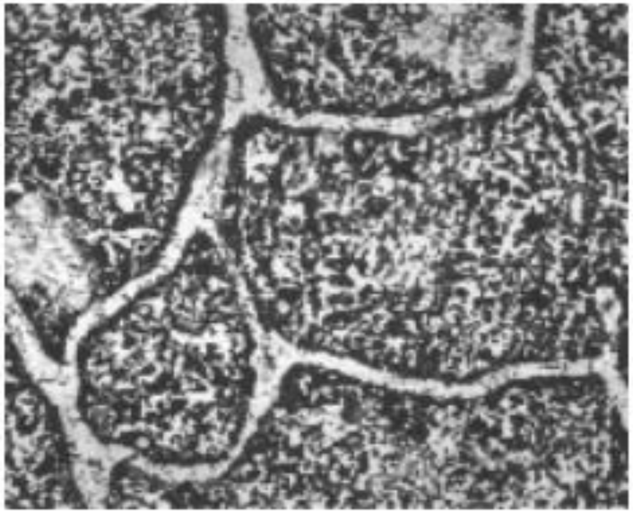
2. **Time:** Time in heat treating involves the rate at which the steel is heated to its hardening temperature, the degree of soaking at this temperature, the length of soaking at the tempering temperature etc.

3. **Atmosphere:** There are three types of atmosphere found in heat-treatment furnaces: (i) Neutral, (ii) Oxidising and (iii) Reducing.

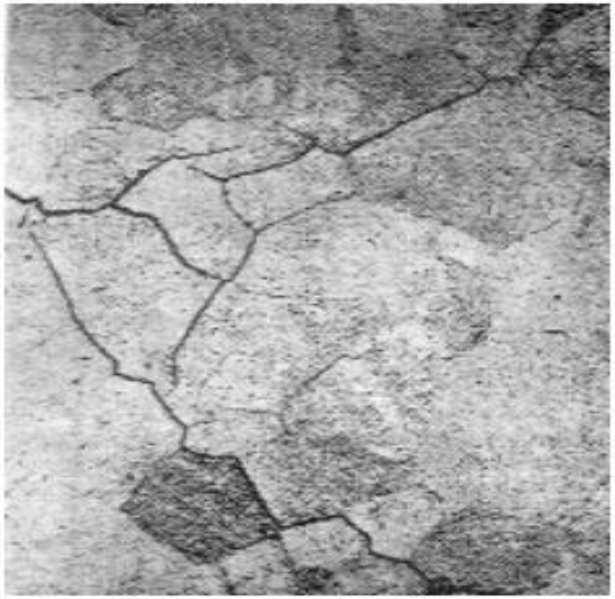
(i) **Neutral:** A truly neutral furnace atmosphere does not affect the composition of the tool being heated.

(ii) **Oxidizing:** An oxidizing atmosphere contains an excess of oxygen caused by more air than necessary being admitted to the fuel mixture.

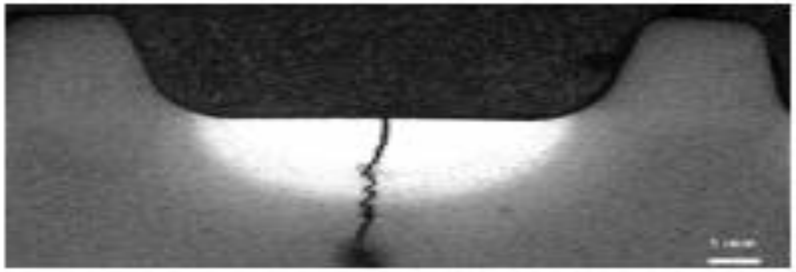
(iii) **Reducing:** A reducing atmosphere is just the opposite, not enough air is admitted to the fuel mixture to burn the fuel completely and as a result an excess of combustion gases is left in the furnace.



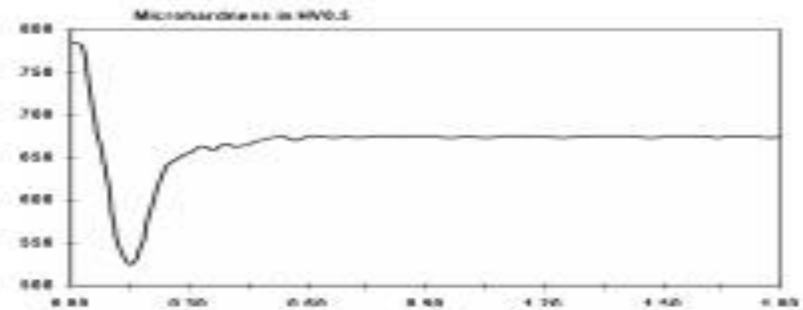
Severely overheated 1038 steel showing initial stage of burning. Ferrite (white) outlines prior coarse austenite grain boundaries; matrix consists of ferrite (white) and pearlite (black).



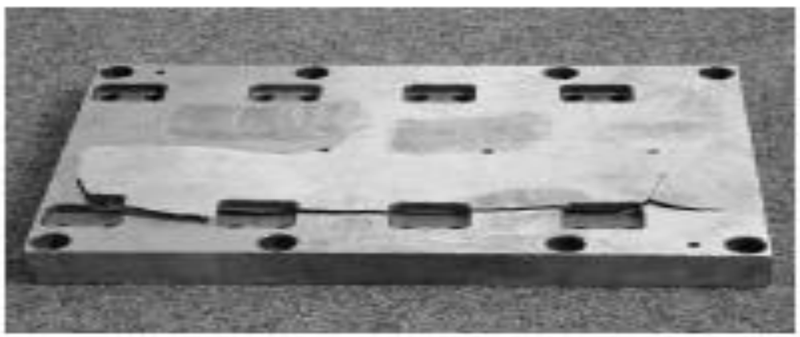
Quench cracks due to excessively large grain boundaries resulting from excessively high austenitizing temperature. Note cracking patterns associated with prior coarse austenite grain boundaries.



(a) Grinding crack with hardening zone in a grooved roll of high alloyed cold work tool steel (Etchant: 3 % HNO_3).



(b) Variation in hardness within the hardening zone of the grooved roll



(c) Crack initiation during spark erosion due to high internal stresses, caused by grinding without sufficient cooling (hardened and tempered plate of steel grade 90MnCrV8 (steel number 1.2842).

UNIT-II

Design of Cutting Tools

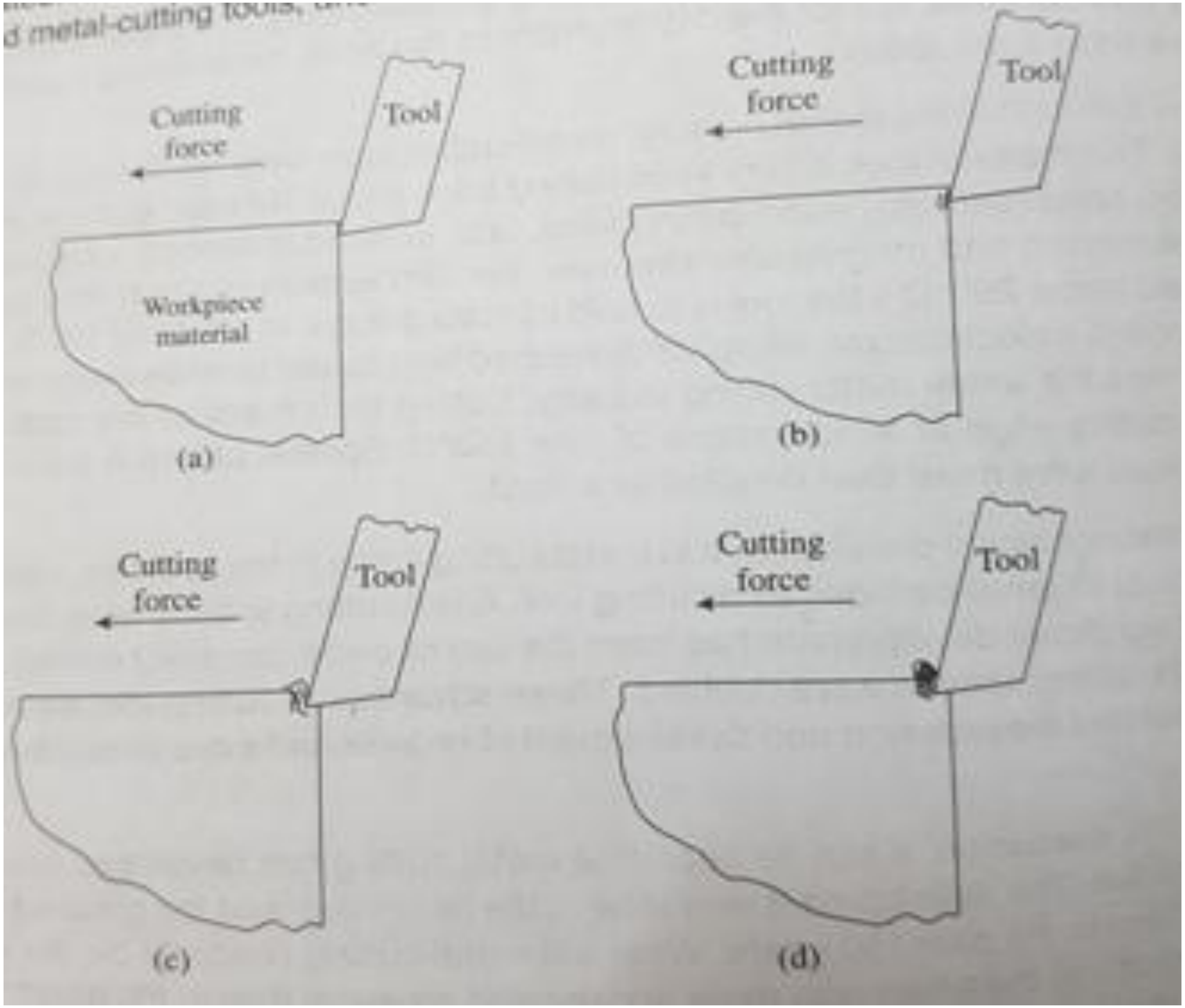
Introduction

- The most common method of metal removal is to use an edge cutting tool.
- The process is based on the separation of the base metal by pressure applied with a cutting tool made from a harder material.
- It has developed through the ages from a crude chisel-like object powered and guided by the human hand to the present state of the art.
- Where a powerful machine tool forces and automatically guides a multi edged cutting tool through a large block of metal.

Metal Cutting Process

Basic requirements of a cutting tool:

- The first requirement of all metal-cutting tools is that the tool must be harder than the material being cut.
- The second is that the tool and material being cut must be held rigidly in a manner that will cause the tool penetrate the workpiece when forces are applied.
- When these conditions are satisfied, providing there is sufficient force and power to overcome the resistance of the workpiece material.



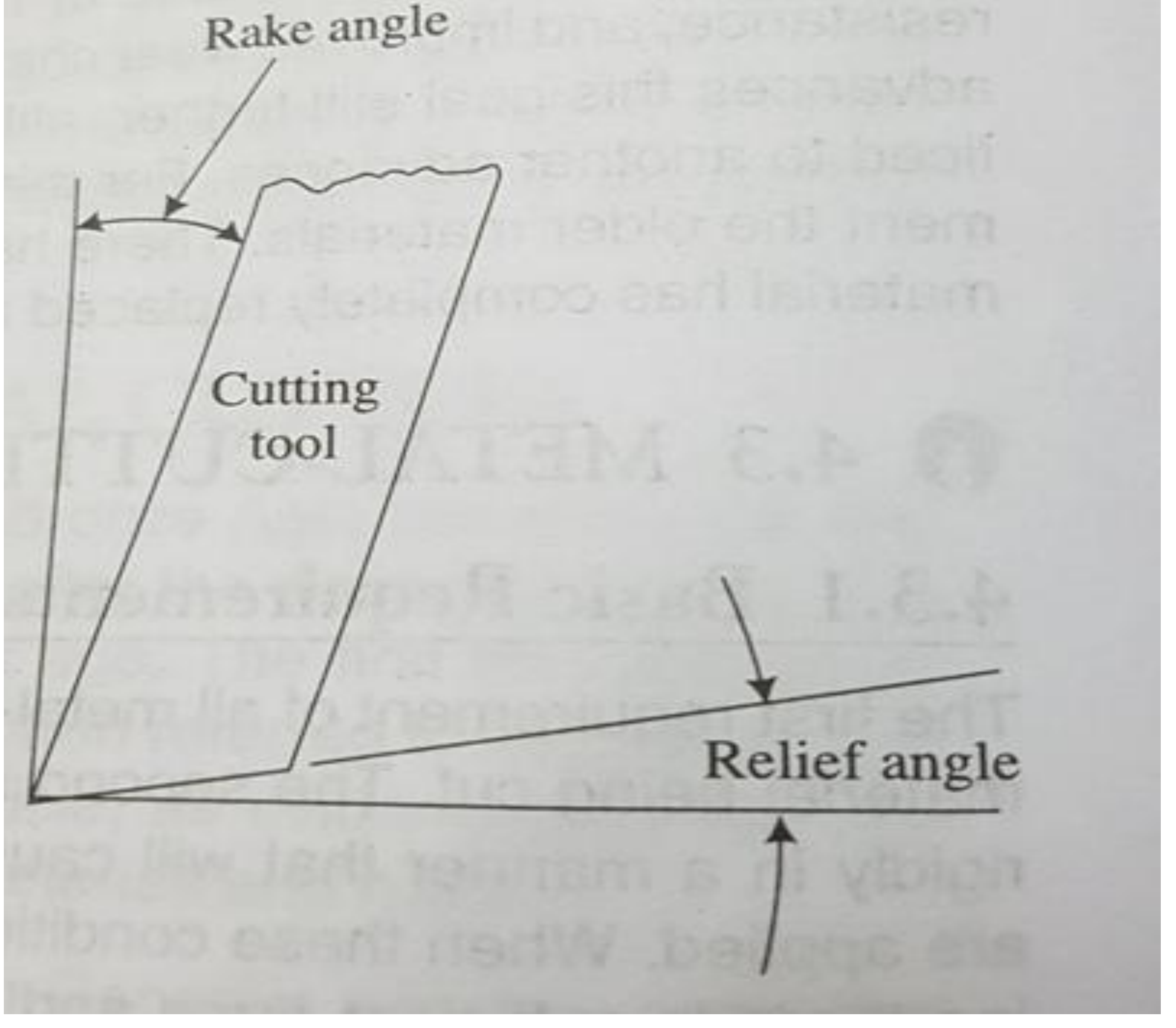
Progressive formation of a metal chip using a single point tool

Progressive formation of a metal chip

- At point **a**, the tool contacts the workpiece material.
- Compression in the workpiece material takes place at the point of contact at point **b**.
- At point **c**, the cutting force overcome the resistance to penetration of the tool and begins to deform by plastic flow.

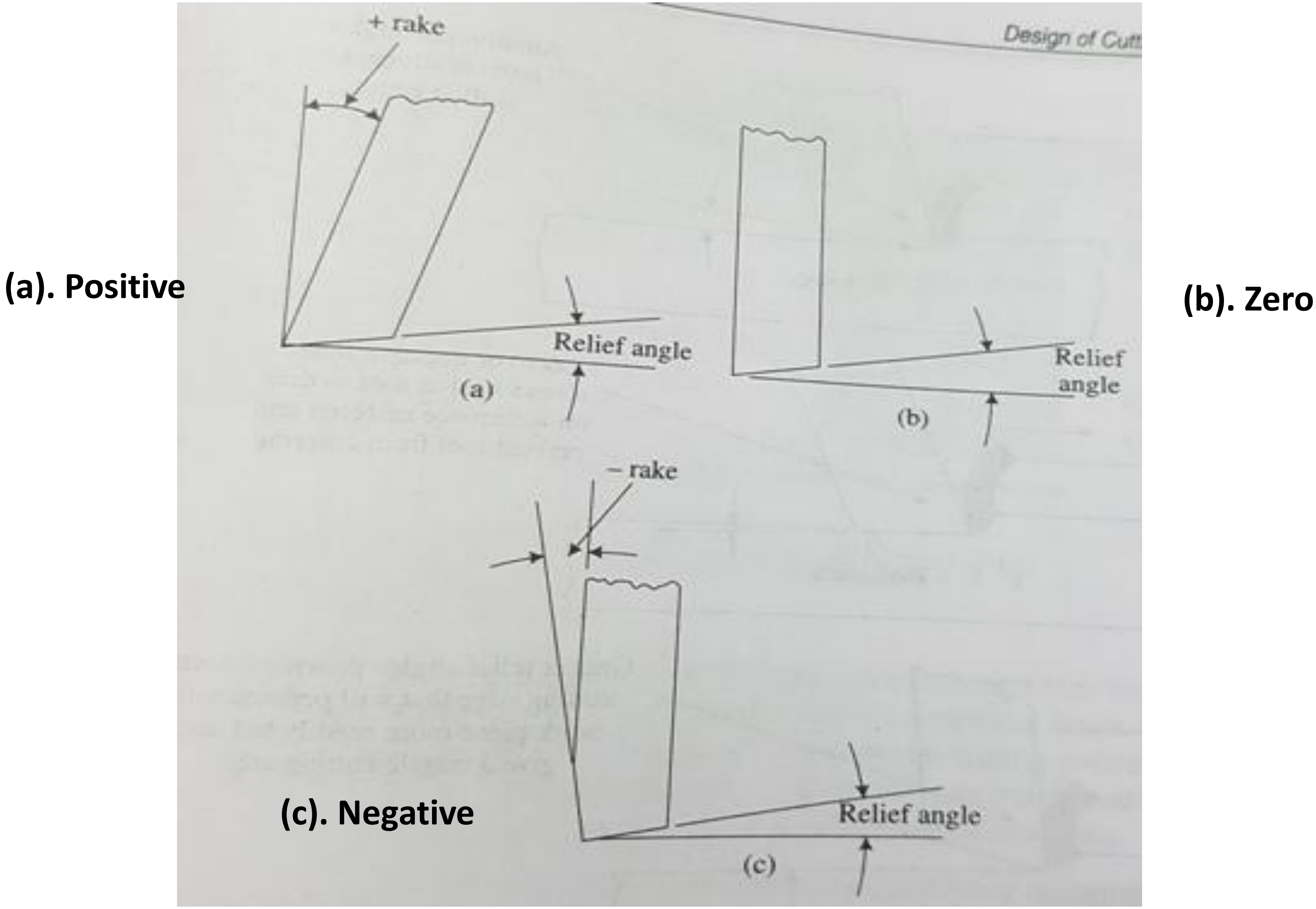
- As the cutting force increases, either a rupture or a plastic flow in a direction generally perpendicular to the face of the tool occurs and the chip is formed at point **d**.
- The formation of new chip segment begins and the sequence of compression, plastic flow and rupture is repeated.
- The cycle is repeated indefinitely.
- The process of chip formation is basic to edge metal cutting tools.

Rake and Relief Angles of a Cutting Tool



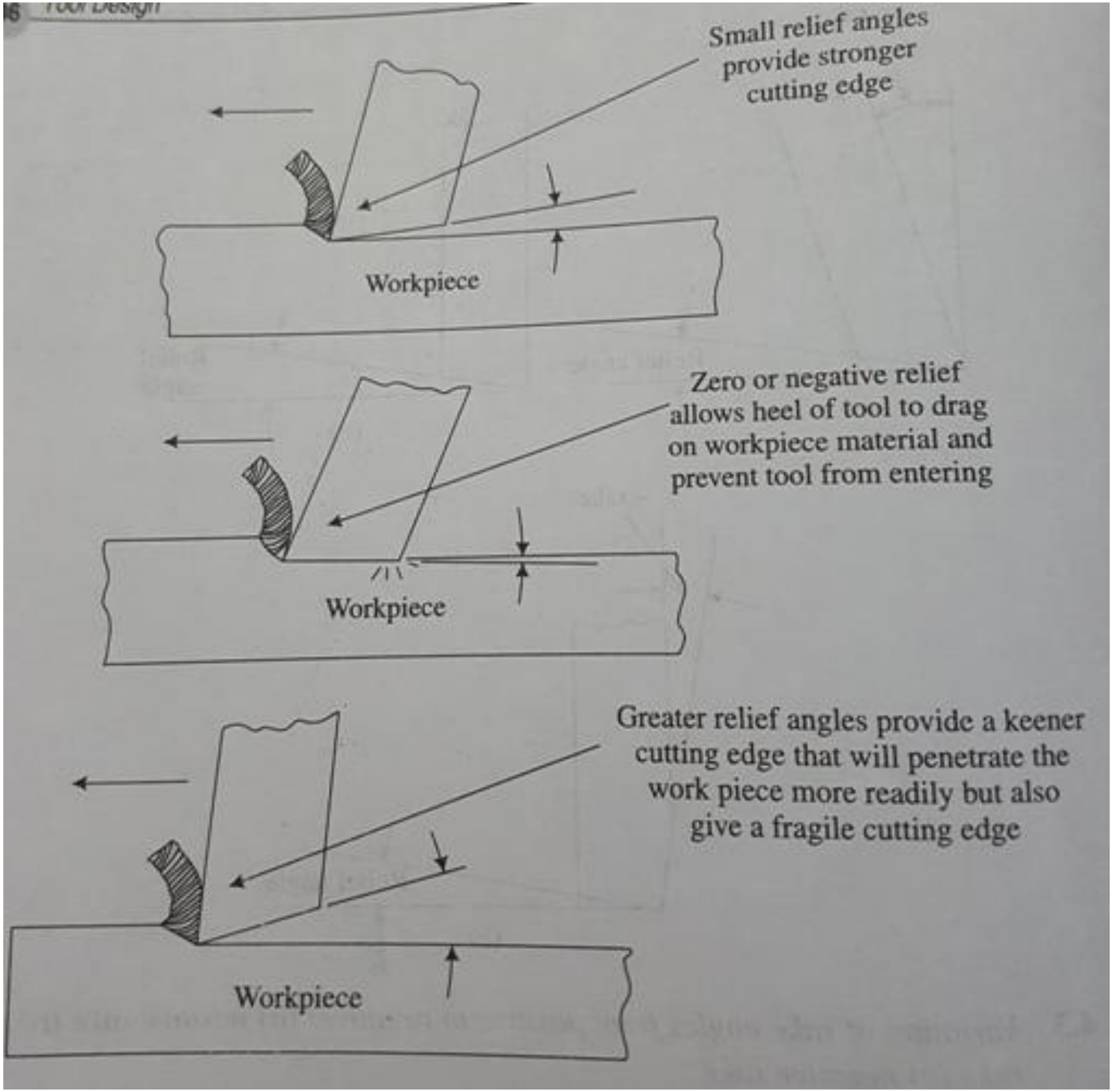
- The term commonly used to define the shape of the tool are **rake angles and relief angles**.
- Rake angles vary from positive to negative.
- In general, the positive rake angles have greater cutting efficiency from the standard point of power requirements and cutting forces.
- The smaller point angle resulting from positive rake angles penetrate the metal more readily and reduces cutting pressures.

- The high positive rake angles result in a fragile (easy or fine) cutting edge.
- They are limited to machining softer materials and are well suited to this type of application because of the keenness (sharpness) of the cutting edge.



Variation of rake angles from positive to negative

- Negative rake angles provide a stronger cutting edge and are suitable for cutting high-strength alloys.
- Relief angles, sometimes incorrectly referred to as clearance angles, are to allow the cutting edge to penetrate the work piece.
- They prevent rubbing or physical interference between the heel of the tool and the workpiece.



Effects of variation in relief angles

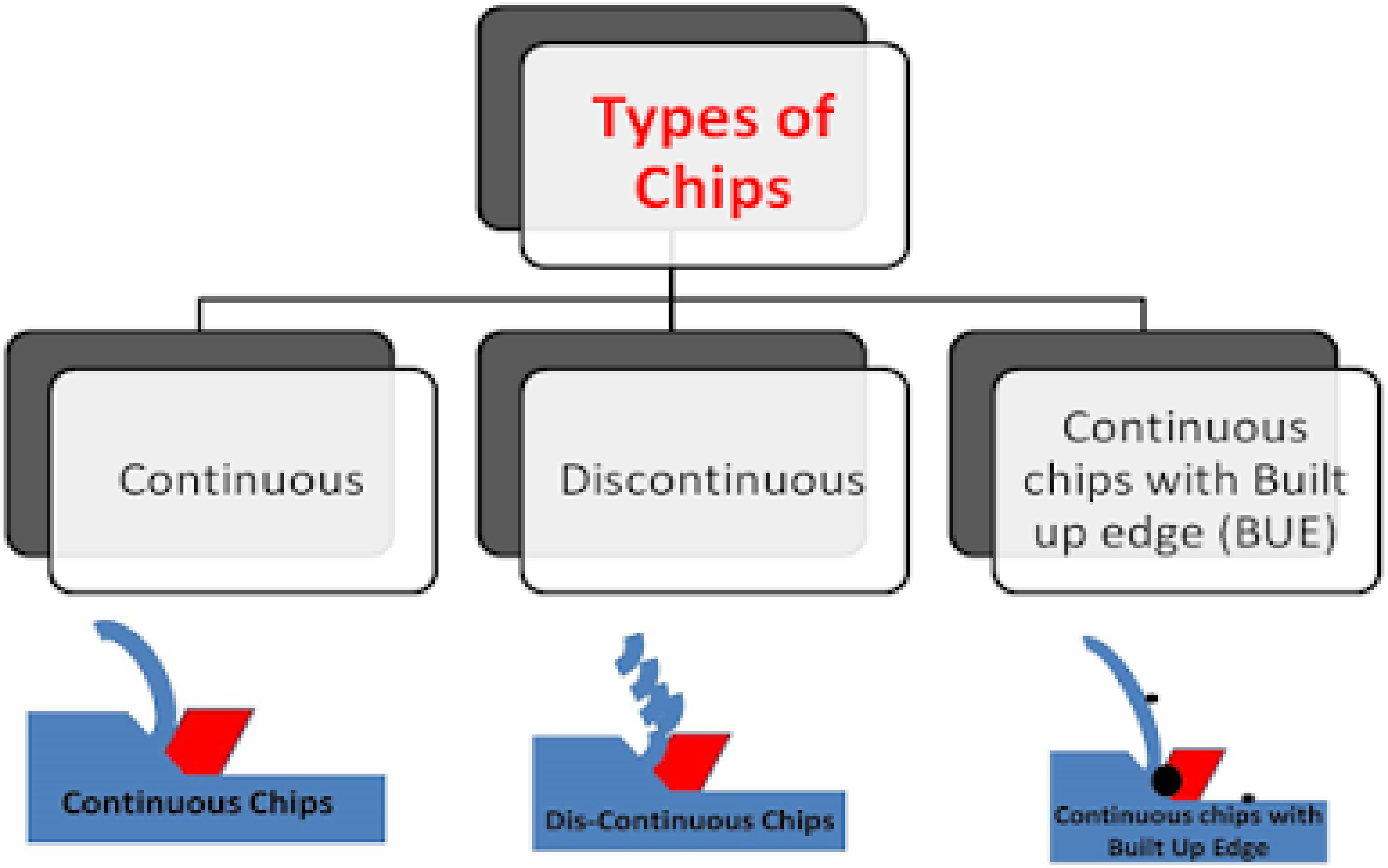
Mechanics and Geometry of Chip Formation

- In order to meet the demands of modern industrial technology, it became necessary to accelerate the development of progress.
- Quantitative and qualitative aspects have to be taken into consideration.
- Forces, stresses, strains, coefficients of friction, velocities, required power and etc makes greater metal-cutting efficiency possible.
- Which results in the greater production output demanded by modern industrial technology.

Chip formation

- Chip formation is part of the process of cutting materials by mechanical means, using tools such as saws, lathes and milling cutters. An understanding of the theory and engineering of this formation is an important part of the development of such machines and their cutting tools.
- The metal deforms by shear in a narrow zone extending from the cutting edge to the work surface.
- The shear zone is treated as a single plane for the purposes of mathematical analysis and is commonly referred to as shear plane.
- The angle which the shear plane makes with the direction of travel of the tool is known as shear angle.

Types of chips



Continuous Chips

- If the metal chips formed during machining is without segments i.e. without breakage, than it is called as continuous types of chips.
- Continuous chips are formed when the ductile material is machined with high cutting speed and minimum friction between the chip and tool face.

The conditions which are responsible for the formation of continuous types of chips are:

(i) Ductile material like mild steel is used.

(ii) Bigger rake angle of the tool.

(iii) High cutting speed.

(iv) Minimum friction between the chip and tool interface.

(v) Small depth of cut.

Discontinuous Chips

- If the chips formed during machining process is not continuous i.e. formed with breakage is called discontinuous chips.
- Discontinuous types of chips are formed when hard and brittle metals like brass, bronze and cast iron is machined.

Conditions which are responsible for the formation of discontinuous chips are:

(i) Low feed rate.

(ii) Small rake angle of the tool.

(iii) High cutting speed.

(iv) High friction forces at the chip tool interface.

(v) Too much depth of cut.

Continuous Chips with Built Up Edge (BUE)

- Continuous chips with built up edge is formed by machining ductile material with high friction at the chip-tool interface.
- It is similar to the continuous types of chips but it is of less smoothness due to the built up edge.

Comparison between Continuous, Discontinues and Continuous Chips with Built up Edge

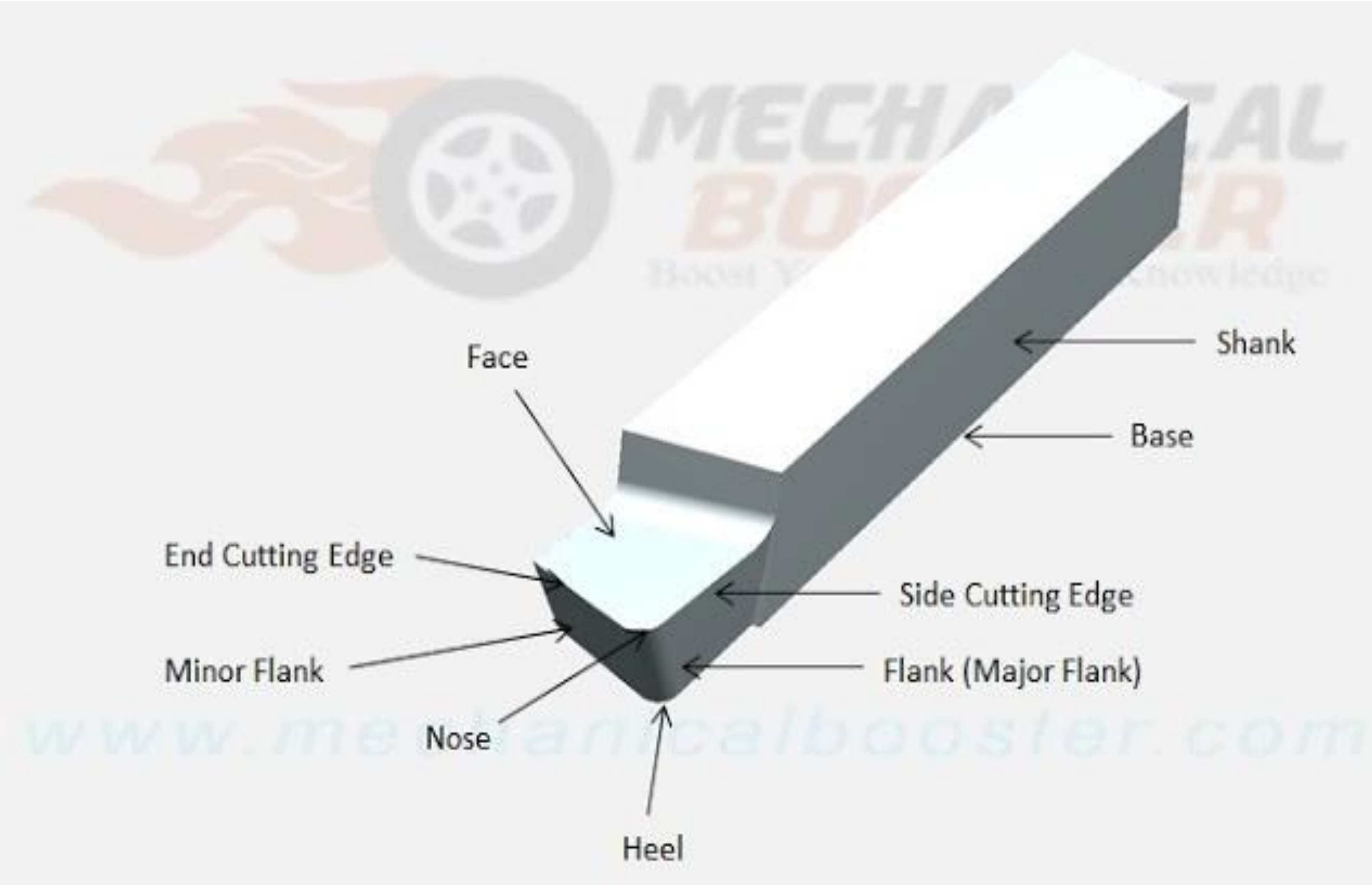
S.no	Factors	Continuous Chips	Discontinuous Chips	Continuous chips with Built Up Edge (BUE)
1.	**Material types**	Ductile	Brittle, ductile but hard	Ductile
2.	**Rake angle**	Large	Small	Small
3.	**Cutting speed**	High	Medium or high	Low or medium
4.	**Friction between chip tool interface**	Minimum	Maximum	Maximum
5.	**Depth of cut**	Small	High	Medium

Metal Cutting Tools

- **Single Point Cutting Tool**

  As its name indicates, a tool that has a single point for cutting purpose is called single point cutting tool. It is generally used in the lathe machine, shaper machine etc. It is used to remove the materials from the workpiece.

Geometry

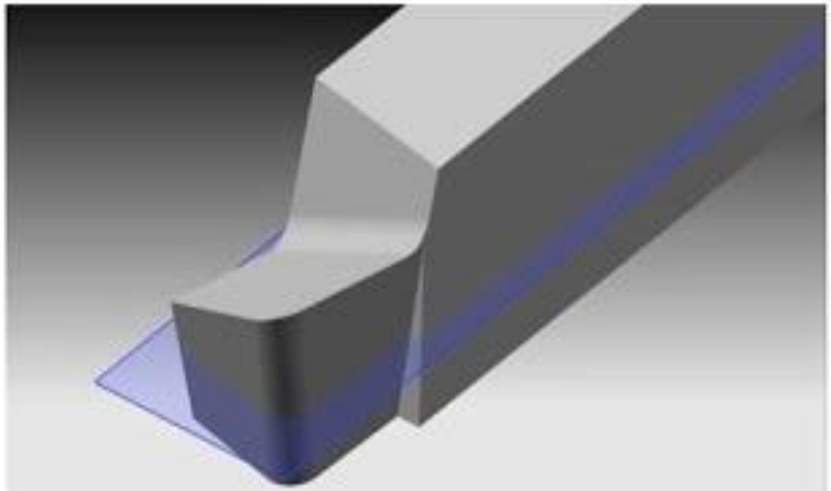


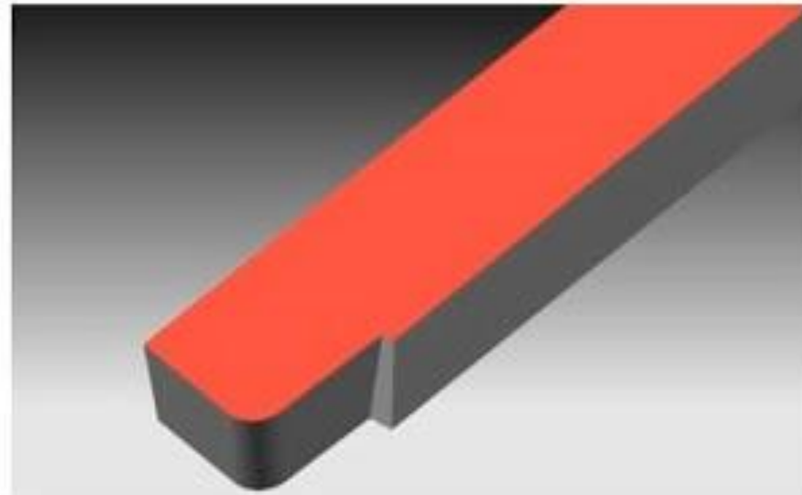
Face
Shank
Base
End Cutting Edge
Side Cutting Edge
Minor Flank
Flank (Major Flank)
Nose
Heel

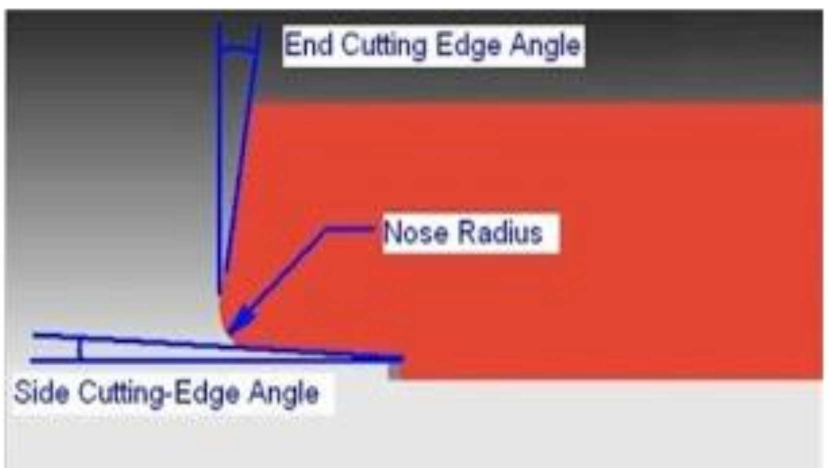
Angles of Single Point Cutting Tool

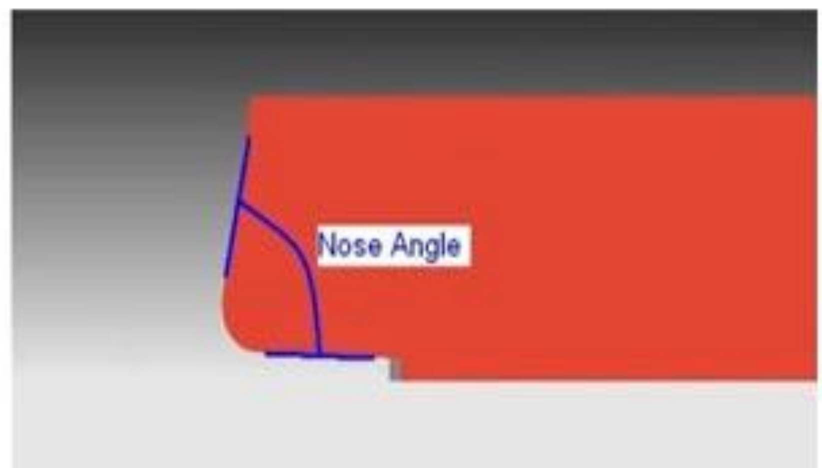
The various angles of the single point cutting tool have great importance. Each angle has its own function and specialty.

1. **End Cutting Edge Angle:** The angle formed in between the end cutting edge and a line perpendicular to the shank is called end cutting edge angle.
2. **Side Cutting Edge Angle:** The angle formed in between the side cutting edge and a line parallel to the shank.





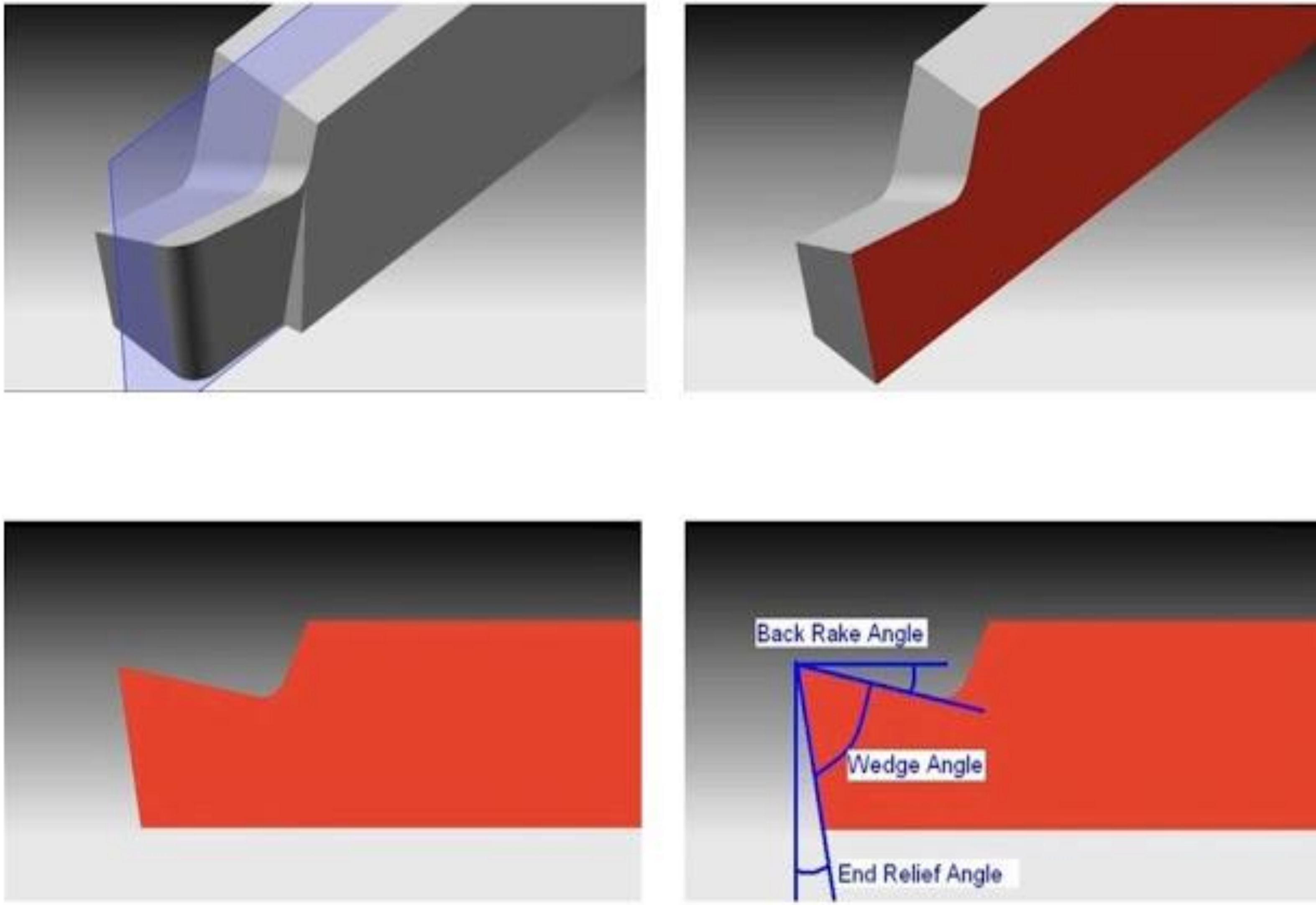

End Cutting Edge Angle
Nose Radius
Side Cutting-Edge Angle


Nose Angle

3. **Back Rack Angle:** The angle formed between the tool face and line parallel to the base is called back rake angle.

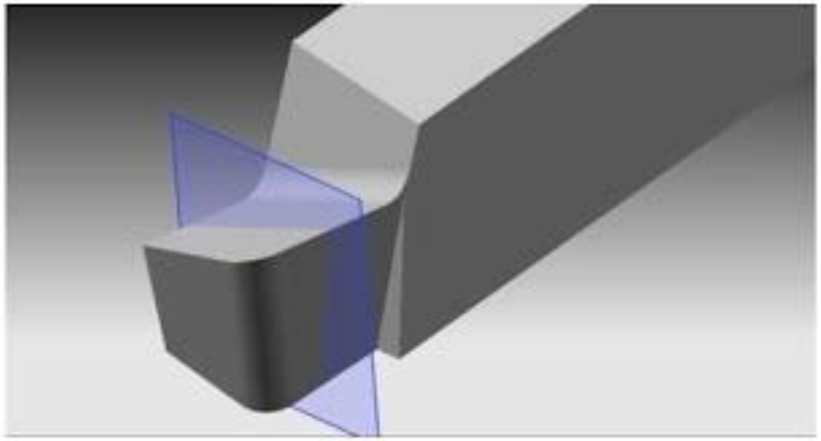
4. **End Relief Angle:** The angle formed between the minor flank and a line normal to the base of the tool is called end relief angle. It is also known as front clearance angle. It avoid the rubbing of the workpiece against tool.

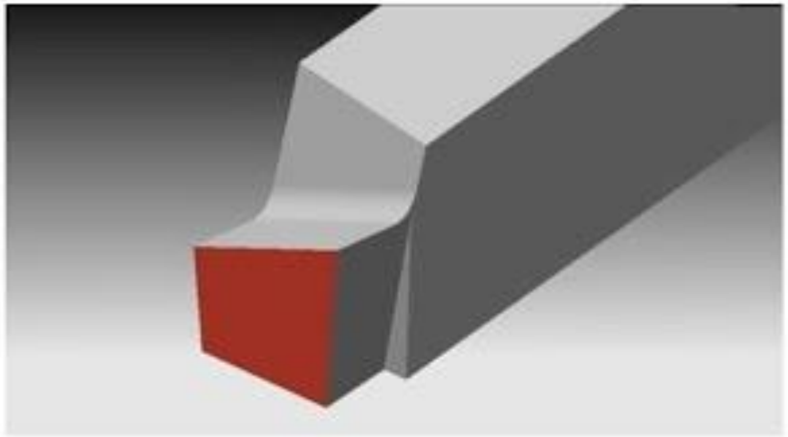
5. **Lip Angle/ Wedge Angle:** It is defined as the angle between face and minor flank of the single point cutting tool.

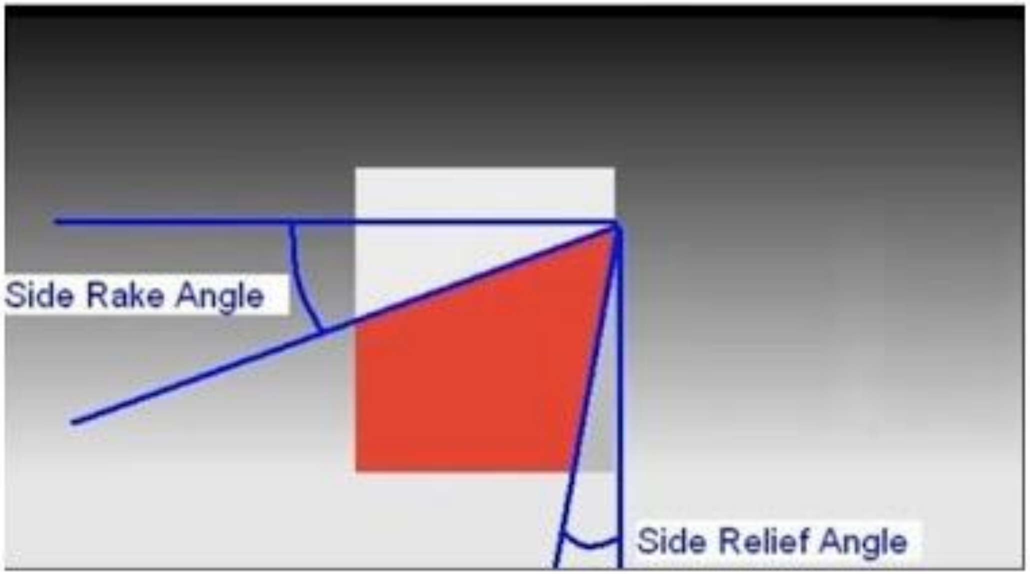

Back Rake Angle
Wedge Angle
End Relief Angle

6. **Side Rake Angle:** the angle formed between the tool face and a line perpendicular to the shank is called side rake angle.

7. **Side Relief Angle:** the angle formed between the major flank surface and plane normal to the base of the tool is called side relief angle. This angle avoids the rubbing between workpiece and flank when the tool is fed longitudinally.






Side Rake Angle
Side Relief Angle

Nomenclature

- There is three coordinate systems which are most popular in tool nomenclature. And these are

  1. Machine Reference System (MRS)
  2. Orthogonal Tool Reference System (ORS) or Orthogonal Rake System
  3. Normal Reference System (NRS)

Signature:

The shape of a tool is specified in a special sequence and this special sequence is called tool signature. The tool signature is given below

(i) Back rake angle

(ii) Side rake angle

(iii) Clearance or End Relief angle

(iv) Side Relief angle

(v) End cutting edge angle

(vi) Side cutting edge angle

(vii) Nose radius

UNIT-III

Design of Jigs and Fixtures

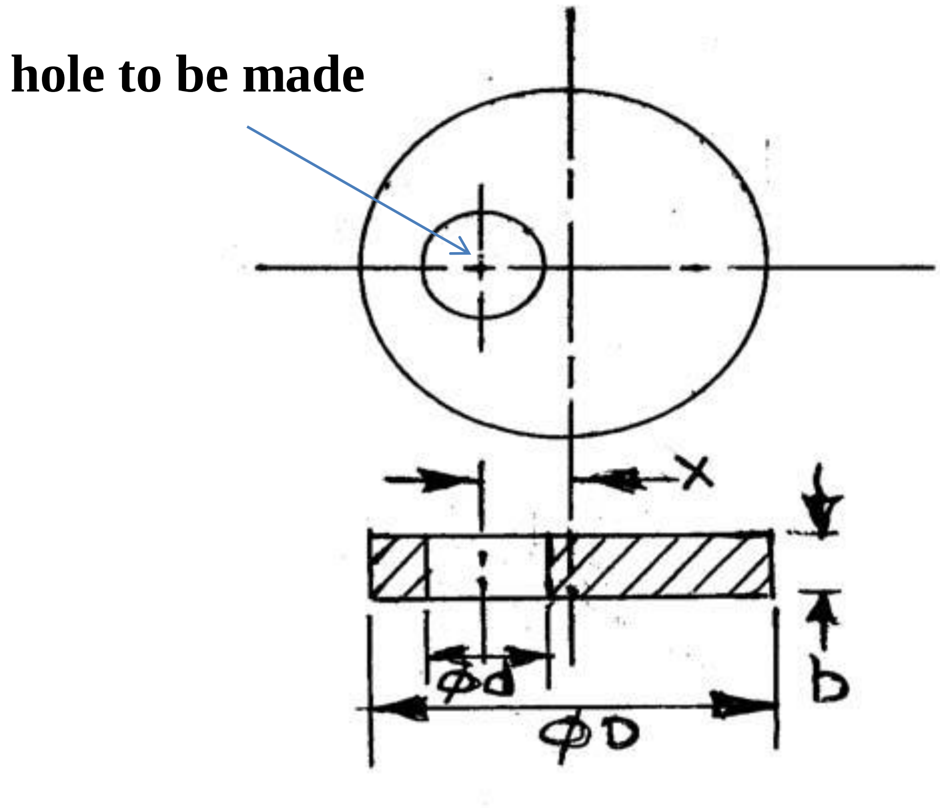
(i) Definition Of Fixture And Jig

Fixtures, being used in machine shop, are strong and rigid mechanical devices which enable easy, quick and consistently accurate locating, supporting and clamping, blanks against cutting tool(s) and result faster and accurate machining with consistent quality, functional ability and interchangeability.

Jig is a fixture with an additional feature of tool guidance.

(ii) Purpose Of Using Fixtures And Jigs

For a machining work, like drilling a through hole of given diameter eccentrically in a pre-machined mild steel disk



A through hole has to be drilled in a pre-machined mild steel disc.

conventional drilling machine without using any fixture or jig, the following elementary steps are to be sequentially followed

(a) cleaning and deburring the blank (disc)

(b) marking on the blank showing the location of the hole and its axis on the blank

(c) punch the centre at the desired location and prick punch the periphery of the hole to be made in the disc

(d) mount the blank in a drilling vice using parallel block, a small V block etc. to provide support and clamp the blank firmly

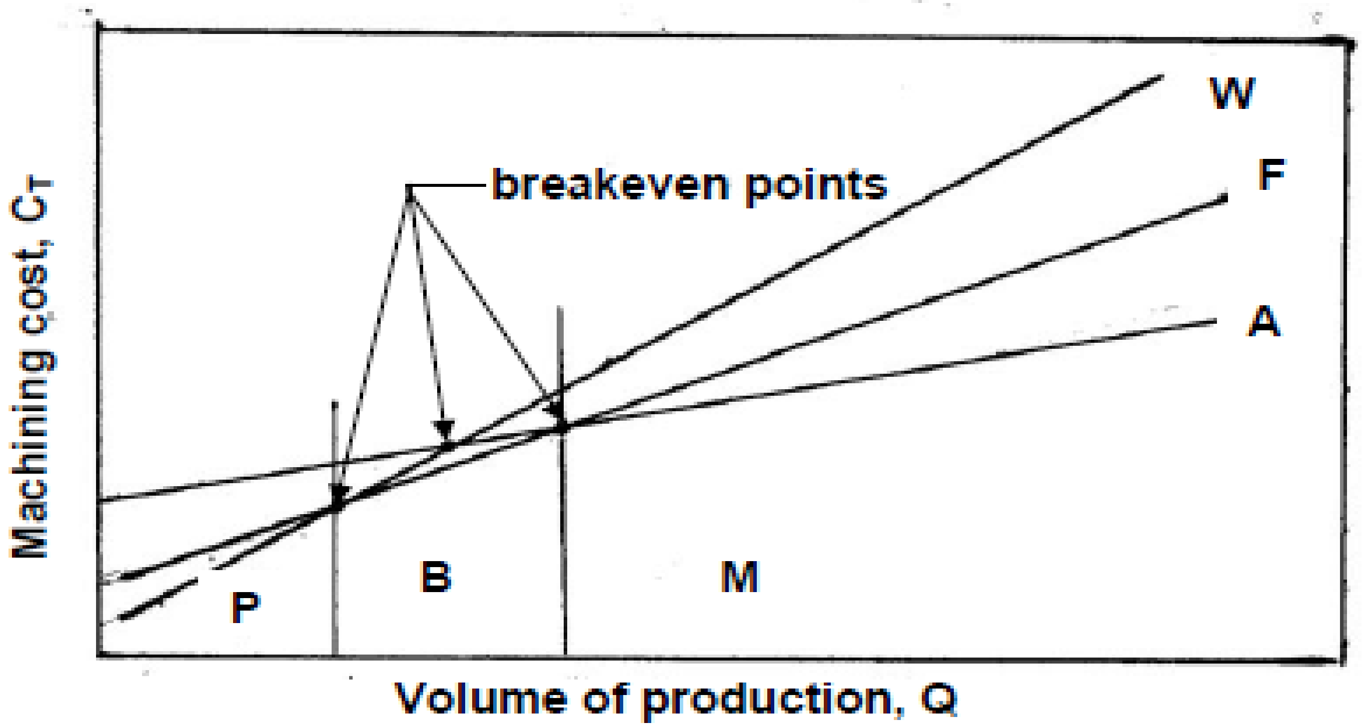
(e) position the vice along with the marked blank to bring the hole axis in alignment with the drill axis by

The basic purposes of developing and using suitable jigs and fixtures for batch production in machine shops are :

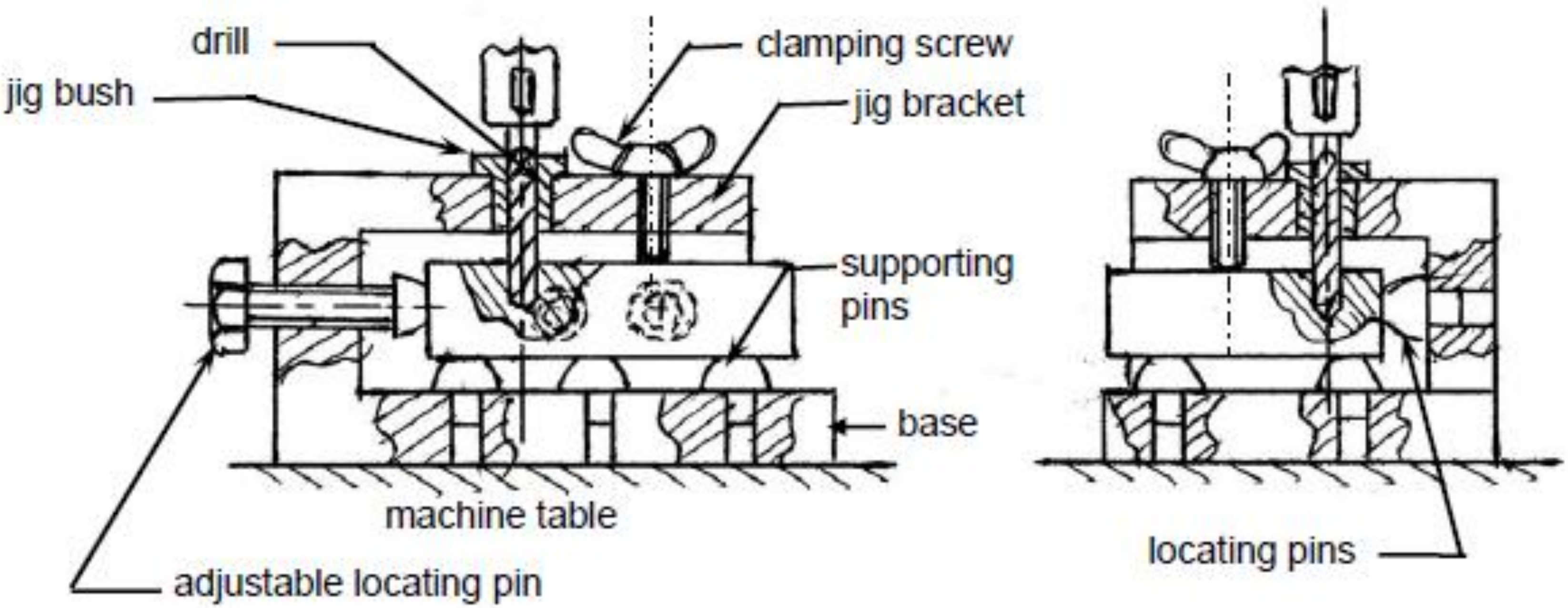
- to eliminate marking, punching, positioning, alignments etc.
- easy, quick and consistently accurate locating, supporting and clamping the blank in alignment of the cutting tool
- guidance to the cutting tool like drill, reamer etc.

increase in productivity and maintain product quality consistently

- to reduce operator's labor and skill – requirement
- to reduce measurement and its cost
- enhancing technological capacity of the machine tools
- reduction of overall machining cost and also increase in interchangeability.



W – without using jig & fixture
F – using jig and fixture
A – automatic (special purpose) machine
P – piece production
B – batch production
M – mass production


drill
jig bush
clamping screw
jig bracket
supporting pins
base
machine table
adjustable locating pin
locating pins

Therefore keeping in view increase in productivity, product quality, repeatability i.e. interchangeability and overall economy in batch production by machining, the following factors are essentially considered during design, fabrication and assembly of jigs and fixtures :

- easy, quick and consistently accurate locating of the blank in the jig or fixture in reference to the cutting tool
- providing strong, rigid and stable support to the blank
- quick, strong and rigid clamping of the blank in the jig or fixture without interrupting any other operations
- tool guidance for slender cutting tools like drills and reamers
- easy and quick loading and unloading the job to and from the jig or fixture
- use of minimum number of parts for making the jig or fixture
- use of standard parts as much as possible
- reasonable amount of flexibility or adjustability, if feasible, to accommodate slight variation in the job - dimensions.
- prevention of jamming of chips, i.e. wide chips-space and easy chip disposal
- easy, quick and accurate indexing system if required.
- easy and safe handling and moving the jig or fixture on the machine table, i.e., their shape, size, weight and sharp edges and corners
- easy and quick removal and replacement of small parts
- manufacturability i.e. ease of manufacture
- durability and maintainability
- service life and overall expenses

Principles And Methods Of Locating, Supporting And Clamping Blanks And Tool Guidance In Jigs And Fixtures

It is already emphasized that the main functions of the jigs and fixtures are :

(a) easily, quickly, firmly and consistently accurately

- locating
- supporting and
- clamping

the blank (in the jig or fixture) in respect to the cutting tool(s)

(b) providing guidance to the slender cutting tools using proper bushes

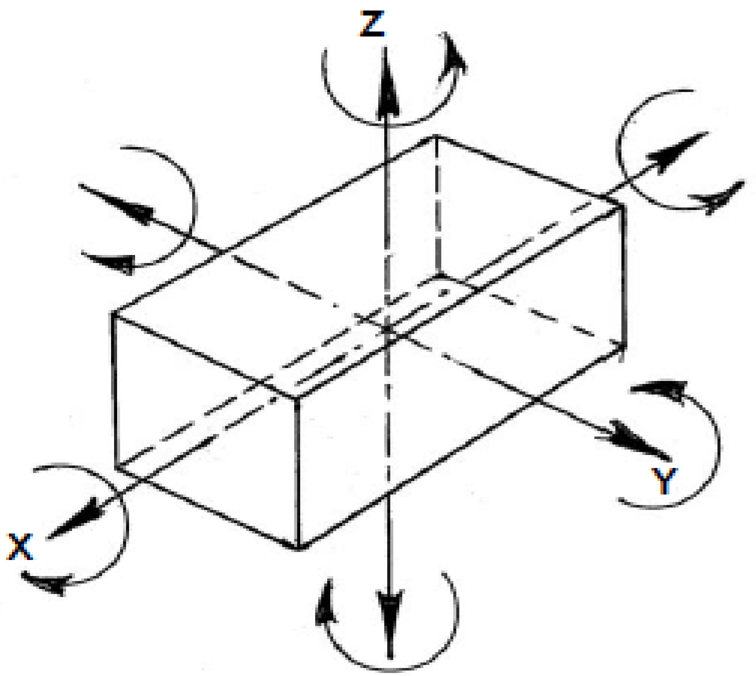
There are and can be several methods of locating, supporting and clamping depending upon the size, shape and material of the job, cutting tool and the machining work required. But some basic principles or rules are usually followed while designing for locating, supporting and clamping of blank in fixtures.

(a) Locating, Supporting and Clamping of jobs in jigs and fixtures

- Locating – principles and methods

  - **Principles or rules of locating in jigs and fixtures**

For accurate machining, the workpiece is to be placed and held in correct position and orientation in the fixture (or jig) which is again appropriately located and fixed with respect to the cutting tool and the machine tool. It has to be assured that the blank, once fixed or clamped, does not move at all.
Any solid body may have maximum twelve degrees of freedom as indicated in Fig. 8.1.4. By properly locating, supporting and clamping the blank its all degrees of freedom are to be arrested as typically shown in Fig. 8.1.5.



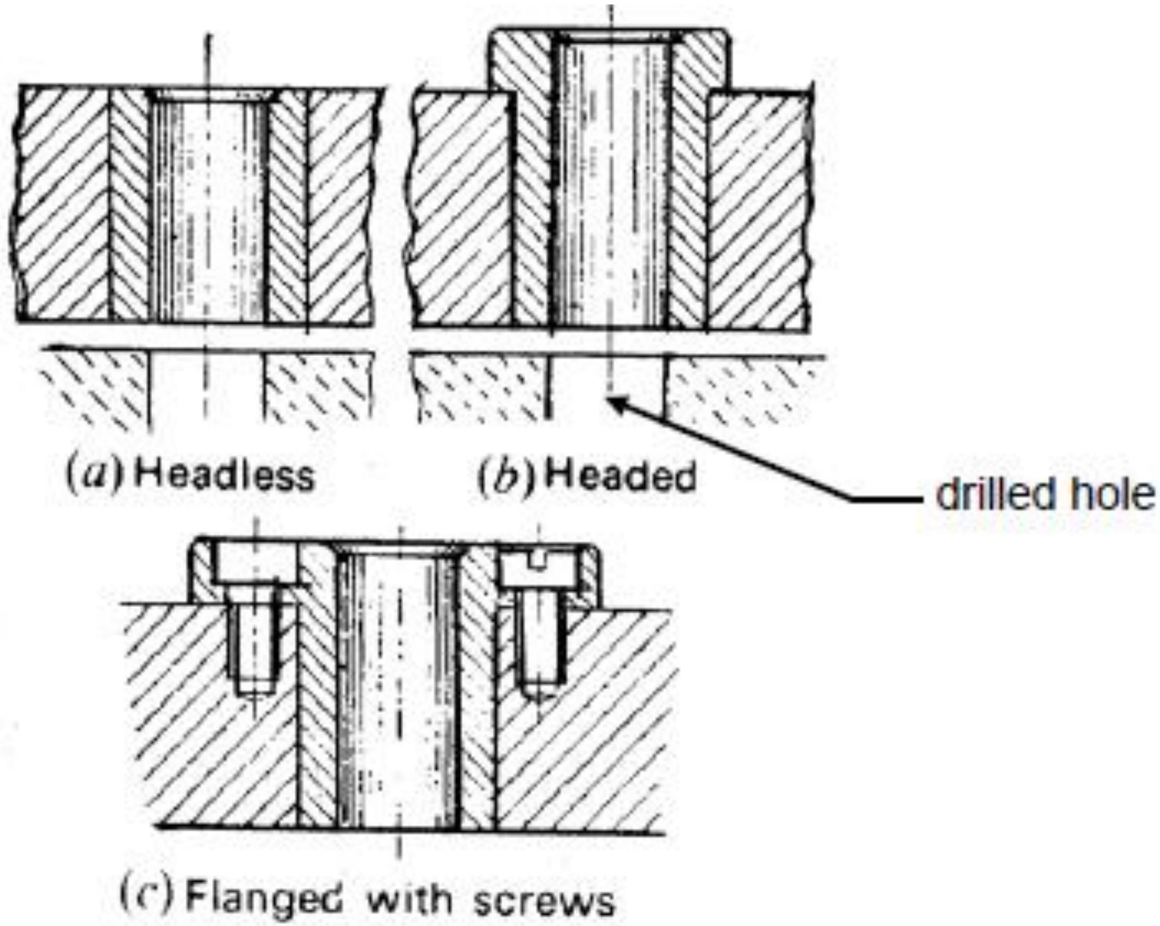
Types of jig bushes

Depending upon nature of fitting, quick mounting and replacement, job requirement etc. jig bushes are classified into several types.

- Bushes may be
  - — Press fitted type
  - — Slip type
  - — Screwed type

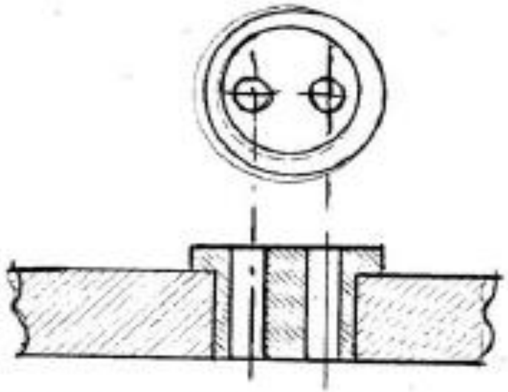
Press fitted thin sleeve type bushes are generally used for shorter runs and are not renewable. Renewable type slip bushes are used with liner. But screw bushes, though renewable may be used without or with liner.

- Bushes may be
  - — Without head
  - — With head
  - — With a flange being screwed on the bracket

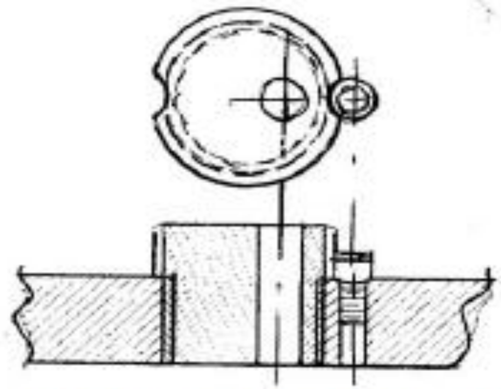


Bushes (a) without head, (b) with head and (c) flange.

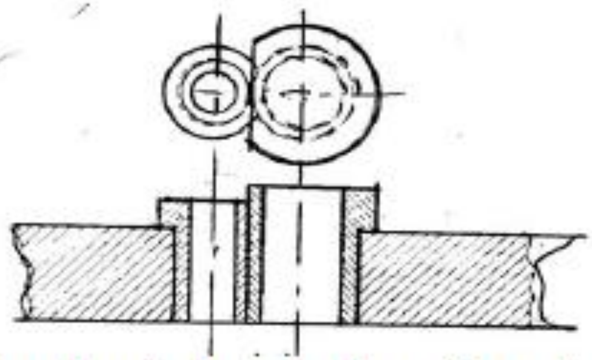
- Some special jig bushings are often designed and used as and when required as indicated in Fig. 8.1.26



(a) two close holes – in one bush



(b) two very close holes – using eccentric bush



(c) two close holes – by two adjacent modified bushes

Special jig – bushes for critical requirements.

Many other types are possible and made depending upon the working situation and critical requirements.

UNIT-IV

Design for Sheet Metal Forming-I

Blanking and piercing

- Blanking and piercing are shearing processes in which a punch and die are used to modify webs. The tooling and processes are the same between the two, only the terminology is different: in blanking the punched out piece is used and called a *blank*; in piercing the punched out piece is scrap. The process for parts manufactured simultaneously with both techniques is often termed "pierce and blank." An alternative name of piercing is punching.

Fundamental of Die Cutting Operation

- The cutting of sheet metal in press work is a shearing process, in which the metal is stressed in shear between two cutting edges to the point of fracture (beyond its ultimate strength). The cutting action is explained in Fig below.
- In die cutting when the punch presses the sheet metal into the die opening the material is subjected to different types of stresses at various places as shown in Fig. The various steps in the rupture or fracture of the material are :

- stressing the material beyond its elastic limit,
- plastic deformation,
- reduction in thickness and
- fracture

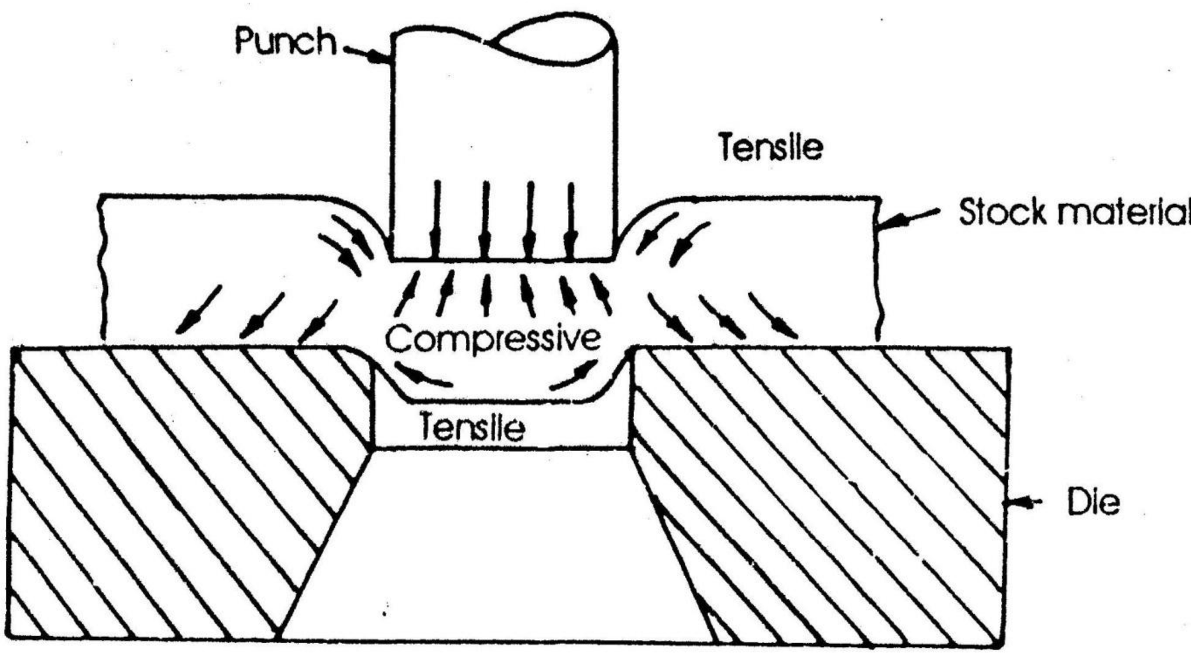


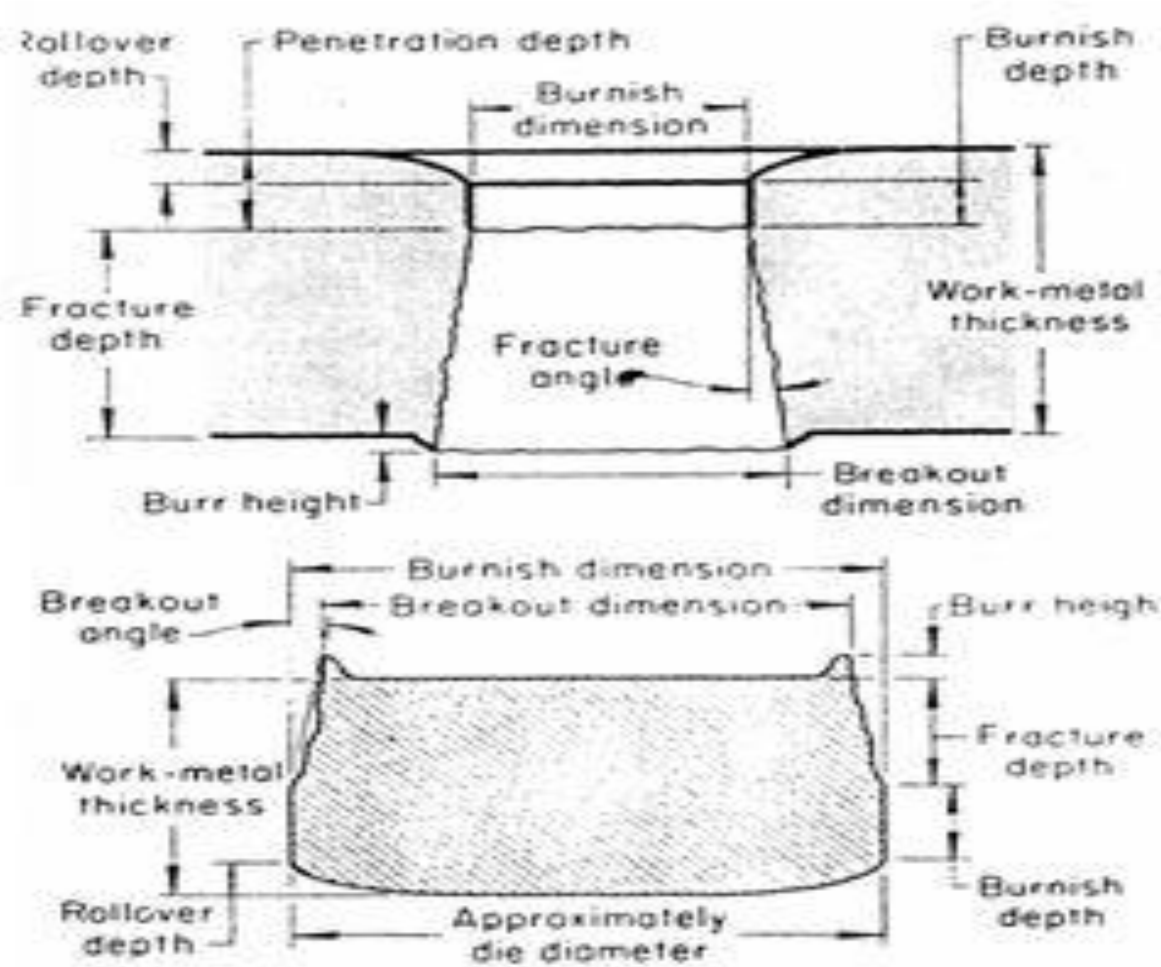
Fig : Stresses in die cutting

Characteristics of blanked edges

- The sheared edge of a blank produced in a conventional die are not smooth and vertical for the entire thickness of the part as shown in the figure.
- Rollover on the lower edges of the blank develops by plastic deformation of the work metal as it is forced into the die by the punch. Compression of the metal above the rollover zone against the walls of the die opening burnishes a portion of the edge of the blank.

- The angle of the fractured portion of the edge is identified as the breakout angle. The breakout dimension of the blank and the burnish dimension of the hole in the scrap skeleton are approximately equal to the corresponding punch dimension, and the burnish dimension of the blank is very close to the corresponding die dimension. Thus , the punch determines the hole size and the die governs the blank size.
- As the punch completes its stroke, the remaining portion of the blank edge is broken away or fractured (resulting in die break), and a tensile burr is formed along the top of the blank edge.

- The penetration depth or the amount of penetration of the punch into the work metal before fracture occurs, is approximately equal to the sum of roll$ over depth and burnish depth on the blank, except when low die clearance produced secondary burnish. It is usually expressed as a percentage of the work$ metal thickness. The percentage of penetration (before fracture) depends on the properties of the work metal as shown in table (1), which gives approximate values for various steel and nonferrous metals under typical blanking conditions.



Characteristics of blanked edges

Penetration depth:

- Is the depth of stroke during which the cutting force is exerted, before the metal fracture or breaks away. This depth is approximately equal to the sum of rollover depth plus burnish depth on the blank. It is usually expressed as a percentage of the work metal thickness as shown in the table below. Penetration affects energy consumption and cutting force in blanking.

Rollover zone:

- Is a curved surface caused by plastic deformation of the work piece before cutting commenced. Rollover depth and burnish depth are greater in thick material than in thin material and are greater in soft material than in hard material.

Sheet Material	% Penetration depth
Carbon steel 0. 1% Annealled	50
Carbon steel 0. 1% Cold rolled	38
Carbon steel 0.2 % Annealed	40
Carbon steel 0.2 % Cold rolled	28
Carbon steel 0.3 % Annealed	33
Carbon steel 0.3 % Cold rolled	22
Silicon steel	30
Aluminum alloys	60
Copper	55
Brass	50
Bronze	25
Nickel alloys	55
Zinc alloys	50

Table 1:Approximate penetration of sheet thickness before fracture

The difference between the hole edge and the blank edge

- Rollover is greater on hole edge than on slug or blank edge.
- Furnish depth is greater on the hole edge than on slug or blank edge.
- Fracture depth is smaller (and fracture angle greater) on hole edge than on slug or blank edge.
- Burr height on hole edge is smaller on hole edge than on slug or blank edge, and varies with tool sharpness.

The parameters that affect the profile of cutting edge of blank or pierced hole

- The properties of working material, stock thickness, and punch to die clearance is the major parameters that affect the profile of the cutting edge.

Results may also affected to a minor degree by:

- Face shear on punch or die.
- Punch to die alignment.
- Proximity to adjacent hole. Distance to adjacent blanked edge.
- Orientation of the different portions of the cut edge with respect to the rolling direction.
- Ratio of hole size to stock thickness.
- Internal construction of the die cavity. lubrication.

Die clearance between die and punch

- The clearance between each side of the punch and the die is normally expressed as percentage of the material thickness. The clearance provided between the punch and die depends largely upon the mechanical properties of the metal to be sheared and the operation being performed. For most non-ferrous materials very small clearances should be used. For mild steel, a clearance of (16)% is usually provided. Generally the die clearance varies from (, to 16)% of the metal thickness.

Die operations (press working operations)

Press working operations may be classified as:

A) Cutting or shearing operations: blanking , Piercing , punching, Notching , perforating , trimming, slitting , lancing , Parting, Cutoff, Shaving etc

B) Bending operation Angle bending, Curling, folding, forming, etc

C) Drawing operations, Cupping, forming flanges, embossing, bulging, etc

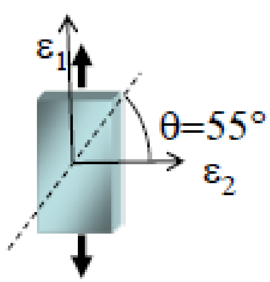
D) Squeezing operations, Coining, Sizing, Cold forging, Riveting, Upsetting, Extruding ,Hot piercing flattening . etc

UNIT-V

Design for Sheet Metal Forming-II

Introduction

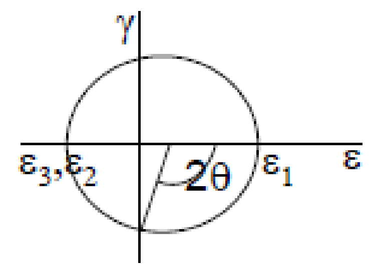
- Cutting and forming thin sheets of metal usually performed as cold working
- Sheet metal = 0.4 (1/64) to 6 mm (1/4in) thick
- Plate stock > 6 mm thick
- Advantage - High strength, good dimensional accuracy, good surface finish, economical mass production (low cost).
- Cutting, bending, drawing



Localized necking

Because $\nu=0.5$ in plasticity,

$$\varepsilon_1=-2\varepsilon_2=-2\varepsilon_3$$

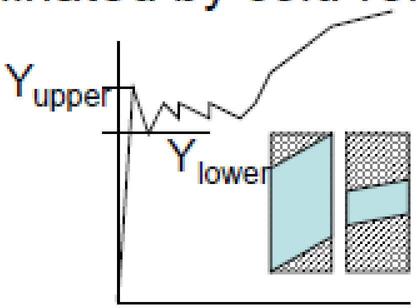


Sheet Metalworking Terminology

- "Punch-and-die"
  - Tooling to perform cutting, bending, and drawing
- "Stamping press"
  - Machine tool that performs most sheet metal operations
- "Stampings"
  - Sheet metal products

Sheet-metal Characteristics

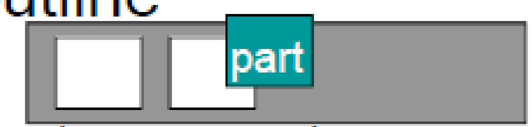
- Elongation – the capability of the sheet metal to stretch without necking and failure.
- Yield-point elongation
  - Lüeder's bands on Low-carbon steels and Al-Mg alloys. Lüder's bands can be eliminated by cold-rolling the thickness by 0.5-1.5%.



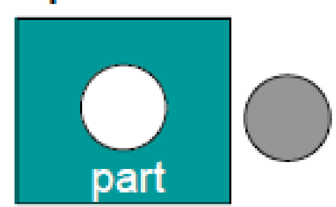
- Anisotropy
  - Crystallographic and mechanical fibering anisotropy
- Grain Size effect on mechanical properties
- Residual Stress, Springback and Wrinkling
- Testing method
  - Cupping test
  - Forming Limit Diagram

1. Cutting Operation

- Cutting operation
  - Plastic deformation
  - Penetration (1/3 thickness)
  - Fracture
- **Shearing** using a machine called power shear or square shear.
- **Blanking** – shearing a closed outline (desired part called blank)



- **Punching** – sheared part is slag (or scrap) and remaining stock is a desired part

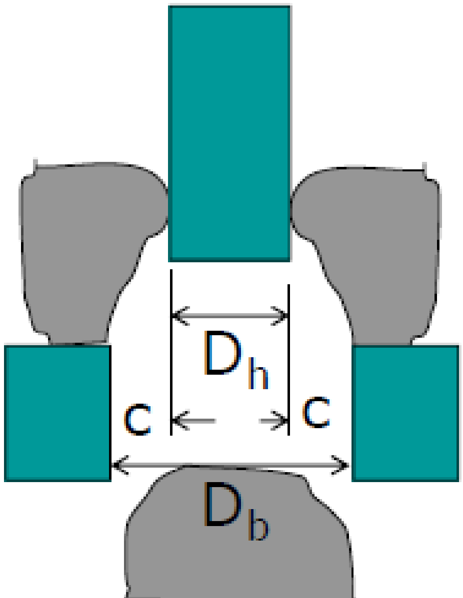


Analysis

- Clearance - 4-8% but sometime 1% of thickness
  - Too small – fracture does not occur requiring more force.
  - Too large – Get pinched and cause an excessive burr
- Clearance: c=a*t

Metal group	a
1100S and 5052S aluminum alloys, all tempers	0.045
2024ST and 6061ST aluminum alloys; brass, soft cold rolled steel, soft stainless steel	0.060
Cold rolled steel, half hard; stainless steel, half hard and full hard	0.075

Die, blank and punch size



For a round blank,

Blank punch diameter=D_b-2c

Blank die diameter = D_b

For a round hole,

Hole punch diameter=D_h

Hole die diameter = D_h+2c

Angular clearance of 0.25° to 1.5°

Cutting forces: $F=S*t*L=0.7*TS*t*L$

where S= Shear strength

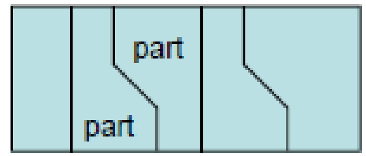
t=thickness

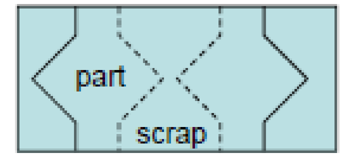
L=length of cutting edge

TS =Ultimate tensile strength

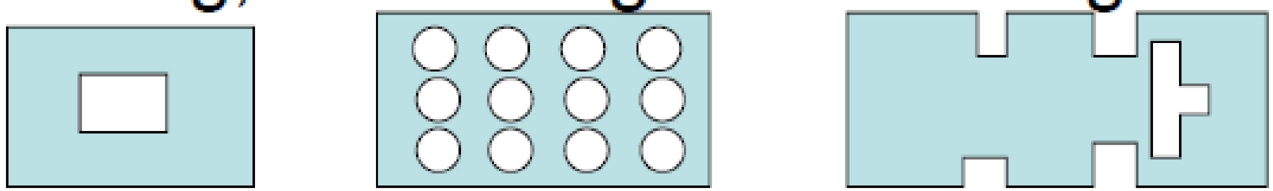
Other Cutting Operations

- Cutoff and Parting

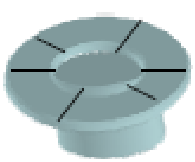




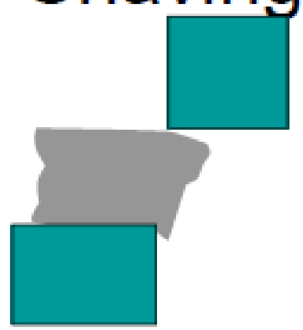
- Slotting, Perforating and Notching



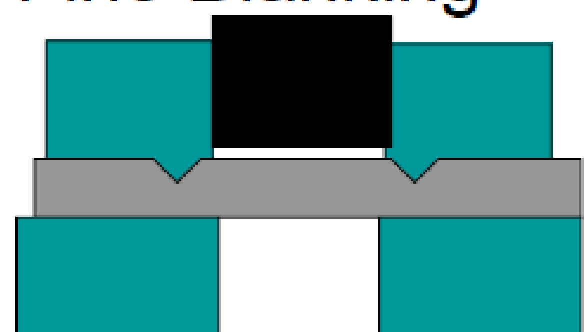
- Trimming, Shaving and Fine Blanking



Trimming



Shaving

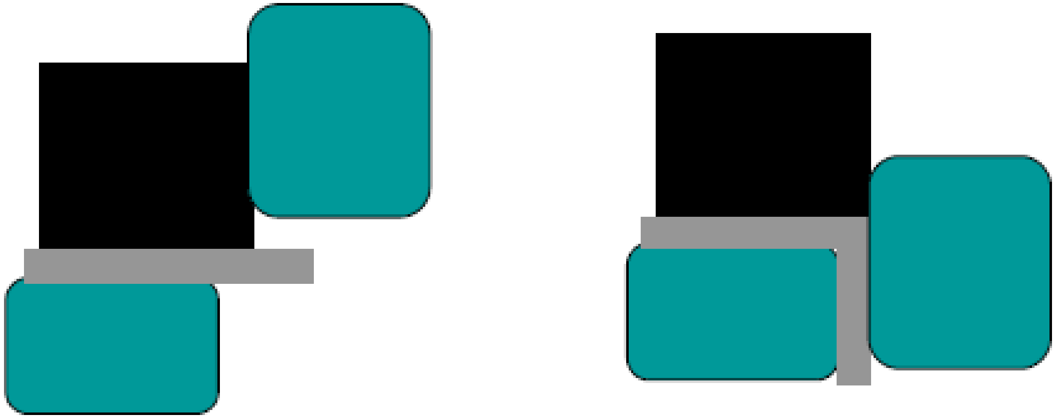


Fine Blanking

2. Bending Operations

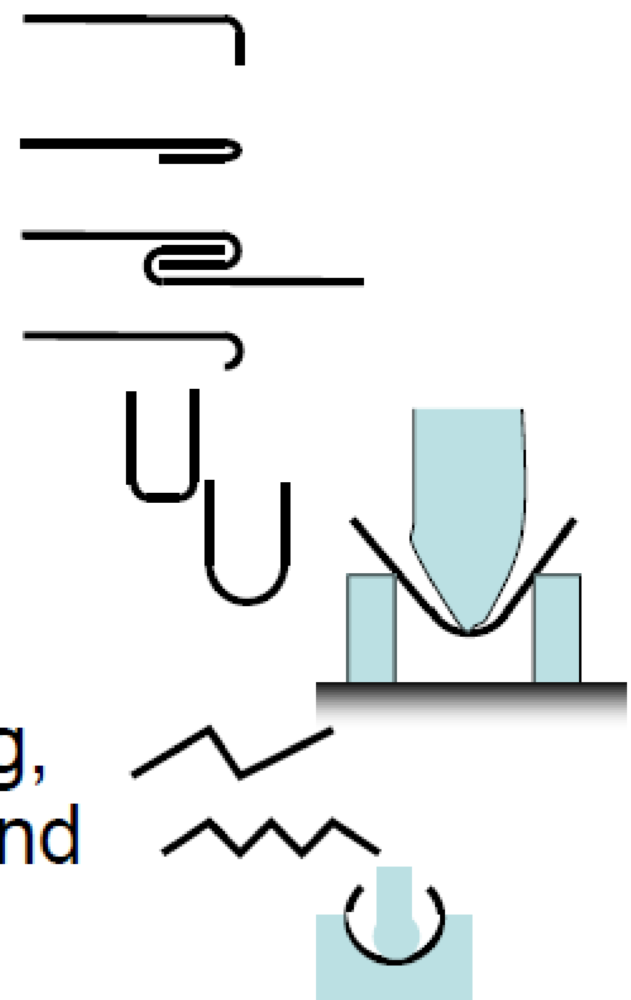
- V-bending

- Edge Bending



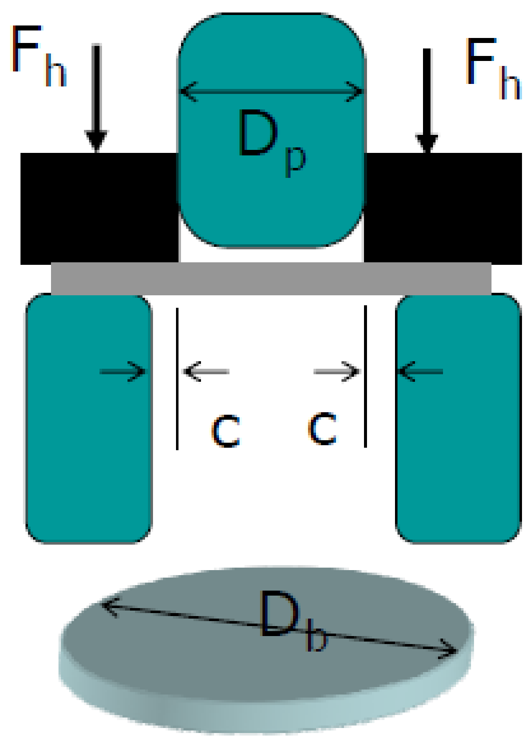
Other Bending Operation

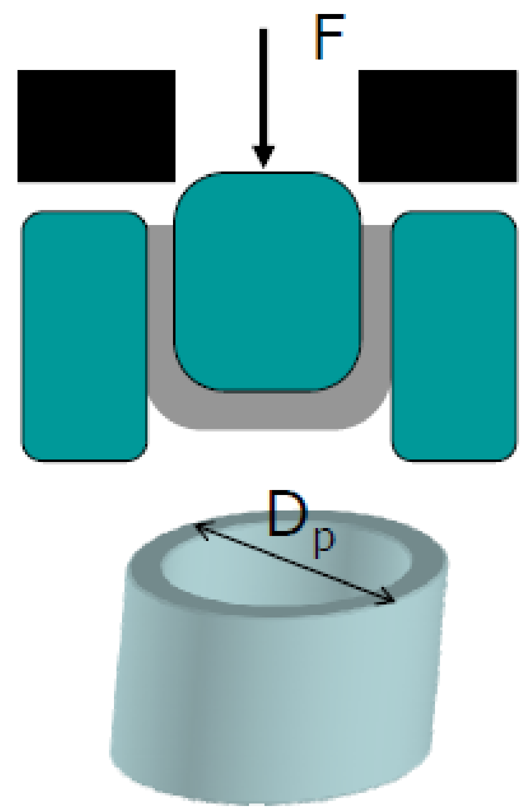
- Flanging
- Hemming
- Seaming
- Curling
- Channel,
- U-bending
  Air bending,
  Offset bending,
  Corrugating and
  Tube forming



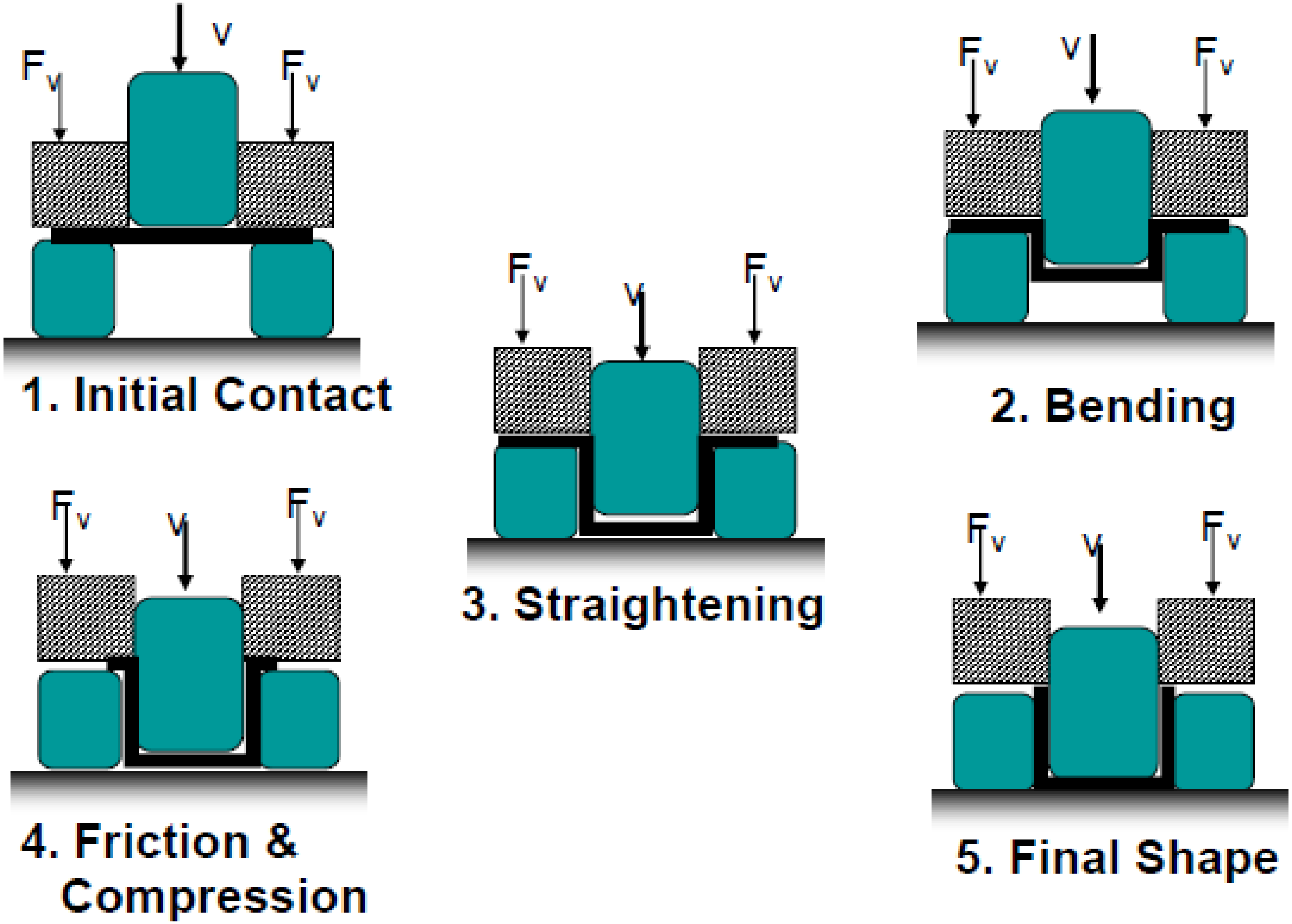
3. Drawing

- Basic drawing operation – a cup-shape part



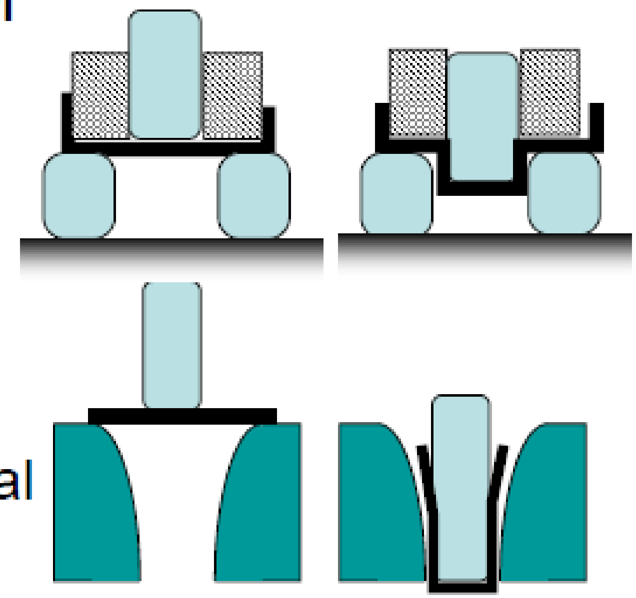


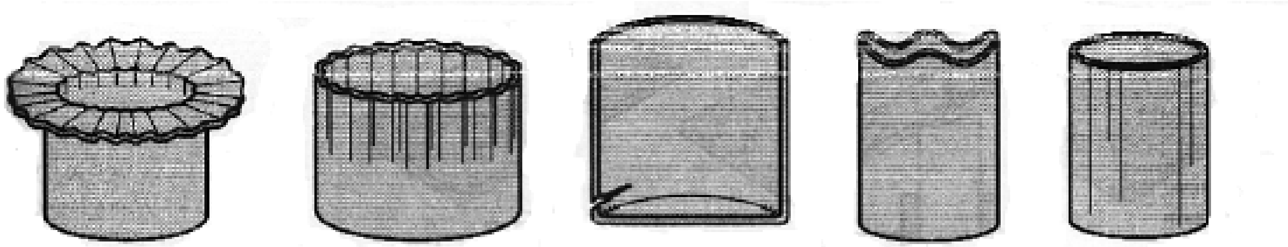
Detail Steps of Drawing



Other Drawing Operation

- Redrawing
- Drawing without a Blankholder
- Not cylindrical cups
- Defects
  - Wrinkling in the flange
  - Wrinkling in the wall
  - Tearing
  - Earing – Anistropy in sheet metal
  - Surface scratch

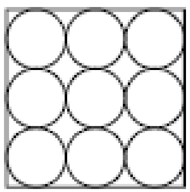


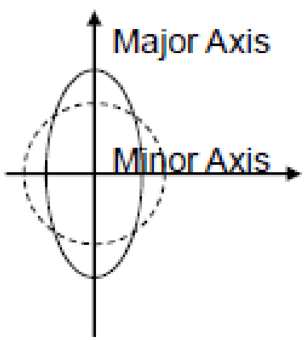


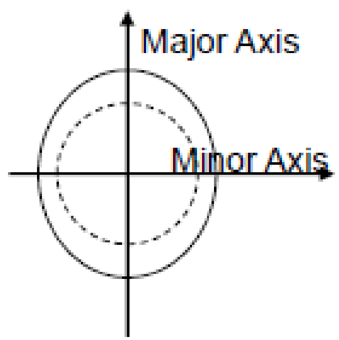
(a) Wrinkling in the flange (b) Wringkling in the wall (c) Tearing (d) Earing (e) Surface Scratches

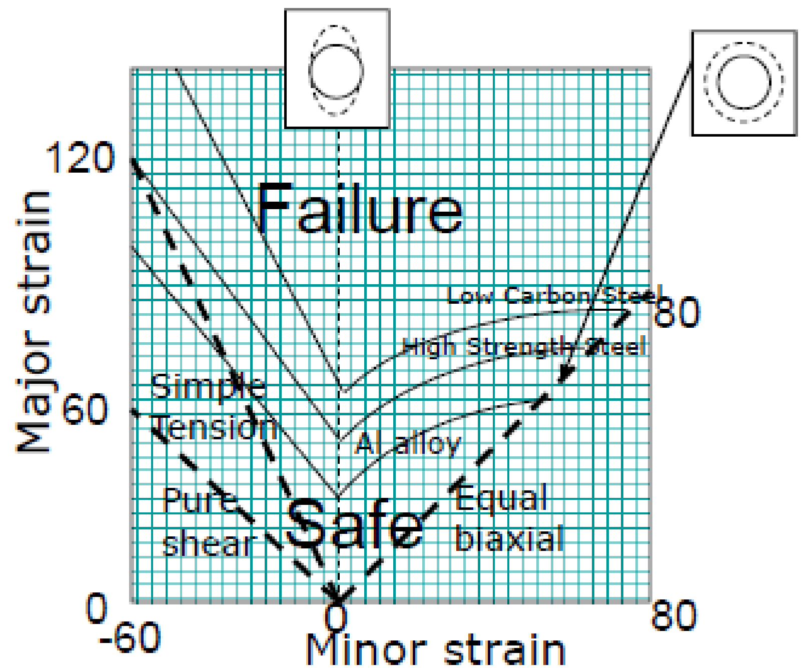
Forming-Limit Diagram

- A grid pattern of circles, typically 2.5 to 5mm in diameter, produced by electrochemical or photoprinting.
- After drawing, the circles are observed for failure.
- The major strain is on the major direction and magnitude of strain





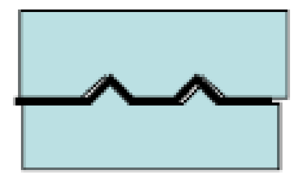




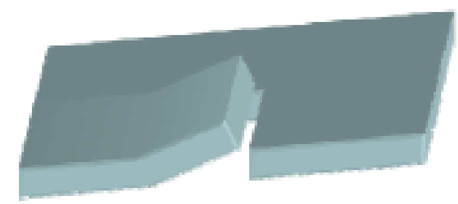
4. Other Sheet-Metal Operations

- With Metal Tooling
  - Ironing

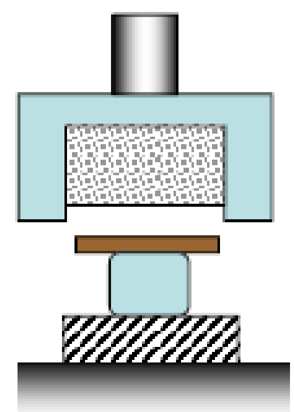
  - Coining and Embossing



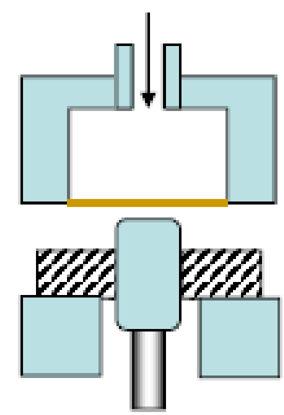
  - Lancing



- Using hydrostatic pressure
  - Guerin Process – Rubber pad



  - Hydroforming - Hydraulic fluid



5. Dies and Presses

- Stamping Die
  - Punch
  - Die
  - Stripper
- Types
  - Simple
  - Compound
  - Progressive
- Press
  - Hydraulic
  - Mechanical