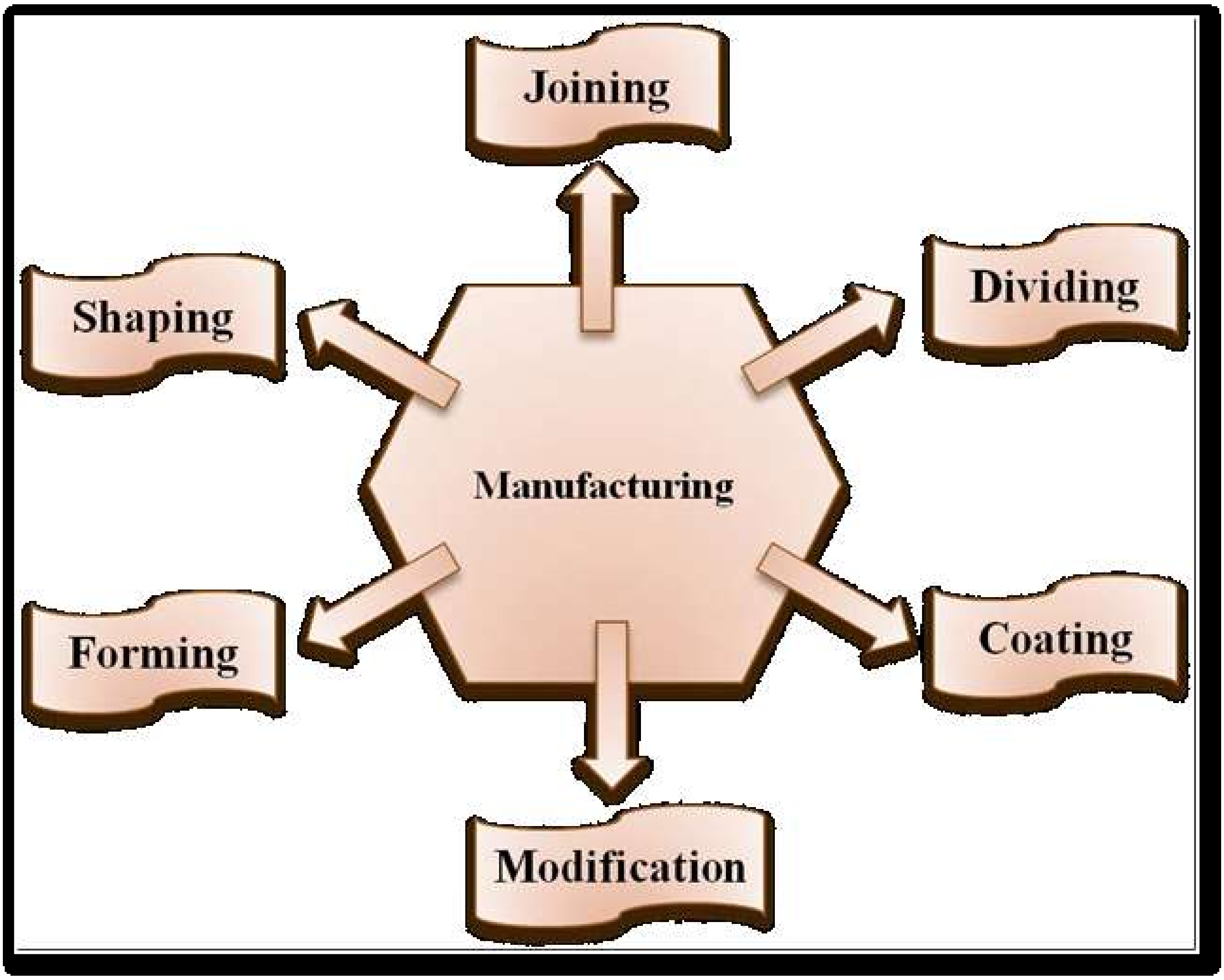
METAL FORMING

Lecture 1

FUNDAMENTALS OF METAL FORMING

There are four basic production processes for producing desired shape of a product. These are casting, machining, joining (welding, mechanical fastners, epoxy, etc.), and deformation processes. Casting process exploit the fluidity of a metal in liquid state as it takes shape and solidifies in a mold. Machining processes provide desired shape with good accuracy and precision but tend to waste material in the generation of removed portions. Joining processes permit complex shapes to be constructed from simpler components and have a wide domain of applications.



Deformation processes make use of a remarkable property of metals, which is their ability to flow plastically in the solid state without deterioration of their properties. With the application of suitable pressures, the material is moved to obtain the desired shape with almost no wastage. The required pressures are generally high and the tools and equipment needed are quite expensive. Large production quantities are often necessary to justify the process.

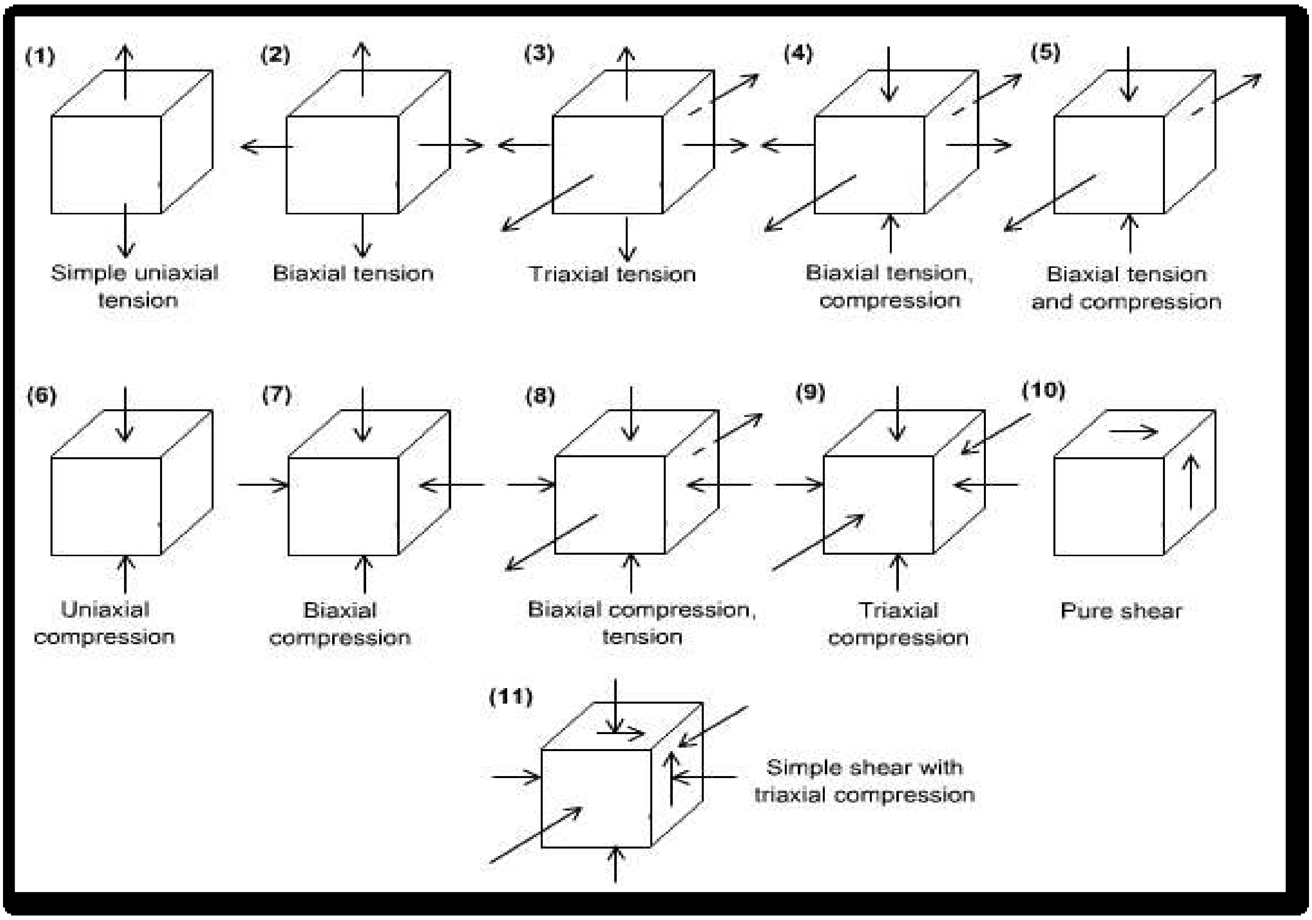
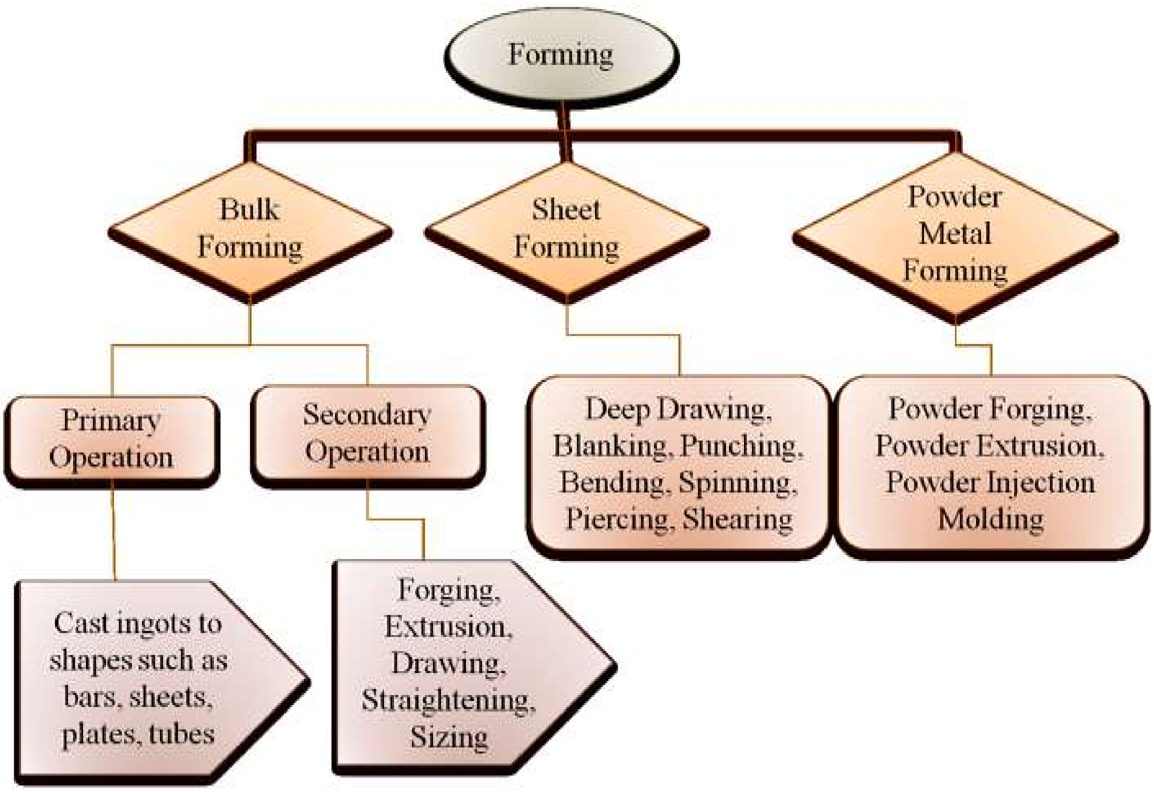
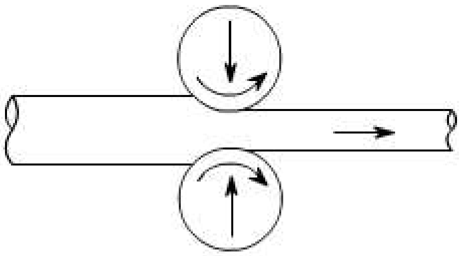
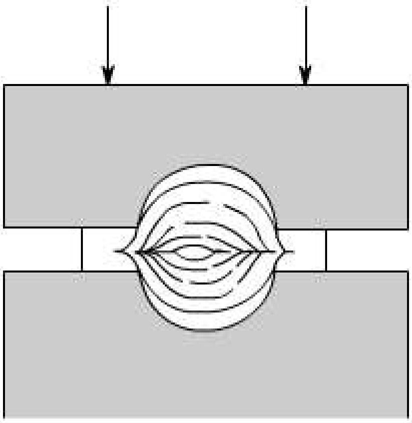
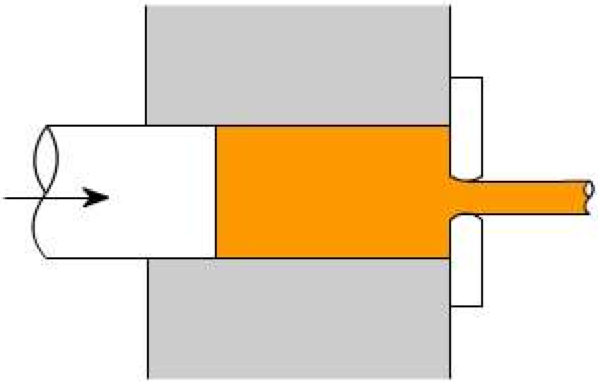


Fig.: State of the stresses metal undergo during deformation.

❖ Classification of Forming Process



As a metal is deformed (or formed, as often called) into useful shape, it experiences stresses such as tension, compression, shear, or various combinations thereof Fig 1.1 illustrates these states of stresses. Some common metal forming processes are schematically given in Fig 1.2 along with the state of stress experienced by the metal during the process.

Number	Process	State of Stress in Main Part During Forming
1	Rolling 	Bi-axial compression
2	Forging 	Tri-axial compression
3	Extrusion 	Tri-axial compression

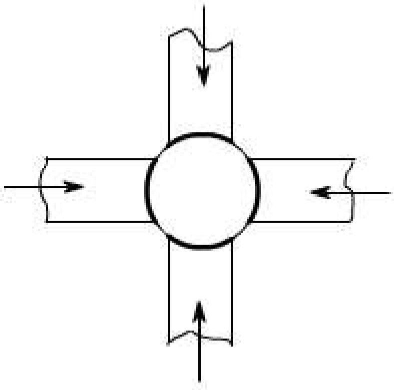
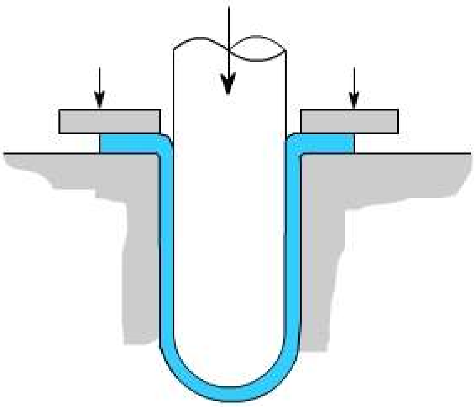
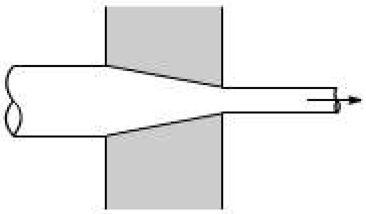
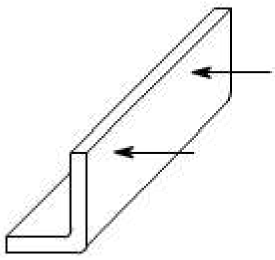
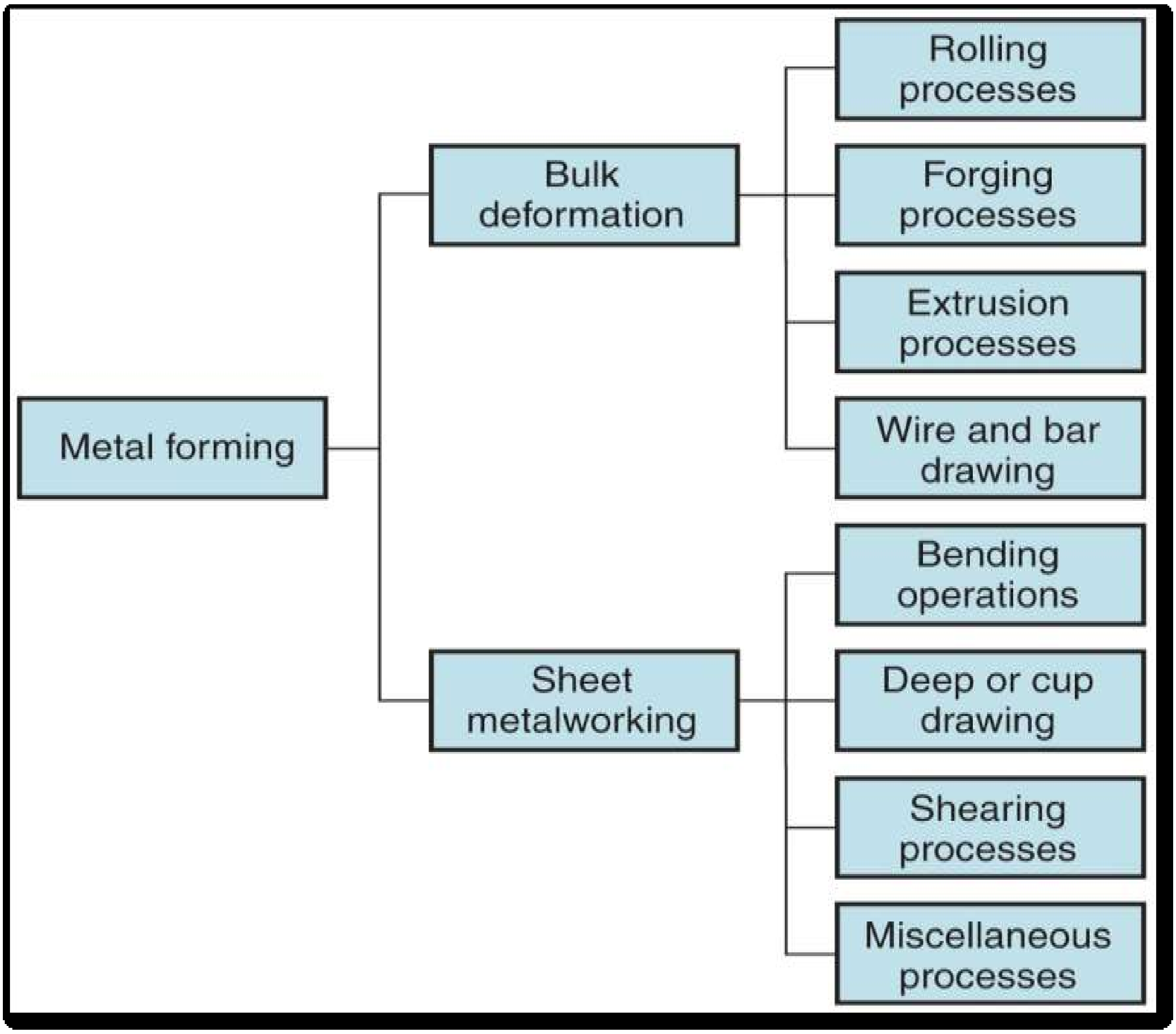
4	swaging 	Bi-axial compression
5	Deep drawing 	In flange of blank, bi-axial tension and compression. In wall of cup, simple uni-axial tension.
6	Wire and tube drawing 	Bi-axial compression, tension.
7	Straight bending 	At bend, bi-axial compression and bi-axial tension

Fig .: Common metal forming processes. State of stress experienced by metal is also given

Lecture-2

Metal Forming Operations (Rolling & Forging)

❖ Classification of Metal Forming Process:



Bulk Forming Processes:

1). Rolling Process:

Rolling is a compressive deformation process, which is used for producing semi-finished products such as bars, sheets, plates and finished products such as angles, channels, sections. Rolling can be carried out both in hot and cold conditions.

- **Hot rolling**

  Hot rolling is a metalworking process that occurs above the recrystallization temperature of the material. After the grains deform during processing, they recrystalline, which maintains an equiaxed microstructure and prevents the metal from work hardening. The starting material is usually large pieces of metal, like semi-finished casting products, such as slabs, blooms, and billets. If these products came from a continuous casting operation the products are usually fed directly into the rolling mills at the proper temperature. In smaller operations the material starts at room temperature and must be heated. This is done in a gas- or oil-fired soaking pit for larger work pieces and for smaller work pieces induction heating is used. As the material is worked the temperature must be monitored to make sure it remains above the recrystallization temperature. To maintain a safety factor a finishing temperature is defined above the recrystallization temperature; this is usually 50 to 100 °C (90 to 180 °F) above the recrystallization temperature. If the temperature does drop below this temperature the material must be re-heated before more hot rolling

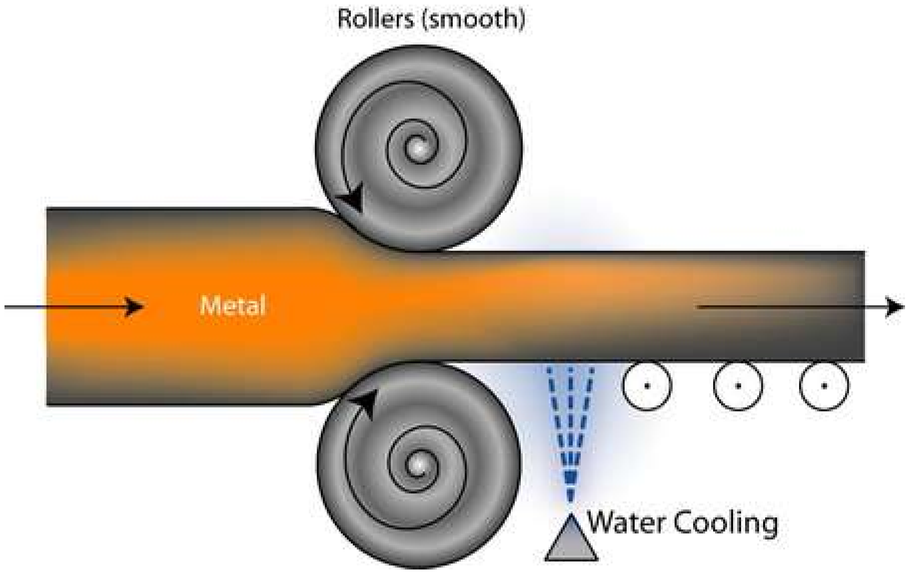
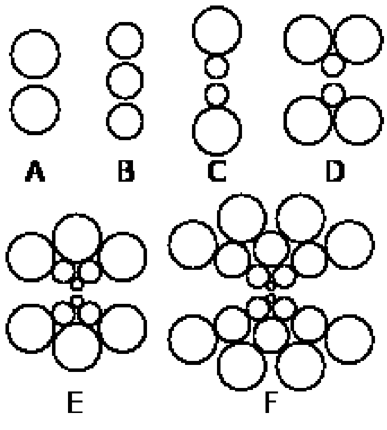


Fig.: Rolling Process

- **Cold rolling**

Cold rolling occurs with the metal below its recrystallization temperature (usually at room temperature), which increases the strength via strain hardening up to 20%. It also improves the surface finish and holds tighter tolerances. Commonly cold-rolled products include sheets, strips, bars, and rods; these products are usually smaller than the same products that are hot rolled. Because of the smaller size of the work pieces and their greater strength, as compared to hot rolled stock, four-high or cluster mills are used. Cold rolling cannot reduce the thickness of a work piece as much as hot rolling in a single pass



Various rolling mill configurations:

A.= 2-high

B. = 3-high

C.= 4-high

D. = 6-high

E. = 12-high cluster

F. = 20-high

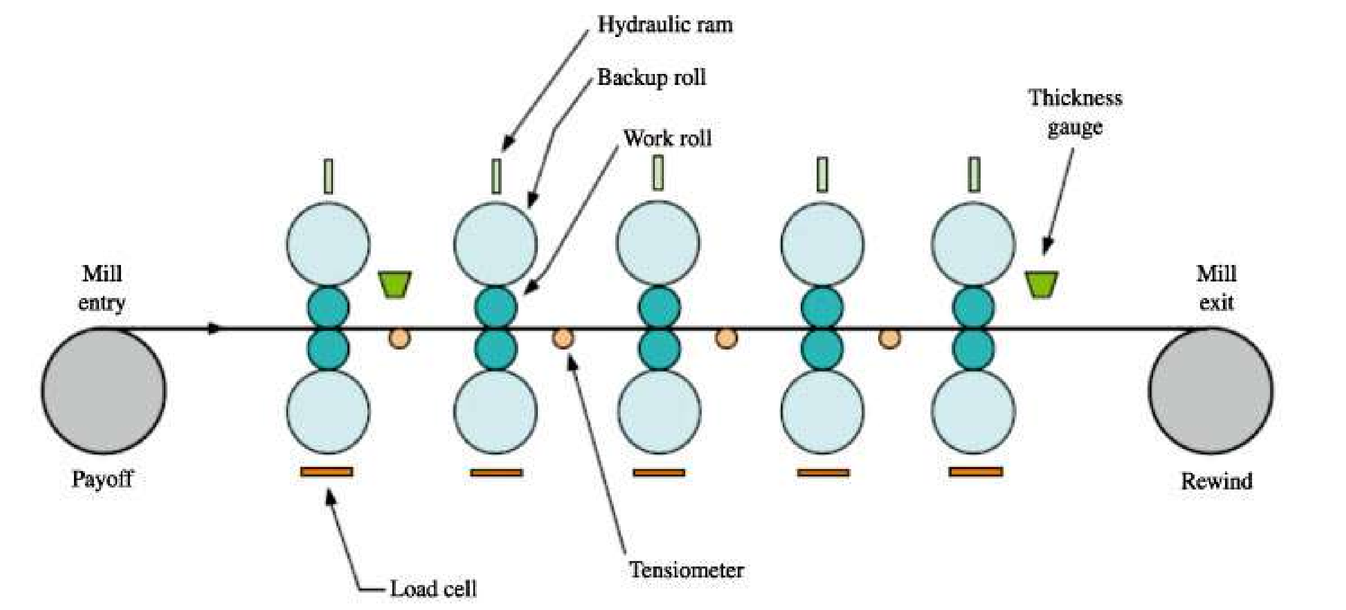
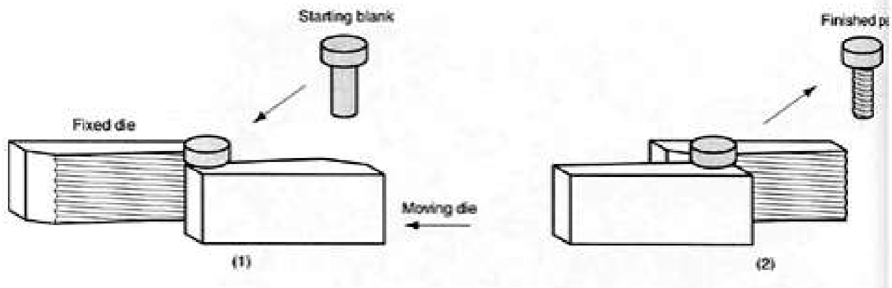
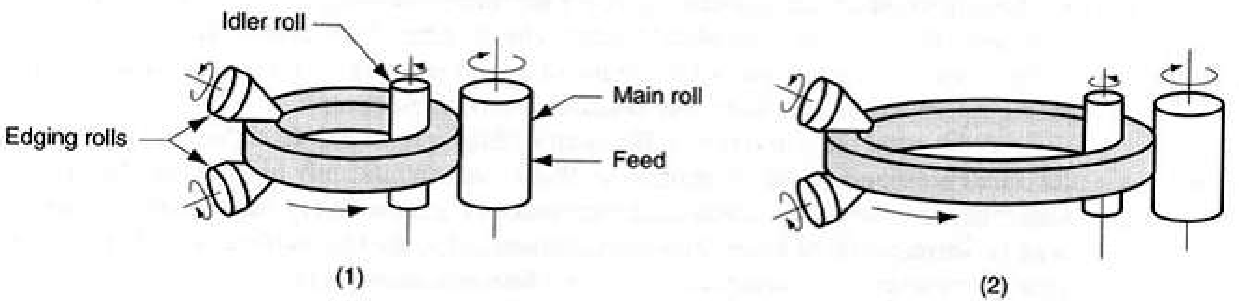
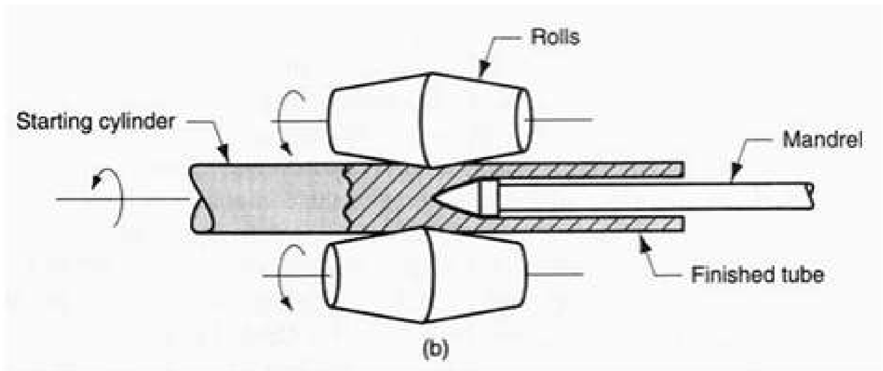


Figure 1. Typical 5-stand tandem cold mill[11].

Other deformation processes related to rolling







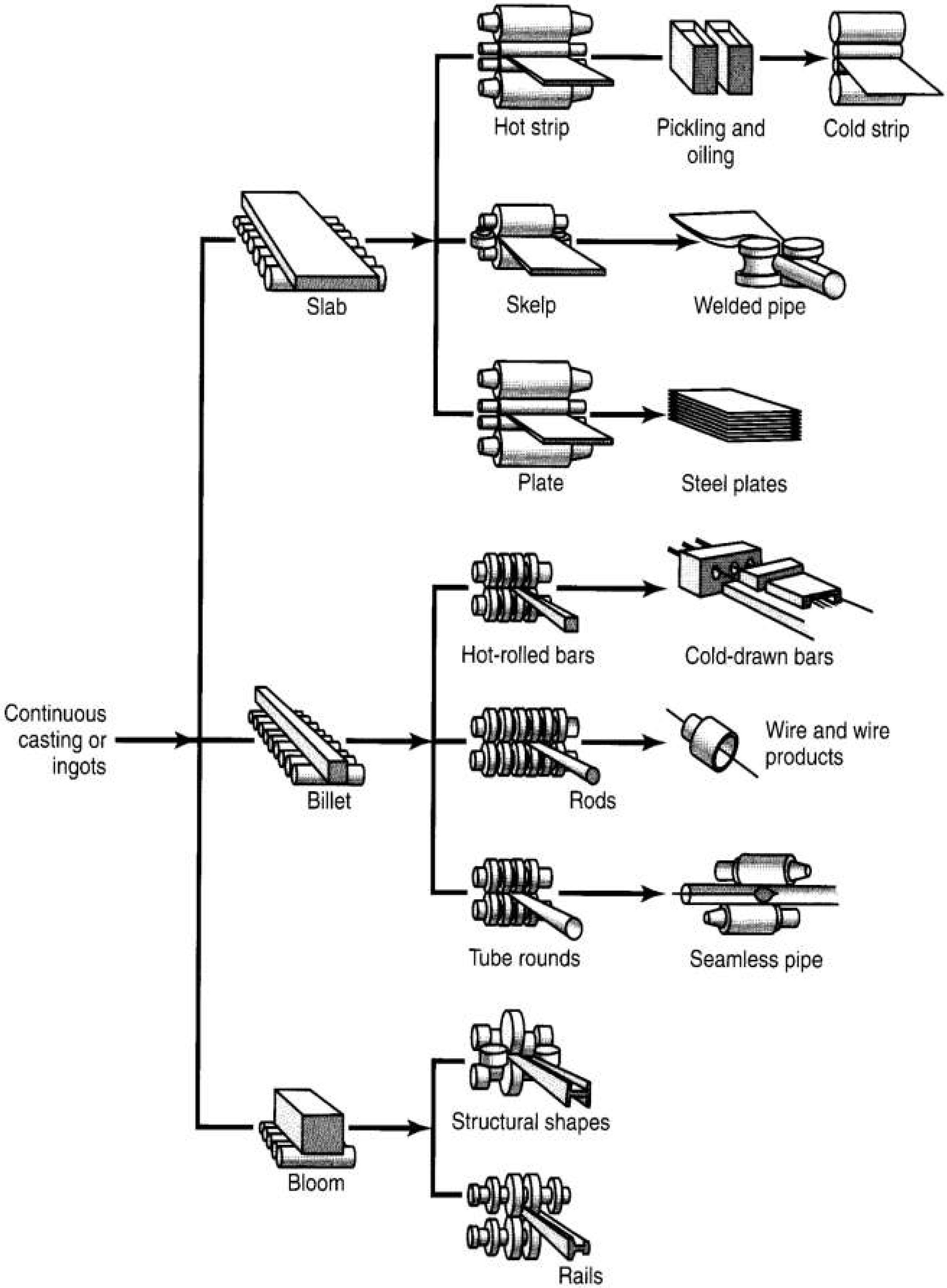


FIGURE 13.1 Schematic outline of various flat-rolling and shape-rolling processes.
Source: After American Iron and Steel Institute.

2). Forging:

Metal forging is a metal forming process that involves applying compressive forces to a work piece to deform it, and create a desired geometric change to the material. The forging process is very important in industrial metal manufacture, particularly in the extensive iron and steel manufacturing industry. A steel forge is often a source of great output and productivity. Work stock is input to the forge, it may be rolled, it may also come directly from cast ingots or continuous castings. The forge will then manufacture steel forgings of desired geometry and specific material properties. These material properties are often greatly improved.

Metal forging is known to produce some of the strongest manufactured parts compared to other metal manufacturing processes, and obviously, is not just limited to iron and steel forging but to other metals as well. Different types of metals will have a different factors involved when forging them, some will be easier to forge than others. Metal forging, specifically, can strengthen the material by sealing cracks and closing empty spaces within the metal.

Forging is a bulk forming process in which the work piece or billet is shaped into finished part by the application of compressive and tensile forces with the help of a pair of tools called die and punch. Forging can be done in open dies or closed dies. Open die forging is usually used for preliminary shaping of raw materials into a form suitable for subsequent forming or machining

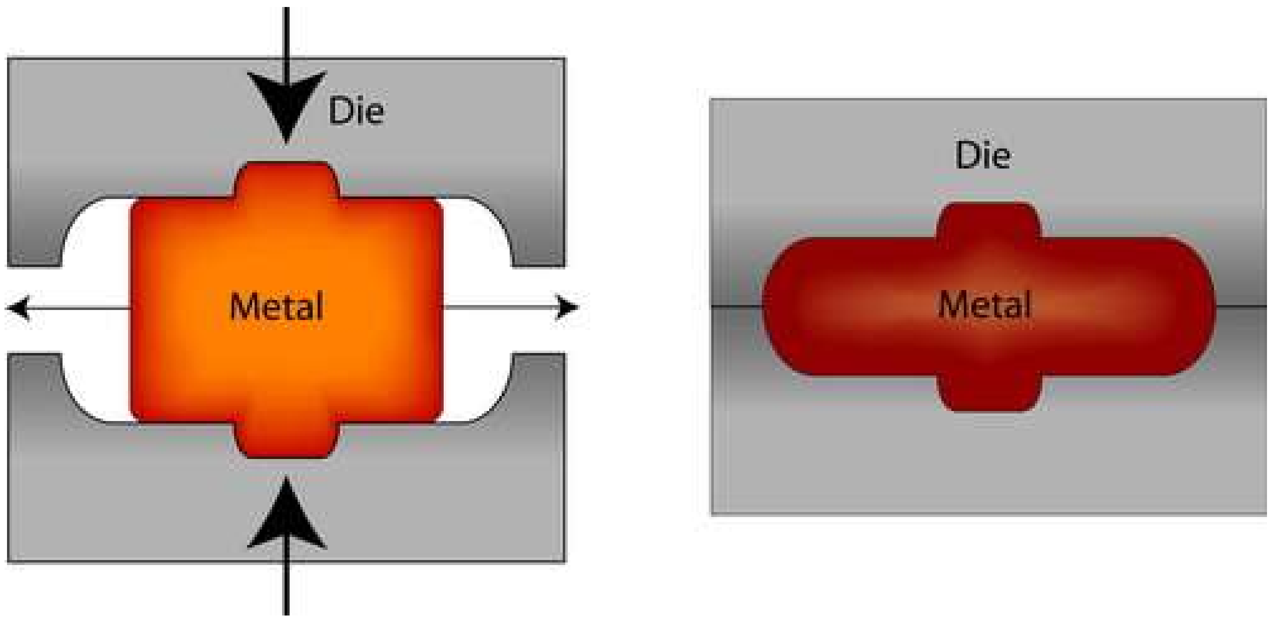
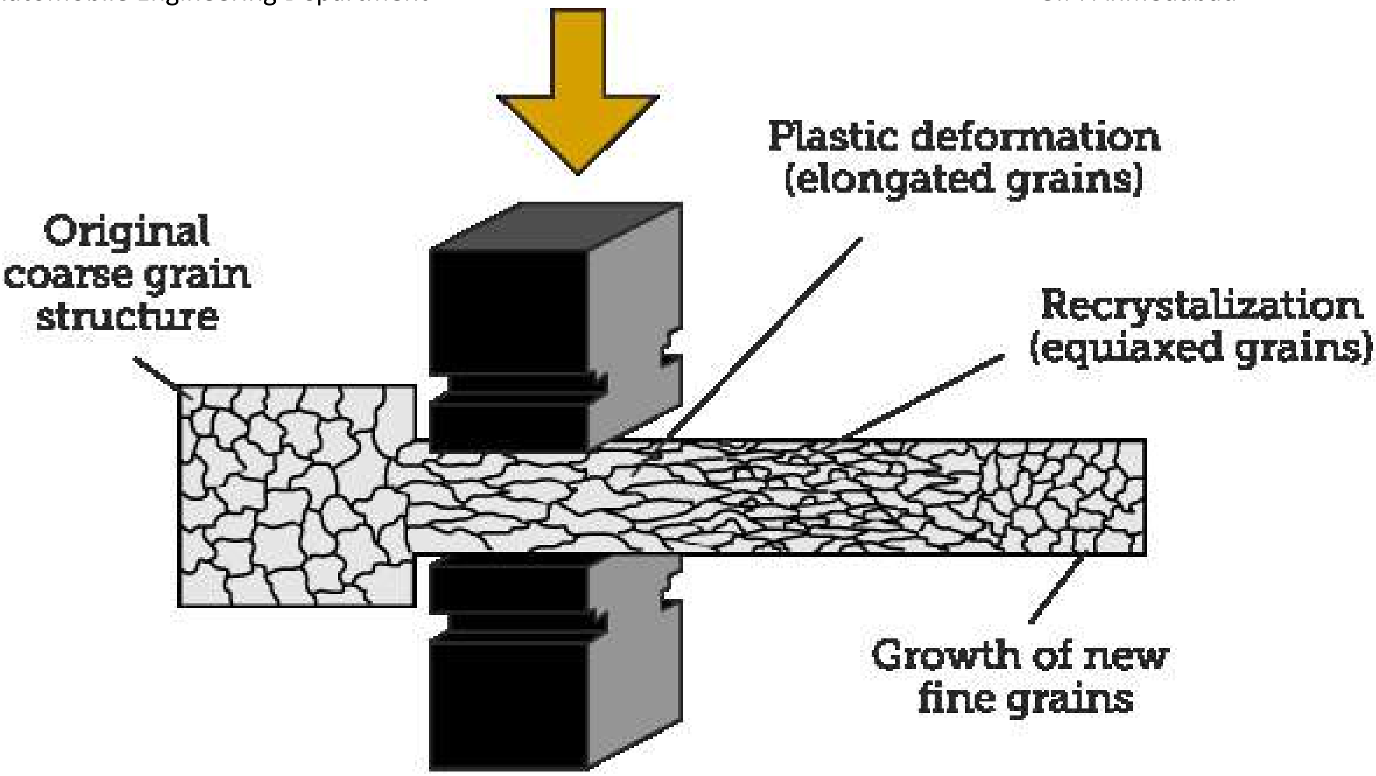


Fig.: Forging processes



How the open die forging process affects the crystal structure.

Open die forming is done using a pair of flat faced dies for operations such as drawing out, thinning, etc.

Closed die forming is performed by squeezing the raw material called billet inside the cavity formed between a pair of shaped dies. Formed products attain the shape of the die cavity. Valve parts, pump parts, small gears, connecting rods, spanners, etc are produced by closed die forming

Metal forging manufacture gives distinct advantages in the mechanical properties of work produced, over that of parts manufactured by other processes such as only casting or machining

Lecture 3

Metal Forming Operations (Extrusion & Wire Drawing)

3). Extrusion:

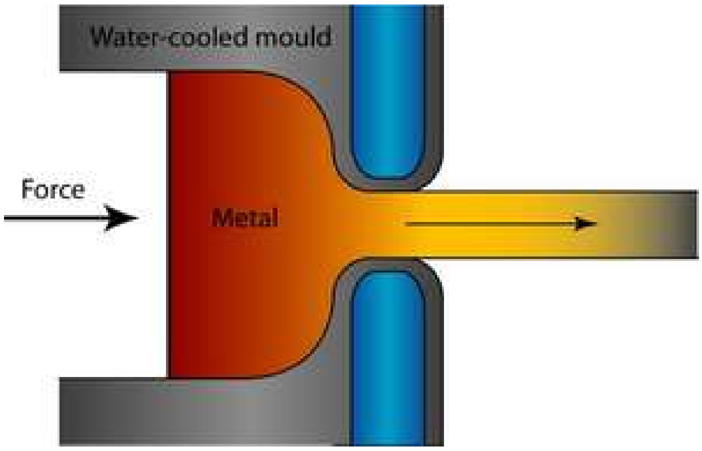


Fig.: Direct extrusion process

Extrusion involves forcing the raw material through a narrow opening of constant cross-section or varying cross-section in order to reduce the diameter and increase the length. Extrusion can be done hot or cold. Extruded products include shafts, tubes, cans, cups, gears. Basically there are two methods of extrusion, forward and backward extrusions. In forward extrusion the work and the extrusion punch move along the same direction. In backward extrusion the punch moves opposite to the direction of movement of the work piece

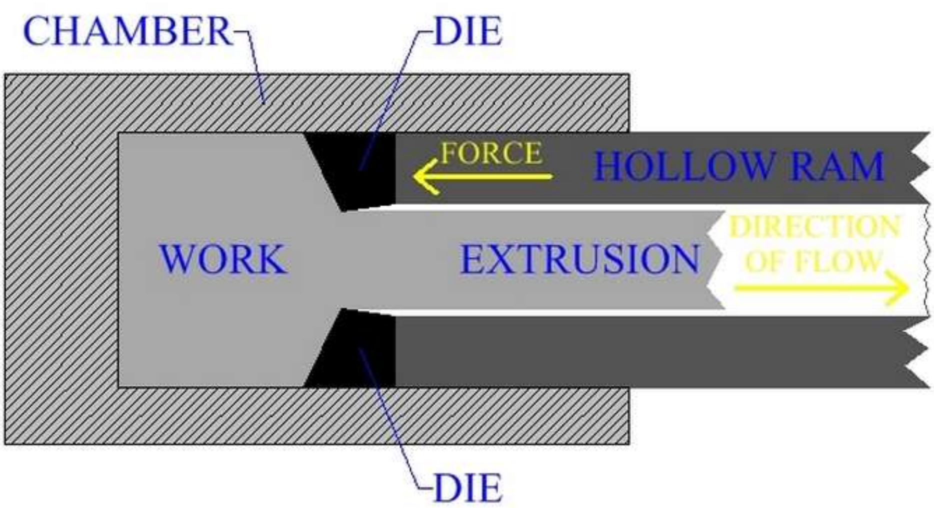


Fig.: Backward extrusion or indirect extrusion

Forward or direct extrusion	*Backward or indirect extrusion*
1. Simple, but the material must slide along the chamber wall.	1. In this case, material does not move but die moves.
2. High friction forces must be overcome.	2. Low friction forces are generated as the mass of material does not move.
3. High extrusion forces required but mechanically simple and uncomplicated.	3. 25–30% less extruding force required as compared to direct extrusion. But hollow ram required limited application.
4. High scrap or material waste—18–20% on an average.	4. Low scrap or material waste only 5–6% of billet weight.

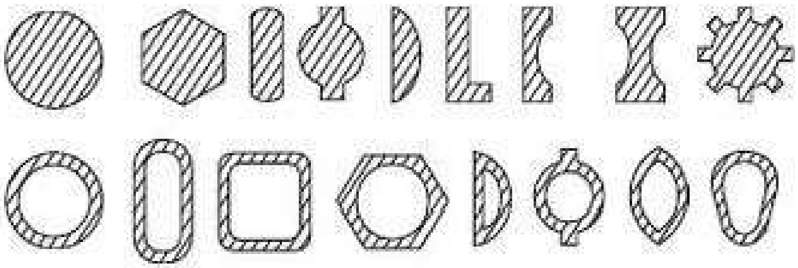


Fig: Various shapes can be made by extrusion process

❖ **EXTRUSION PROCESSES:**

- Hot Extrusion
- Forward or Direct extrusion.
- Backward or Indirect extrusion.
- Cold Extrusion
- Hooker extrusion.
- Hydrostatic extrusion.
- Impact extrusion.
- Cold extrusion forging.

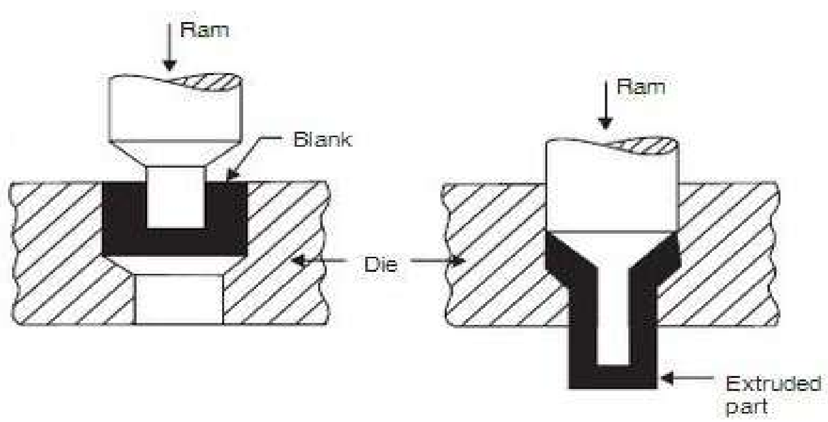


Fig. 4.4 Hooker extrusion

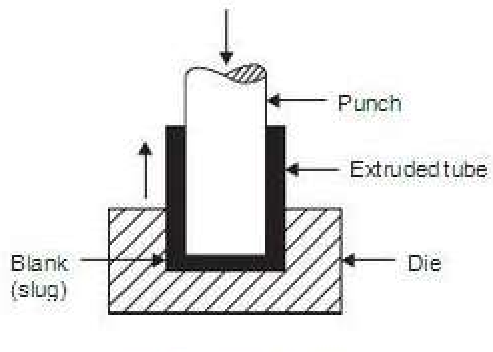


Fig. 4.5 Impact extrusion

Cold extrusion	*Hot extrusion*
1. Better surface finish and lack of oxide layers.	1. Surface is coated with oxide layers. Surface finish not comparable with cold extrusion.
2. Good control of dimensional tolerance—no machining or very little machining required.	2. Dimensional control not comparable with cold extrusion products.
3. High production rates at low cost. Fit for individual component production.	3. High production rates but process fit for bulk material, not individual components.
4. Improved mechanical properties due to strain hardening.	4. Since processing is done hot, recrystallisation takes place.
5. Tooling subjected to high stresses.	5. Tooling subjected to high stresses as well as to high temperature. Tooling stresses are however lower than for cold extrusion.
6. Lubrication is crucial.	6. Lubrication is crucial.

❖ **Advantages of extrusion process:**

1. The complexity and range of parts which can be produced by extrusion process is very large. Dies are relative simple and easy to make.
2. The extrusion process is complete in one pass only. This is not so in case of rolling, amount of reduction in extrusion is very large indeed. Extrusion process can be easily automated.
3. Large diameter, hollow products, thin walled tubes etc. are easily produced by extrusion process.
4. Good surface finish and excellent dimensional and geometrical accuracy is the hall mark of extruded products. This cannot be matched by rolling.

4). Wire drawing

Wire drawing is a simple process. In this process, rods made of steel or non ferrous metals and alloys are pulled through conical dies having a hole in the centre. The included angle of the cone is kept between 8° to 24°. As the material is pulled through the cone, it undergoes plastic deformation and it gradually undergoes a reduction in its diameter. At the sometime, the length is increased proportionately. The process is illustrated in Fig.

Wire drawing process is used for producing small diameter wires from rods by reducing their diameter and stretching their length through the application of tensile force. Musical strings are produced by wire drawing process. Seamless tubes can be produced by tube drawing process.

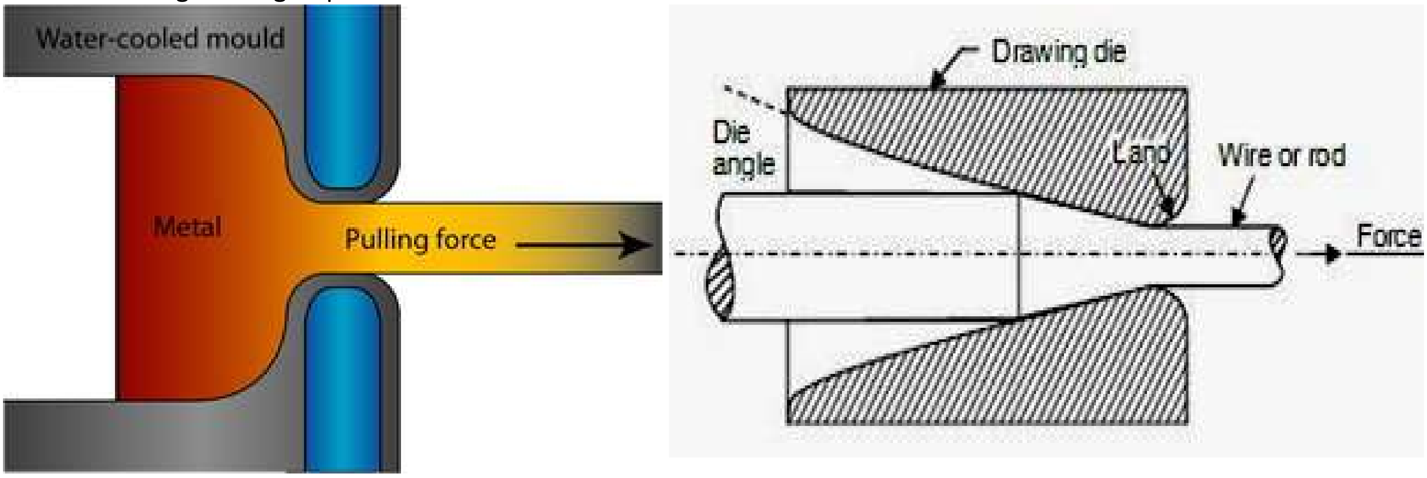


Fig.: Wire Drawing

The dies tend to wear out fast due to continuous rubbing of metal being pulled through it. Hence they are made of very hard material like alloy steel, tungsten carbide or even diamond. In one pass, the reduction in cross-sectional area achieved is about 25–30%. Hence in a wire drawing plant, the wire has to pass through a number of dies of progressively reducing diameter to achieve the required reduction in diameter. However as the wire passes through dies and undergoes plastic deformation, it gets strain hardened. Its strength increases and capacity to further undergo plastic deformation decreases. There-fore during the entire run of the wire, from time to time, it has to be heated (and cooled) to remove the effect of work-hardening. This process is called "**in process annealing**". The aim is to make the material soft and ductile again so that the process of drawing may be smoothly carried out.

The metal rods to be drawn into wires must be absolutely clean. If necessary, they are pickled in an acid bath to dissolve the oxide layer present on the surface. Its front end is then tapered down so that it may pass through the hole in the die which is firmly held in the wire drawing machine. The wire is drawn by means of a number of power driven spools or rotating drums.

During wire drawing, a great deal of heat is generated due to friction between the wire rod and the die. To reduce friction, dry soap or a synthetic lubricant is used. But despite reducing friction, the dies and drums may have to be water cooled. The preferred material for dies is tungsten carbide but for drawing fine wire, use of ruby or diamond dies is preferred.

Lecture 4

Metal Forming Operations (Deep Drawing & Spinning)

Sheet metal operations:

1). Deep drawing:

Deep drawing is sheet metals process, the process in which a sheet metal is forced into cup of hollow shape without altering its thickness – using tensile and compressive forces. Complex shapes can be produced by deep drawing of blanks in stages – redrawing, multiple draw deep drawing etc

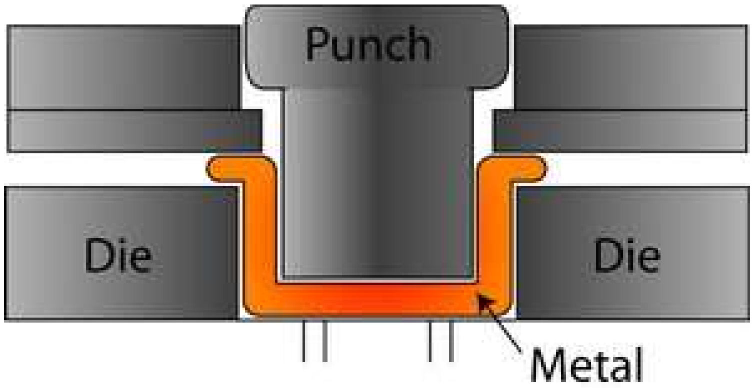


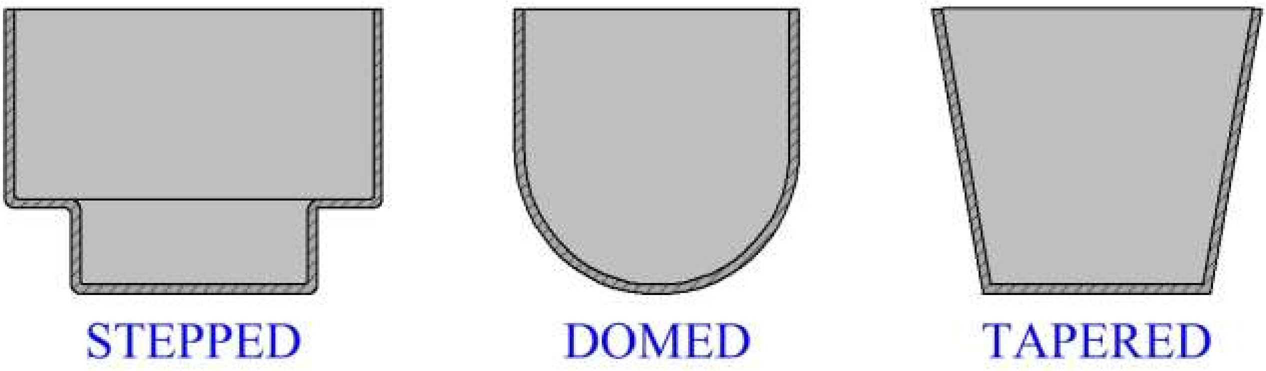
Fig.: Deep drawing

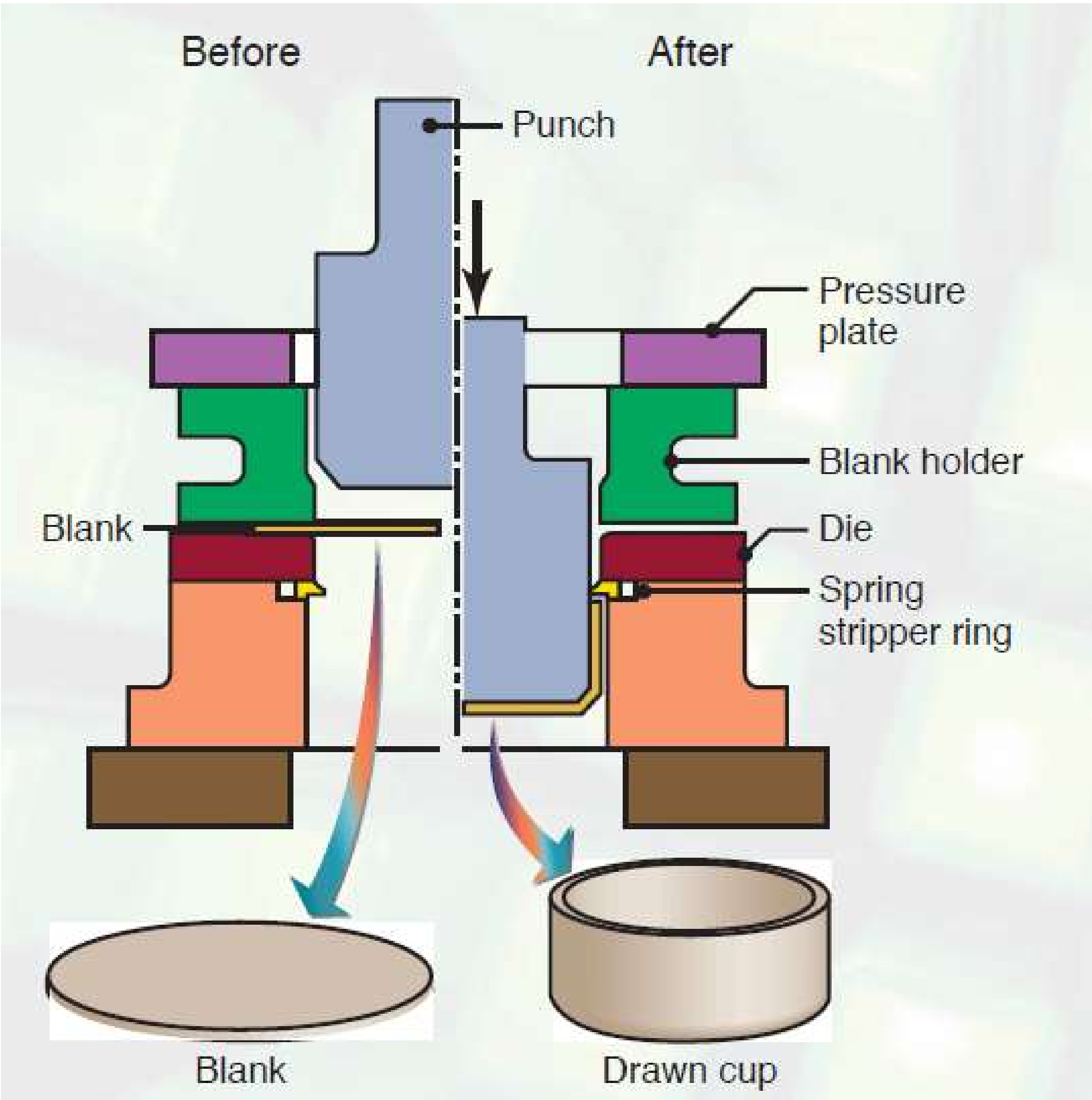
The metal flow during deep drawing is extensive and hence, requires careful administration to avoid tearing or fracture. Following are some of key issues affecting metal flow during deep drawing process and each of them should be considered when designing or troubleshooting sheet metal deep drawing stamping tools.

Deep drawing of sheet metal is performed with a punch and die. The punch is the desired shape of the base of the part, once drawn. The die cavity matches the punch and is a little wider to allow for its passage, as well as clearance. This setup is similar to sheet metal cutting operations. As in cutting, clearance is the lateral distance between the die edge and the punch edge. The sheet metal work piece, called a blank, is placed over the die opening. A blank holder, that surrounds the punch, applies pressure to the entire surface of the blank, (except the area under the punch), holding the sheet metal work flat against the die. The punch travels towards the blank. After contacting the work, the punch forces the sheet metal into the die cavity, forming its shape.

Hydro mechanical deep drawing uses both punch force and hydrostatic force of a pressurized fluid for achieving the shape. Flanges and collars are formed by flanging process.

NON STANDARD DEEP DRAWING SHAPES





2). Spinning:

Spinning transforms a sheet metal into a hollow shape by compressive and tensile stresses. Spinning mandrel of given shape is used against a roll head. Metal spinning, also known as spin forming or spinning or metal turning most commonly, is a metalworking process by which a disc or tube of metal is rotated at high speed and formed into an axially symmetric part. Spinning can be performed by hand or by a CNC lathe.

Metal spinning does not involve removal of material, as in conventional wood or metal turning, but forming (moulding) of sheet material over an existing shape. Metal spinning ranges from an artisan's specialty to the most advantageous way to form round metal parts for commercial applications. Artisans use the process to produce architectural detail, specialty lighting, decorative household goods and urns.

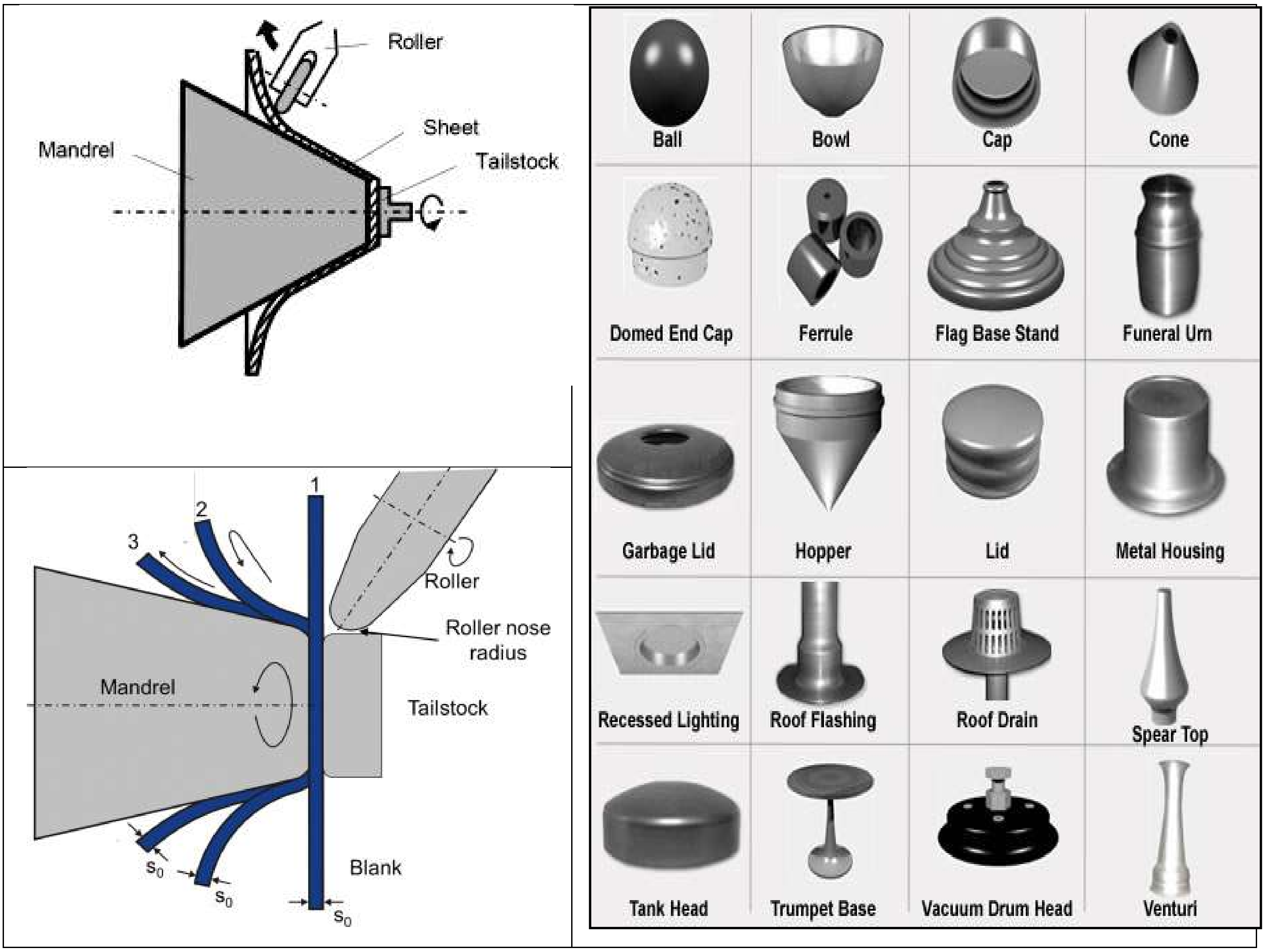


Fig.: Spinning Process & Applications

Lecture 5

Metal Forming Operations (Embossing, & Bending)

3). Embossing:

Embossing imparts an impression on the work piece by means of an embossing punch. The metal sheet embossing operation is commonly accomplished with a combination of heat and pressure on the sheet metal, depending on what type of embossing is required. Theoretically, with any of these procedures, the metal thickness is changed in its composition.

Metal sheet is drawn through the male and female roller dies, producing a pattern or design on the metal sheet. Depending on the roller dies used, different patterns can be produced on the metal sheet. The pressure and a combination of heat actually "irons" while raising the level of the image higher than the substrate to make it smooth. The term "impressing" refers to an image lowered into the surface of a material, in distinction to an image raised out of the surface of a material.

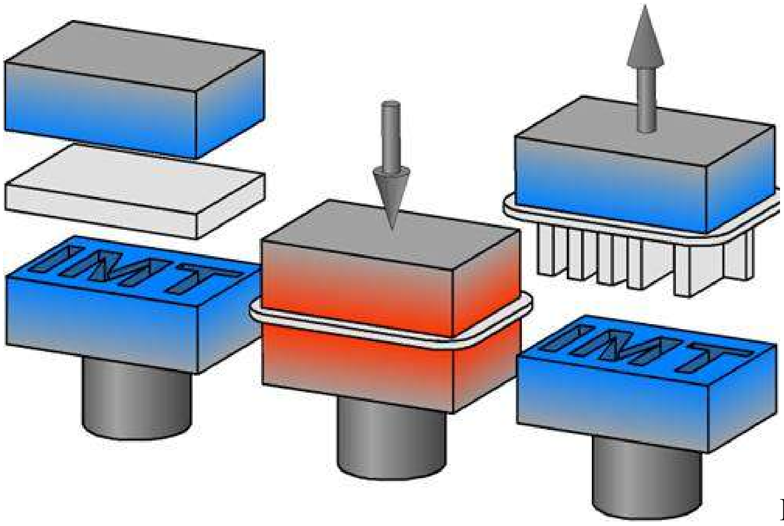


Fig.: Embossing Process

Fig: applications of metal Embossing process

4). Bending:

Bending of sheet metal is a common and vital process in manufacturing industry. **Sheet metal bending** is the plastic deformation of the work over an axis, creating a change in the part's geometry. Similar to other metal forming processes, bending changes the shape of the work piece, while the volume of material will remain the same. In some cases bending may produce a small change in sheet thickness. For most operations, however, bending will produce essentially no change in the thickness of the sheet metal. In addition to creating a desired geometric form, bending is also used to impart strength and stiffness to sheet metal, to change a part's moment of inertia, for cosmetic appearance and to eliminate sharp edges.

Bending of sheets includes rotary bending, swivel bending, and roll bending using rotary die. Die bending using flat die or shaped die is used for bending of sheets, or die coining of sheets

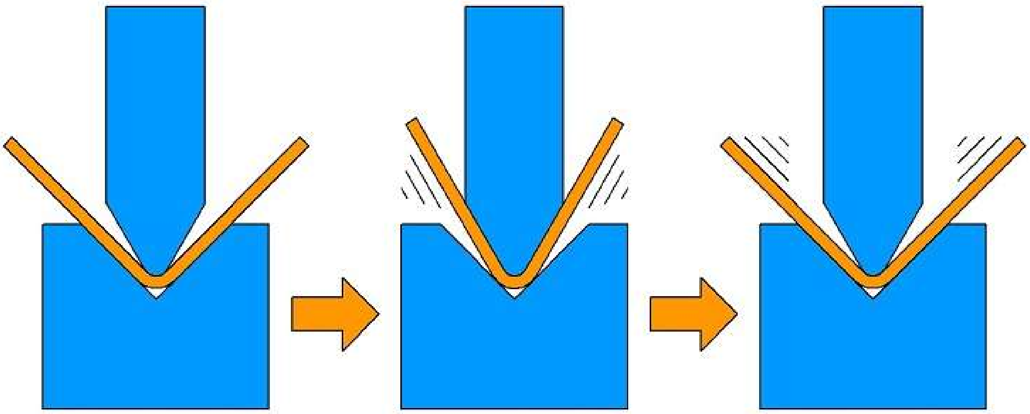
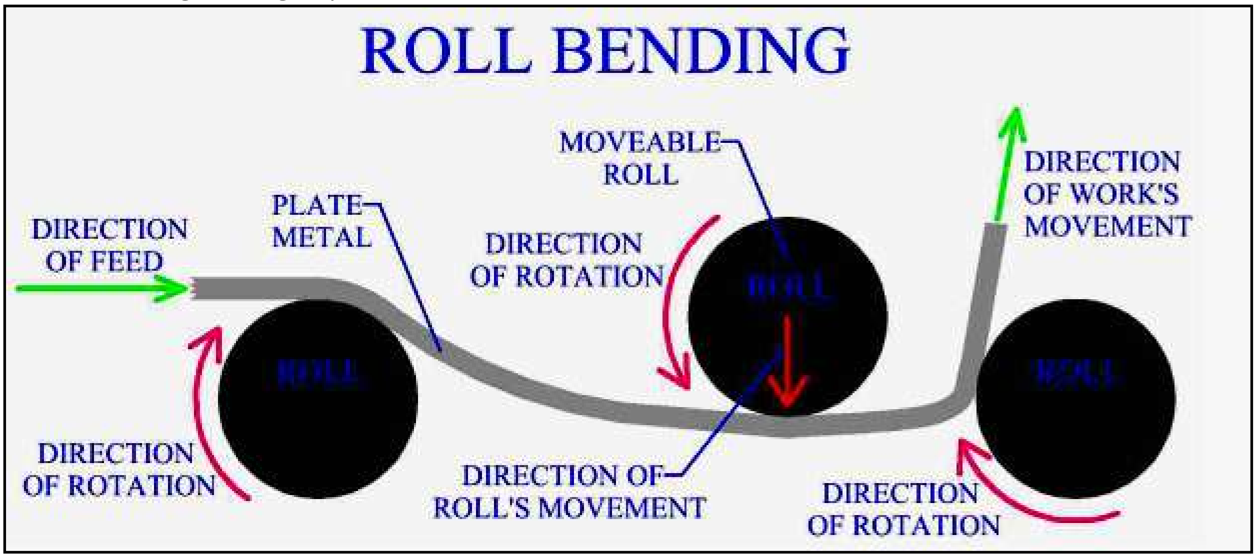
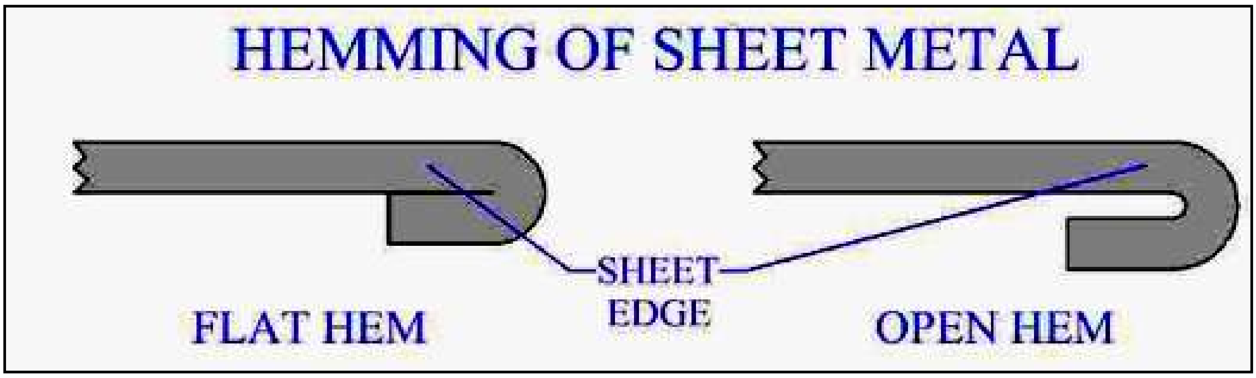


Fig: Bending process

Most sheet metal bending operations involve a punch die type setup, although not always. There are many different punch die geometries, setups and fixtures. Tooling can be specific to a bending process and a desired angle of bend. Bending die materials are typically gray iron, or carbon steel, but depending on the work piece, the range of punch-die materials varies from hardwood to carbides.

Force for the punch and die action will usually be provided by a press. A work piece may undergo several metal bending processes. Sometimes it will take a series of different punch and die operations to create a single bend. or many progressive bending operations to form certain geometry.





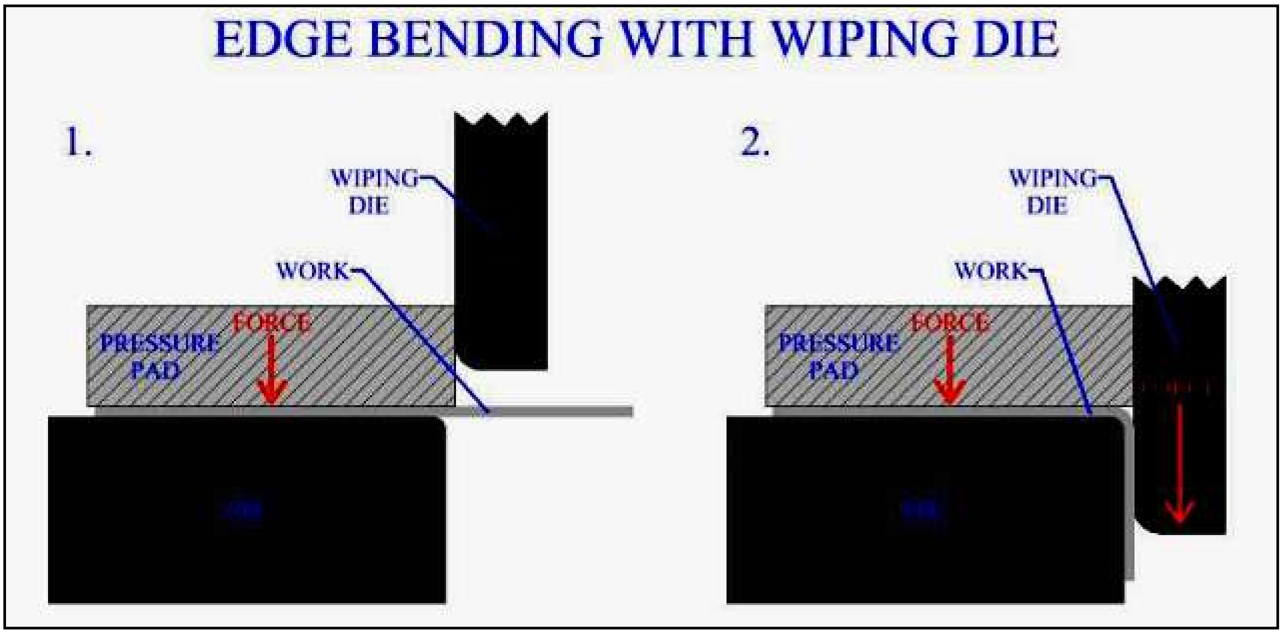


Fig: various sheet metal bending methods

Lecture 6

Metal Forming Operations (Stamping, Piercing & Blanking)

5). Stamping

Stamping is used to make high volume parts such as aviation or car panels or electronic components. Mechanical or hydraulic powered presses stamp out parts from continuous sheets of metal or individual blanks. The upper die is attached to the ram and the lower die is fixed. Whereas mechanical machinery transfers all energy as a rapid punch, hydraulic machinery delivers a constant, controlled force**.**

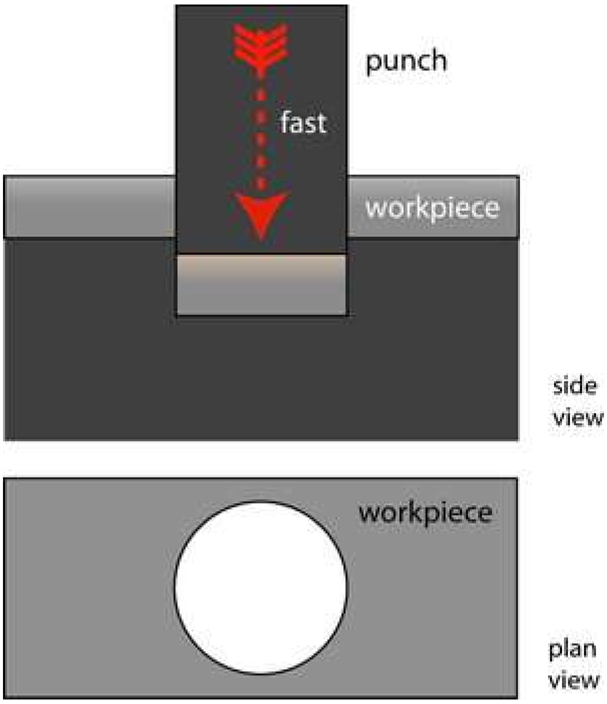
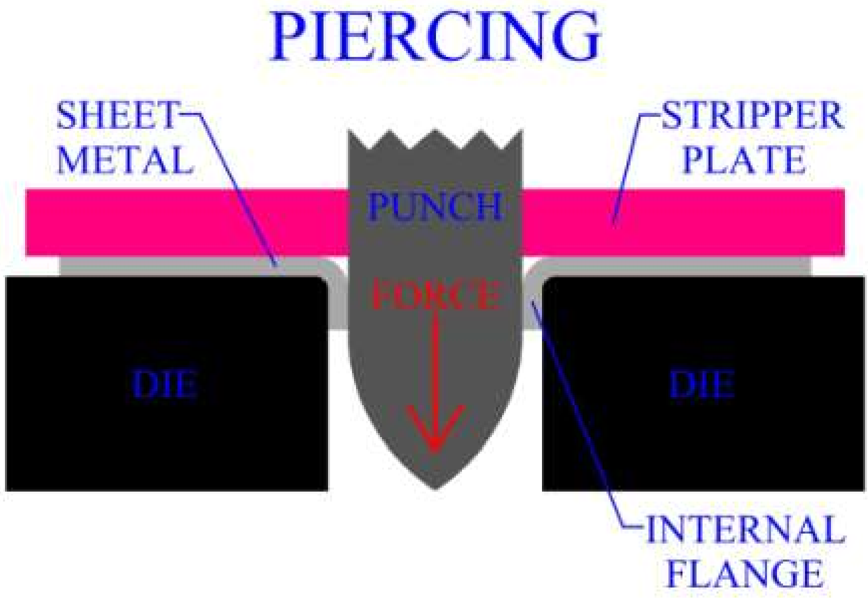


Fig.: Stamping process

6). Piercing & Blanking:

Piercing is a metal forging technique that is often performed as an auxiliary process in conjunction with other forging processes, in the manufacture of a part. It can be used to create a cavity or hole in the work piece. Piercing does not break through the metal's surface, like a drilling operation. Instead, the cavity is pressed into the work, hence it is a forging operation. Similar to other metal forging processes, piercing will change the properties of the work material, and affect the grain structure of the part. Often in manufacturing practice, more complex cavities can be further forged using side acting equipment attached to the punch

In blanking, the piece is cut off from the sheet, and it becomes a finished part. In piercing, the cutout portion is scrap which gets disposed off while the product part travels on through the remainder of the die. The terminology is different here, though both processes are basically the same and therefore belong to the same category, which is the process of metal cutting



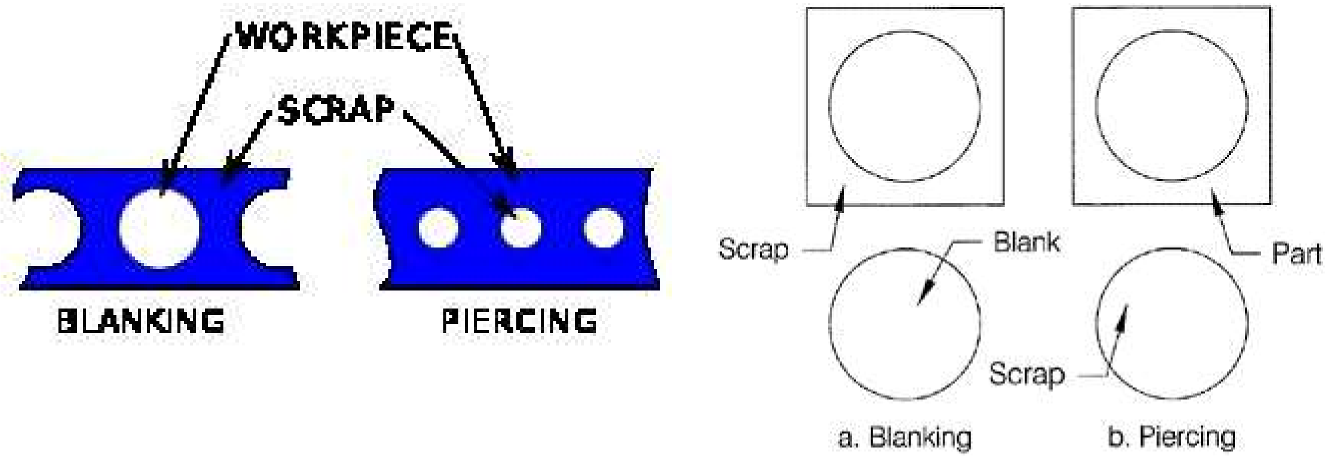


Fig: Difference between Blanking & Piercing

Lecture 7

Metal Forming Operations (Cold & Hot Working)

❖ COLD AND HOT WORKING OF METALS

1). Cold Working:

Plastic deformation of metals below the recrystallization temperature is known as cold working. It is generally performed at room temperature. In some cases, slightly elevated temperatures may be used to provide increased ductility and reduced strength. Cold working offers a number of distinct advantages, and for this reason various cold-working processes have become extremely important. Significant advances in recent years have extended the use of cold forming, and the trend appears likely to continue.

Advantages of cold working:

1. No heating is required
2. Better surface finish is obtained
3. Better dimensional control is achieved; therefore no secondary machining is generally needed.
4. Products possess better reproducibility and interchangeability.
5. Better strength, fatigue, and wear properties of material.
6. Directional properties can be imparted.
7. Contamination problems are almost negligible.

Disadvantages of cold-working processes:

1. Higher forces are required for deformation.
2. Heavier and more powerful equipment is required.
3. Less ductility is available.
4. Metal surfaces must be clean and scale-free.
5. Strain hardening occurs (may require intermediate annealing).
6. Undesirable residual stresses may be produced

Cold forming processes, in general, are better suited to large-scale production of parts because of the cost of the required equipment and tooling.

2). Warm Working:

Metal deformation carried out at temperatures intermediate to hot and cold forming is called Warm Forming. Compared to cold forming, warm forming offers several advantages. These include:

• Lesser loads on tooling and equipment

• Greater metal ductility

• Fewer number of annealing operation (because of less strain hardening)

❖ **Advantages of warm forming compare to hot forming:**

- Lesser amount of heat energy requirement
- Better precision of components
- Lesser scaling on parts
- Lesser decarburization of parts
- Better dimensional control
- Better surface finish
- Lesser thermal shock on tooling
- Lesser thermal fatigue to tooling, and so greater life of tooling.

3). Hot Working:

Plastic deformation of metal carried out at temperature above the recrystallization temperature, is called hot working. Under the action of heat and force, when the atoms of metal reach a certain higher energy level, the new crystals start forming. This is called recrystallization. When this happens, the old grain structure deformed by previously carried out mechanical working no longer exist, instead new crystals which are strain-free are formed.

In hot working, the temperature at which the working is completed is critical since any extra heat left in the material after working will promote grain growth, leading to poor mechanical properties of material.

❖ **Advantages of hot working are:**

1. No strain hardening
2. Lesser forces are required for deformation
3. Greater ductility of material is available, and therefore more deformation is possible.
4. Favorable grain size is obtained leading to better mechanical properties of material
5. Equipment of lesser power is needed
6. No residual stresses in the material.

❖ **Disadvantages associated in the hot-working of metals are:**

1. Heat energy is needed
2. Poor surface finish of material due to scaling of surface
3. Poor accuracy and dimensional control of parts
4. Poor reproducibility and interchangeability of parts
5. Handling and maintaining of hot metal is difficult and troublesome
6. Lower life of tooling and equipment.

Difference between Hot and Cold Working

Hot Working	Cold Working
1. Process is done above recrystallisation temperature	1. Below recrystallisation temperature.
2. Process is done on hot metal.	2. Process is done on metals at room temperature.
3. Less force is required.	3. More force is required.
4. No residual stress is formed in the metal.	4. Residual stresses formed is more.

Lecture 8

Metal Forming Defects

Forging Defects

Though forging process give generally prior quality product compared other manufacturing processes. There are some defects that are lightly to come a proper care is not taken in forging process design. A brief description of such defects and their remedial method is given below.

1. **Unfilled Section:**

In this some section of the die cavity are not completely filled by the flowing metal. The causes of these defects are improper design of the forging die or using forging techniques.

2. **Cold Shut:**

This appears as small cracks at the corners of the forging. This is caused mainly by the improper design of die. Where in the corner and the fillet radii are small as a result of which metal does not flow properly into the corner and the ends up as a cold shut.

3. Laps and Folds:

This is caused by the improper die design, making the laps created onto the final part which is very much undesirable as they distort the surface finish and also tend to weaken the product due to internal or external cracks.

4. **Scale Pits:**

This is seen as irregular depurations on the surface of the forging. This is primarily caused because of improper cleaning of the stock used for forging. The oxide and scale gets embedded into the finish forging surface. When the forging is cleaned by pickling, these are seen as depurations on the forging surface.

5. **Die Shift:**

This is caused by the miss alignment of the die halve, making the two halve of the forging to be improper shape.

6. **Flakes:**

These are basically internal ruptures caused by the improper cooling of the large forging. Rapid cooling causes the exterior to cool quickly causing internal fractures. This can be remedied by following proper cooling practices.

7. **Improper Grain Flow:**

This is caused by the improper design of the die, which makes the flow of the metal not flowing the final interred direction.

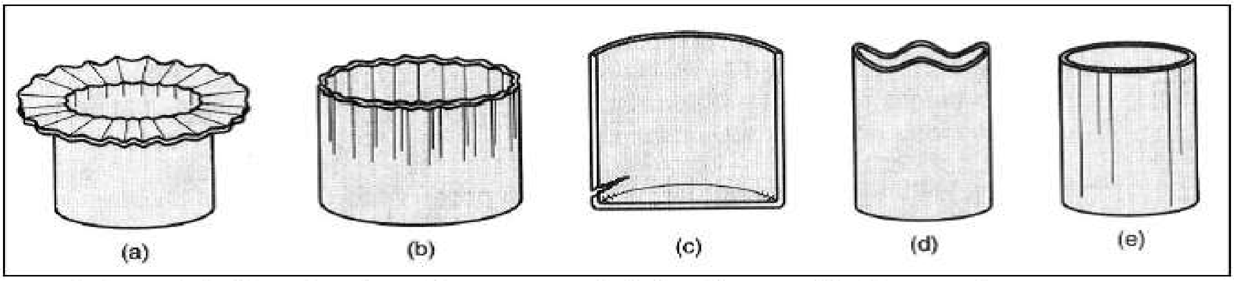
8. **Spring back Effect:**

In Bending, after plastic deformation there is an elastic recovery this recovery is called spring back spring back Effect. Spring back cannot be avoided but can be minimized by several methods such as Warm and hot forming, over bending, applying tension.

9. **Wrinkles in Deep Drawing operation:**

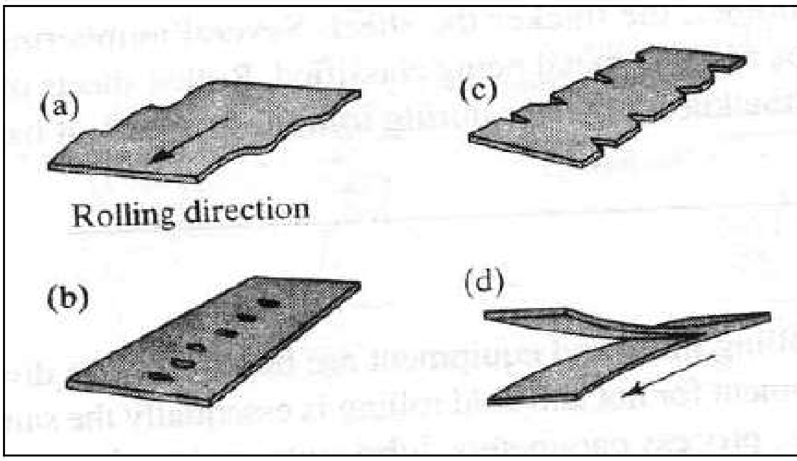
Wrinkles can be prevented by using a blank holder, the function of which is to facilitate controlled material flow into the die radius. The main geometric parameters of the die which influence the wrinkling are diameter of the punch and punch edge radiuses

Defects in drawing



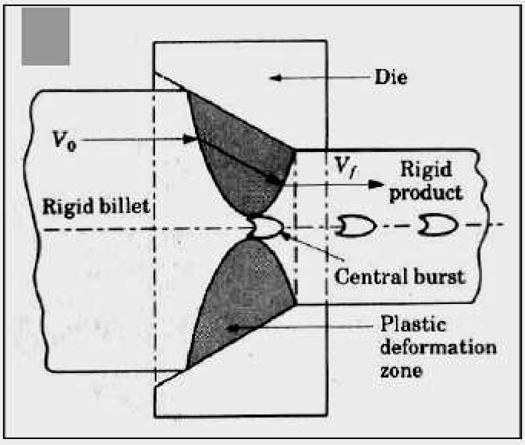
(a)Wrinkling in the flange or (b) in the wall (c) tearing, (d) earing, (e) surface scratches

Defects in Rolling



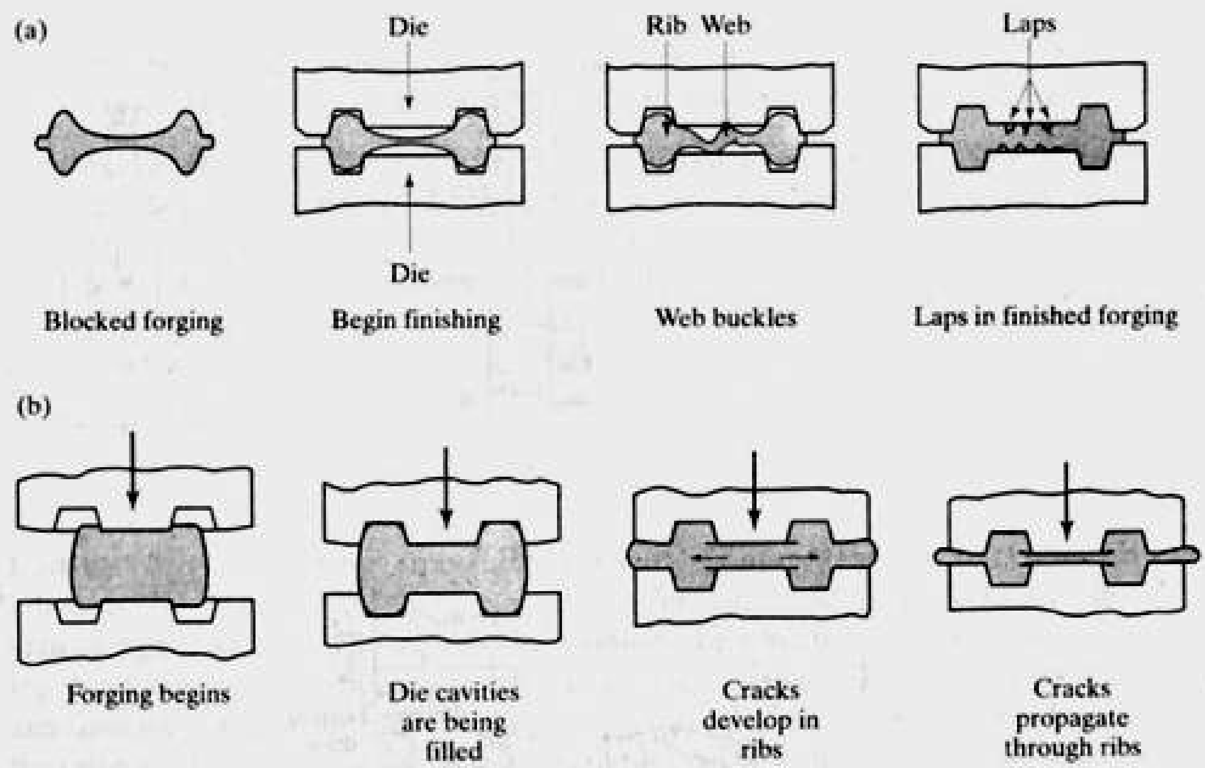
Schematic illustration of typical defects in flat rolling: (a) wavy edges; (b) zipper cracks in the center of the strip; (c) edge cracks; and (d) alligatoring.

Defects in extrusion



- •Surface cracking
- •piping
- •Internal cracking

Defects in forging



Examples of defects in forged parts. (a) Laps formed by web buckling during forging; web thickness should be increased to avoid this problem. (b) Internal defects caused by oversized billet; die cavities are filled prematurely, and the material at the center flows past the filled regions as the dies close.

Lecture 9

Metal Forming Process Comparison

Metal Forming Process	Advantages	Limitations
Open-die forging	• Inexpensive tooling and equipment. • Simple to operate. • Wide range of workpiece sizes can be used. • Suitable for low production volume.	• Can be used for simple shapes only. • Fairly skilled operators are required. • Production rate is low. • Dimensional accuracy and surface finish achieved are poorer. • Finishing required for achieving final shape.
Closed-die forging	• Suitable for high production rate. • Can be used for production of complex shapes. • Good dimensional accuracy and reproducibility	• High equipment and tooling cost. • Appropriate die set for production of each component. • More than one step required for each forging. • Finishing required for achieving final shape.
Hot rolling	• High production rate. • Suitable for large reduction. • Wide range of shapes (Billets, blooms, slabs, sheets, bars, tubes, structural sections, etc.) can be produced	• High equipment cost • Suitable for production of large sections. • Poor dimensional accuracy and finish.

Metal Forming Process	Advantages	Limitations
Cold rolling	• High production rate. • Suitable for production of plates, sheets, foils, etc. • Good dimensional accuracy and finish.	• High equipment cost. • Deformation limited to small reductions.
Hot extrusion	• Moderate cost of equipment and toolings. • Suitable for large reduction. • Complex sections and long products can be produced.	• Only constant cross-section can be produced. • Components with thin walls are difficult to produce. • Lubrication is necessary. • Dimensional accuracy and finish achieved are not good.
Impact extrusion	• High production rate. • Good finish and dimensional accuracy. • Generally no finishing is required. • Suitable for production of thin sections.	• Suitable for production of light components from softer materials. • Deformation limited to small reductions.

Metal Forming Process	Advantages	Limitations
Drawing	• Low equipment and tooling cost. • Good surface finish and dimensional accuracy. • High production rate. • Long lengths of rounds, tubings, square, angles, etc. can be produced.	• Deformation limited to small reductions. • Production of constant cross-sections only. • Lubrication is necessary.
Deep drawing	• High production rate. • Moderate equipment and tooling cost. • Good surface finish.	• Limited to forming of thin sheets. • Forming of shallow or deep parts of simple shapes only. • Finishing required
Punching and blanking	• High production rate. • Low cost of labour. • Almost any shape can be obtained. • Moderate equipment cost.	• Limited to thin sheet applications. • Cost of tooling can be high.

Assignment

Metal Forming

1. List out metal manufacturing processes and give advantages of metal forming over other process.
2. Classify metal forming Process.
3. Explain about working Process of following metal forging operations:

   1). Extrusion, 2). Wire Drawing
4. Explain about working Process of following metal forging operations:

   1). Rolling, 2). Forging
5. Explain about working Process of following metal forging operations:

   1). Bending, 2). Deep Drawing, 3). Embossing
6. Explain about working Process of following metal forging operations:

   1). Punching, 2). Piercing, 3). Stamping
7. Give Difference between Hot working and Cold working Metal Forming Process.
8. List out various Metal forming Defects with example.