LECTURE NOTES

ON

METAL FORMING PROCESS

2018 – 2019

III B. Tech II Semester (JNTUA-R15)

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B. Tech III-II Sem. (ME)

15A03605 METAL FORMING PROCESSES

UNIT 1

Stress, strain, Two dimensional stress analysis and three dimensional stress analysis, relation between engineering stress and true stress, relation between engineering strain and true strain, yield criteria, yield locus, theory of plasticity, Hot working, cold working, strain hardening, recovery, recrystallisation and grain growth, Comparison of properties of Cold and Hot worked parts

UNIT II

ROLLING: Bulk deformation processes – Economics of bulk forming, principles and theory of rolling, types of Rolling mills and products. Forces in rolling and power requirements, applications and, limitations, defects in rolled products – machinery and Equipment.

FORGING PROCESSES: Principles of forging –Types Forging – Smith forging, Drop Forging – Roll forging – Forging hammers: Rotary forging – forging defects, Forces in forging of strip, disc and power requirements, applications, Equipment and their selection.

UNIT III

EXTRUSION PROCESSES: Basic extrusion process and its characteristics. Mechanics of hot and cold extrusion - Forward extrusion and backward extrusion – Impact extrusion Hydrostatic extrusion, forces in extrusion of cylindrical and non cylindrical components – characteristics and defects in extruded parts.

Wire Drawing: Process Mechanics and its characteristics, determination of degree of drawing, drawing force, power, and number of stages-defects in products.

UNIT IV

Sheet Metal Working – Economical Considerations - Stamping, forming and other cold working processes: Blanking and piercing – Bending and forming – Drawing and its types – Cup drawing and Tube drawing – coining – Hot and cold spinning. Force and power requirement in sheet metal operations, defects in sheet metal products – Equipment, tooling and their characteristics.

UNIT V

Processing of plastics, injection and blow moulding, calendaring, thermo forming, compression moulding, transfer moulding, High energy rate forming methods Rapid manufacturing: - Introduction – concepts of rapid manufacturing, information flow for rapid prototyping, classification of rapid prototyping process, sterer holography fused deposition modeling, selective laser sintering, Applications of rapid prototyping process

Text Books:

1. Manufacturing Technology, Schmid and kalpakjin, Pearson Education.

2. Manufacturing Technology, Foundry forming and welding, Vol I , P.N. Rao,TMH

UNIT.I

METAL FORMING

1.0 INTRODUCTION:

Metal forming is a general term for a large group, that includes a wide variety of manufacturing processes. Metal forming processes are characteristic in that the metal being processed is plastically deformed to shape it into a desired geometry. In order to plastically deform a metal, a force must be applied that will exceed the yield strength of the material. When low amounts of stress are applied to a metal it will change its geometry slightly, in correspondence to the force that is exerted.

Basically it will compress, stretch, and/or bend a small amount. The magnitude of the amount will be directly proportional to the force applied. Also the material will return to its original geometry once the force is released. Think of stretching a rubber band, then releasing it, and having it go back to its original shape. This is called elastic deformation. Once the stress on a metal increases past a certain point, it no longer deforms elastically, but starts to undergo plastic deformation. In plastic deformation, the geometric change in the material is no longer directly proportional to stress and geometric changes remain after the stress is released; meaning that the material does not recover its shape. The actual level of stress applied to a metal where elastic deformation turns to plastic deformation is called the proportional limit, and is often difficult to determine exactly. The .002 offset convention is usually used to determine the yield point, which is taken for practical purposes as the stress level where plastic deformation, (yielding), begins to occur. For more information on this topic review the mechanical properties of metals section in a material science text book.

1.1 Stress:

Stress is "*force per unit area*" - the ratio of applied force *F* to cross section area - defined as "force per area".

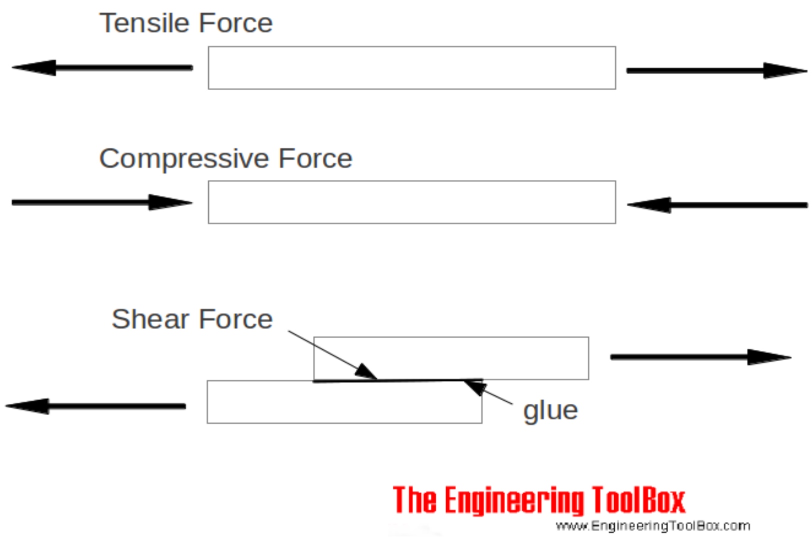


Fig: 1.1

- *tensile stress* - stress that tends to stretch or lengthen the material - acts normal to the stressed area
- *compressive stress* - stress that tends to compress or shorten the material - acts normal to the stressed area
- *shearing stress* - stress that tends to shear the material - acts in plane to the stressed area at right-angles to compressive or tensile stress

1.1.1 Tensile or Compressive Stress - Normal Stress

Tensile or compressive stress normal to the plane is usually denoted "**normal stress**" or "**direct stress**" and can be expressed as

$$\sigma = F_n / A \qquad (1)$$

where

σ = normal stress ((Pa) N/m^2, psi)

F_n = normal component force (N, lb_f (alt. kips))

A = area (m^2, in^2)

- *a kip is a non-SI unit of force - it equals 1,000 pounds-force*
- *1 kip = 4448.2216 Newtons (N) = 4.4482216 kilonewtons (kN)*

Example - Tensile Force acting on a Rod

A force of *10 kN* is acting on a circular rod with diameter *10 mm*. The stress in the rod can be calculated as

$$\sigma = (10\ 10^3\ N) / (\pi\ ((10\ 10^{-3}\ m) / 2)^2)$$
$$= \underline{127388535}\ (N/m^2)$$
$$= \underline{127}\ (MPa)$$

Example - Force acting on a Douglas Fir Square Post

A compressive load of *30000 lb* is acting on short square *6 x 6 in* post of Douglas fir. The dressed size of the post is *5.5 x 5.5 in* and the compressive stress can be calculated as

$$\sigma = (30000\ lb) / ((5.5\ in)\ (5.5\ in))$$
$$= \underline{991}\ (lb/in^2,\ psi)$$

1.1.2 Shear Stress

Stress parallel to the plane is usually denoted "**shear stress**" and can be expressed as

$$\tau = F_p / A \qquad (2)$$

where

τ = shear stress ((Pa) N/m^2, psi)

F_p = parallel component force (N, lb_f)

A = area (m^2, in^2)

1.2 Strain

Strain is defined as "deformation of a solid due to stress" and can be expressed as

$$\varepsilon = dl / l_o$$
$$= \sigma / E \qquad (3)$$

where

dl = change of length (m, in)

l_o = initial length (m, in)

ε = unit less measure of engineering strain

E = Young's modulus (Modulus of Elasticity) (N/m^2 (Pa), lb/in^2 (psi))

- Young's modulus can be used to predict the elongation or compression of an object.

1.3 Two dimensional stress analysis and three dimensional stress analysis

- Stress–strain analysis (or stress analysis) is an engineering discipline covering methods to determine the stresses and strains in materials and structures subjected to forces or loads. In continuum mechanics, stress is a physical quantity that expresses the internal forces that neighboring particles of a continuous material exert on each other, while strain is the measure of the deformation of the material.
- Stress analysis is a primary task for civil, mechanical and aerospace engineers involved in the design of structures of all sizes, such as tunnels, bridges and dams, aircraft and rocket bodies, mechanical parts, and even plastic cutlery and staples. Stress analysis is also used in the maintenance of such structures, and to investigate the causes of structural failures.
- Typically, the input data for stress analysis are a geometrical description of the structure, the properties of the materials used for its parts, how the parts are joined, and the maximum or typical forces that are expected to be applied to each point of the structure. The output data is typically a quantitative description of the stress over all those parts and joints, and the deformation (strain) caused by those stresses. The analysis may consider forces that vary with time, such as engine vibrations or the load of moving vehicles. In that case, the stresses and deformations will also be functions of time and space
- In engineering, stress analysis is often a tool rather than a goal in itself; the ultimate goal being the design of structures and artifacts that can withstand a specified load, using the minimum amount of material (or satisfying some other optimality criterion).
- Stress analysis may be performed through classical mathematical techniques, analytic mathematical modelling or computational simulation, through experimental testing techniques, or a combination of methods.

It can be seen by the stress-strain graph that once the yield point of a metal is reached and it is deforming plastically, higher levels of stress are needed to continue its deformation. The metal actually gets stronger, the more it is deformed plastically. This is called strain hardening or work hardening. As may be expected, strain hardening is a very important factor in metal forming processes. Strain hardening is often a problem that must be overcome, but many times strain hardening, when used correctly, is a vital part of the manufacturing process in the production of stronger parts.

1.4 Relation between True stress and Engineering stress

When a ductile material is subjected to tensile stress, beyond a certain stress, the cross sectional area of the material decreases at a particular position in the material; i.e. a construction develops at a particular position. This is called necking. The area of the specimen at the neck changes continuously as the load is increased. The **true stress** at any time of loading, is the force divided by the instantaneous cross sectional area A, at the instant of time (at the neck); i.e.

$$\text{True stress } (\sigma_T) = F/A_i$$

The **engineering stress**, on the other hand, is the force divided by the original area of cross-section AO; i.e.

$$\text{Engineering stress } (\sigma) = F/A_o$$

The **true strain** is defined by

$$\text{True strain } (\varepsilon_T) = \ln (L_i/L_o)$$

Where l_i is the instantaneous length of the specimen and l_o is the original length.

The **Engineering strain** is given by

$$\varepsilon = (L_i - L_o)/L_o$$

Relation between engineering strain ε and true strain ε_T :

$$\varepsilon = L_i/L_o - 1 \Rightarrow L_i/L_o = \varepsilon + 1$$

$$\ln (L_i/L_o) = \ln (\varepsilon + 1) \Rightarrow \varepsilon_T = \ln (\varepsilon + 1)$$

Relation between engineering stress σ and true stress σ_T :

Assuming that there is no volume change during deformation $A_oL_o = A_iL_i$

$$A_i = A_o (L_o/L_i) \text{ so that}$$

$$\sigma_T = F/A_i = (F \times L_i)/(A_o \times L_o) \text{ and therefore}$$
$$\sigma_T = \sigma(\varepsilon + 1)$$

1.5 RELATION BETWEEN ENGINEERING STRAIN AND TRUE STRAIN
Engineering Strain- It is change in length upon initial length. True Strain- It is change in length upon instantaneous length. Engineering Strain is used in stress-strain graph n other numerical because it is easy since u only need to know change in length

1.6 YIELD CRITERIA

A **yield criterion** is a hypothesis defining the limit of elasticity in a material and the onset of plastic deformation under any possible combination of stresses.
There are several possible yield criteria. We will introduce two types here relevant to the description of yield in metals.

To help understanding of combinations of stresses, it is useful to introduce the idea of principal stress space. The orthogonal principal stress axes are not necessarily related to orthogonal crystal axes.

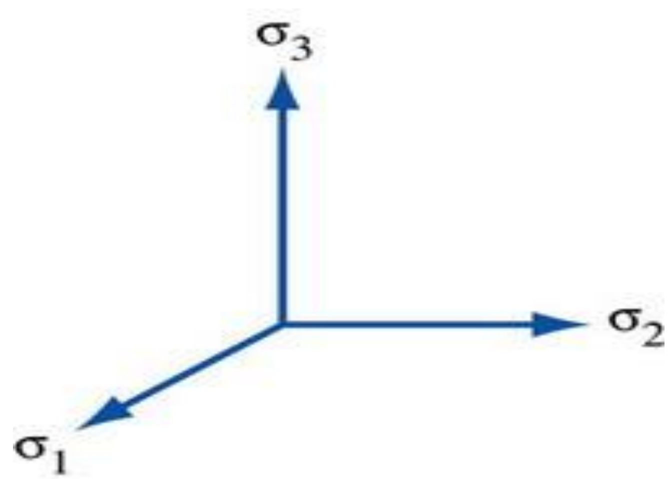


FIG:1.2
Using this construction, *any* stress can be plotted as a point in 3D stress space.

$$\begin{pmatrix} \sigma & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

For example, the uniaxial stress where $\sigma_1 = \sigma$; $\sigma_2 = \sigma_3 = 0$, plots as a point on the $\sigma_1$axis.

1.7 YIELD LOCUS

Yield locus or yield point is the material property defined as the stress at which a material begins to deform plastically. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible. In the three-dimensional space of the principal stresses (an infinite number of yield points form together a yield surface.

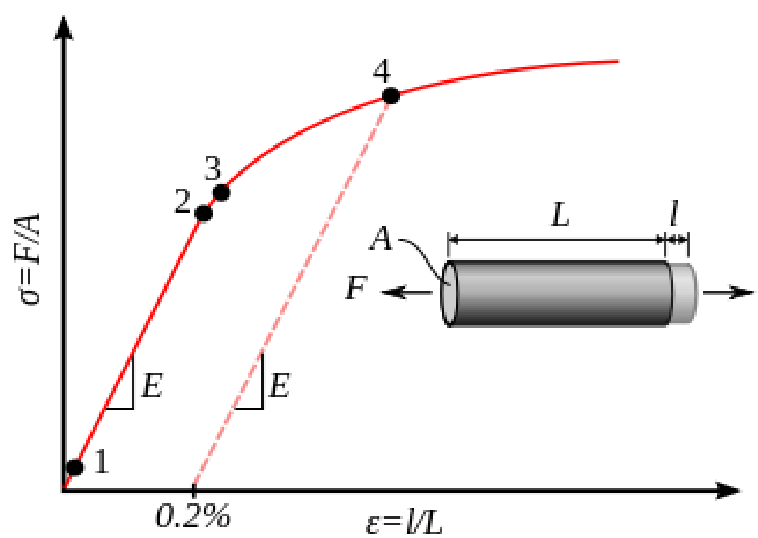


Fig: 1.3

1: True elastic limit

2: Proportionality limit

3: Elastic limit

4: Offset yield strength

1.8 THEORY OF PLASTICITY

The classical theory of plasticity grew out of the study of metals in the late nineteenth century. It is concerned with materials which initially deform elastically, but which deform plastically upon reaching a yield stress. In metals and other crystalline materials the occurrence of plastic deformations at the micro-scale level is due to the motion of dislocations and the migration of grain boundaries on the micro-level. In sands and other granular materials plastic flow is due both to the irreversible rearrangement of individual particles and to the irreversible crushing of individual particles. Similarly, compression of bone to high stress levels will lead to particle crushing. The deformation of micro-voids and the development of micro-cracks is also an important cause of plastic deformations in materials such as rocks.

A good part of the discussion in what follows is concerned with the plasticity of metals; this is the 'simplest' type of plasticity and it serves as a good background and introduction to the modeling of plasticity in other material-types. There are two broad groups of metal plasticity problem which are of interest to the engineer and analyst. The first involves relatively small plastic strains, often of the same order as the elastic strains which occur. Analysis of problems involving small plastic strains allows one to design structures optimally, so that they will not fail when in service, but at the same time are not stronger than they really need to be. In this sense, plasticity is seen as a material failure.

The second type of problem involves very large strains and deformations, so large that the elastic strains can be disregarded. These problems occur in the analysis of metals manufacturing and forming processes, which can involve extrusion, drawing, forging, rolling and so on. In these latter-type problems, a simplified model known as perfect plasticity is usually employed (see below), and use is made of special limit theorems which hold for such models.

Plastic deformations are normally rate independent, that is, the stresses induced are independent of the rate of deformation (or rate of loading). This is in marked contrast to classical Newtonian fluids for example, where the stress levels are governed by the rate of deformation through the viscosity of the fluid.

1.9 Hot Working

Hot working, (or hot forming), is a metal forming process that is carried out at a temperature range that is higher than the recrystallization temperature of the metal being formed. The behavior of the metal is significantly altered, due to the fact that it is above its recrystallization temperature. Utilization of different qualities of the metal at this temperature is the characteristic of hot working.

Although many of these qualities continue to increase with increasing temperature, there are limiting factors that make overly high temperatures undesirable. During most metal forming processes the die is often cold or slightly heated. However, the metal stock for hot working will usually be at a higher temperature relative to the die. In the design of metal forming process, it is critical to consider the flow of metal during the forming of the work. Specific metal flow, for different forming processes, is discussed in latter sections under each specific process. For metal forming manufacturing, in general, the temperature gradient between the die and the work has a large effect on metal flow during the process. The metal nearer to the die surfaces will be cooler than the metal closer to the inside of the part, and cooler metal does not flow as easily. High temperature gradients, within the work, will cause greater differences in flow characteristics of different sections of the metal, these could be problematic. For example, metal flowing significantly faster at the center of the work compared to cooler metal near the die surfaces that is flowing slower, can cause part defects. Higher temperatures are harder to maintain throughout the metal forming process. Work cooling during the process can also result in more metal flow variations. Another consideration with hot forming manufacture, with regard to the temperature at which to form the part, is that the higher the temperature the more reactive the metal is likely to be. Also if a part for a hot working process is too hot then friction, caused during the process, may further increase heat to certain areas causing melting, (not good), in localized sections of the work. In an industrial hot metal working operation, the optimum temperature should be determined according to the material and the specific manufacturing process.

When above its recrystallization temperature a metal has a reduced yield strength, also no strain hardening will occur as the material is plastically deformed. Shaping a metal at the hot working temperature range requires much less force and power than in cold working. Above its recrystallization temperature, a metal also possesses far greater ductility than at its cold worked temperature. The much greater ductility allows for massive shape changes that would not be possible in cold worked parts. The ability to perform these massive shape changes is a very important characteristic of these high temperature metal forming processes.

The work metal will recrystallize, after the process, as the part cools. In general, hot metal forming will close up vacancies and porosity in the metal, break up inclusions and eliminate them by distributing their material throughout the work piece, destroy old weaker cast grain structures and produce a wrought isotropic grain structure in the part. These high temperature forming processes do not strain harden or reduce the ductility of the formed material. Strain hardening of a part may or may not be wanted, depending upon the application. Qualities of hot forming that are considered disadvantageous are poorer surface finish, increased scale and oxides, decarburization, (steels), lower dimensional accuracy, and the need to heat parts. The heating of parts reduces tool life, results in a lower productivity, and a higher energy requirement than in cold working.

1.10 Cold Working

Cold working, (or cold forming), is a metal forming process that is carried out at room temperature or a little above it. In cold working, plastic deformation of the work causes strain hardening as discussed earlier. The yield point of a metal is also higher at the lower temperature range of cold forming. Hence, the force required to shape a part is greater in cold working than for warm working or hot working. At cold working temperatures, the ductility of a metal is limited, and only a certain amount of shape change may be produced. Surface preparation is important in cold forming. Fracture of the material can be a problem, limiting the amount of deformation possible. In fact, some metals will fracture from a small amount of cold forming and must be hot formed. One main disadvantage of this type of process is a decrease in the ductility of the part's material, but there are many advantages.

The part will be stronger and harder due to strain hardening. Cold forming causes directional grain orientation, which can be controlled to produce desired directional strength properties. Also, work manufactured by cold forming can be created with more accurate geometric tolerances and a better surface finish. Since low temperature metal forming processes do not require the heating of the material, a large amount of energy can be saved and faster production is possible. Despite the higher force requirements, the total amount of energy expended is much lower in cold working than in hot working.

1.11 STRAIN HARDENING

Work hardening, also known as strain hardening or cold working, is the strengthening of a metal by plastic deformation. This strengthening occurs because of dislocation movements and dislocation generation within the crystal structure of the material. Many non-brittle metals with a reasonably high melting point as well as several polymers can be strengthened in this fashion. Alloys not amenable to heat treatment, including low-carbon steel, are often work-hardened. Some materials cannot be work-hardened at low temperatures, such as indium, however others can only be strengthened via work hardening, such as pure copper and aluminum.

Work hardening may be desirable or undesirable depending on the context.

- An example of undesirable work hardening is during machining when early passes of a cutter inadvertently work-harden the workpiece surface, causing damage to the cutter during the later passes. Certain alloys are more prone to this than others; super alloys such as Inconel require machining strategies that take it into account.
- An example of desirable work hardening is that which occurs in metal working processes that intentionally induce plastic deformation to exact a shape change. These processes are known as cold working or cold forming processes. They are characterized by shaping the work piece at a temperature below its recrystallization temperature, usually at ambient temperature. Cold forming techniques are usually classified into four major groups: squeezing, bending, drawing, and shearing. Applications include the heading of bolts and cap screws and the finishing of cold rolled steel. In cold

forming, metal is formed at high speed and high pressure using tool steel or carbide dies. The cold working of the metal increasing the hardness, yield strength, and tensile strength.

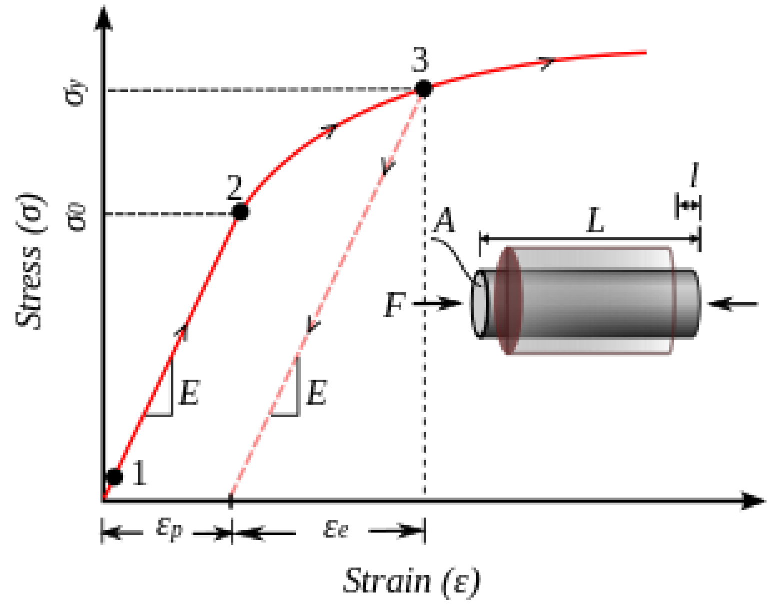


Fig: 1.4

1.12 Recovery

Recovery is a process by which deformed grains can reduce their stored energy by the removal or rearrangement of defects in their crystal structure. These defects, primarily dislocations, are introduced by plastic deformation of the material and act to increase the yield strength of a material. Since recovery reduces the dislocation density the process is normally accompanied by a reduction in materials strength and a simultaneous increase in the ductility. As a result, recovery may be considered beneficial or detrimental depending on the circumstances. Recovery is related to the similar process of recrystallization and grain growth. Recovery competes with recrystallization, as both are driven by the stored energy, but is also thought to be a necessary prerequisite for the nucleation of recrystallized grains. It is so called because there is a recovery of the electrical conductivity due to a reduction in dislocations. This creates defect-free channels, giving electrons an increased mean-free path.

1.13 RECRYSTALLISATION AND GRAIN GROWTH

Recrystallization is a process by which deformed grains are replaced by a new set of defects-free grains that nucleate and grow until the original grains have been entirely consumed. Recrystallization is usually accompanied by a reduction in the strength and hardness of a material and a simultaneous increase in the ductility. Thus, the process may be introduced as a deliberate step in metals processing or may be an undesirable byproduct of another processing step. The most important industrial uses are the softening of metals previously hardened by cold work, which have lost their ductility, and the control of the grain structure in the final product.

Grain growth is the increase in size of grains (crystallites) in a material at high temperature. This occurs when recovery and recrystallisation are complete and further reduction in the internal energy can only be achieved by reducing the total area of grain boundary. The term is commonly used in metallurgy but is also used in reference to ceramics and minerals.

1.14 COMPARISON BETWEEN HOT ROLLING AND COLD ROLLING PROCESSES

Hot rolling	Cold rolling
1: Metal is fed to the rolls after being heated above the recrytallization temperature.	1: Metal is fed to the rolls when it is below the recrystallization temperature.
2: In general rolled metal does not shows work hardening effect.	2: The metal shows the working hardening effect after being cold rolled.
3: Co-efficient of friction between two rolls and the stock is higher; it may even caused shearing of the metal in contact with rolls.	3: Co-efficient of friction between two rolls and the stock is comparatively lower.
4: Experiment measurements are difficult to make.	4: Experiment measurement can be

	carried out easily in cold rolling.
5: Heavy reduction in area of the work piece can be obtained.	5: Heavy reduction is not possible.
6: Mechanical properties are improved by breaking cast structure are refining grain sizes below holes and others, similar deformation in ingot (get welded) and or removed the strength and the toughness of the job should increases.	6: Hotness increased excessive cold working greatness crackers ductility of metal reduction. Cold rolling increased the tensile strength and yield strength of the steel.
7:Rolls radius is generally larger in siz.	7: Rolls radius is smaller.
8: Very thin sections are not obtained.	8:Thin sections are obtained.
9: Hot roll surface has(metal oxide) on it , this surface finish is not good.	9: The cold rolled surface is smooth and oxide free.
10: Hot rolling is used un ferrous as well as non ferrous metals such as industries for steel , aluminum, copper , brass, bronze , alloy to change ingot into slabs.	10: Cold rolling is equally applicable to both plain and alloys steels and non ferrous metals and their alloys.
11: Hot rolling is the father of the cold rolling.	11: Cold rolling follows the hot rolling.

UNIT.II

UNIT-2

2. ROLLING

In metalworking, rolling is a metal forming process in which metal stock is passed through one or more pairs of rolls to reduce the thickness and to make the thickness uniform. The concept is similar to the rolling of dough. Rolling is classified according to the temperature of the metal rolled. If the temperature of the metal is above its recrystallization temperature, then the process is known as hot rolling. If the temperature of the metal is below its recrystallization temperature, the process is known as cold rolling. In terms of usage, hot rolling processes more tonnage than any other manufacturing process, and cold rolling processes the most tonnage out of all cold working processes. Roll stands holding pairs of rolls are grouped together into rolling mills that can quickly process metal, typically steel, into products such as structural steel (I-beams, angle stock, channel stock, and so on), bar stock, and rails. Most steel mills have rolling mill divisions that convert the semi-finished casting products into finished products.

2.1 BULK DEFORMATION PROCESSES

- Rolling
- Other Deformation Processes Related to Rolling
- Forging
- Other Deformation Processes Related to Forging
- Extrusion
- Wire and Bar Drawing

Fig :2.1

Metal forming operations which cause significant shape change by deformation in metal parts whose initial form is bulk rather than sheet

- Starting forms: cylindrical bars and billets, rectangular billets and slabs, and similar shapes
- These processes work by stressing metal sufficiently to cause plastic flow into desired shape
- Performed as cold, warm, and hot working operations
- Produces common shapes inexpensively
- Good mechanical properties

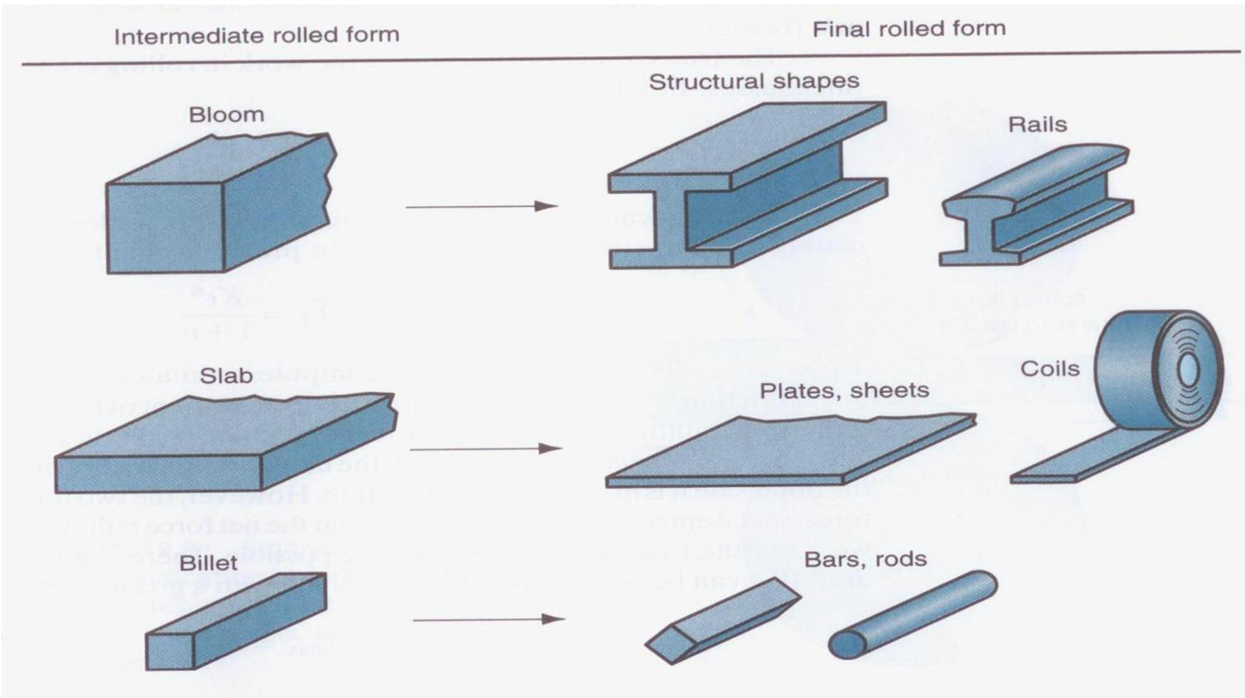


Fig: 2.2 Common shapes

2.1.1 Basic principle of bulk deformation:

1. Push or pull
2. Single shot or continuous
3. Hot or cold
4. Malleable material
5. Refine and redirect the grain
6. Alters geometry
7. Alters material property

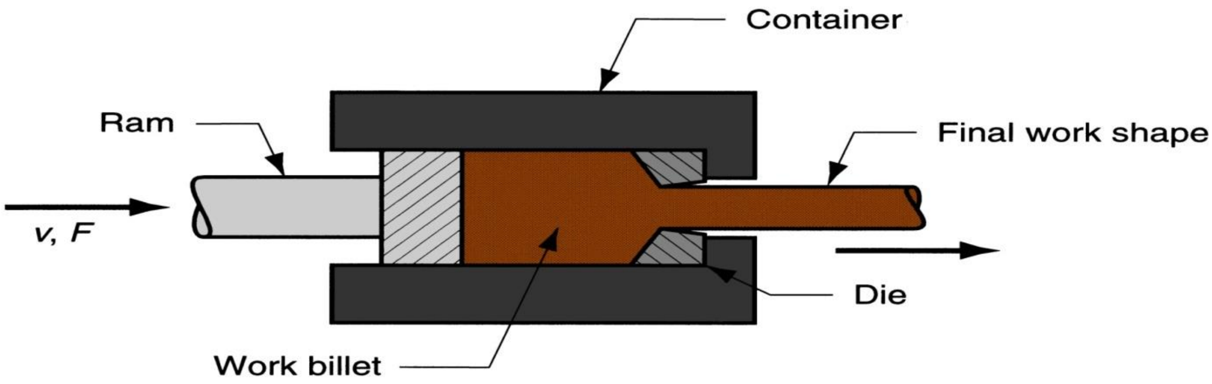


Fig: 2.3

2.1.2 Importance of Bulk Deformation:

1. In hot working, significant shape change can be accomplished
2. In cold working, strength can be increased during shape change
3. Little or no waste - some operations are near net shape or net shape processes
    a. The parts require little or no subsequent machining

2.1.3 Four Basic Bulk Deformation Processes:

1. Rolling – slab or plate is squeezed between opposing rolls
2. Forging – work is squeezed and shaped between between opposing dies
3. Extrusion – work is squeezed through a die opening, thereby taking the shape of the opening
4. Wire and bar drawing – diameter of wire or bar is reduced by pulling it through a die opening

2.2 ROLLING

Deformation process in which work thickness is reduced by compressive forces exerted by two opposing rolls.

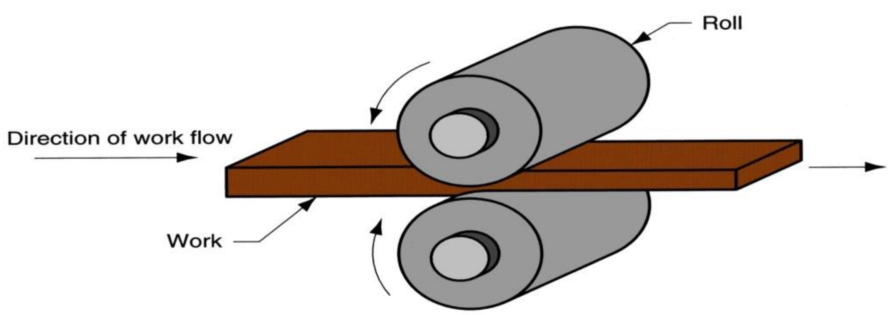


Fig:2.4

The rotating rolls perform two main functions:

- Pull the work into the gap between them by friction between workpart and rolls
- Simultaneously squeeze the work to reduce cross section

2.2.1 TYPES OF ROLLING

- By geometry of work:
  - Flat rolling - used to reduce thickness of a rectangular cross-section
  - Shape rolling - a square cross-section is formed into a shape such as an I-beam
- By temperature of work:
  - Hot Rolling – most common due to the large amount of deformation required
  - Cold rolling – produces finished sheet and plate stock

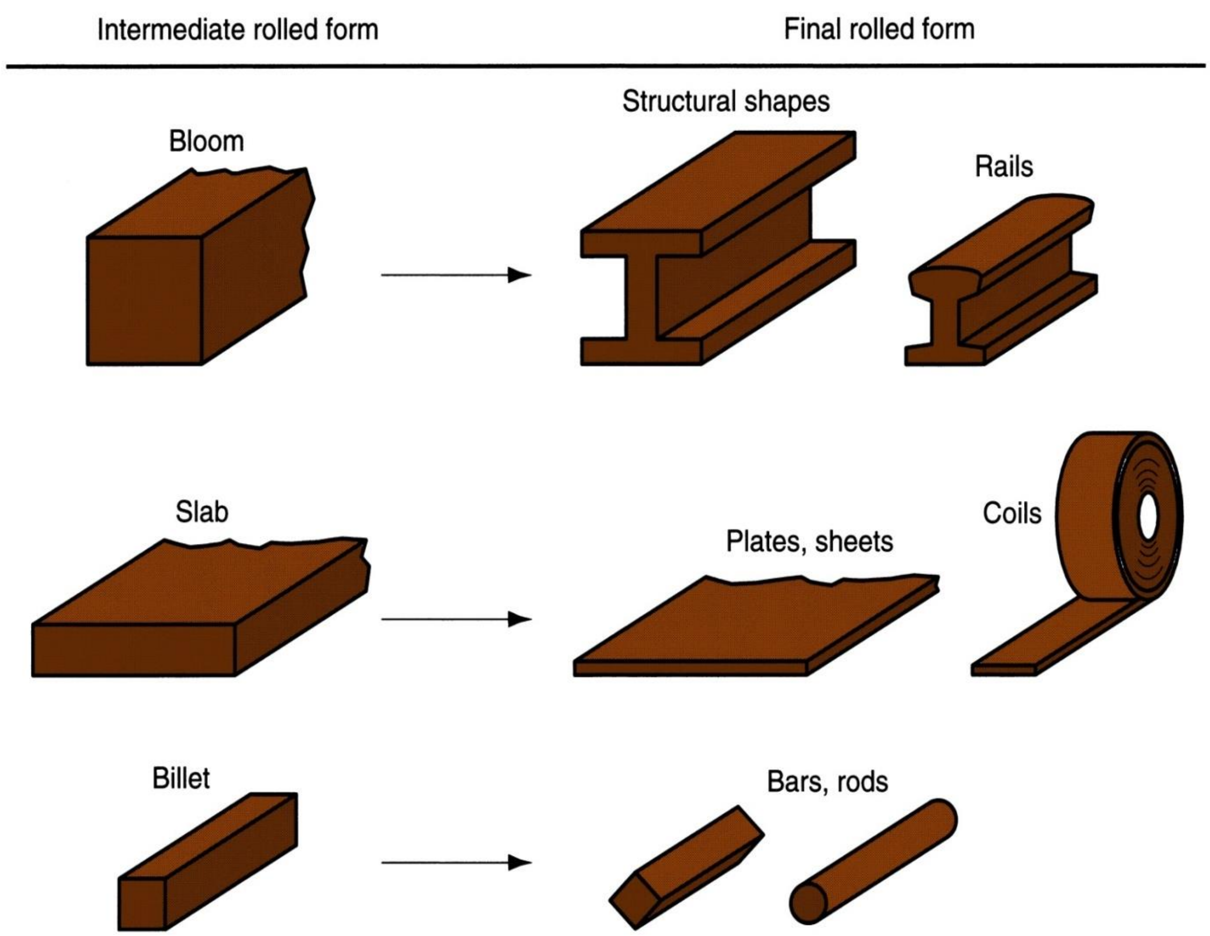


Fig 2.5 - Some of the steel products made in a rolling mill

2.3 Types of Rolling mills

Rolling mills may be classified according to the number and arrangement of the rolls.

(a): Two high rolling mills

(b): Three high rolling mills

(c): Four high rolling mills

(d): Tandem rolling mills

(e): Cluster rolling mills

2.3.1 Two high rolling mills

Two high rolling mills may further classified as

1. Reversing mill
2. Non reversing mill

A two high rolling mill has two rolls only.

2.3.1.1 Two high reversing mill:

In two high reversing rolling mills the rolls rotate is in one direction and then in the other, so that rolled metal may pass back and forth through the rolls several times. This type is used in pluming and slabing mills and for roughing work in plate, rail, structural and other mills. These are more expensive compared to the non reversing rolling mills. Because of the reversible drive needed.

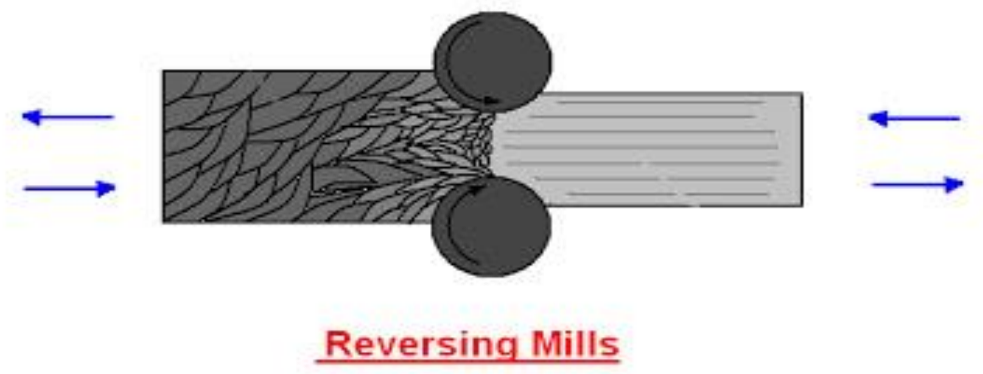


Fig: 2.6

2.3.2 Two high non reversing mill:

In two high non reversing mills as two rolls which revolve continuously in same direction therefore smaller and less costly motive power can be used. However every time material is to be carried back over the top of the mill for again passing in through the rolls. Such an arrangement is used in mills through which the bar passes once and in open train plate mill.

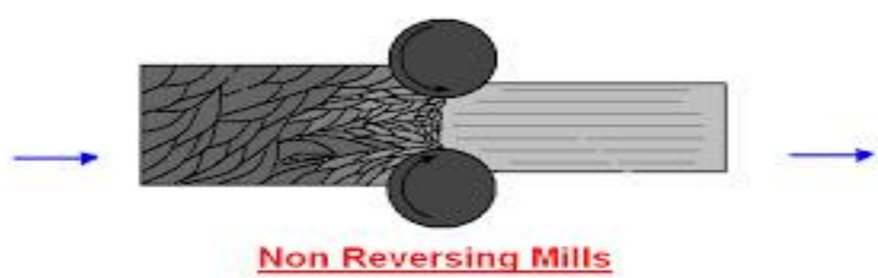


Fig: 2.7

2.3.2 Three high rolling mill:

It consists of a roll stand with three parallel rolls one above the other. Adjacent rolls rotate in opposite direction. So that the material may be passed between the top and the middle roll in one direction and the bottom and middle rolls in opposite one. In three high rolling mills the work piece is rolled on both the forward and return passes. First of all the work piece passes through the bottom and middle rolls and the returning between the middle and the top rolls.

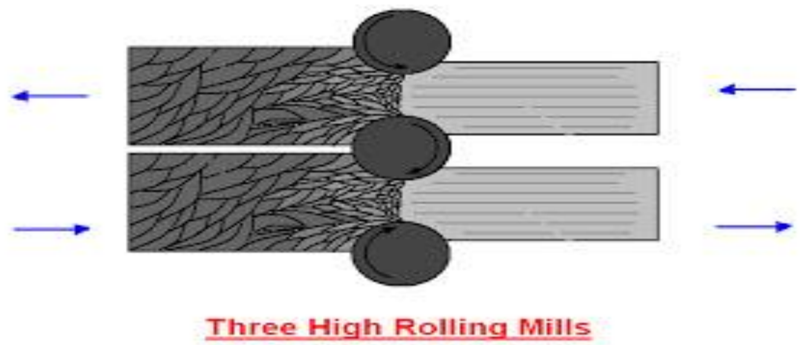


Fig:2.8

So that thickness is reduced at each pass. Mechanically operated lifted tables are used which move vertically or either side of the stand. So that the work piece fed automatically into the roll gap. Since the rolls run in one direction only a much less powerful motor and transmission system is required. The rolls of a three high rolling mills may be either plain or grooved to produce plate or sections respectively.

2.3.3 Four high rolling mill:

It has a roll stand with four parallel rolls one above the other. The top and the bottom rolls rotate in opposite direction as do the two middle rolls. The two middle are smaller in size than the top and bottom rolls which are called backup rolls for providing the necessary rigidity to the smaller rolls.

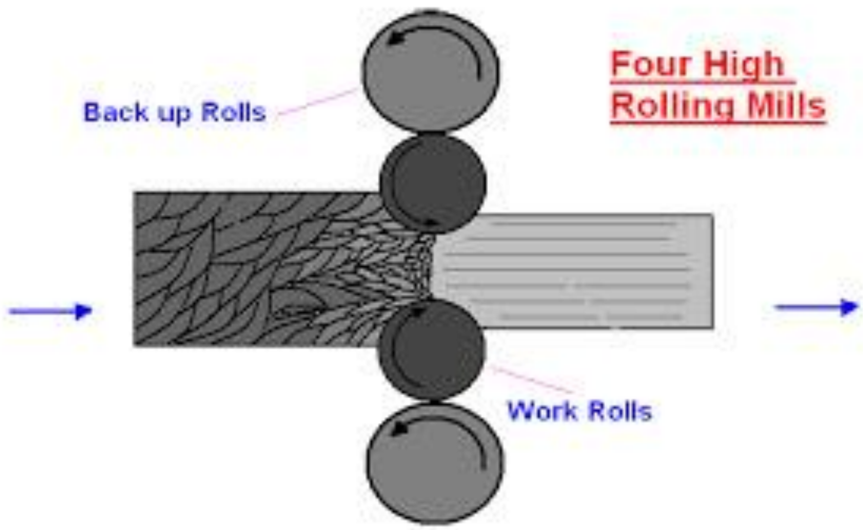


Fig: 2.9

A four high rolling mill is used for the hot rolling of armor and other plates as well as cold rolling of plates, sheets and strips.

2.3.4 Tandem rolling mills:

It is a set of two or three stands of roll set in parallel alignment. So that a continuous pass may be made through each one successively with change the direction of material.

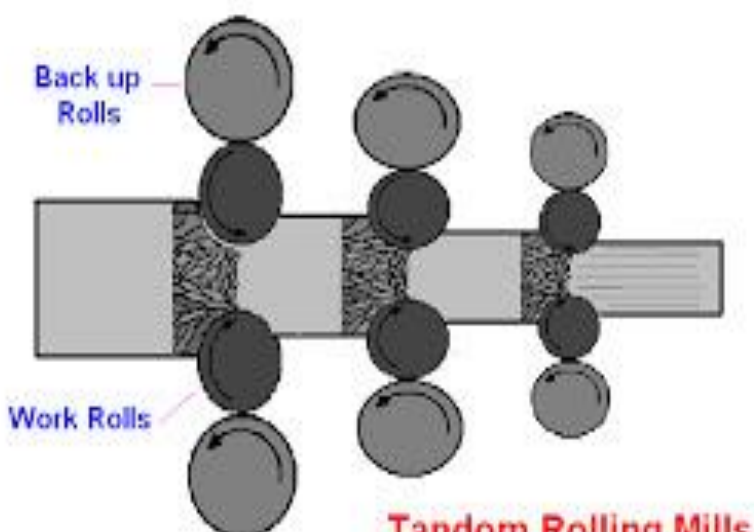


FIG: 2.10

2.3.5 Cluster rolling mills:

It is a special type of four high rolling mill in which each of the two working rolls is backup by two or more of the larger backup rolls for rolling hard in materials. It may be necessary to employ work rolls of a very small diameter but of considerable length. In such cases adequate of the working rolls can be obtained by using a cluster mill.

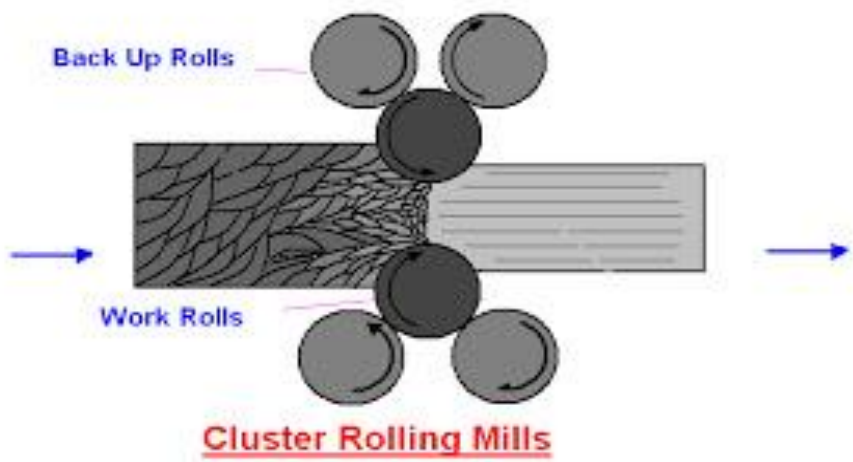
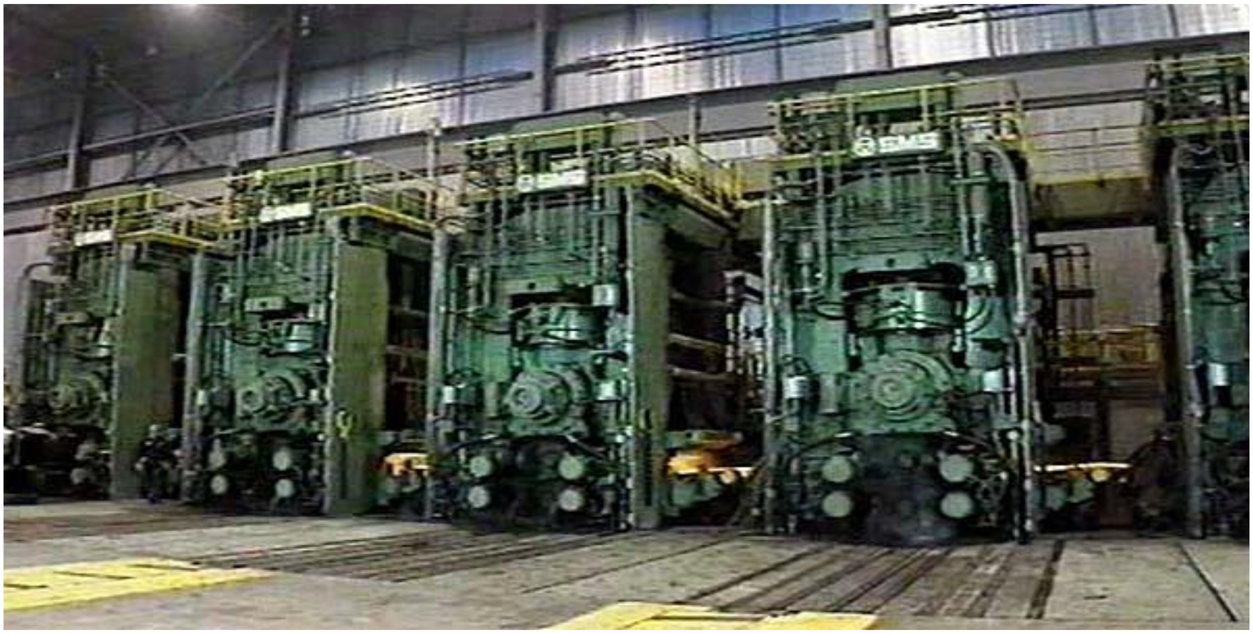


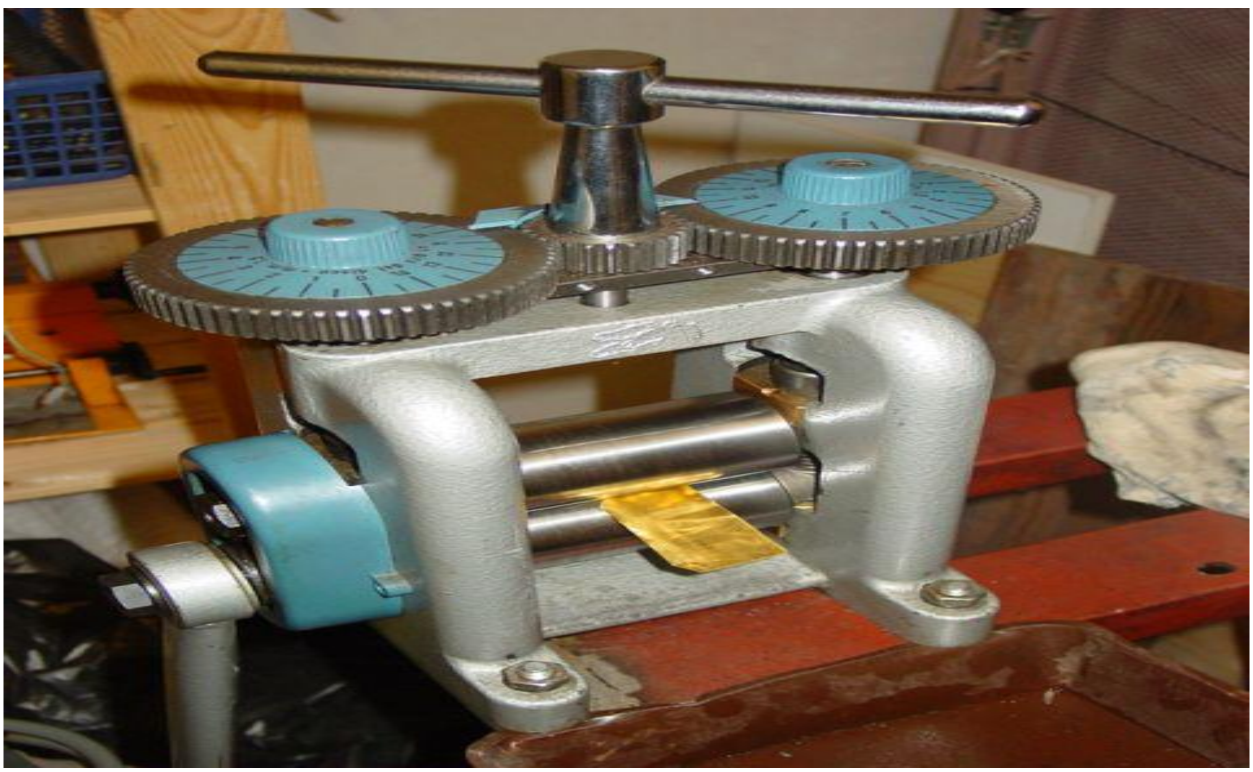
FIG: 2.11

2.4 FORCES IN ROLLING AND POWER REQUIREMENTS:

A rolling mill, also known as a reduction mill or mill, has a common construction independent of the specific type of rolling being performed:

Rolling mills





Rolling mill for cold rolling metal sheet like this piece of brass sheet

- Work rolls
- Backup rolls - are intended to provide rigid support required by the working rolls to prevent bending under the rolling load

- Rolling balance system - to ensure that the upper work and back up rolls are maintained in proper position relative to lower rolls
- Roll changing devices - use of an overhead crane and a unit designed to attach to the neck of the roll to be removed from or inserted into the mill.
- Mill protection devices - to ensure that forces applied to the backup roll chocks are not of such a magnitude to fracture the roll necks or damage the mill housing
- Roll cooling and lubrication systems
- Pinions - gears to divide power between the two spindles, rotating them at the same speed but in different directions
- Gearing - to establish desired rolling speed
- Drive motors - rolling narrow foil product to thousands of horsepower
- Electrical controls - constant and variable voltages applied to the motors
- Coilers and uncoilers - to unroll and roll up coils of metal

Slabs are the feed material for hot strip mills or plate mills and blooms are rolled to billets in a billet mill or large sections in a structural mill. The output from a strip mill is coiled and, subsequently, used as the feed for a cold rolling mill or used directly by fabricators. Billets, for re-rolling, are subsequently rolled in either a merchant, bar or rod mill. Merchant or bar mills produce a variety of shaped products such as angles, channels, beams, rounds (long or coiled) and hexagons.

2.5 APPLICATIONS AND LIMITATIONS:

2.5.1 Hot rolling Advantages:

- Larger deformation can be accomplished and more rapidly by hot working since the metal is in plastic state.
- 2. Porosity of the metal is considerably minimised.
- Concentrated impurities, if any in the metal are disintegrated and distributed throughout the metal.
- Grain structure of the metal is refined and physical properties improved.

Disadvantages

- Due to high temperature a rapid oxidation or scale formation takes place on the metal surface, leading to poor surface finish and loss of metal.

- On account of the lost of carbon from the surface of the steel piece being worked the surface layer loses its strength, which is a disadvantage when the part is put to service.
- This weakening of the surface layer may give rise to crack which may ultimately result in fatigue failure of the part.
- Close tolerances cannot be maintained.
- It involves excessive expenditure on account of high cost of tooling. This, however, is compensated by the high production rate and better quality of products

2.5.1 Cold rolling Advantages:

Quarter Hard, Half Hard, Full Hard stock have higher amounts of reduction. This increases the

- yield point;
- grain orientation and
- material properties assume
- Ductility decreases.
- Quarter Hard material can be bent (perpendicular to the direction of rolling) on itself without fracturing.
- Half hard material can be bent 90º; full hard can be bent 45º.

Disadvantages:

- Better dimensional control than hot working is possible because the reduction in size is not much.
- Surface finish of the component is better because no oxidation takes place during the process.
- Strength and hardness of the metal are increased.
- It is an ideal method for increasing hardness of those metals which do not respond to the heat treatment.
- Only ductile metals can be shaped through cold working.

2.6 FORGING PROCESSES:

Forging is a manufacturing process involving the shaping of metal using localized compressive forces. The blows are delivered with a hammer (often a power hammer) or a die. Forging is often classified according to the temperature at which it is performed: cold forging (a type of cold working), warm forging, or hot forging (a type of hot working). For the latter two, the metal is heated, usually in a forge. Forged parts can range in weight from less than a kilogram to hundreds of metric tons. Forging has been done by smiths for millennia; the traditional products were kitchenware, hardware, hand tools, edged weapons, and jewellery. Since the Industrial Revolution, forged parts are widely used in mechanisms and machines wherever a component requires high strength; such forgings usually require further processing (such as machining) to achieve a finished part. Today, forging is a major worldwide industry.

2.7 PRINCIPLE OF FORGING PROCESSES:

Forging is one of the oldest known metalworking processes. Traditionally, forging was performed by a smith using hammer and anvil, though introducing water power to the production and working of iron in the 12th century allowed the use of large trip hammers or power hammers that exponentially increased the amount and size of iron that could be produced and forged easily. The smithy or forge has evolved over centuries to become a facility with engineered processes, production equipment, tooling, raw materials and products to meet the demands of modern industry.

In modern times, industrial forging is done either with presses or with hammers powered by compressed air, electricity, hydraulics or steam. These hammers may have reciprocating weights in the thousands of pounds. Smaller power hammers, 500 lb (230 kg) or less reciprocating weight, and hydraulic presses are common in art smithies as well. Some steam hammers remain in use, but they became obsolete with the availability of the other, more convenient, power sources.

2.8 TYPES FORGING:

When forging, an initially simple part- a billet, is plastically deformed between two dies to obtain the desired final configuration. For understanding and optimization of forging operations, it is useful to classify this process in a systematic way.

a) Cold forging:

Forging is carried out at or near room temperature (below the recrystallization temp.) of the metal. Carbon and standard alloy steels are most commonly cold forged. Cold forging is generally preferred when the metal is already a soft, like aluminum. This process is usually less expensive than hot forging and the end product requires little or no finishing work. Cold forging is also less susceptible to contamination problems, and the final component features a better overall surface.

Advantages:

Production rates are very high with exceptional die life, Improves mechanical properties, Less friction between die surface and work piece, Lubrication is easy, No oxidation

Disadvantages: Residual stress may occur, Heavier and more powerful equipment is needed, stronger tooling is required, Tool design and manufacturing are critical.

b) Warm forging:

The temperature range for the warm forging of steel runs from above room temperature to below the recrystallization temperature. Compared with cold forging, warm forging has the potential advantages of: Reduced tooling loads, reduced press loads, increased steel ductility, elimination of need to anneal prior to forging, and favorable as-forged properties that can eliminate heat treatment. In warm forging, the billet is heated below the recrystallization temperature, up to 700 to 800 0C for steels, in order to lower the flow stress and the forging pressures.

Advantages:

High production rates, excellent dimensional tolerances and surface finish for forged parts, significant savings in material and machining, Favorable grain flow to improve strength, Greater toughness of the forged part.

c) Hot forging (most widely used):

Forging is carried out at a temperature above the recrystallization temperature of the metal. The recrystallization temperature is defined as the temperature at which the new grains are formed in the metal. This kind of extreme heat is necessary in avoiding strain hardening of the metal during deformation.

Advantages:

High strain rates and hence easy flow of the metal, recrystallization and recovery are possible, forces required are less.

Disadvantages:

Lubrication is difficult at high temperatures, oxidation and scaling occur on the work piece, poor surface finish, less precise tolerances, possible warping of the material during the cooling process.

Table- 1: Hot forging temperature range for different metals and alloys [1].

Metal or alloy	Temperature Range (^{0}C)
Aluminum alloys	400 – 550
Magnesium alloys	250 – 350
Copper alloys	600 – 900
Carbon and Low-alloy steels	850 – 1150
Martensitic stainless steels	1100 – 1250
Austenitic stainless steels	1100 – 1250
Titanium alloys	700 – 950
Iron-base superalloys	1050 – 1180
Cobalt-base superalloys	1180 – 1250
Tantalum alloys	1050 – 1350
Molybdenum alloys	1150 – 1350
Nickel-base superalloys	1050 – 1200
Tungsten alloys	1200 – 1300

Fig: 2.12

2.9 SMITH FORGING:

1. Smith forging is also called flat die and open die forging. It includes the broad field of forging work produced between flat faced dies and possibly supplemented by stock tooling.
2. The final shape of the forging depends on the skill of the smith for size and shape.

3. Smith forging produces work pieces of lesser accuracy as compared to impression or closed die forging.
4. Tooling is simple, inexpensive and allows the production of a large variety of shapes.

Fig: 2.13

2.10 DROP FORGING:

Drop forging is a forging process where a hammer is raised and then "dropped" onto the work piece to deform it according to the shape of the die. There are two types of drop forging: open-die drop forging and closed-die drop forging. As the names imply, the difference is in the shape of the die, with the former not fully enclosing the work piece, while the latter does.

Open-die drop forging

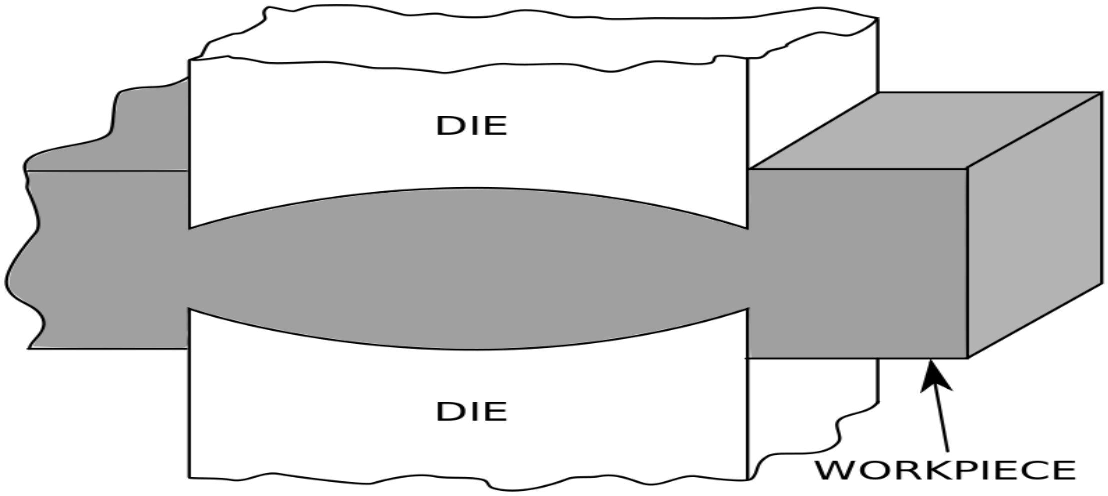


FIG: 2.14 EDGING

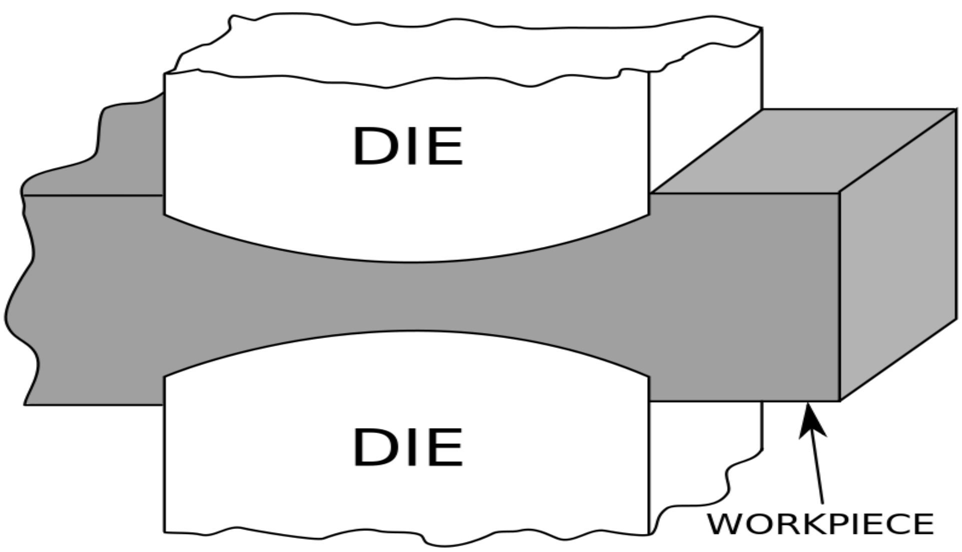


FIG: 2.15 FULLERING

FIG: 2.16 OPEN-DIE DROP FORGING (WITH TWO DIES) OF AN INGOT TO BE FURTHER PROCESSED INTO A WHEEL

Open-die forging is also known as *smith forging*. In open-die forging, a hammer strikes and deforms the work piece, which is placed on a stationary anvil. Open-die forging gets its name from the fact that the dies (the surfaces that are in contact with the work piece) do not enclose the work piece, allowing it to flow except where contacted by the dies. Therefore, the operator needs to orient and position the work piece to get the desired shape. The dies are usually flat in shape, but some have a specially shaped surface for specialized operations. For example, a die may have a round, concave, or convex surface or be a tool to form holes or be a cut-off tool. Open-die forgings can be worked into shapes which include discs, hubs, and blocks, shafts (including step shafts or with flanges), sleeves, cylinders, flats, hexes, rounds, plate, and some custom shapes. Open-die forging lends itself to short runs and is appropriate for art smiting and custom work. In some cases, open-die forging may be employed to rough-shape to prepare them for subsequent operations. Open-die forging may also orient the grain to increase strength in the required direction.

Advantages of open-die forging

- Reduced chance of voids
- Better fatigue resistance
- Improved microstructure
- Continuous grain flow
- Finer grain size
- Greater strength

"Cogging" is the successive deformation of a bar along its length using an open-die drop forge. It is commonly used to work a piece of raw material to the proper thickness. Once the proper thickness is achieved the proper width is achieved via "edging"."Edging" is the process of concentrating material using a concave shaped open-die. The process is called "edging" because it is usually carried out on the ends of the work piece. "Fullering" is a similar process that thins out sections of the forging using a convex shaped die. These processes prepare the work pieces for further forging processes.

2.11 ROLL FORGING

Roll forging or roll forming is a forging technique that utilizes opposing rolls to shape a metal part. Even though roll forging uses rolls in order to accomplish the deformation of the material, it is classified as a metal forging process and not a rolling process. More similarly to metal forging than metal rolling, it is a discrete process and not a continuous one. Roll forging is usually performed hot. The precisely shaped geometry of grooves on the roll, forge the part to the required dimensions. The forging geometry of the rolls used to forge metal parts is only present over a portion of the roll's circumference. Only part of a full revolution of a roll is needed to forge the work piece. Typically in manufacturing industry, the forging geometry on the rolls may occupy from one quarter to three quarters of the roll's circumference.

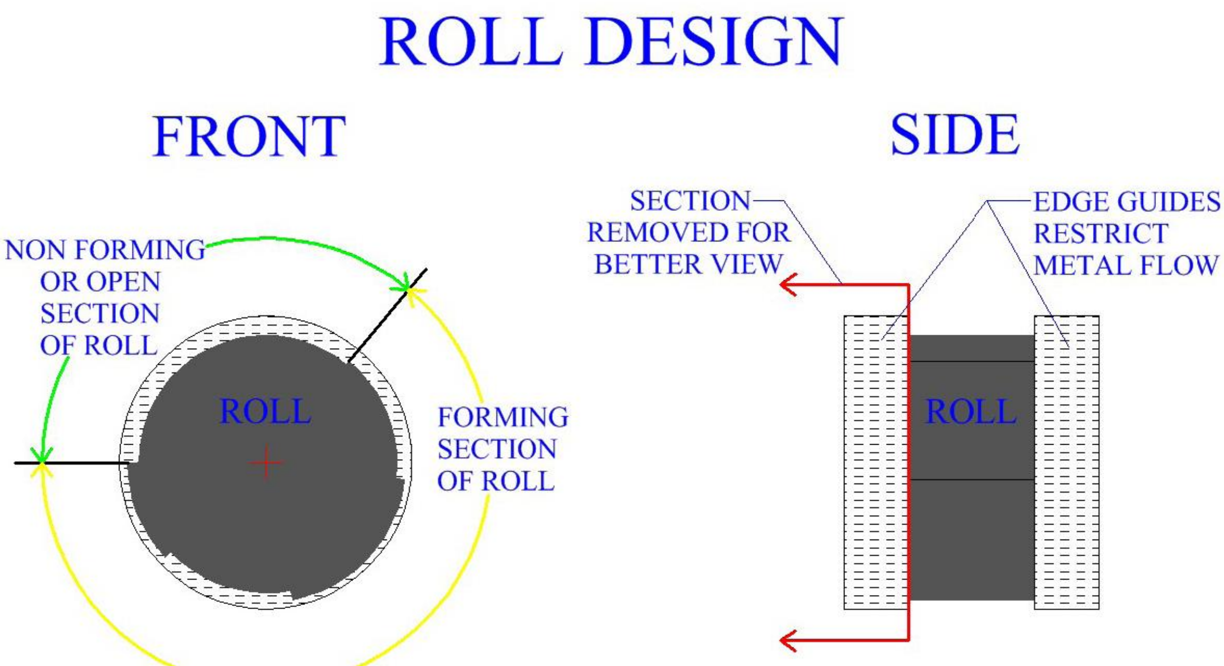


FIG: 2.17 ROLL DESIGN

2.12 FORGING HAMMERS:

Types according to forging equipments

Forged components are shaped either by a hammer or press. Forging on the hammer is carried out in a succession of die impressions using repeated blows. The quality of the forging, and the economy and productivity of the hammer process depend upon the tooling and the skill of the operator. In press forging, the stock is usually hit only once in each die impression and the design of each impression become more important while operator skill is less critical. The continuous development of forging technology requires a sound and fundamental understanding of equipment capabilities and characteristics. The equipment i.e. presses and hammers used in forging, influences the forging process, since it affects the deformation rate and temperature conditions, and it determines the rate of production. The requirements of a given forging process must be compatible with the load, energy, time, and accuracy characteristics of a given forging machine.

2.12.1 HAMMER FORGING:

The most common type of forging equipment is the hammer and anvil. The hammer is the least expensive and most versatile type of equipment for generating load and energy to carry out a forging process. This technology is characterized by multiple impact blows between contoured dies. Hammers are primarily used for hot forging. There are basically two types of anvil hammers: Gravity-drop hammers and power drop hammers. In a simple gravity-drop hammer, the upper ram is connected to a board (board-drop hammer), a belt (belt-drop hammer), a chain (chain-drop hammer),or a piston (oil-, air-, or steam-lift drop hammer).The ram is lifted to a certain height and then dropped on the stock placed on the anvil. During the down stroke, the ram is accelerated by gravity and builds up the blow energy. The upstroke takes place immediately after the blow.

The operation principle of a power-drop hammer is similar to that of an air-drop hammer. In the down stroke, in addition to gravity, the ram is accelerated by steam, cold air, or hot air pressure. In the power-drop hammer, the acceleration of the ram is enhanced with air pressure applied on the top side of the ram cylinder. Figure 3 shows mechanical board hammer- It is a stroke restricted machine. Repeatedly the board (weight) is raised by friction rolls and is dropped on the die. Its rating is in the terms of weight of the ram and energy delivered. Figure 4 shows steam hammer- It uses steam in a piston and cylinder arrangement.

It has greater forging capacity. It can produce forgings ranging from a few kgs to several tones. It is preferred in closed-die forging.

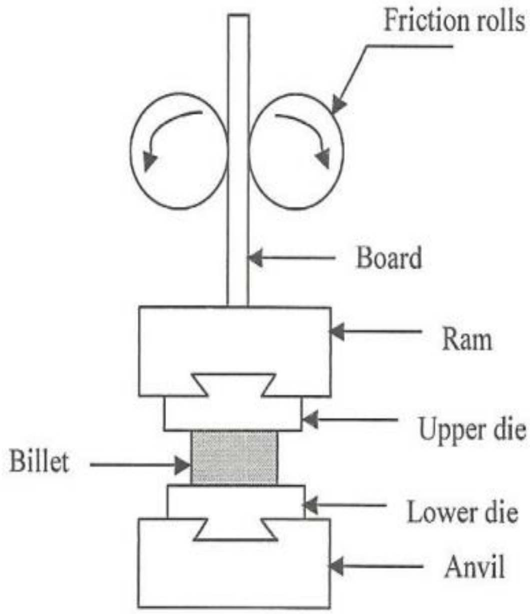


Figure 3: Mechanical board hammer

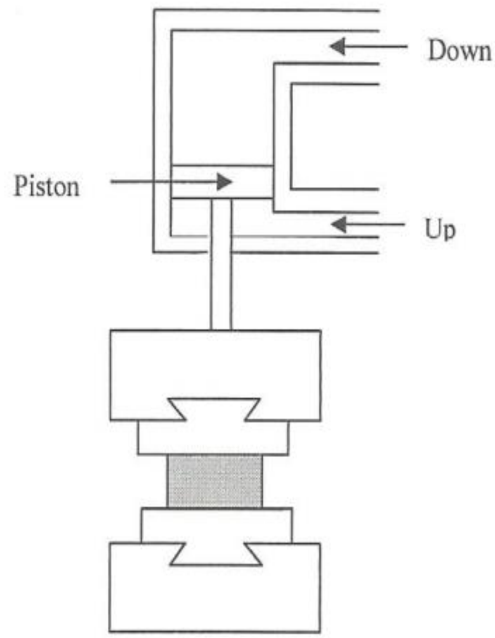


Figure 4: Steam hammer

2.12.2 PRESS FORGING:

In press forging, the metal is shaped not by means of a series of blows as in hammer forging, but by means of a single continuous squeezing action. There are two main types: mechanical and hydraulic presses. Mechanical presses function by using cams, cranks and/or toggles to produce a preset (a predetermined force at a certain location in the stroke) and reproducible stroke. Due to the nature of this type of system, different forces are available at different stroke positions. Mechanical presses are faster than their hydraulic counterparts (up to 50 strokes per minute).Their capacities range from 3 to 160 MN (300 to 18,000 short tons-force).Hydraulic presses use fluid pressure and a piston to generate force. Figure 5 shows hydraulic press. It is a load restricted machine. It has more of squeezing action than hammering action. Hence dies can be smaller and have longer life than with a hammer. Features of Hydraulic Press: Full press load is available during the full stroke of the ram, ram velocity can be controlled and varied during the stroke, it is a slow speed machine and hence has longer contact time and hence higher die temperatures, the slow squeezing action gives close tolerance on forgings, initial cost is higher compared to hammers.

The advantages of a hydraulic press over a mechanical press are its flexibility and greater capacity. The disadvantages include a slower, larger, and costlier machine to operate.

2.13 ROTARY FORGING:

Components weight reduction is top priority for many metal formed parts. Together with LABEIN Teklanika, DENN is providing solutions to this issue. We apply the rotary forging process to manufacture components, which exceed the forming suitability of conventional processes. The rotary forging process offers the advantage of combining an incremental process with the end product properties provided by conventional forging.

Rotary forging is an incremental manufacturing process characterized by its combination of two actions, rotational and an axial compression movement, for precise component forming that can be carried out cold or hot. Parts manufacture by this process are wheel performs, gears, discs, rings, etc..

This technology enables greater use to be made of materials, minimizing (in some cases eliminating) machining and welding operations. Rotary forging requires less force, between 5% to 20% of conventional forming presses, due to reduction in contact and friction; resulting in smaller presses and simpler tools.

- Rotary forging machines (presses)
- High flexibility (small modifications allow new geometries)
- Lower tooling costs, less number of tooling changes and shaping stages
- Very high dimensional precision (near net shape)
- Reduction / elimination of burrs
- High finish quality (elimination of cracks)
- Hardening of the material and optimized grained structure
- Minimizing / elimination of machining and welding operations

2.14 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.

(A): Unfilled Section:

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

(B): Cold Shut:

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

(C): 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.

(D): Die Shift:

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

(E): 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.

(F): 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.

UNIT.III

EXTRUSION

3.1 INTRODUCTION TO EXTRUSION

Extrusion is a process used to create objects of a fixed cross-sectional profile. A material is pushed through a die of the desired cross-section. The two main advantages of this process over other manufacturing processes are its ability to create very complex cross-sections, and to work materials that are brittle, because the material only encounters compressive and shear stresses. It also forms parts with an excellent surface finish.

Drawing is a similar process, which uses the tensile strength of the material to pull it through the die. This limits the amount of change which can be performed in one step, so it is limited to simpler shapes, and multiple stages are usually needed. Drawing is the main way to produce wire. Metal bar and tube are also often drawn.

Extrusion may be continuous (theoretically producing indefinitely long material) or semi-continuous (producing many pieces). The extrusion process can be done with the material hot or cold. Commonly extruded materials include metals, polymers, ceramics, concrete, play dough, and foodstuffs. The products of extrusion are generally called "extrudates". Hollow cavities within extruded material cannot be produced using a simple flat extrusion die, because there would be no way to support the centre barrier of the die. Instead, the die assumes the shape of a block with depth, beginning first with a shape profile that supports the center section. The die shape then internally changes along its length into the final shape, with the suspended center pieces supported from the back of the die. The material flows around the supports and fuses together to create the desired closed shape.

3.2 Basic Extrusion Processes:

The two basic types of extrusion are direct and indirect, which are commonly used in aluminum industries. Solid and hollow shapes are designed and extruded for a wide range of programs:

• Solid sections, bars, and rods extruded from solid billets by direct extrusion

• Tubes and hollow sections extruded from solid billets through porthole or bridge-type dies (for certain alloys) by direct extrusion

• Tubes and hollow sections extruded from hollow or solid billets (latter pierced in the press via floating mandrel) by direct extrusion

• Tubes and hollow sections extruded from hollow or solid billets (latter pierced in the press via stationary mandrel) by direct extrusion

- Critical solid sections, bars, and rods extruded from solid billets with sealed container through the die mounted on the stem by indirect extrusion
- Tubes and hollow sections extruded from hollow or solid billets (latter pierced in press) via stationary mandrel through the die mounted on the stem by the indirect extrusion process.

3.3 HOT EXTRUSION:

Hot extrusion is a hot working process, which means it is done above the material's recrystallization temperature to keep the material from work hardening and to make it easier to push the material through the die. Most hot extrusions are done on horizontal hydraulic presses that range from 230 to 11,000 metric tons (250 to 12,130 short tons). Pressures range from 30 to 700 MPa (4,400 to 101,500 psi), therefore lubrication is required, which can be oil or graphite for lower temperature extrusions, or glass powder for higher temperature extrusions. The biggest disadvantage of this process is its cost for machinery and its upkeep.

HOT EXTRUSION TEMPERATURE FOR VARIOUS METALS	
Material	**Temperature [°C (°F)]**
Magnesium	350–450 (650–850)
Aluminium	350–500 (650–900)
Copper	600–1100 (1200–2000)
Steel	1200–1300 (2200–2400)
Titanium	700–1200 (1300–2100)
Nickel	1000–1200 (1900–2200)
Refractory alloys	up to 2000 (4000)

The extrusion process is generally economical when producing between several kilograms (pounds) and many tons, depending on the material being extruded. There is a crossover point where roll forming becomes more economical. For instance, some steels become more economical to roll if producing more than 20,000 kg (50,000 lb).

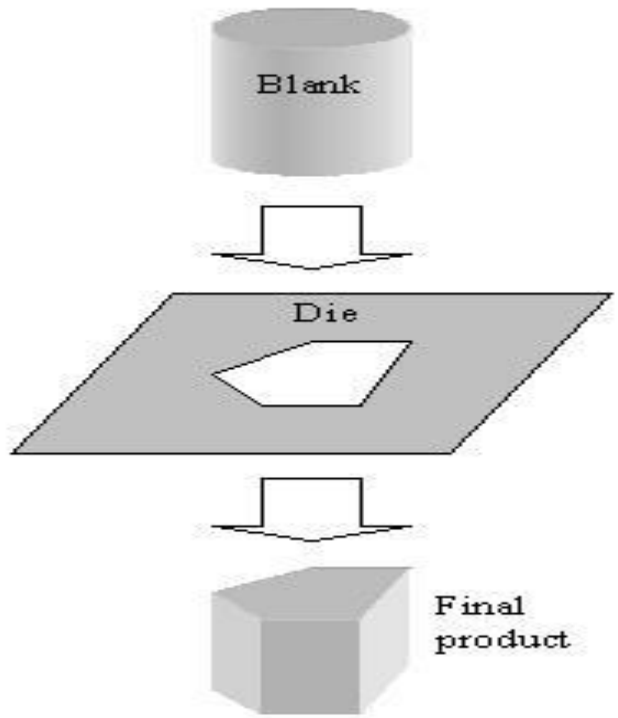


Fig: 3.1 Extrusion of a round blank through a die.

Fig: 3.2 Aluminium hot extrusion die

3.4 COLD EXTRUSION

Cold extrusion is done at room temperature or near room temperature. The advantages of this over hot extrusion are the lack of oxidation, higher strength due to cold working, closer tolerances, better surface finish, and fast extrusion speeds if the material is subject to hot shortness. Materials that are commonly coldextrudedinclude: lead, tin, aluminum, copper, zirconium, titanium, molybdenum , beryllium, vanadium, niobium, and steel. Examples of products produced by this process are: collapsible tubes, fire extinguisher cases, shock absorber cylinders and gear blanks.

3.5 Extrusion Process in forward and back ward

Extrusion fits under the general category of forming in manufacturing processes. The term applies to a variety of processes that involve confining a material in a container and applying a force to push the material through an orifice to produce a required shape.

There are several different types of extrusion:

- Direct Extrusion of Metals, where a heated billet is forced through a die to produce long continuous lengths limited by the amount of material held in the container. The die shape can be simple or complex, a good example of a simple die is for the production of extruded bar.
- Direct Extrusion of Polymers, this is where polymer granules are fed into a heated barrel with a screw feed. The polymer melts and is compacted before being forced through a shaped die.
- Forward Extrusion, where metal is forced to flow in the same direction as the ram being used to apply pressure. The ram is close fitting to the die cavity consequently preventing material extruding past it and controlling the flow of the material in the same direction as the ram. A loose fitting pin can be used to create a cavity in the material as it is forced past.
- Backward Extrusion, as the description suggests is the opposite of forward extrusion and is where metal is forced to flow in the opposite direction to the ram. The ram can be recessed to create a mirror image of the recess in the material as required.

- Indirect Extrusion, this is where a heated billet is backward extruded by a smaller diameter punch containing a die e.g. a washer shaped die can be forced into the billet with the result that the material is extruded back through the centre of the washer. This method produces shorter lengths than the forward extrusion process.The direct and indirect extrusion processes produce continuous shapes where re-entrant angles can be generated on 2D profiles. Froward and backward extrusion processes are used to produce small 3D components.

3.6 IMPACT EXTRUSION:

Impact extrusion is a discrete manufacturing process, in which a metal part is extruded through the impact of a die with the work stock. The part is formed at a high speed and over a relatively short stroke. In standard metal extrusions, the force to extrude the work is commonly delivered by way of a hydraulic press. In impact extrusions, mechanical presses are most often employed. The force used to form standard extrusions is usually delivered over a horizontal vector, producing a long continuous product. Force used to form impact extrusions is usually delivered over a vertical vector, producing a single part with each impact of the punch. Impact extrusion is most often performed cold. Occasionally with some metals and thicker walled structures, the work is heated before impact forming it. This process is best suited for softer metals; aluminum is a great material for forming by impacting.

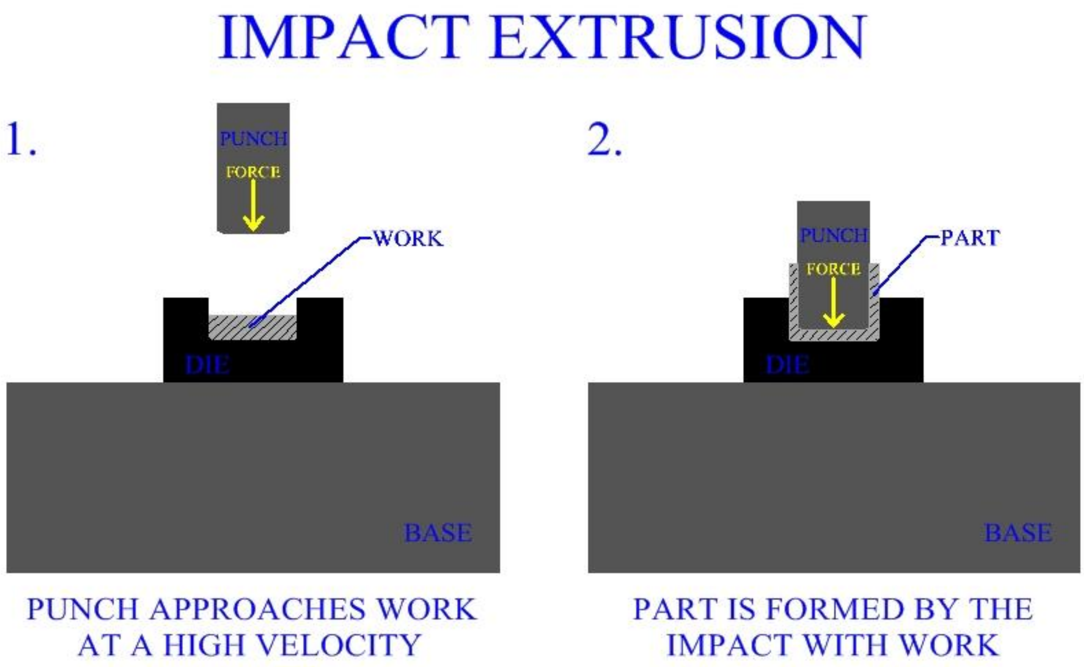


Fig: 3.3 Forward Impact Extrusions

When designing an impact extrusion process, it is important that the part geometry be symmetrical about the punch. In addition, it is essential to the proper forming of the extruded component, that the punch die delivers a precise blow concentric to the work.

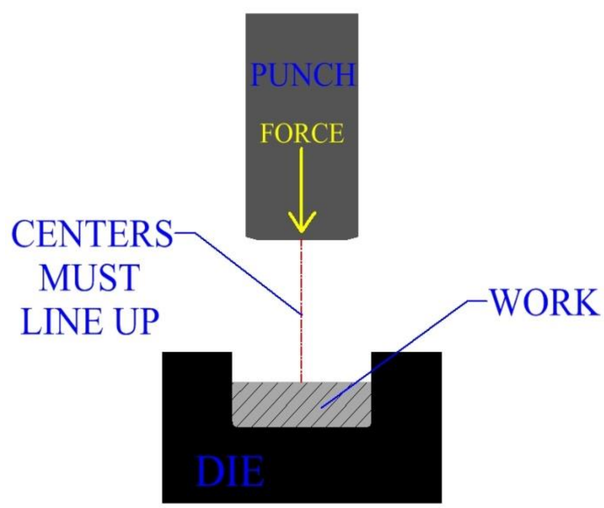


Fig: 3.4

The end of the punch is better designed not to be completely flat, to avoid slipping at the punch-work interface. Sometimes a center point recess can help keep the punch concentric to the work.

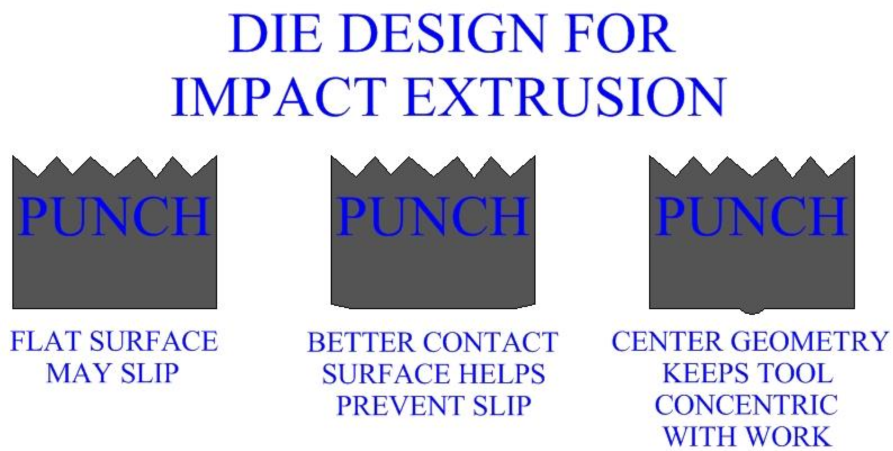


Fig: 3.5

Another factor, when manufacturing by this process, is the proportion between an impact extrusion's length and its internal diameter. Long punches with relatively small diameters may fail during manufacture.

Hollow thin walled tubes, closed on one end, are often produced in manufacturing industry by backward impact extrusion. It is good practice to design the extrusion so that the bottom is at least 20% thicker than the sides, to help prevent metal breakage.

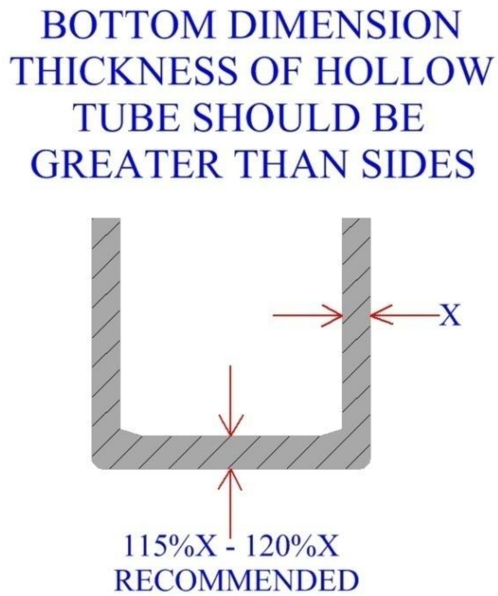


Fig: 3.6

3.6.1 Impact Extrusion In Modern Manufacturing:

Impact extrusion is used to manufacture a variety of parts, such as components for machinery and appliances. Impacted metal parts of complex geometries can be produced as long as the part is symmetrical over the axis by which it is formed. One of the best utilizations of this type of operation is in the production of hollow metal tubes with one end partially or completely closed. Hollow metal tubes may be extruded with internal and external geometry.

The wall thickness of a part manufactured by impact extrusion may vary along its length, so may its interior and exterior diameters. Metal extrusions created by this manufacturing process do not need to have a circular cross section. Noncircular, but symmetrical, parts are also formed. The impact extrusion manufacturing process is very effective at forming flanges on tubular parts. Flanges with varying diameters and geometric attributes may be formed along the length of the extruded metal section. Bosses and hollow tubes, concentric to the extrusion axis, can be formed within hollow metal tubes by impact extrusion.

Many of the parts formed by impacting, in industry, will require further manufacturing processes, such as metal forging, ironing or machining, before completion. Impact extrusion can work harden a part, this may or may not be desirable. If necessary, a component may be annealed before further processing occurs. Favorable grain structures, good surface finish and high productivity are some possible advantages of manufacturing by impact extrusion.

3.7 HYDROSTATIC EXTRUSION:

In the hydrostatic extrusion process the billet is completely surrounded by a pressurized liquid, except where the billet contacts the die. This process can be done hot, warm, or cold, however the temperature is limited by the stability of the fluid used. The process must be carried out in a sealed cylinder to contain the hydrostatic medium. The fluid can be pressurized two ways:

1. Constant-rate extrusion: A ram or plunger is used to pressurize the fluid inside the container.
2. Constant-pressure extrusion: A pump is used, possibly with a pressure intensifier, to pressurize the fluid, which is then pumped to the container.

The advantages of this process include:

- No friction between the container and the billet reduces force requirements. This ultimately allows for faster speeds, higher reduction ratios, and lower billet temperatures.
- Usually the ductility of the material increases when high pressures are applied.
- An even flow of material.
- Large billets and large cross-sections can be extruded.
- No billet residue is left on the container walls.

The disadvantages are:

- The billets must be prepared by tapering one end to match the die entry angle. This is needed to form a seal at the beginning of the cycle. Usually the entire billet needs to be machined to remove any surface defects.
- Containing the fluid under high pressures can be difficult.
- A billet remnant or a plug of a tougher material must be left at the end of the extrusion to prevent a sudden release of the extrusion fluid.

3.8 Extrusion defects

- Surface cracking occurs when the surface of an extrusion splits. This is often caused by the extrusion temperature, friction, or speed being too high. It can also happen at lower temperatures if the extruded product temporarily sticks to the die.

- Pipe – A flow pattern that draws the surface oxides and impurities to the center of the product. Such a pattern is often caused by high friction or cooling of the outer regions of the billet.
- Internal cracking – When the center of the extrusion develops cracks or voids. These cracks are attributed to a state of hydrostatic tensile stress at the centerline in the deformation zone in the die. (A similar situation to the necked region in a tensile stress specimen)
- Surface lines – When there are lines visible on the surface of the extruded profile. This depends heavily on the quality of the die production and how well the die is maintained, as some residues of the material extruded can stick to the die surface and produce the embossed lines.

EXTRUDED PARTS

A horizontal hydraulic press for hot aluminum extrusion (loose dies and scrap visible in foreground)

There are many different variations of extrusion equipment. They vary by four major characteristics:

1. Movement of the extrusion with relation to the ram. If the die is held stationary and the ram moves towards it then it is called "direct extrusion". If the ram is held stationary and the die moves towards the ram it is called "indirect extrusion".
2. The position of the press, either vertical or horizontal.
3. The type of drive, either hydraulic or mechanical.
4. The type of load applied, either conventional (variable) or hydrostatic.

A single or twin screw auger, powered by an electric motor, or a ram, driven by hydraulic pressure (often used for steel and titanium alloys), oil pressure (for aluminium), or in other specialized processes such as rollers inside a perforated drum for the production of many simultaneous streams of material.

3.9 Wire drawing:

Wire drawing is a metalworking process used to reduce the cross-section of a wire by pulling the wire through a single, or series of, drawing die(s). There are many applications for wire drawing, including electrical wiring, cables, tensionloaded structural components, springs, paper clips, spokes for wheels, and stringed musical instruments. Although similar in process, drawing is different from extrusion, because in drawing the wire is pulled, rather than pushed, through the die. Drawing is usually performed at room temperature, thus classified as a cold working process, but it may be performed at elevated temperatures for large wires to reduce forces.

Fig: 3.7 Drawing silver wire by hand pulling

3.10 PROCESS MECHANICS AND ITS CHARACTERISTICS

The wire drawing process is quite simple in concept. The wire is prepared by shrinking the beginning of it, by hammering, filing, rolling or swaging, so that it will fit through the die; the wire is then pulled through the die. As the wire is pulled through the die, its volume remains the same, so as the diameter decreases, the length increases. Usually the wire will require more than one draw, through successively smaller dies, to reach the desired size. The American wire gauge scale is based on this. This can be done on a small scale with a draw plate, or on a large commercial scale using automated machinery.[1][2] The process of wire drawing changes material properties due to cold working.

The area reduction in small wires is generally 15–25% and in larger wires is 20–45%.[1] The exact die sequence for a particular job is a function of area reduction, input wire size and output wire size. As the area reduction changes, so does the die sequence.[3]

Very fine wires are usually drawn in bundles. In a bundle, the wires are separated by a metal with similar properties, but with lower chemical resistance so that it can be removed after drawing.[citation needed] If the reduction in area is greater than 50%, the process may require an intermediate step of annealing before it can be redrawn.

Commercial wire drawing usually starts with a coil of hot rolled 9 mm (0.35 in) diameter wire. The surface is first treated to remove scales. It is then fed into a wire drawing machine which may have one or more blocks in series.

Single block wire drawing machines include means for holding the dies accurately in position and for drawing the wire steadily through the holes. The usual design consists of a cast-iron bench or table having a bracket standing up to hold the die, and a vertical drum which rotates and by coiling the wire around its surface pulls it through the die, the coil of wire being stored upon another drum or "swift" which lies behind the die and reels off the wire as fast as required. The wire drum or "block" is provided with means for rapidly coupling or uncoupling it to its vertical shaft, so that the motion of the wire may be stopped or started instantly. The block is also tapered, so that the coil of wire may be easily slipped off upwards when finished. Before the wire can be attached to the block, a sufficient length of it must be pulled through the die; this is effected by a pair of gripping pincers on the end of a chain which is wound around a revolving drum, so drawing the wire until enough can be coiled two or three times on the block, where the end is secured by a small screw clamp or vice. When the wire is on the block, it is set in motion and the wire is drawn steadily through the die; it is very important that the block rotates evenly and that it runs true and pulls the wire at a constant velocity, otherwise "snatching" occurs which will weaken or even break the wire. The speeds at which wire is drawn vary greatly, according to the material and the amount of reduction.

Machines with continuous blocks differ from single block machines by having a series of dies through which the wire is drawn in a continuous fashion. Due to the elongation and slips, the speed of the wire changes after each successive redraw. This increased speed is accommodated by having a different rotation speed for each block. One of these machines may contain 3 to 12 dies. The operation of threading the wire through all the dies and around the blocks is termed "stringing-up". The arrangements for lubrication include a pump which floods the dies, and in many cases also the bottom portions of the blocks run in lubricant.

Often intermediate anneals are required to counter the effects of cold working, and to allow further drawing. A final anneal may also be used on the finished product to maximize ductility and electrical conductivity.

An example of product produced in a continuous wire drawing machine is telephone wire. It is drawn 20 to 30 times from hot rolled rod stock.

While round cross-sections dominate most drawing processes, non-circular cross-sections are drawn. They are usually drawn when the cross-section is small and quantities are too low to justify rolling. In these processes, a block or Turk's-head machine are used.

Lubrication[edit]

Lubrication in the drawing process is essential for maintaining good surface finish and long die life. The following are different methods of lubrication:

- Wet drawing: the dies and wire or rod are completely immersed in lubricants
- Dry drawing: the wire or rod passes through a container of lubricant which coats the surface of the wire or rod
- Metal coating: the wire or rod is coated with a soft metal which acts as a solid lubricant
- Ultrasonic vibration: the dies and mandrels are vibrated, which helps to reduce forces and allow larger reductions per pass
- Roller die Drawing (also referred as **Roll drawing**): roller dies are used instead of fixed dies to convert shear friction to rolling friction with dramatic reduction in the drawing forces as reported by Lambiase. When roller dies are adopted, the drawing stages are composed by 2-4 idle rolls and he wire is pulled within the rolls clearance. This type of solution can be easily adopted also to produce flat or profiled drawn wires.

Various lubricants, such as oil, are employed. Another lubrication method is to immerse the wire in a copper(II) sulfate solution, such that a film of copper is deposited which forms a kind of lubricant. In some classes of wire the copper is left after the final drawing to serve as a preventive of rust or to allow easy soldering. The best example of copper coated wire is in MIG wire used in welding.

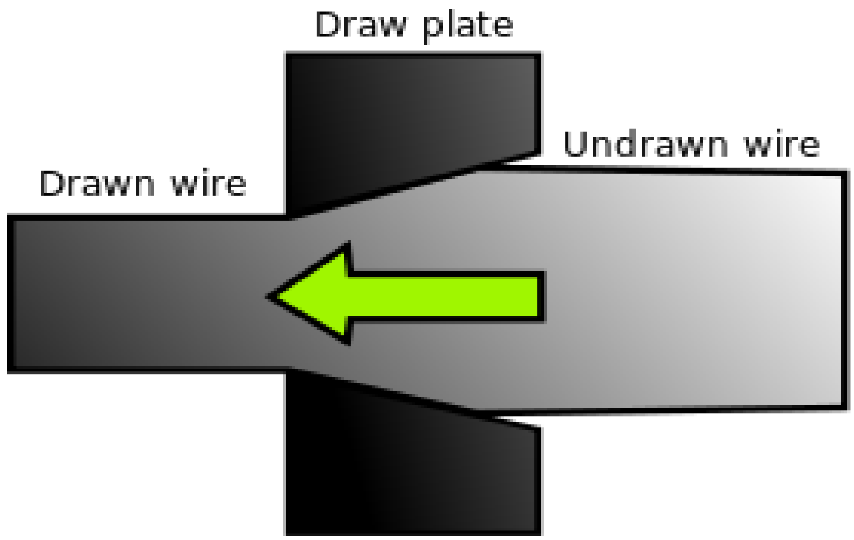


Fig: 3.8 Wire drawing concept

WIRE DRAWING VS BAR DRAWING

- Difference between bar drawing and wire drawing is stock size
  - Bar drawing - large diameter bar and rod stock
  - Wire drawing - small diameter stock - wire sizes down to 0.03 mm (0.001 in.) are possible
- Although the mechanics are the same, the methods, equipment, and even terminology are different
- Drawing practice:
  - Usually performed as cold working
  - Most frequently used for round cross-sections
- Products:
  - Wire: electrical wire; wire stock for fences, coat hangers, and shopping carts
  - Rod stock for nails, screws, rivets, and springs
  - Bar stock: metal bars for machining, forging, and other processes

- Continuous drawing machines consisting of multiple draw dies (typically 4 to 12) separated by accumulating drums
  - Each drum (capstan) provides proper force to draw wire stock through upstream die
  - Each die provides a small reduction, so desired total reduction is achieved by the series

UNIT.IV

SHEET METAL WORKING

4.1 INTRODUCTION:

Sheet metal is simply metal formed into thin and flat pieces. It is one of the fundamental forms used in metalworking, and can be cut and bent into a variety of different shapes. Countless everyday objects are constructed of the material. Thicknesses can vary significantly, although extremely thin thicknesses are considered foil or leaf, and pieces thicker than 6 mm (0.25 in) are considered plate.

4.2 SHEET METAL PROCESSING:

The raw material for sheet metal manufacturing processes is the output of the rolling process. Typically, sheets of metal are sold as flat, rectangular sheets of standard size. If the sheets are thin and very long, they may be in the form of rolls. Therefore the first step in any sheet metal process is to cut the correct shape and sized 'blank' from larger sheet.

4.3 SHEET METAL FORMING PROCESSES:

Sheet metal processes can be broken down into two major classifications and one minor classification

- **Shearing processes** -- processes which apply shearing forces to cut, fracture, or separate the material.
- **Forming processes** -- processes which cause the metal to undergo desired shape changes without failure, excessive thinning, or cracking. This includes bending and stretching.
- **Finishing processes** -- processes which are used to improve the final surface characteristics.

4.4 SHEARING PROCESS:

1. Punching: shearing process using a die and punch where the **interior** portion of the sheared sheet is to be **discarded.**

2. Blanking: shearing process using a die and punch where the **exterior** portion of the shearing operation is to be **discarded**.

3. Perforating: punching a number of holes in a sheet

4. Parting: shearing the sheet into two or more pieces

5. Notching: removing pieces from the edges

6. Lancing: leaving a tab without removing any material

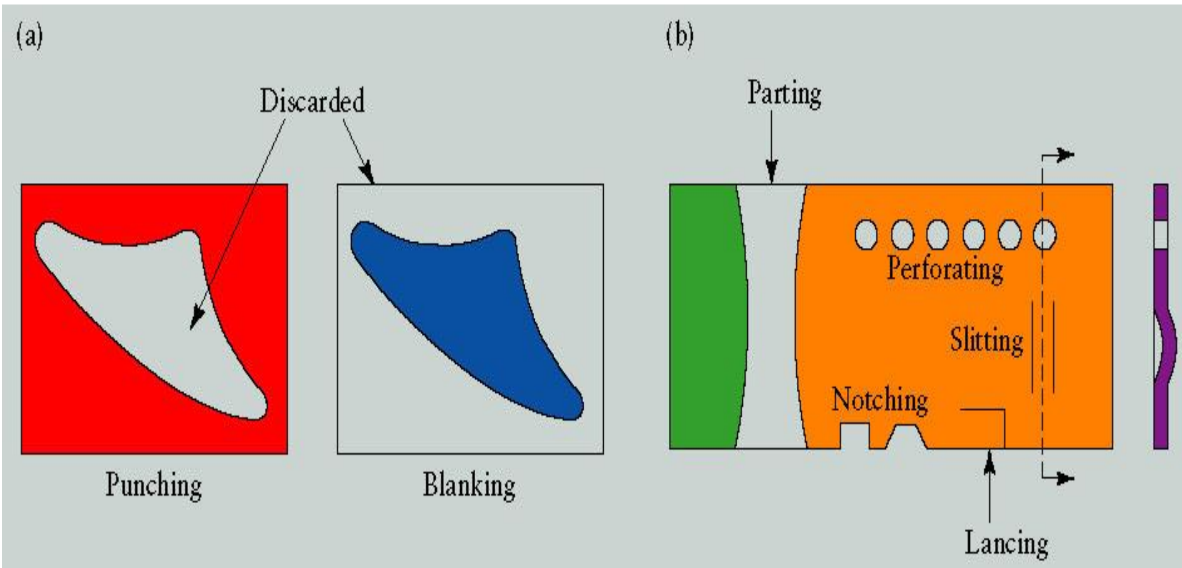


Fig.4.1 Shearing Operations: Punching, Blanking and Perforating

4.5 FORMING PROCESSES:

- **Bending:** forming process causes the sheet metal to undergo the desired shape change by bending without failure. Ref fig.2 & 2a

- **Stretching:** forming process causes the sheet metal to undergo the desired shape change by stretching without failure. Ref fig.3
- **Drawing:** forming process causes the sheet metal to undergo the desired shape change by drawing without failure. Ref fig.4
- **Roll forming:** Roll forming is a process by which a metal strip is progressively bent as it passes through a series of forming rolls. Ref fig.5

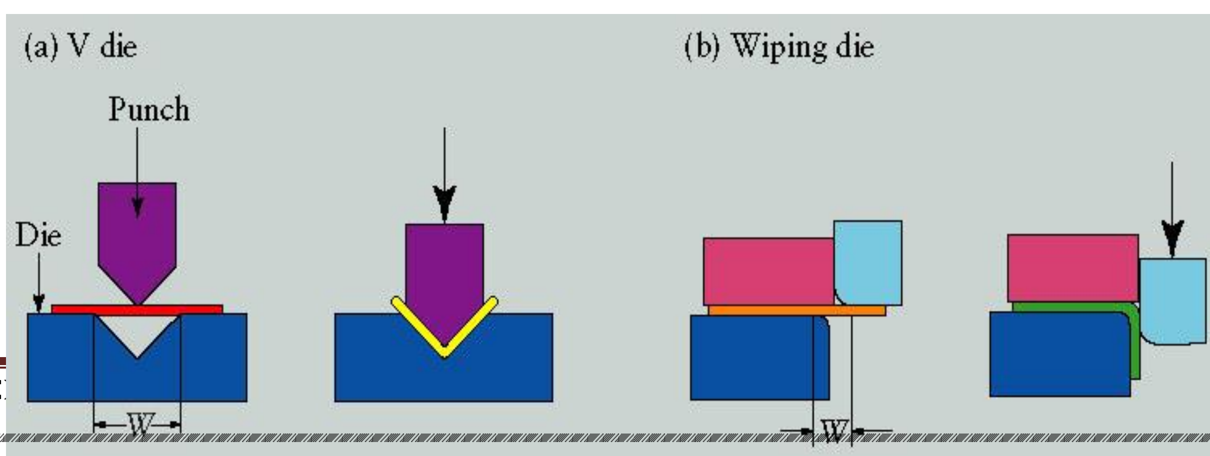


Fig 4.2 Common Die-Bending Operations

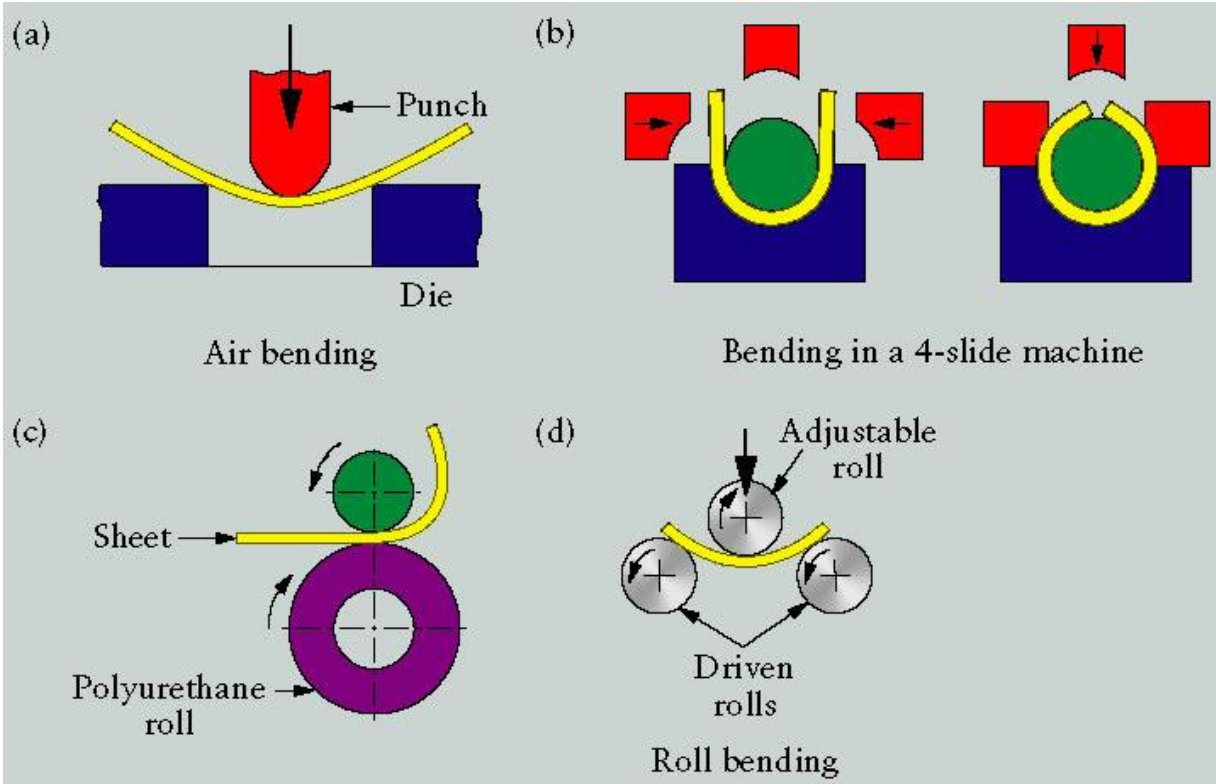


Fig.4.2a Various Bending Operations

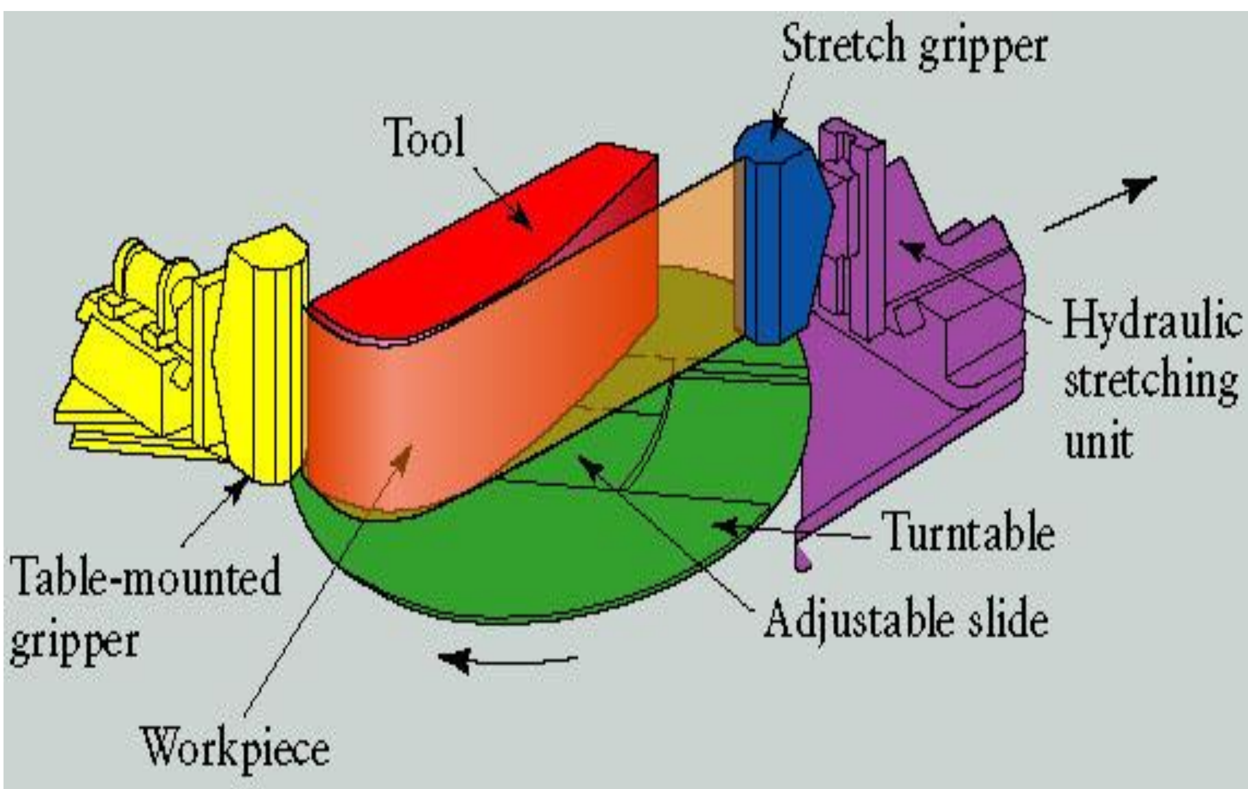


Fig.4.3 Schematic illustration of a stretch-forming process.

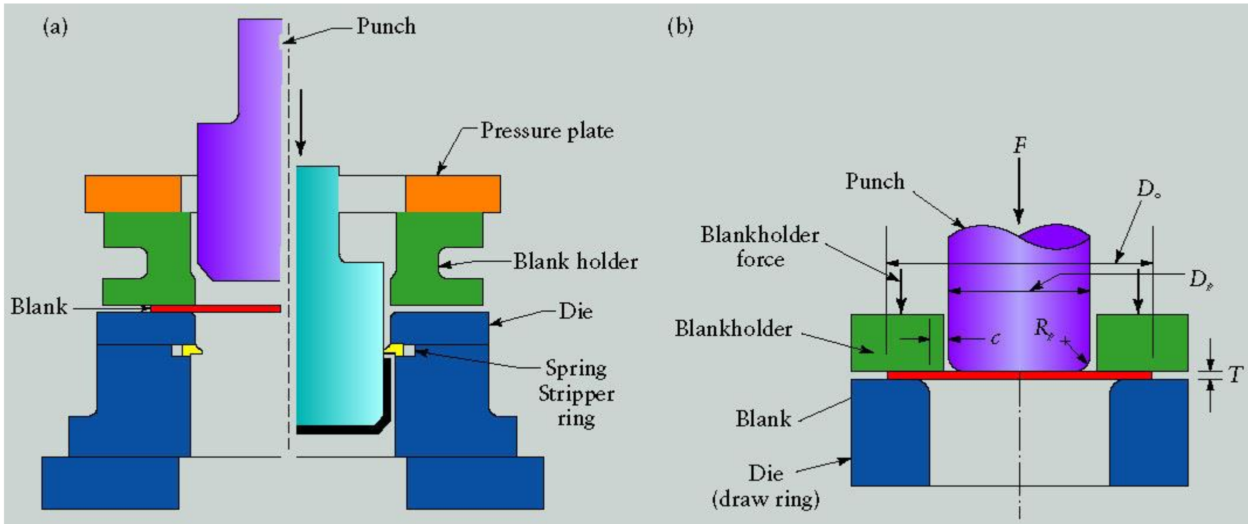


Fig.4.4 Schematic of the Drawing process.

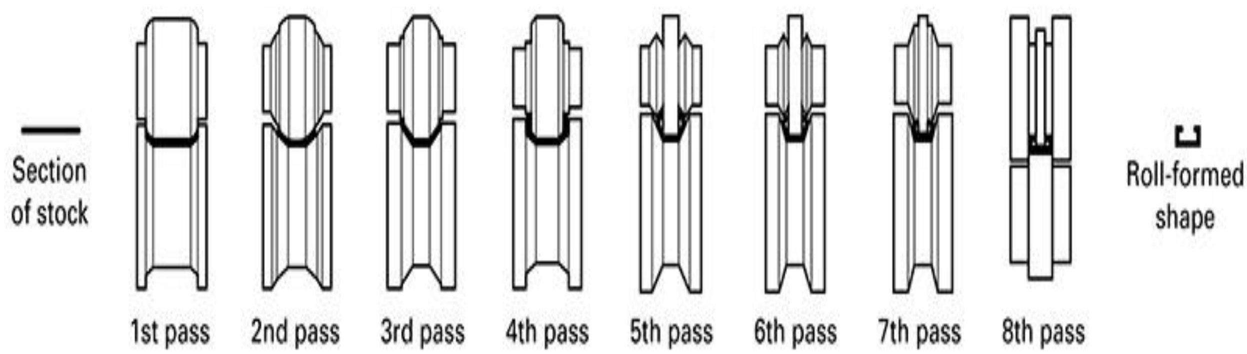


Fig 4.5 Eight-roll sequence for the roll forming of a box channel

4.4 FINISHING PROCESSES:

Material properties, geometry of the starting material, and the geometry of the desired final product play important roles in determining the best process

4.5 EQUIPMENTS:

Basic sheet forming operations involve a press, punch, or ram and a set of dies

4.5.1 Presses:

- **Mechanical Press -** The ram is actuated using a flywheel. Stroke motion is not uniform. Ref fig.6
- **Hydraulic Press -** Longer strokes than mechanical presses, and develop full force throughout the stroke. Stroke motion is of uniform speed, especially adapted to deep drawing operations. Ref fig.7

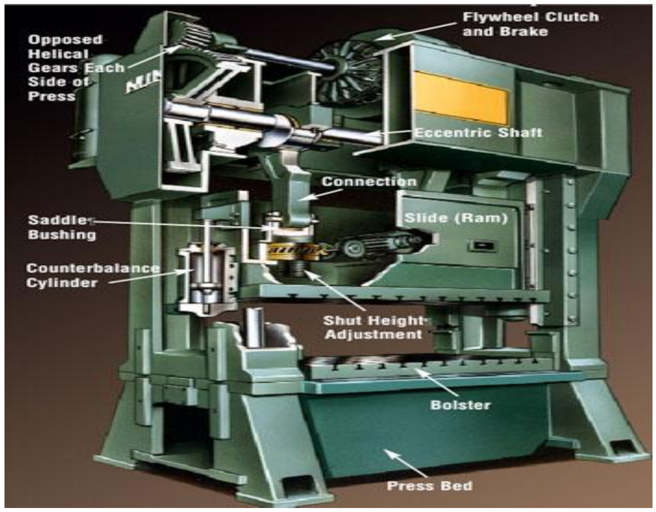


Fig 4.6 Mechanical Press

Fig 4.7 Hydraulic Press

4.5.2 Dies and Punches

- **Simple**- single operation with a single stroke
- **Compound**- two operations with a single stroke

- **Combination**- two operations at two stations
- **Progressive**- two or more operations at two or more stations with each press stroke, creates what is called a strip development

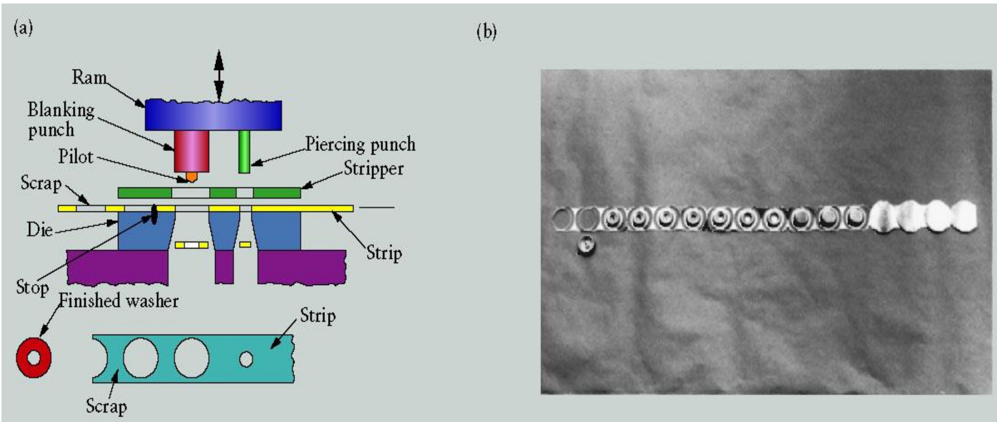


Fig 4.8 Progressive dies Punches

4.5.3 Tools and Accessories

The various operations such as cutting, shearing, bending, folding etc. are performed by these tools.

4.5.4 Marking and measuring tools

- **Steel Rule -** It is used to set out dimensions.
- **Try Square** - Try square is used for making and testing angles of 90degree
- **Scriber – I**t used to scribe or mark lines on metal work pieces.
- **Divider -** This is used for marking circles, arcs, laying out perpendicular lines, bisecting lines, etc

Fig 4.9 Marking and measuring tools

4.5.5 Cutting Tools

- **Straight snip -** They have straight jaws and used for straight line cutting.
- **Curved snip -** They have curved blades for making circular cuts.

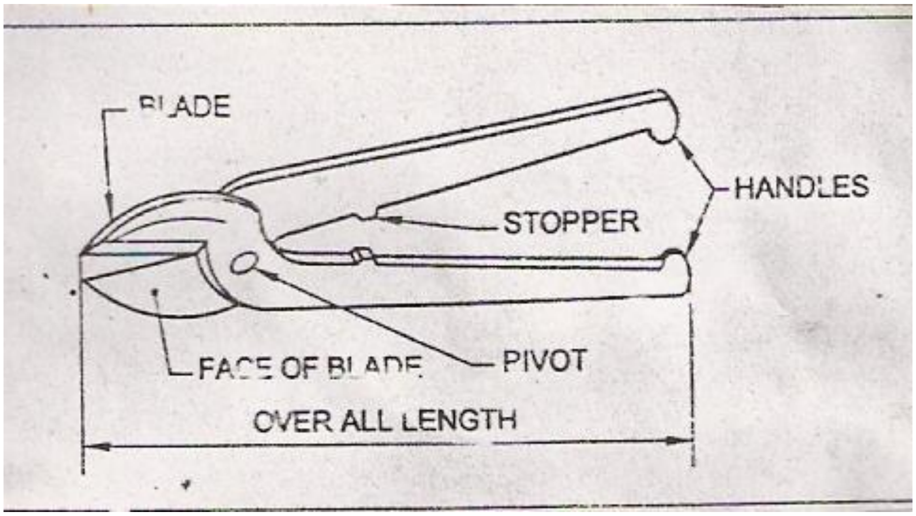


Fig 4.10 Straight snip

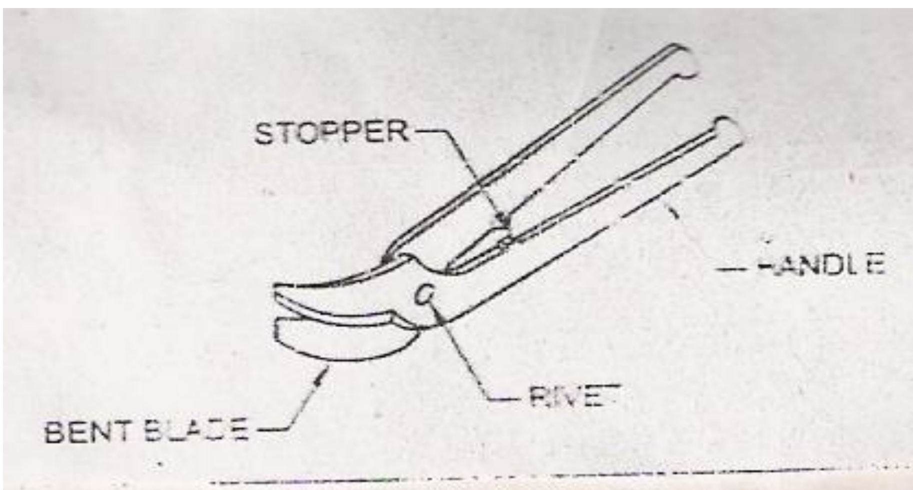
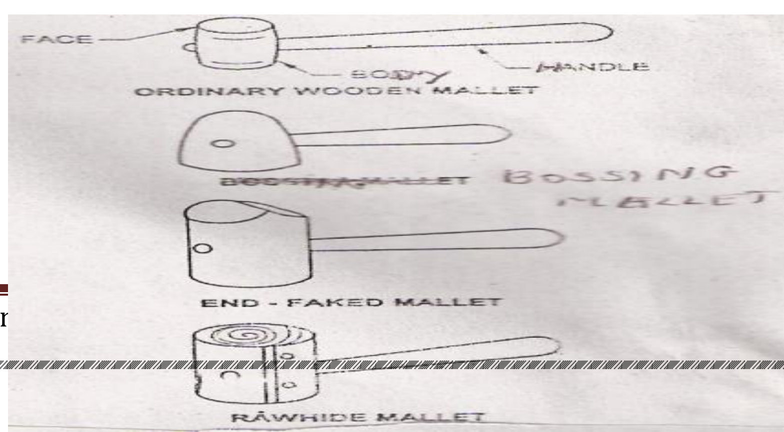


Fig 4.10a Curved Snip

4.6 STRIKING TOOLS:

- **Mallet -** It is wooden-headed hammer of round or rectangular cross section. The striking face is made flat to the work. A mallet is used to give light blows to the Sheet metal in bending



and finishing.

Fig 4.11 Types of Mallets

4.6.1 MERITS

- High strength
- Good dimensional accuracy and surface finish
- Relatively low cost

4.6.2 DEMERITS

- Wrinkling and tearing are typical limits to drawing operations
- Different techniques can be used to overcome these limitations
    - Draw beads
    - Vertical projections and matching grooves in the die and blank holder
- Trimming may be used to reach final dimensions

4.6.3 APPLICATIONS

- Roofings
- Ductings
- Vehicles body buildings like 3 wheelers, 4 wheelers, ships, aircrafts etc.
- Furnitures, House hold articles and Railway equipment

4.7 ECONOMIC CONSIDERATIONS:

- Production rates vary, up to 3000/h for small components using automated processes.
- Deep drawing punch speeds a function of material; high to low – brass, aluminum, copper, zinc, steel, stainless steel (typically 800/h).
- High degree of automation is possible.

- Cycle time is usually determined by loading and unloading times for the stock material.
- Lead times vary, up to several weeks for deep drawing and stretch forming; could be less than an hour for bending.
- Material utilization is moderate to high (10–25 per cent scrap generated). Bending and roll forming do not produce scrap directly. Deep drawing and stretch forming may require a trimming operation.
- Production quantities should be high for dedicated tooling, 10 000+. Minimum economical quantities range from 1 for bending to 1000 for deep drawing.
- Tooling cost is moderate to high, depending on component complexity.

- Equipment costs vary greatly; low for simple bending machines, moderate for roll forming machines and high for automated deep drawing, sheet metal presses and stretch forming.
- Labor costs are low to moderate, depending on degree of automation.
- Finishing costs are low. Trimming and cleaning may be required.

4.8 STAMPING:

Stamping (also known as **pressing**) is the process of placing flat sheet metal in either blank or coil form into a stamping press where a tool and die surface forms the metal into a net shape. Stamping includes a variety of sheet-metal forming manufacturing processes, such as punching using a machine press or stamping press, blanking, embossing, bending, flanging, and coining.[1] This could be a single stage operation where every stroke of the press produces the desired form on the sheet metal part, or could occur through a series of stages. The process is usually carried out on sheet metal, but can also be used on other materials, such as polystyrene. Stamping is usually done on cold metal sheet. See Forging for hot metal forming operations.

4.9 FORMING AND OTHER COLD WORKING PROCESSES:

Below the recrystallization temperature if the mechanical work is done on the metals , there will no grain growth but it must be grain this integration elongation , the process is known is cold working processes. In cold working process greater pressure is required than that required in hot working. As the metal is in a more rigid state. It is not permanently deform until stress exceeds the elastic limit. Most of the cold processes are performed at room temperature, the different cold working processes are

1: Drawing

- Wire drawing
- Tube drawing
- Blanking
- Spinning

2: SEQUEEZING

- Coining
- Sizing
- Riveting

3: Bending

- Angle bending
- Plate bending
- Roll forming

4: Shearing

>Punching >Blanking

> Trimming > Perforating

>Notching >Launcing

>Slittig

5: Extruding

4.10 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.

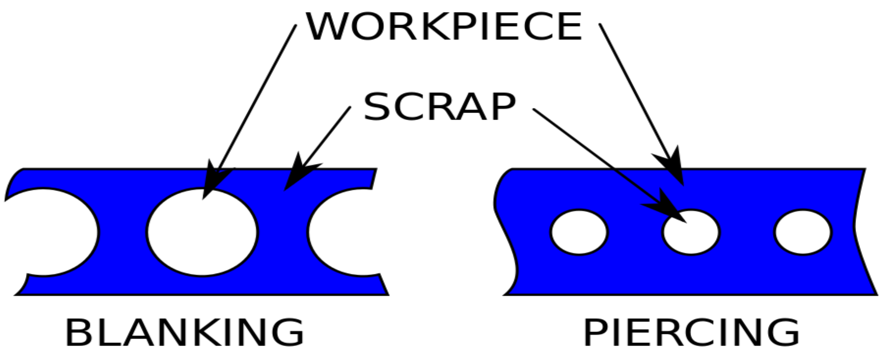


Fig: 4.12

There are various types of blanking and piercing: lancing, perforating, notching, nibbling, shaving, cutoff, and dinking.

Lancing

Lancing is a piercing operation in which the work piece is sheared and bent with one strike of the die. A key part of this process is that there is not reduction of material, only a modification in its geometry. This operation is used to make tabs, vents, and louvers. The cut made in lancing is not a closed cut, like in perforation even though a similar machine is used, but a side is left connected to be bent sharply or in more of a rounded manner.

Lancing can be used to make partial contours and free up material for other operations further down the production line. Along with these reasons lancing is also used to make tabs (where the material is bent at a 90 degree angle to the material), vents (where the bend is around 45 degrees), and louvers (where the piece is rounded or cupped).It also help to cut or slight shear of sheet on cylindrical shape.

Normally lancing is done on a mechanical press, lancing requires the use of punches and dies to be used. The different punches and dies determine the shape and angle (or curvature) of the newly made section of the material. The dies and punches are needed to be made of tool steel to withstand the repetitious nature of the procedure.

Perforating

Perforating is a piercing operation that involves punching a large number of closely spaced holes.

Notching

Notching is a piercing operation that removes material from the edge of the work piece.

Nibbling

The nibbling process cuts a contour by producing a series of overlapping slits or notches. This allows for complex shapes to be formed in sheet metal up to 6 mm (0.25 in) thick using simple tools. The nibbler is essentially a small punch and die that reciprocates quickly; around 300–900 times per minute. Punches are available in various shape and sizes; oblong and rectangular punches are common because they minimize waste and allow for greater distances between strokes, as compared to a round punch. Nibbling can occur on the exterior or interior of the material, however interior cuts require a hole to insert the tool.

The process is often used on parts that do not have quantities that can justify a dedicated blanking die. The edge smoothness is determined by the shape of the cutting die and the amount the cuts overlap; naturally the more the cuts overlap, the cleaner the edge. For added accuracy and smoothness most shapes created by nibbling undergo filing or grinding processes after completion.

Shaving

The shaving process is a finishing operation where a small amount of metal is sheared away from an already blanked part. Its main purpose is to obtain better dimensional accuracy, but secondary purposes include squaring the edge and smoothing the edge. Blanked parts can be shaved to an accuracy of up to 0.025 mm (0.001 in).

Trimming

The trimming operation is the last operation performed because it cuts away excess or unwanted irregular features from the walls of drawn sheets.

Cutoff

The cutoff process is used to separate a stamping or other product from a strip or stock. This operation is very common with progressive die sequences. The cutoff operation often produces the periphery counter to the work piece.

Fine blanking

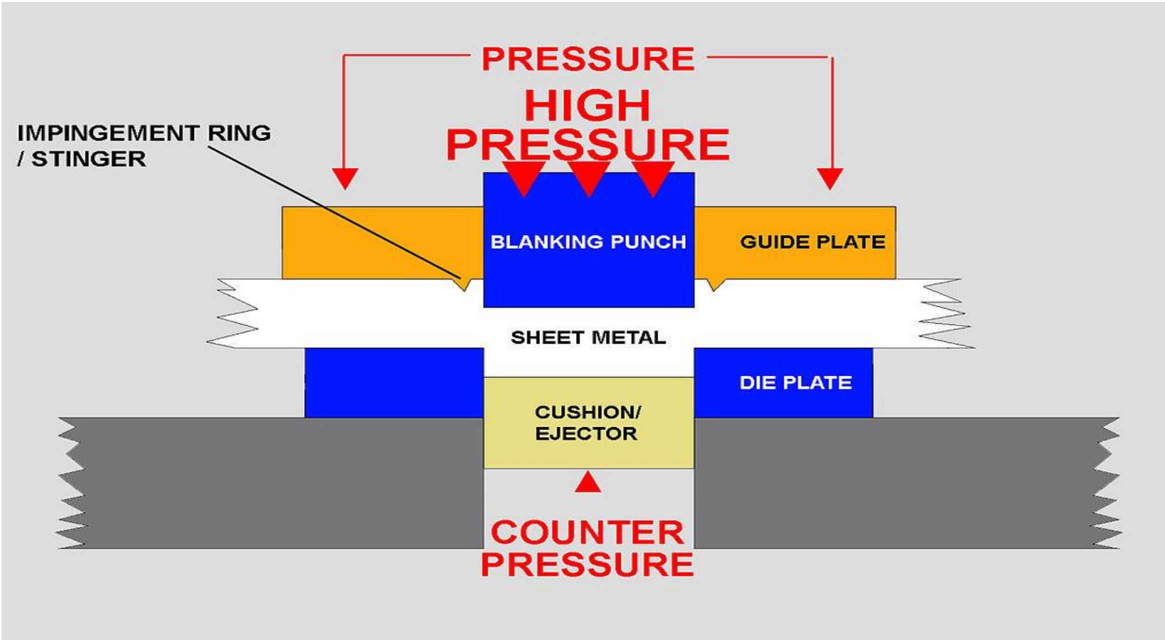


Fig: 4.13 Typical fine blanking press cross section

Fine blanking is a specialized form of blanking where there is no fracture zone when shearing. This is achieved by compressing the whole part and then an upper and lower punch extracts the blank. This allows the process to hold very tight tolerances, and perhaps eliminate secondary operations. Materials that can be fine blanked include aluminum, brass, copper, and carbon, alloy, and stainless steels.

Fine blanking presses are similar to other metal stamping presses, but they have a few critical additional parts. A typical compound fine blanking press includes a hardened die punch (male), the hardened blanking die (female), and a guide plate of similar shape/size to the blanking die. The guide plate is the first applied to the material, impinging the material with a sharp protrusion or *stinger* around the perimeter of the die opening. Next a counter pressure is applied opposite the punch, and finally the die punch forces the material through the die opening. Since the guide plate holds the material so tightly, and since the counter pressure is applied, the material is cut in a manner more like extrusion than typical punching. Mechanical properties of the cut benefit similarly with a hardened layer at the cut edge of the part. Because the material is so tightly held and controlled in this setup, part flatness remains very true, distortion is nearly eliminated, and edge burr is minimal. Clearances between the die and punch are generally around 1% of the cut material thickness, which typically varies between 0.5–13 mm (0.020–0.512 in). Currently parts as thick as 19 mm (0.75 in) can be cut using fine blanking. Tolerances between ±0.0003–0.002 in (0.0076–0.0508 mm) are possible based on material thickness & tensile strength, and part layout. With standard compound fine blanking processes, multiple parts can often be completed in a single operation. Parts can be pierced, partially pierced, offset (up to 75°), embossed, or coined, often in a single operation. Some combinations may require progressive fine blanking operations, in which multiple operations are performed at the same pressing station.

The advantages of fine blanking are:

- excellent dimensional control, accuracy, and repeatability through a production run;
- excellent part flatness is retained;
- straight, superior finished edges to other metal stamping processes;
- little need to machine details;
- multiple features can be added simultaneously in 1 operation;
- more economical for large production runs than traditional operations when additional machining cost and time are factored in (1000–20000 parts minimum, depending on secondary machining operations).

One of the main advantages of fine blanking is that slots or holes can be placed very near to the edges of the part, or near to each other. Also, fine blanking can produce holes that are much smaller (as compared to material thickness) than can be produced by conventional stamping.

The disadvantages are:

- slightly slower than traditional punching operations;
- Higher equipment costs, due higher tooling cost when compared to traditional punching operations and to higher tonnage requirements for the presses.

4.11 BENDING:

Bending is a manufacturing process that produces a V-shape, U-shape, or channel shape along a straight axis in ductile materials, most commonly sheet metal. Commonly used equipment include box and pan brakes, brake presses, and other specialized machine presses. Typical products that are made like this are boxes such as electrical enclosures and rectangular ductwork.

In press brake forming, a work piece is positioned over the die block and the die block presses the sheet to form a shape. Usually bending has to overcome both tensile stresses and compressive stresses. When bending is done, the residual stresses cause the material to *spring back* towards its original position, so the sheet must be over-bent to achieve the proper bend angle. The amount of spring back is dependent on the material, and the type of forming. When sheet metal is bent, it stretches in length. The *bend deduction* is the amount the sheet metal will stretch when bent as measured from the outside edges of the bend.

The U-punch forms a U-shape with a single punch.

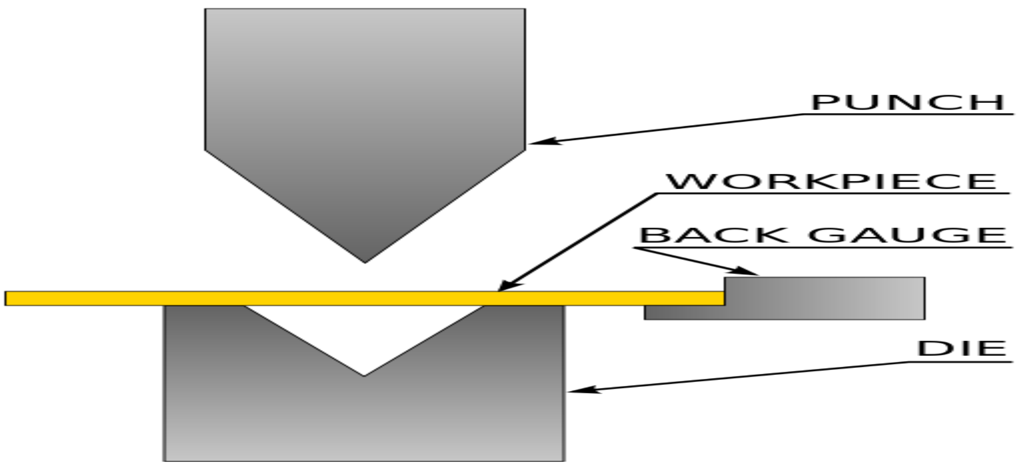


FIG: 4.14

There are three basic types of bending on a press brake, each is defined by the relationship of the end tool position to the thickness of the material. These three are Air Bending, Bottoming and Coining. The configuration of the tools for these three types of bending is nearly identical. A die with a long rail form tool with a radi used tip that locates the inside profile of the bend is called a punch. Punches are usually attached to the ram of the machine by clamps and move to produce the bending force. A die with a long rail form tool that has concave or V shaped lengthwise channel that locate the outside profile of the form is called a die. Dies are usually stationary and located under the material on the bed of the machine. Note that some locations do not differentiate between the two different kinds of dies (punches and dies.) The other types of bending listed use specially designed tools or machines to perform the work.

Air bending

This bending method forms material by pressing a punch (also called the upper or top die) into the material, forcing it into a bottom V-die, which is mounted on the press. The punch forms the bend so that the distance between the punch and the side wall of the V is greater than the material thickness (T).Either a V-shaped or square opening may be used in the bottom die (dies are frequently referred to as tools or tooling). Because it requires less bend force, air bending tends to use smaller tools than other methods. Some of the newer bottom tools are adjustable, so, by using a single set of top and bottom tools and varying press-stroke depth, different profiles and products can be produced. Different materials and thicknesses can be bent in varying bend angles, adding the advantage of flexibility to air bending. There are also fewer tool changes, thus, higher productivity.

A disadvantage of air bending is that, because the sheet does not stay in full contact with the dies, it is not as precise as some other methods, and stroke depth must be kept very accurate. Variations in the thickness of the material and wear on the tools can result in defects in parts produced. Air bending's angle accuracy is approximately ±0.5 deg. Angle accuracy is ensured by applying a value to the width of the V opening, ranging from 6 T (six times material thickness) for sheets to 3 mm thick to 12 T for sheets more than 10 mm thick. Spring back depends on material properties, influencing the resulting bend angle.

Air bending does not require the bottom tool to have the same radius as the punch. Bend radius is determined by material elasticity rather than tool shape.[2]

The flexibility and relatively low tonnage required by air bending are helping to make it a popular choice. Quality problems associated with this method are countered by angle-measuring systems, clamps and crowning systems adjustable along the x and y axes, and wear-resistant tools.

The K-Factor approximations given below are more likely to be accurate for air bending than the other types of bending due to the lower forces involved in the forming process.

Bottoming

In bottoming, the sheet is forced against the V opening in the bottom tool. U-shaped openings cannot be used. Space is left between the sheet and the bottom of the V opening. The optimum width of the V opening is 6 T (T stands for material thickness) for sheets about 3 mm thick, up to about 12 T for 12 mm thick sheets. The bending radius must be at least 0.8 T to 2 T for sheet steel. Larger bend radius require about the same force as larger radii in air bending, however, smaller radii require greater force—up to five times as much—than air bending. Advantages of bottoming include greater accuracy and less spring back. A disadvantage is that a different tool set is needed for each bend angle, sheet thickness, and material. In general, air bending is the preferred technique.

Coining

In coining, the top tool forces the material into the bottom die with 5 to 30 times the force of air bending, causing permanent deformation through the sheet. There is little, if any, spring back. Coining can produce an inside radius is as low as 0.4 T, with a 5 T width of the V opening. While coining can attain high precision, higher costs mean that it is not often used.

Three-point bending

Three-point bending is a newer process that uses a die with an adjustable-height bottom tool, moved by a servo motor. The height can be set within 0.01 mm. Adjustments between the ram and the upper tools are made using a hydraulic cushion, which accommodates deviations in sheet thickness. Three-point bending can achieve bend angles with 0.25 deg. precision. While three-point bending permits high flexibility and precision, it also entails high costs and there are fewer tools readily available. It is being used mostly in high-value niche markets.[2]

Folding

In folding, clamping beams hold the longer side of the sheet. The beam rises and folds the sheet around a bend profile. The bend beam can move the sheet up or down, permitting the fabricating of parts with positive and negative bend angles. The resulting bend angle is influenced by the folding angle of the beam, tool geometry, and material properties. Large sheets can be handled in this process, making the operation easily automated. There is little risk of surface damage to the sheet.

Wiping

In wiping, the longest end of the sheet is clamped, then the tool moves up and down, bending the sheet around the bend profile. Though faster than folding, wiping has a higher risk of producing scratches or otherwise damaging the sheet, because the tool is moving over the sheet surface. The risk increases if sharp angles are being produced. Wiping on press brakes.

This method will typically bottom or coin the material to set the edge to help overcome spring back. In this bending method, the radius of the bottom die determines the final bending radius. Manual setup

Rotary bending

Rotary bending is similar to wiping but the top die is made of a freely rotating cylinder with the final formed shape cut into it and a matching bottom die. On contact with the sheet, the roll contacts on two points and it rotates as the forming process bends the sheet. This bending method is typically considered a "non-marking" forming process suitable to pre-painted or easily marred surfaces. This bending process can produce angles greater than 90° in a single hit on standard press brakes process.

4.12 DRAWING AND ITS TYPES:

Drawing is a metalworking process which uses tensile forces to stretch metal. As the metal is drawn (pulled), it stretches thinner, into a desired shape and thickness. Drawing is classified in two types: sheet metal drawing and wire, bar, and tube drawing. The specific definition for sheet metal drawing is that it involves plastic deformation over a curved axis. For wire, bar, and tube drawing the starting stock is drawn through a die to reduce its diameter and increase its length. Drawing is usually done at room temperature, thus classified a cold working process, however it may be performed at elevated temperatures to hot work large wires, rods or hollow sections in order to reduce forces. **DRAWING IS ONE TYPE OF** EXTRUSION

Drawing differs from rolling in that the pressure of drawing is not transmitted through the turning action of the mill but instead depends on force applied locally near the area of compression. This means the amount of possible drawing force is limited by the tensile strength of the material, a fact that is particularly evident when drawing thin wires.

SHEET METAL

The success of forming is in relation to two things, the flow and stretch of material. As a die forms a shape from a flat sheet of metal, there is a need for the material to move into the shape of the die. The flow of material is controlled through pressure applied to the blank and lubrication applied to the die or the blank. If the form moves too easily, wrinkles will occur in the part. To correct this, more pressure or less lubrication is applied to the blank to limit the flow of material and cause the material to stretch or set thin. If too much pressure is applied, the part will become too thin and break. Drawing metal is the science of finding the correct balance between wrinkles and breaking to achieve a successful part.

DEEP DRAWING

Sheet metal drawing becomes deep drawing when the work piece is drawing longer than its diameter. It is common that the work piece is also processed using other forming processes, such as piercing, ironing, necking, rolling, and beading.

BAR, TUBE & WIRE

Bar, tube, and wire drawing all work upon the same principle: the starting stock drawn through a die to reduce the diameter and increase the length. Usually the die is mounted on a draw bench. The end of the work piece is reduced or pointed to get the end through the die. The end is then placed in grips and the rest of the work piece is pulled through the die. Steels, copper alloys, and aluminium alloys are common materials that are drawn. Drawing can also be used to produce a cold formed shaped cross-section. Cold drawn cross-sections are more precise and have a better surface finish than hot extruded parts. Inexpensive materials can be used instead of expensive alloys for strength requirements, due to work hardening.

BAR DRAWING

Bars or rods that are drawn cannot be coiled therefore straight-pull draw benches are used. Chain drives are used to draw work pieces up to 30 m (98 ft). Hydraulic cylinders are used for shorter length work pieces. The reduction in area is usually restricted to between 20 and 50%, because greater reductions would exceed the tensile strength of the material, depending on its ductility. To achieve a certain size or shape multiple passes through progressively smaller dies or intermediate anneals may be required.

THE COLD DRAWING PROCESS FOR STEEL BARS AND WIRE

CARBIDE DIE CROSS SECTION

RAW STOCK: Hot rolled steel bar or rod coils are used as raw material. Because the hot rolled products are produced at elevated temperatures (1700 - 2200 Deg. F. i.e. hot rolling), they generally have a rough and scaled surface and may also exhibit variations in section and size.

CLEANING: Abrasive scale (iron oxide) on the surface of the hot rolled rough stock is removed.

COATING: The surface of the bar or coil is coated with a drawing lubricant to aid cold drawing.

POINTING: Several inches of the lead end of the bar or coil are reduced in size by swaging or extruding so that it can pass freely through the drawing die. Note: This is done because the die opening is always smaller than the original bar or coil section size.

COLD DRAWING PROCESS DRAWING: In this process, the material being drawn is at room temperature (i.e. Cold-Drawn). The pointed/reduced end of the bar or coil, which is smaller than the die opening, is passed through the die where it enters a gripping device of the drawing machine. The drawing machine pulls or draws the remaining unreduced section of the bar or coil through the die. The die reduces the cross section of the original bar or coil, shapes the profile of the product and increases the length of the original product.

TUBE DRAWING

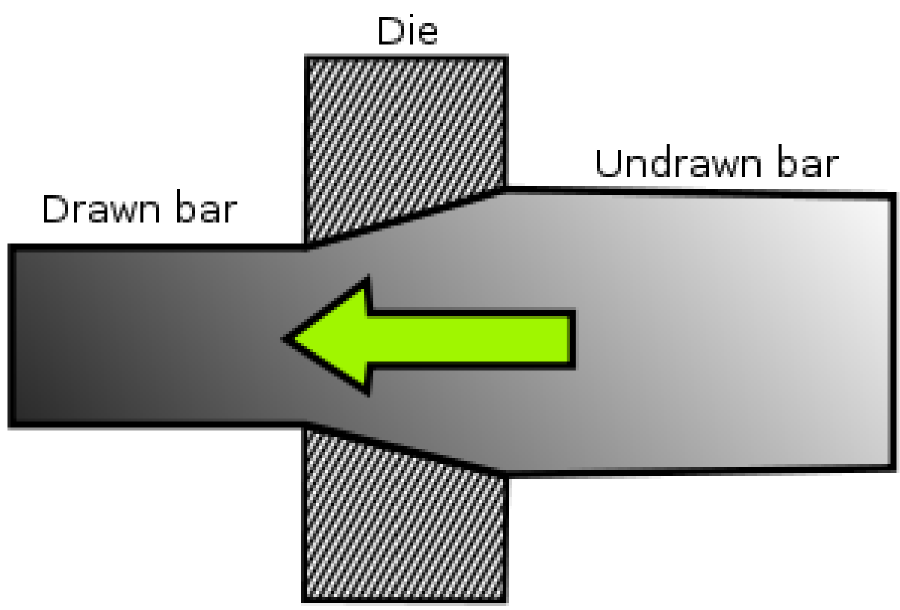
Tube drawing is very similar to bar drawing, except the beginning stock is a tube. It is used to decrease the diameter, improve surface finish and improve dimensional accuracy. A mandrel may or may not be used depending on the specific process used.

WIRE DRAWING

This technique has long been used to produce flexible metal wire by drawing the material through a series of dies of decreasing size. These dies are manufactured from a number of materials, the most common being tungsten carbide and diamond.

PLASTIC DRAWING

Plastic drawing, sometimes referred to as *cold drawing*, is the same process as used on metal bars, but applied to plastics. Cold drawing is primarily used in manufacturing plastic fibers. The process was discovered by Julian Hill (1904–1996) in 1930 while trying to make fibers from an early polyester. It is performed after the material has been "spun" into filaments; by extruding the polymer melt through pores of a spinneret. During this process, the individual polymer chains tend to somewhat align because of viscous flow. These filaments still have an amorphous structure, so they are drawn to align the fibers further, thus increasing crystallinity, tensile strength and stiffness. This is done on a draw twister machine.



4.14 HOT AND COLD SPINNING:

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.[1] 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. Commercial applications include rocket nose cones, cookware, gas cylinders, brass instrument bells, and public waste receptacles. Virtually any ductile metal may be formed, from aluminum or stainless steel, to high-strength, high-temperature alloys. The diameter and depth of formed parts are limited only by the size of the equipment available.

PROCESS:

The spinning process is fairly simple. A formed block is mounted in the drive section of a lathe. A pre-sized metal disk is then clamped against the block by a pressure pad, which is attached to the tailstock. The block and work piece are then rotated together at high speeds. A localized force is then applied to the work piece to cause it to flow over the block. The force is usually applied via various levered tools. Simple work pieces are just removed from the block, but more complex shapes may require a multi-piece block. Extremely complex shapes can be spun over ice forms, which then melt away after spinning. Because the final diameter of the work piece is always less than the starting diameter, the work piece must thicken, elongate radically, or buckle circumferentially.

A more involved process, known as reducing or necking, allows a spun work piece to include reentrant geometries. If surface finish and form are not critical, then the work piece is "spun on air"; no mandrel is used. If the finish or form are critical then an eccentrically mounted mandrel is used.

"Hot spinning" involves spinning a piece of metal on a lathe while high heat from a torch is applied to the work piece. Once heated, the metal is then shaped as the tool on the lathe presses against the heated surface forcing it to distort as it spins.

Parts can then be shaped or necked down to a smaller diameter with little force exerted, providing a seamless shoulder.

5. Tools and Accessories

The various operations such as cutting, shearing, bending, folding etc. are performed

by these tools.

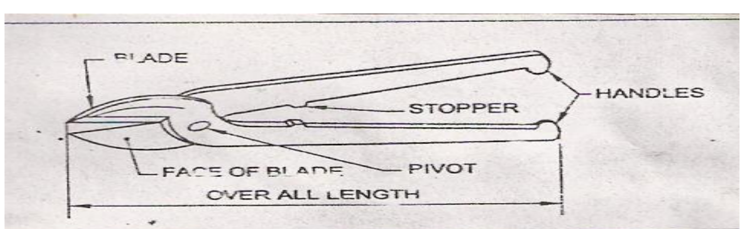
4.14 Marking and measuring tools

- **Steel Rule -** It is used to set out dimensions.
- **Try Square** - Try square is used for making and testing angles of 90degree
- **Scriber – I**t used to scribe or mark lines on metal work pieces.
- **Divider -** This is used for marking circles, arcs, laying out perpendicular lines, bisecting lines, etc

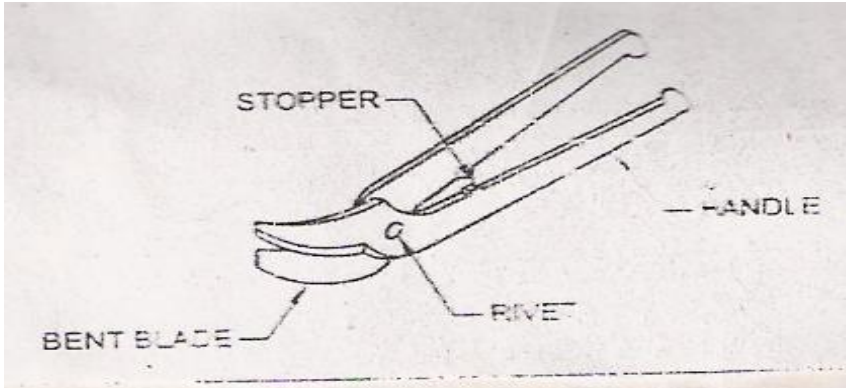
Fig 4.15 Marking and measuring tools

4.14.1Cutting Tools

- **Straight snip -** They have straight jaws and used for straight linecutting.
- **Curved snip -** They have curved blades for making circular cuts.



Ref fig.10 Straight snip



Ref Fig.10a Curved Snip

4.14.2. Striking Tools

- **Mallet -** It is wooden-headed hammer of round or rectangular cross section. The striking face is made flat to the work. A mallet is used to give light blows to the Sheet metal in bending and finishing. Ref fig.11

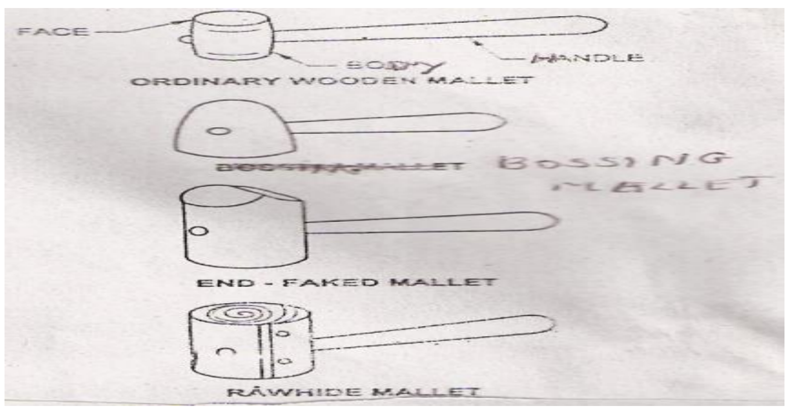


Fig.4.16 Types of Mallets

Merits

- High strength
- Good dimensional accuracy and surface finish
- Relatively low cost

Demerits

- Wrinkling and tearing are typical limits to drawing operations
- Different techniques can be used to overcome these limitations
  - Draw beads
  - Vertical projections and matching grooves in the die and blank holder
- Trimming may be used to reach final dimensions

UNIT.V

PLASTICS

5.1 PROCESSING OF PLASTICS:

Plastic Part Manufacture, Injection Molding In the last 30 years, plastics have become the most dominant engineering material for most products. We take a brief look at the most common types of plastics, and how they are processed. All plastics are polymers; these polymers are further divided into two basic types: thermoplastics and thermosets. Thermoplastics melt when heated – so they can be melted and re-formed again and again. Thermosets harden when they are heated, if heated further, they will break down chemically and lose their properties. Some thermosets have properties very similar to rubber, and are used as synthetic rubber; they are categorized as elastomers. Here are some typical plastics and their uses:

Thermosets General properties: more durable, harder, tough, light. Typical uses: automobile parts, construction materials. Examples:

• Unsaturated Polyesters: lacquers, varnishes, boat hulls, furniture • Epoxies and Resins: glues, coating of electrical circuits, composite materials like fiberglass used in helicopter blades, boats etc Elastomers General properties: these are thermosets, and have rubber-like properties.

Typical uses: medical masks, gloves, rubber-substitutes Examples:

• Polyurethanes: mattress, cushion, insulation, toys

• Silicones: surgical gloves, oxygen masks in medical and other applications, joint seals,… Thermoplastics General properties: low melting point, softer, flexible. Typical uses: bottles, food wrappers, toys,

Examples:

• Polyethylene: packaging, electrical insulation, milk and water bottles, packaging film

• Polypropylene: carpet fibers, automotive bumpers, microwave containers, prosthetic body parts for disabled people

• Polyvinyl chloride (PVC): sheathing for electrical cables, floor and wall coverings, siding, credit cards, automobile instrument panels 2

• Polystyrene: disposable spoons, forks etc., also used to make Styrofoam™ (soft packaging material)

• Acrylics (PMMA: polymethyl methacrylate): paints, fake fur, plexiglass

• Polyamide (nylon): textiles and fabrics, gears, bushing and washers, bearings

• PET (polyethylene terephthalate): bottles for acidic foods like juices, food trays, mylar tapes

• PTFE (polytetrafluoroethylene): non-stick coating, Gore-Tex™ (raincoats), dental floss. The most common methods of processing plastics to manufacture plastic parts are similar to methods we have learnt for metals and glass. These include Extrusion, Injection molding, Blow molding, Casting, etc. Among these, perhaps injection molding is the most significant for local industry – almost all manufacturing companies use parts that are injection molded, whether they make toys, home-appliances, electronics or electrical parts, watches, computers, etc. 7.1. Plastic Extrusion Extrusion can be used for thermoplastics.

The raw material is in the form of pellets (~10mm sized pieces), granules (~5 mm), or powder. Extrusion machines are used to make long pieces of constant cross-section. The cross-section geometry can be solid or hollow, and may be quite complex in shape. Usually, extruded parts are used as raw stock for use in manufacture of other products (e.g. channels on the sides of windows, etc. You can find plastic extruded parts in many bathroom and kitchen fittings). Figure 1 shows a typical extrusion machine.

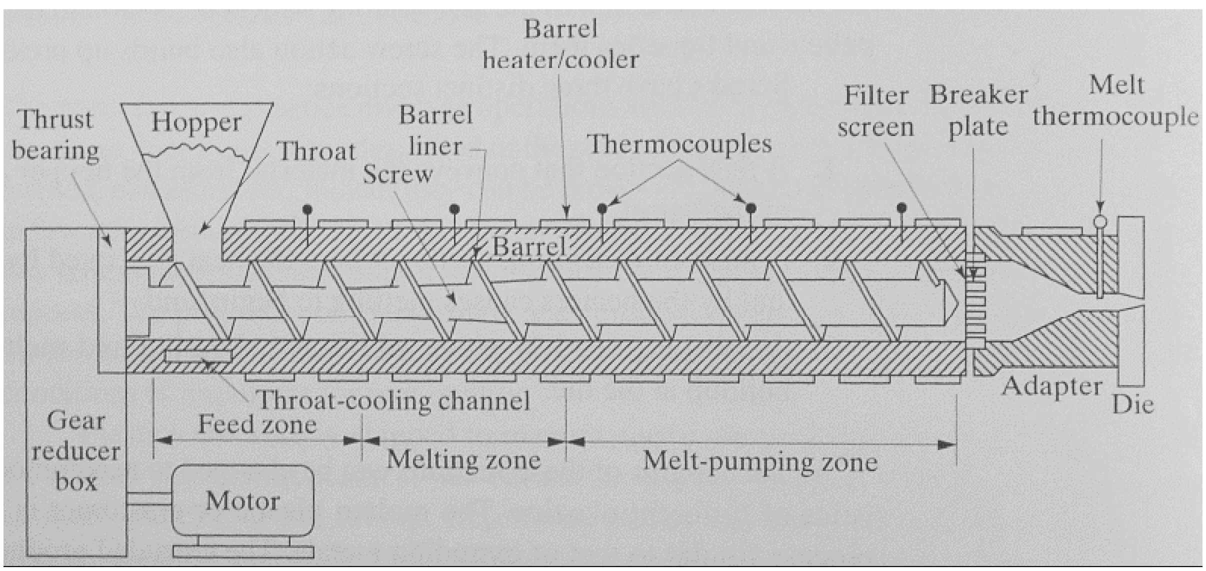


Fig: 5.1 Extrusion machine schematic [source: Kalpakjian and Schmid]

The main difference from metal extrusion is the mechanism for pumping out the molten plastic: plastic extrusion uses a large screw in a cylinder, which simultaneously mixes, and pushes the pellets/granules towards the die; along the way, the heating chamber melts the plastic. Interesting note: many plastic processes use plastic pellets as raw material; these pellets are the shape of short cylinders, which are themselves formed by plastic extrusion.

5.2 BLOW MOLDING :

This process is almost identical to the blow-molding of glass that we studied earlier.

Blow molding (BrE moulding) is a manufacturing process by which hollow plastic parts are formed. In general, there are three main types of blow molding: extrusion blow molding, injection blow molding, and injection stretch blow molding. The blow molding process begins with melting down the plastic and forming it into a parison or in the case of injection and injection stretch blow moulding (ISB) a preform. The parison is a tube-like piece of plastic with a hole in one end through which compressed air can pass.

The parison is then clamped into a mold and air is blown into it. The air pressure then pushes the plastic out to match the mold. Once the plastic has cooled and hardened the mold opens up and the part is ejected.

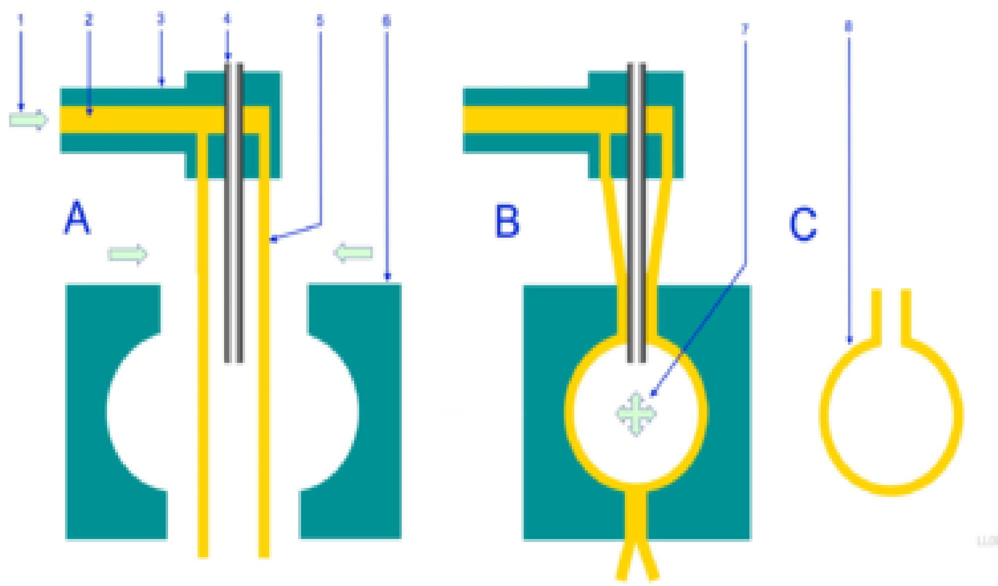


Fig 5.2 The blow molding process

Types of Blow Moulding

In Extrusion Blow Moulding (EBM), plastic is melted and extruded into a hollow tube (a parison). This parison is then captured by closing it into a cooled metal mold. Air is then blown into the parison, inflating it into the shape of the hollow bottle, container, or part. After the plastic has cooled sufficiently, the mold is opened and the part is ejected. Continuous and Intermittent are two variations of Extrusion

Blow Molding. In Continuous Extrusion Blow Molding the parison is extruded continuously and the individual parts are cut off by a suitable knife. In Intermittent blow molding there are two processes: straight intermittent is similar to injection molding whereby the screw turns, then stops and pushes the melt out. With the accumulator method, an accumulator gathers melted plastic and when the previous mold has cooled and enough plastic has accumulated, a rod pushes the melted plastic and forms the parison. In this case the screw may turn continuously or intermittently. with continuous extrusion the weight of the parison drags the parison and makes calibrating the wall thickness difficult. The accumulator head or reciprocating screw methods use hydraulic systems to push the parison out quickly reducing the effect of the weight and allowing precise control over the wall thickness by adjusting the die gap with a parison programming device.

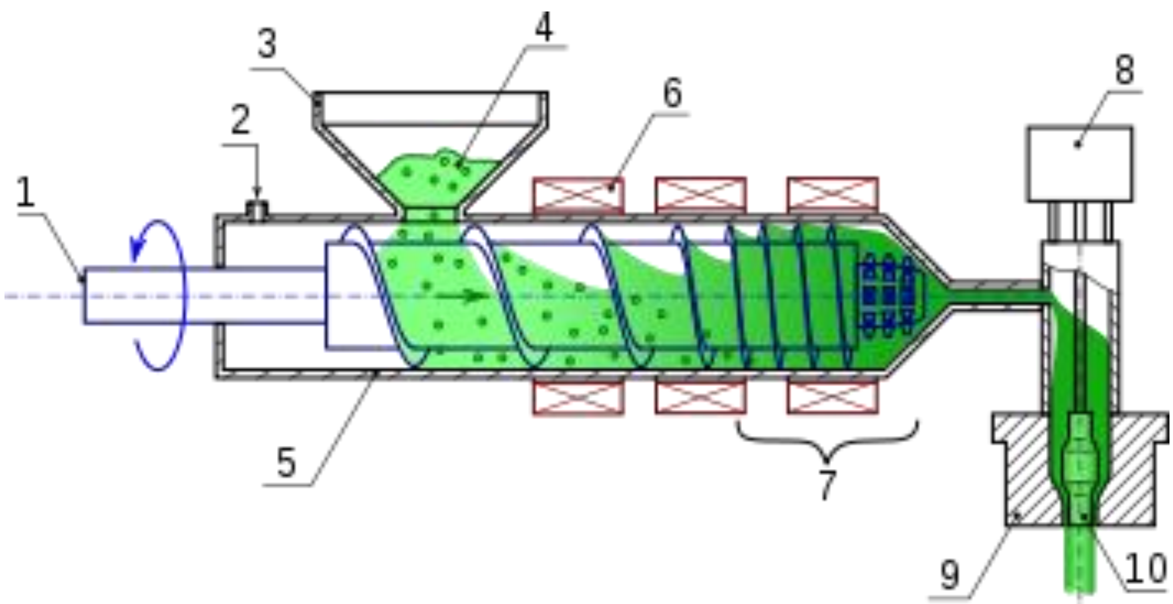


Fig : 5.3 Extrusion blow molding

EBM processes may be either continuous (constant extrusion of the parison) or intermittent. Types of EBM equipment may be categorized as follows:

Continuous extrusion equipment

- rotary wheel blow molding systems
- shuttle machinery

Intermittent extrusion machinery

- reciprocating screw machinery
- accumulator head machinery

Examples of parts made by the EBM process include most polyethylene hollow products, milk bottles, shampoo bottles, automotive ducting, watering cans and hollow industrial parts such as drums.

Advantages of blow molding include: low tool and die cost; fast production rates; ability to mold complex part; Handles can be incorporated in the design.

Disadvantages of blow molding include: limited to hollow parts, low strength, to increase barrier properties multilayer parisons of different materials are used thus not recyclable. To make wide neck jars spin trimming is necessary

Spin trimming

Containers such as jars often have an excess of material due to the molding process. This is trimmed off by spinning a knife around the container which cuts the material away. This excess plastic is then recycled to create new moldings. Spin Trimmers are used on a number of materials, such as PVC, HDPE and PE+LDPE. Different types of the materials have their own physical characteristics affecting trimming. For example, moldings produced from amorphous materials are much more difficult to trim than crystalline materials. Titanium coated blades are often used rather than standard steel to increase life by a factor of 30 times.

Injection blow molding

The process of **injection blow molding** (IBM) is used for the production of hollow glass and plastic objects in large quantities. In the IBM process, the polymer is injection molded onto a core pin; then the core pin is rotated to a blow molding station to be inflated and cooled. This is the least-used of the three blow molding processes, and is typically used to make small medical and single serve bottles. The process is divided into three steps: injection, blowing and ejection.

The injection blow molding machine is based on an extruder barrel and screw assembly which melts the polymer. The molten polymer is fed into a hot runner manifold where it is injected through nozzles into a heated cavity and core pin. The cavity mold forms the external shape and is clamped around a core rod which forms the internal shape of the preform. The preform consists of a fully formed bottle/jar neck with a thick tube of polymer attached, which will form the body. similar in appearance to a test tube with a threaded neck.

The preform mold opens and the core rod is rotated and clamped into the hollow, chilled blow mold. The end of the core rod opens and allows compressed air into the preform, which inflates it to the finished article shape.

After a cooling period the blow mold opens and the core rod is rotated to the ejection position. The finished article is stripped off the core rod and as an option can be leak-tested prior to packing. The preform and blow mold can have many cavities, typically three to sixteen depending on the article size and the required output. There are three sets of core rods, which allow concurrent preform injection, blow molding and ejection.

Advantages: It produces an injection moulded neck for accuracy.

Disadvantages: only suits small capacity bottles as it is difficult to control the base centre during blowing. No increase in barrier strength as the material is not biaxially stretched. Handles can't be incorporated.

Injection Stretch blow molding process

This has two main different methods, namely Single-stage and two-stage process. Single-stage process is again broken down into 3-station and 4-station machines. In the two-stage injection stretch blow molding (ISB) process, the plastic is first molded into a "preform" using the injection molding process. These preforms are produced with the necks of the bottles, including threads (the "finish") on one end. These preforms are packaged, and fed later (after cooling) into a reheat stretch blow molding machine. In the ISB process, the preforms are heated (typically using infrared heaters) above their glass transition temperature, then blown using high-pressure air into bottles using metal blow molds. The preform is always stretched with a core rod as part of the process.

Advantages: Very high volumes are produced. Little restriction on bottle design. Preforms can be sold as a completed item for a third party to blow. Is suitable for cylindrical, rectangular or oval bottles.

Disadvantages: High capital cost. Floor space required is high, although compact systems have become available.

In the single-stage process both preform manufacture and bottle blowing are performed in the same machine. The older 4-station method of injection, reheat, stretch blow and ejection is more costly than the 3-station machine which eliminates the reheat stage and uses latent heat in the preform, thus saving costs of energy to reheat and 25% reduction in tooling. The process explained: Imagine the molecules are small round balls, when together they have large air gaps and small surface contact, by first stretching the molecules vertically then blowing to stretch horizontally the biaxial stretching makes the molecules a cross shape. These "crosses" fit together leaving little space as more surface area is contacted thus making the material less porous and increasing barrier strength against permeation. This process also increases the strength to be ideal for filling with carbonated drinks.

Advantages: Highly suitable for low volumes and short runs. As the preform is not released during the entire process the preform wall thickness can be shaped to allow even wall thickness when blowing rectangular and non-round shapes.

Disadvantages: Restrictions on bottle design. Only a champagne base can be made for carbonated bottles.

5.3 CALENDERING:

Calendering is a finishing process used on cloth, paper, or plastic film. A calender is employed, usually to smooth, coat, or thin a material.With textiles, fabric is passed under rollers at high temperatures and pressures. Calendering is used on fabrics such asmoire to produce its watered effect and also on cambric and some types of sateens.

In preparation for calendering, the fabric is folded lengthwise with the front side, or face, inside, and stitched together along the edges. The fabric can be folded together at full width, however this is not done as often as it is more difficult. The fabric is then run through rollers that polish the surface and make the fabric smoother and more lustrous. High temperatures and pressure are used as well. Fabrics that go through the calendering process feel thin, glossy and papery.

The wash durability of a calendared finish on thermoplastic fibres like polyester is higher than on cellulosic fibres such as cotton. On blended fabrics such as Polyester/Cotton the durability depends largely on the proportion of synthetic fibre component present as well as the amount and type of finishing additives used and the machinery and process conditions employed.

5.4 THERMOFORMING:

Thermoforming is a manufacturing process where a plastic sheet is heated to a pliable forming temperature, formed to a specific shape in a mold, and trimmed to create a usable product. The sheet, or "film" when referring to thinner gauges and certain material types, is heated in an oven to a high-enough temperature that permits it to be stretched into or onto a mold and cooled to a finished shape. Its simplified version is vacuum forming.

In its simplest form, a small tabletop or lab size machine can be used to heat small cut sections of plastic sheet and stretch it over a mold using vacuum. This method is often used for sample and prototype parts. In complex and high-volume applications, very large production machines are utilized to heat and form the plastic sheet and trim the formed parts from the sheet in a continuous high-speed process, and can produce many thousands of finished parts per hour depending on the machine and mold size and the size of the parts being formed.

Thermoforming differs from injection molding, blow molding, rotational molding and other forms of processing plastics. Thin-gauge thermoforming is primarily the manufacture of disposable cups, containers, lids, trays, blisters, clamshells, and other products for the food, medical, and general retail industries. Thick-gauge thermoforming includes parts as diverse as vehicle door and dash panels, refrigerator liners, utility vehicle beds, and plastic pallets.

In the most common method of high-volume, continuous thermoforming of thin-gauge products, plastic sheet is fed from a roll or from an extruder into a set of indexing chains that incorporate pins, or spikes, that pierce the sheet and transport it through an oven for heating to forming temperature. The heated sheet then indexes into a form station where a mating mold and pressure-box close on the sheet, with vacuum then applied to remove trapped air and to pull the material into or onto the mold along with pressurized air to form the plastic to the detailed shape of the mold. (Plug-assists are typically used in addition to vacuum in the case of taller, deeper-draw formed parts in order to provide the needed material distribution and thicknesses in the finished parts.) After a short form cycle, a burst of reverse air pressure is actuated from the vacuum side of the mold as the form tooling opens, commonly referred to as air-eject, to break the vacuum and assist the formed parts off of, or out of, the mold. A stripper plate may also be utilized on the mold as it opens for ejection of more detailed parts or those with negativedraft, undercut areas. The sheet containing the formed parts then indexes into a trim station on the same machine, where a die cuts the parts from the remaining sheet web, or indexes into a separate trim press where the formed parts are trimmed. The sheet web remaining after the formed parts are trimmed is typically wound onto a take-up reel or fed into an inline granulator for recycling.

Most thermoforming companies recycle their scrap and waste plastic, either by compressing in a baling machine or by feeding into a granulator (grinder) and producing ground flake, for sale to reprocessing companies or re-use in their own facility. Frequently, scrap and waste plastic from the thermoforming process is converted back into extruded sheet for forming again.

TYPES OF THERMOFORMING

Wood Patterns - Wood patterns are generally the first stage to a thermoforming project. They are relatively inexpensive and allow the customer to make changes to their design very easily. The number of samples that one is able to get from a wood pattern depends on the size of the part and the thickness of the material. Typically, wood patterns are used to gauge general functionality of both the part and the thickness of the material. Once the specifications of the part have been met, the wood pattern is then used to create a ceramic composite mold, or cast aluminum mold for regular production.

Cast aluminum Molds - Cast aluminum molds are cast at a foundry and typically have temperature control lines running through them. This helps to regulate the heat of the plastic being formed as well as speed up the production process. Aluminum molds can be male or female in nature and can also be used in pressure forming applications. The main drawback with this type of mold is cost.

Machined aluminum Molds - Machined aluminum molds are like cast aluminum except they are cut out of a solid block of aluminum using a CNC machine and some sort of CAD program. Typically machined aluminum is used for shallow draw parts out of thin-gauge material. Applications may include packaging as well as trays. Again, cost is a significant factor with this type of tooling.

Composite Molds - Composite molds are a lower cost alternative to cast or machined aluminum molds. Composite molds are typically made from filled resins that start as a liquid and harden with time. Depending on the application, composite molds last a relatively long time producing high quality parts. Within the category of composite molds, the subset of "Ceramic" molds has consistently proven to be the most durable.

5.5 COMPRESSION MOLDING:

Compression molding is a method of molding in which the molding material, generally preheated, is first placed in an open, heated mold cavity. The mold is closed with a top force or plug member, pressure is applied to force the material into contact with all mold areas, while heat and pressure are maintained until the molding material has cured. The process employs thermosetting resins in a partially cured stage, either in the form of granules, putty-like masses, or preforms.

Compression molding is a high-volume, high-pressure method suitable for molding complex, high-strength fiberglass reinforcements. Advanced composite thermo plastics can also be compression molded with unidirectional tapes, woven fabrics, randomly oriented fiber mat or chopped strand. The advantage of compression molding is its ability to mold large, fairly intricate parts. Also, it is one of the lowest cost molding methods compared with other methods such as transfer molding and injection molding; moreover it wastes relatively little material, giving it an advantage when working with expensive compounds.

However, compression molding often provides poor product consistency and difficulty in controlling flashing, and it is not suitable for some types of parts. Fewerknit lines are produced and a smaller amount of fiber-length degradation is noticeable when compared to injection molding. Compression-molding is also suitable for ultra-large basic shape production in sizes beyond the capacity of extrusion techniques. Materials that are typically manufactured through compression molding include: Polyester fiberglass resin systems (SMC/BMC), Torlon, Vespel,Poly(p-phenylene sulfide) (PPS), and many grades of PEEK.

Compression molding was first developed to manufacture composite parts for metal replacement applications, compression molding is typically used to make larger flat or moderately curved parts. This method of molding is greatly used in manufacturing automotive parts such as hoods, fenders, scoops, spoilers, as well as smaller more intricate parts. The material to be molded is positioned in the mold cavity and the heated platens are closed by a hydraulic ram. Bulk molding compound (BMC) or sheet molding compound (SMC), are conformed to the mold form by the applied pressure and heated until the curing reaction occurs. SMC feed material usually is cut to conform to the surface area of the mold. The mold is then cooled and the part removed.

Materials may be loaded into the mold either in the form of pellets or sheet, or the mold may be loaded from a plasticating extruder. Materials are heated above their melting points, formed and cooled. The more evenly the feed material is distributed over the mold surface, the less flow orientation occurs during the compression stage.

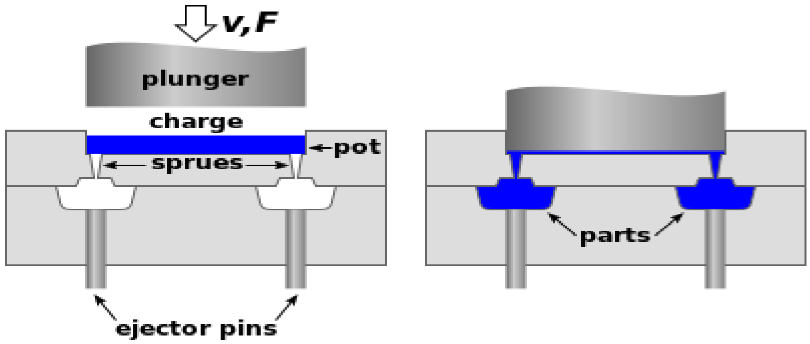
Thermoplastic matrices are commonplace in mass production industries. One significant example are automotive applications where the leading technologies are long fibre reinforced thermoplastics (LFT) and glass fiber mat reinforced thermoplastics (GMT).

In compression molding there are six important considerations that an engineer should bear in mind

- Determining the proper amount of material.
- Determining the minimum amount of energy required to heat the material.
- Determining the minimum time required to heat the material.
- Determining the appropriate heating technique.
- Predicting the required force, to ensure that shot attains the proper shape.
- Designing the mold for rapid cooling after the material has been compressed into the mold.

5.6 TRANSFER MOLDING:

Transfer molding (BrE moulding) is a manufacturing process where casting material is forced into a mold. Transfer molding is different from compression molding in that the mold is enclosed [Hayward] rather than open to the fill plunger resulting in higher dimensional tolerances and less environmental impact. Compared to injection molding, transfer molding uses higher pressures to uniformly fill the mold cavity. This allows thicker reinforcing fiber matrices to be more completely saturated by resin.



The mold interior surfaces may be gel-coated. If desired the mold is first pre-loaded with a reinforcing fiber matrix or perform.[1] Fiber content of a transfer molded composite can be as high as 60% by volume. The fill material may be a preheated solid or a liquid. It is loaded into a chamber known as the pot. A ram or plunger forces material from the pot into the heated mold cavity. If feed-stock is initially solid, the forcing pressure and mold temperature melt it. Standard mold features such as sprue channels, a flow gate and ejector pins may be used. The heated mold ensures that the flow remains liquid for complete filling. Once filled the mold can be cooled at a controlled rate for optimal thermo set curing.

5.8 HIGH ENERGY RATE FORMING PROCESSES:

In these forming processes large amount of energy is applied for a very short interval of time. Many metals tend to deform more readily under extra – fast application of load which make these processes useful to form large size parts out of most metals including those which are otherwise difficult – to – form.

The parts are formed at a rapid rate, and thus these processes are also called high – velocity forming processes. There are several advantages of using these forming processes, like die costs are low, easy maintenance of tolerances, possibility of forming most metals, and material does not show spring-back effect. The production cost of components by such processes is low. The limitation of these processes is the need for skilled personnel.

There are three main high energy rate forming processes: explosive forming, magnetic forming, and electro hydraulic forming. We shall discuss these processes.

Explosive Forming

Explosive forming is distinguished from conventional forming in that the punch or diaphragm is replaced by an explosive charge. The explosives used are generally high – explosive chemicals, gaseous mixtures, or propellants. There are two techniques of high – explosive forming: stand – off technique and the contact technique.

Standoff Technique . The sheet metal work piece blank is clamped over a die and the assembly is lowered into a tank filled with water. The air in the die is pumped out. The explosive charge is placed at some predetermined distance from the work piece. On detonation of the explosive, a pressure pulse of very high intensity is produced. A gas bubble is also produced which expands spherically and then collapses. When the pressure pulse impinges against the work piece, the metal is deformed into the die with as high velocity as 120 m/s.

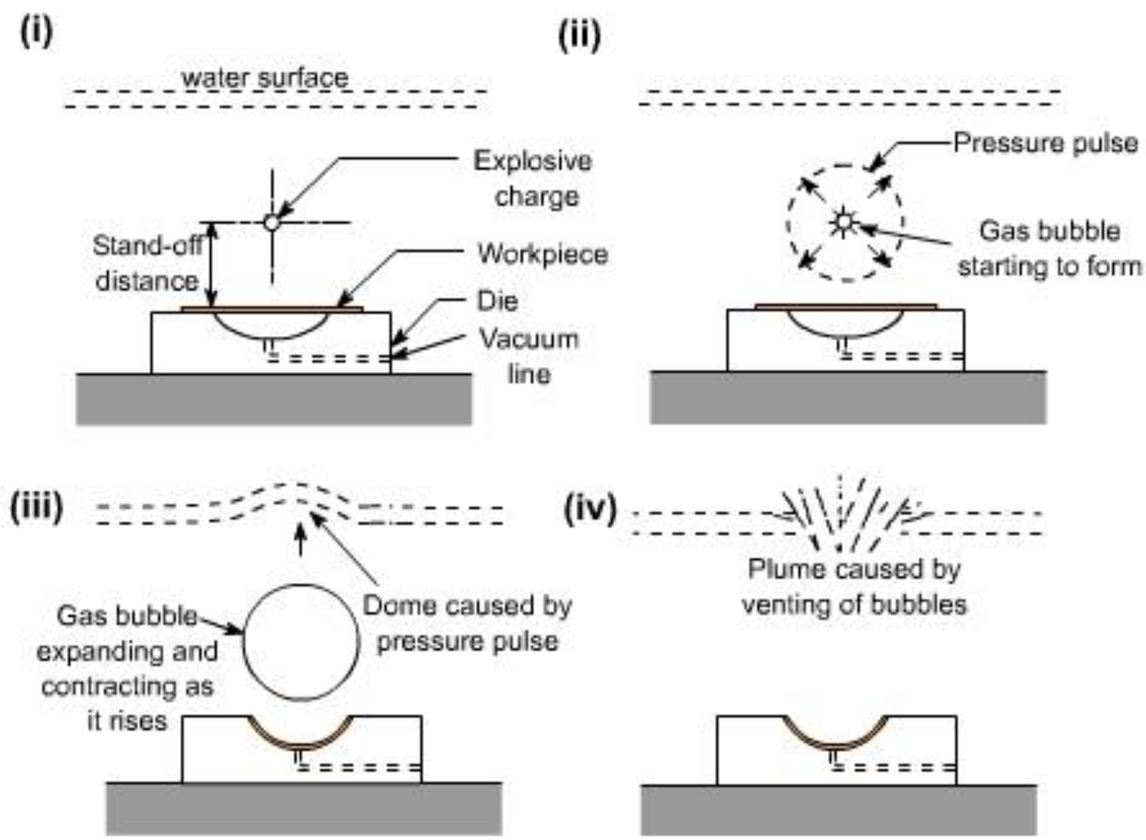


Fig 9.1 Sequeuce of underwater explosive forming operations.

(i) Explosive charge is set in position

(ii) Pressure pulse and gas bubble are formed as the detonation of charge occurs,

(iii) Work piece is deformed, and

(iv) Gas bubbles vent at the surface of water.

The use of water as the energy transfer medium ensures a uniform transmission of energy and muffles the sound of the explosive blast. The process is versatile – a large variety of shapes can be formed, there is virtually no limit to the size of the work piece, and it is suitable for low – quantity production as well.

The process has been successfully used to form steel plates 25 mm thick x 4 m diameter and to bulge steel tubes as thick as 25 mm.

Contact Technique. The explosive charge in the form of cartridge is held in direct contact with the work piece while the detonation is initiated. The detonation builds up extremely high pressures (upto 30,000MPa) on the surface of the work piece resulting in metal deformation, and possible fracture. The process is used often for bulging tubes, as shown in Fig 9.2.

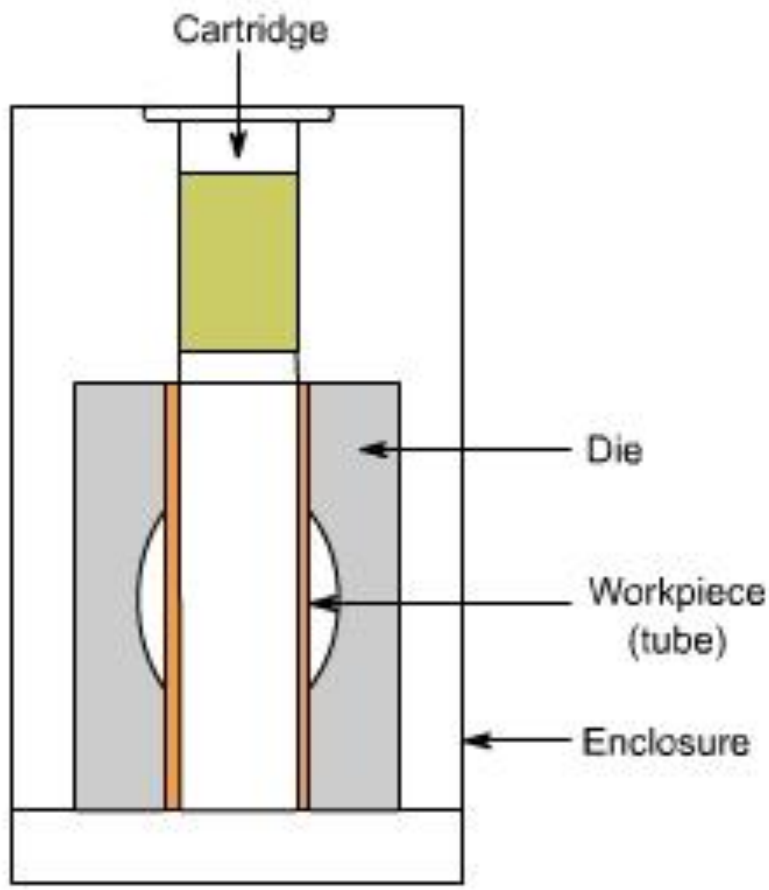


Fig 9.2 Schematic illustration of contact technique of explosive forming.

The process is generally used for bulging of tubes. Applications. Explosive forming is mainly used in the aerospace industries but has also found successful applications in the production of automotive related components. The process has the greatest potential in limited – production prototype forming and for forming large size components for which conventional tooling costs are prohibitively high.

Electro Magnetic Forming

The process is also called *magnetic pulse forming* and is mainly used for swaging type operations, such as fastening fittings on the ends of tubes and crimping terminal ends of cables. Other applications are blanking, forming, embossing, and drawing. The work coils needed for different applications vary although the same power source may be used.

To illustrate the principle of electromagnetic forming, consider a tubular work piece. This work piece is placed in or near a coil, Fig 9.3. A high charging voltage is supplied for a short time to a bank of capacitors connected in parallel. (The amount of electrical energy stored in the bank can be increased either by adding capacitors to the bank or by increasing the voltage). When the charging is complete, which takes very little time, a high voltage switch triggers the stored electrical energy through the coil. A high – intensity magnetic field is established which induces eddy currents into the conductive work piece, resulting in the establishment of another magnetic field. The forces produced by the two magnetic fields oppose each other with the consequence that there is a repelling force between the coil and the tubular work piece that causes permanent deformation of the work piece.

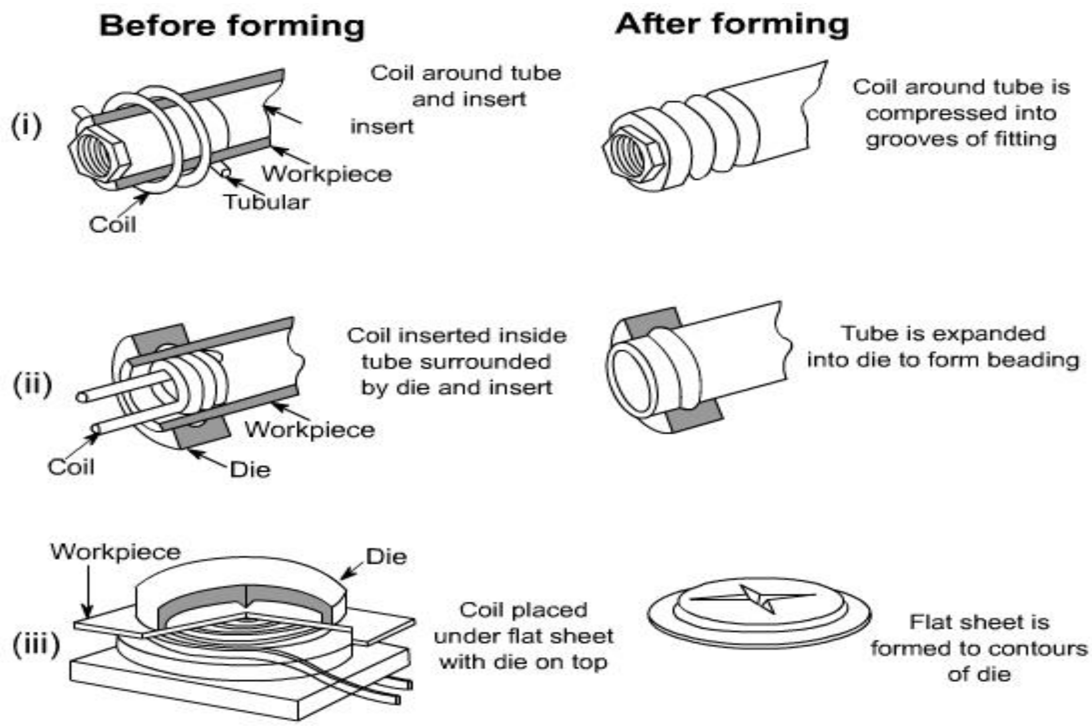


Fig 9.3 Various applications of magnetic forming process. (i) Swaging, (ii) Expanding, and (iii) Embossing or blanking.

Either permanent or expandable coils may be used. Since the repelling force acts on the coil as well the work, the coil itself and the insulation on it must be capable of withstanding the force, or else they will be destroyed. The expandable coils are less costly and are also preferred when high energy level is needed.

Magnetic forming can be accomplished in any of the following three ways, depending upon the requirements.

- Coil surrounding work piece. When a tube – like part x is to fit over another part y (shown as insert in Fig 9.3(i)), coil is designed to surround x so that when energized, would force the material of x tightly around y to obtain necessary fit.
- Coil inside work piece. Consider fixing of a collar on a tube – like part, as shown in Fig 9.3(ii). The magnetic coil is placed inside the tube – like part, so that when energized would expand the material of the part into the collar.
- Coil on flat surface. Flat coil having spiral shaped winding can also be designed to be placed either above or below a flat work piece, see Fig 9.3(iii).These coils are used in conjunction with a die to form, emboss, blank, or dimple the work piece.

In electromagnetic forming, the initial gap between the work piece and the die surface, called the *fly distance* , must be sufficient to permit the material to deform plastically. From energy considerations, the ideal pressure pulse should be of just enough magnitude that accelerates the part material to some maximum velocity and then let the part come to zero velocity by the time it covers the full fly distance. All forming coils fail, expendable coils fail sooner than durable coils, and because extremely high voltages and currents are involved, it is essential that proper safety precautions are observed by the production and maintenance personnel.

Applications

Electromagnetic forming process is capable of a wide variety of forming and assembly operations. It has found extensive applications in the fabrication of hollow, non – circular, or asymmetrical shapes from tubular stock. The compression applications involve swaging to produce compression, tensile, and torque joints or sealed pressure joints, and swaging to apply compression bands or shrink rings for fastening components together. Flat coils have been used on flat sheets to produce stretch (internal) and shrink (external) flanges on ring and disc – shaped work pieces. Electromagnetic forming has also been used to perform shearing, piercing, and rivettting.

Electro Hydraulic Forming

Electro hydraulic forming (EHF), also known as electro spark forming, is a process in which electrical energy is converted into mechanical energy for the forming of metallic parts. A bank of capacitors is first charged to a high voltage and then discharged across a gap between two electrodes, causing explosions inside the hollow work piece, which is filled with some suitable medium, generally water. These explosions produce shock waves that travel radially in all directions at high velocity until they meet some obstruction. If the discharge energy is sufficiently high, the hollow work piece is deformed. The deformation can be controlled by applying external restraints in the form of die or by varying the amount of energy released,

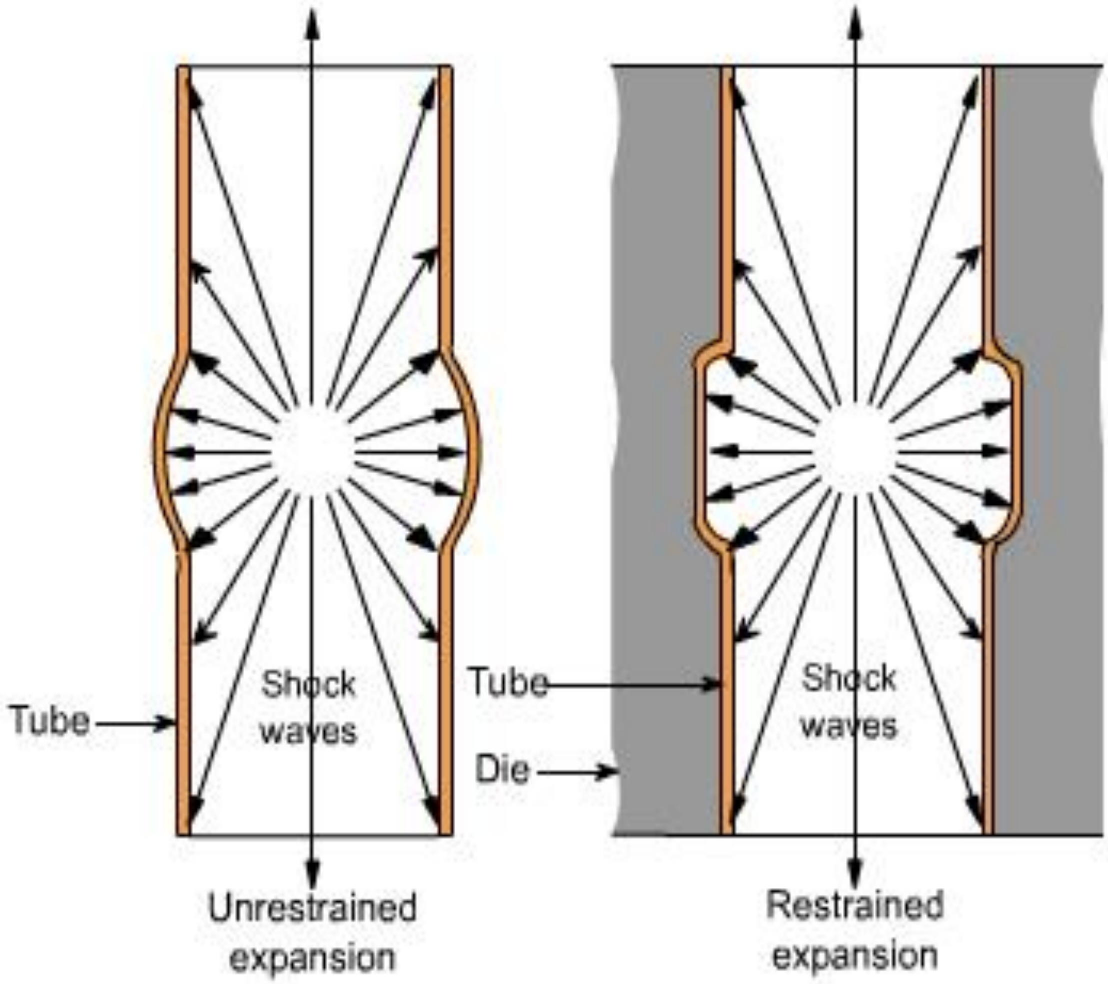


Fig 9.4 Unrestrained and restrained electro-hydraulic forming process.

Advantages

1. EHF can form hollow shapes with much ease and at less cost compared to other forming techniques.
2. EHF is more adaptable to automatic production compared to other high energy rate forming techniques.
3. EHF can produce small – to intermediate sized parts that don't have excessive energy requirements.

Accuracy of parts produced

Accuracy of electro hydraulically formed parts depends on the control of both the magnitude and location of energy discharges and on the dimensional accuracy of the dies used. With the modern equipment, it is now possible to precisely control the energy within specified limits; therefore the primary factor is the dimensional accuracy of the die. External dimensions on tubular parts are possible to achieve within ± 0.05 mm with the current state of technology.

Materials formed

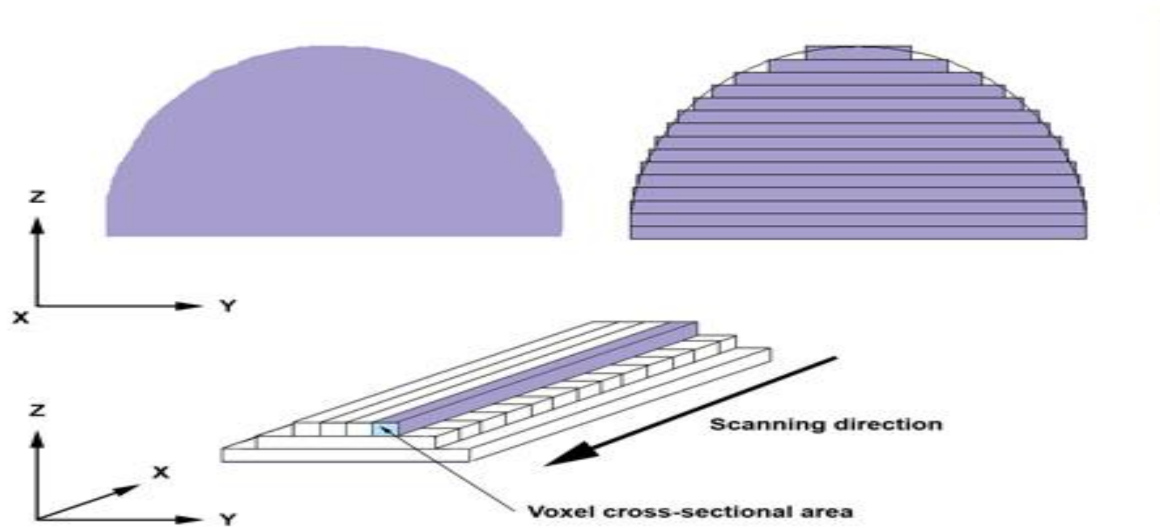
Materials having low ductility or having critical impact velocity less than 30 m/s are generally not considered to be good candidate for EHF. All materials that can be formed by conventional forming processes can be formed by EHF also. These materials are aluminum alloys, nickel alloys, stainless steels, titanium, and Inconel 718.

5.9 RAPID PROTOTYPING:

Rapid prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology.

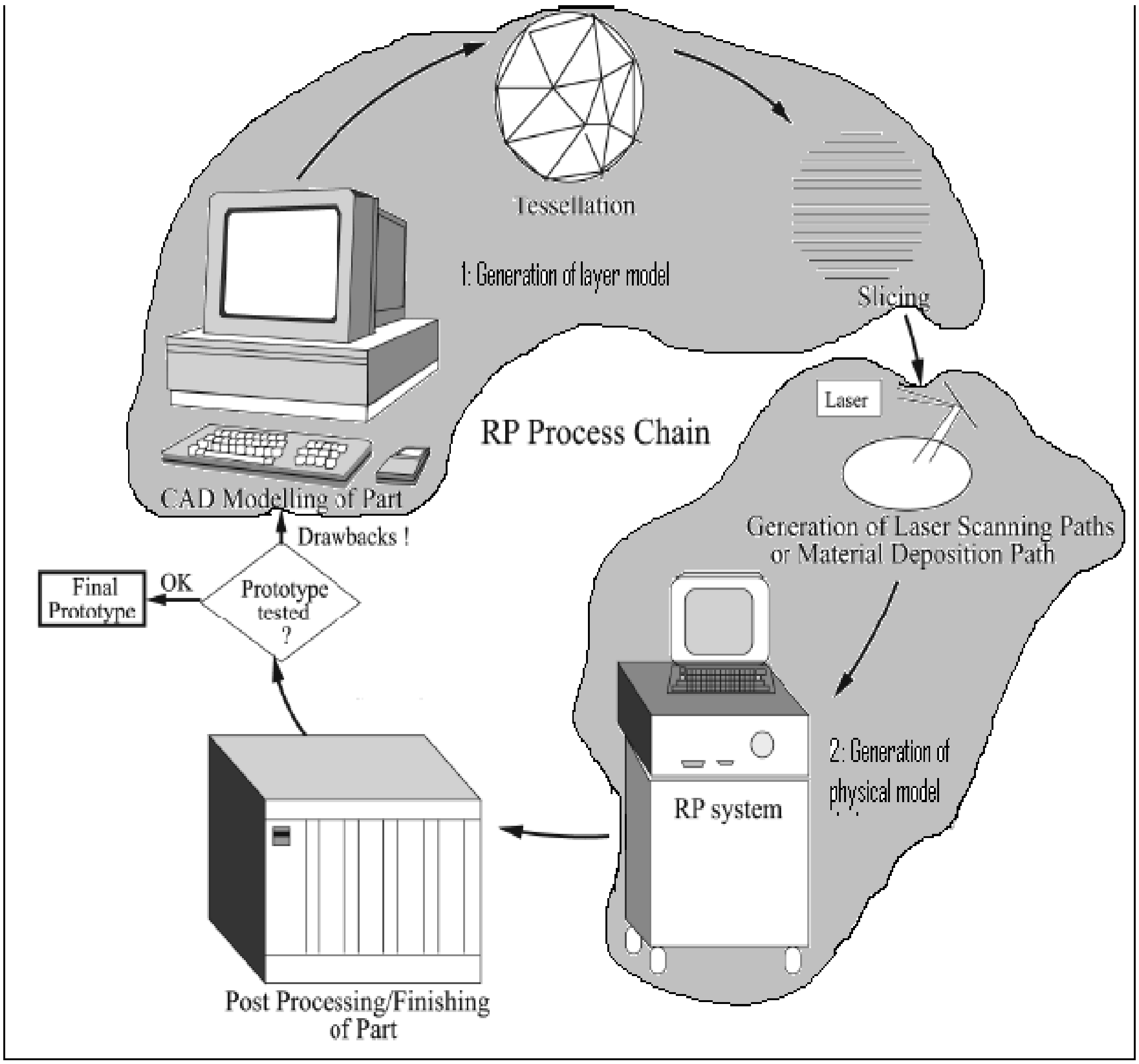
The first methods for rapid prototyping became available in the late 1980s and were used to produce models and prototype parts. Today, they are used for a wide range of applications and are used to manufacture production-quality parts in relatively small numbers if desired without the typical unfavorable short-run economics. This economy has encouraged online service bureaus. Historical surveys of RP technology start with discussions of simulacra production techniques used by 19th-century sculptors. Some modern sculptors use the progeny technology to produce exhibitions. The ability to reproduce designs from a dataset has given rise to issues of rights, as it is now possible to interpolate volumetric data from one-dimensional images.

As with CNC subtractive methods, the computer-aided-design - computer-aided manufacturing CAD-CAM workflow in the traditional Rapid Prototyping process starts with the creation of geometric data, either as a 3D solid using a CAD workstation, or 2D slices using a scanning device. For RP this data must represent a valid geometric model; namely, one whose boundary surfaces enclose a finite volume, contains no holes exposing the interior, and do not fold back on themselves. In other words, the object must have an “inside.” The model is valid if for each point in 3D space the computer can determine uniquely whether that point lies inside, on, or outside the boundary surface of the model. CAD post-processors will approximate the application vendors' internal CAD geometric forms (e.g., B-splines) with a simplified mathematical form, which in turn is expressed in a specified data format which is a common feature in Additive Manufacturing: STL (stereo lithography) a de facto standard for transferring solid geometric models to SFF machines. To obtain the necessary motion control trajectories to drive the actual SFF, Rapid Prototyping, 3D Printing or Additive Manufacturing mechanism, the prepared geometric model is typically sliced into layers, and the slices are scanned into lines [producing a "2D drawing" used to generate trajectory as in CNC`s tool path], mimicking in reverse the layer-to-layer physical building process.

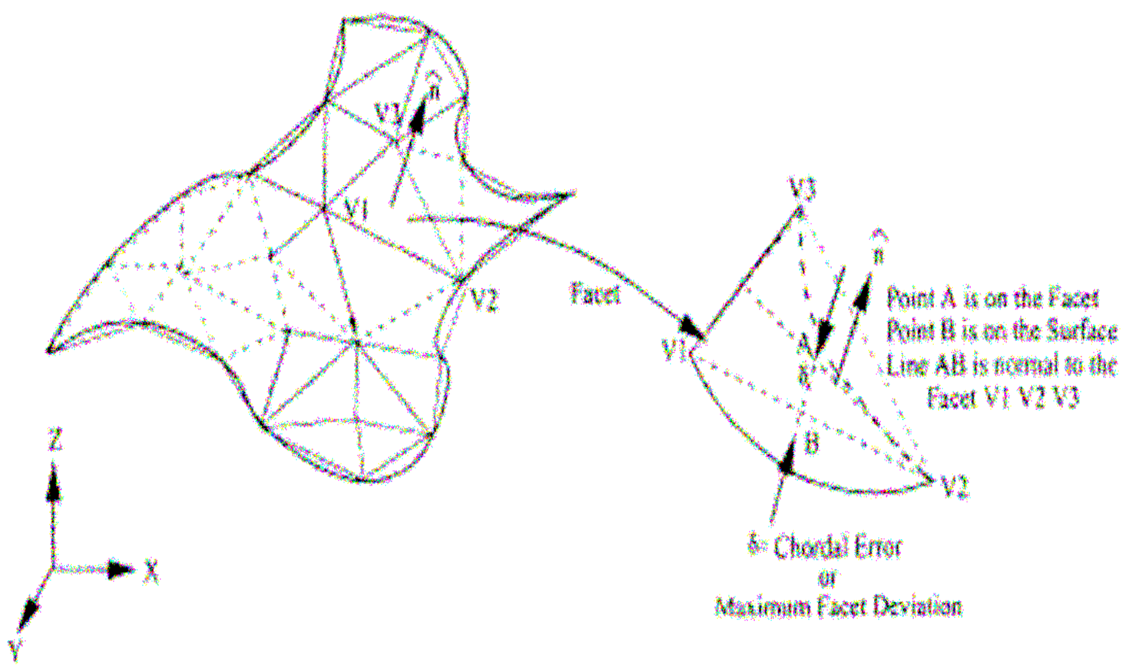


5.10 INFORMATION FLOW FOR RAPID PROTOTYPING

This process belong to the generative (or additive) production processes unlike subtractive or forming processes such as lathing, milling, grinding or coining etc. in which form is shaped by material removal or plastic deformation. In all commercial RP processes, the part is fabricated by deposition of layers contoured in a (x-y) plane two dimensionally. The third dimension (z) results from single layers being stacked up on top of each other, but not as a continuous z-coordinate. Therefore, the prototypes are very exact on the x-y plane but have stair-stepping effect in z-direction. If model is deposited with very fine layers, i.e., smaller z-stepping, model looks like original. RP can be classified into two fundamental process steps namely generation of mathematical layer information and 2 generation of physical layer model.

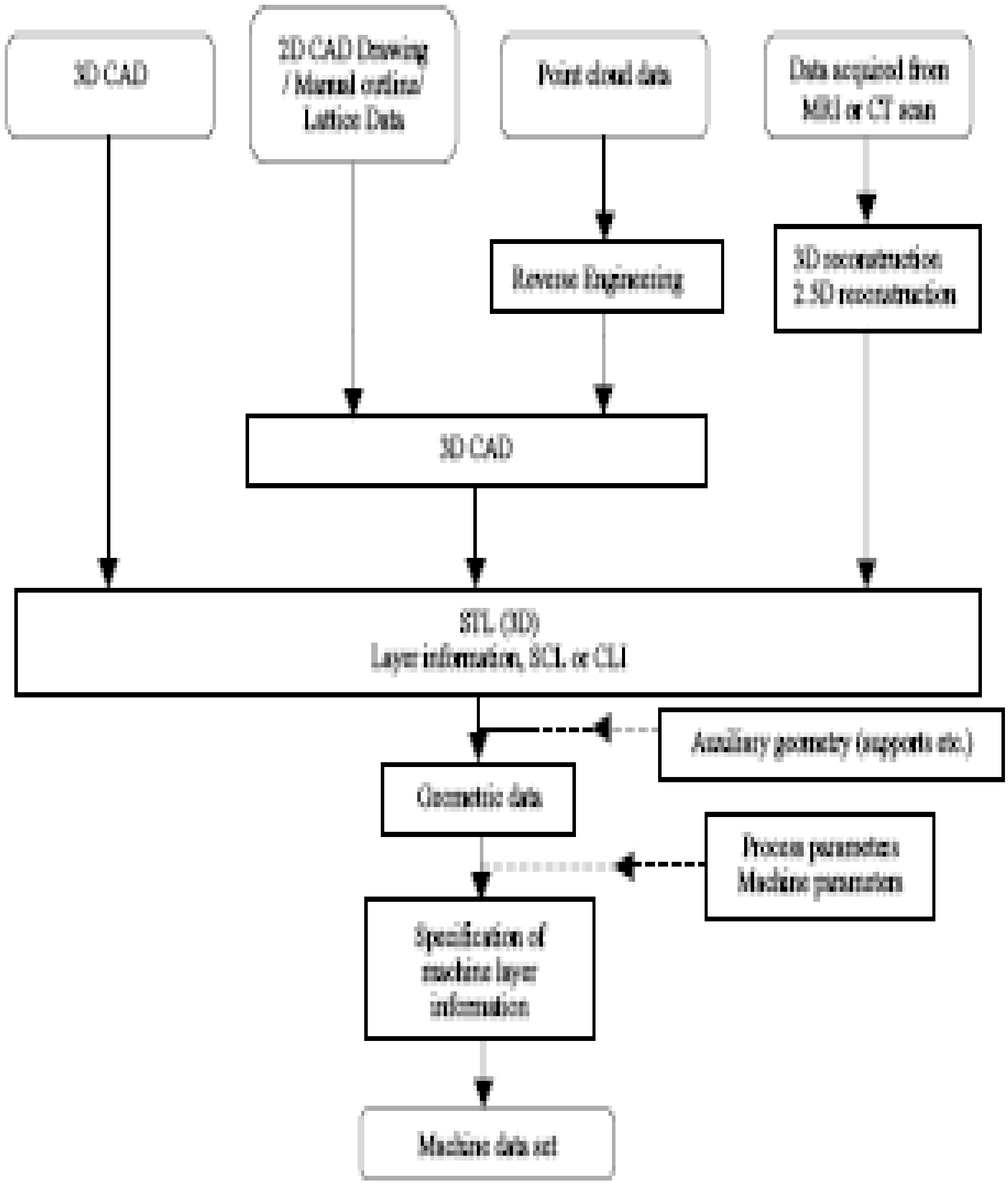


It can be seen from figure 1 that process starts with 3D modeling of the product and then STL file is exported by tessellating the geometric 3D model. In tessellation various surfaces of a CAD model are piecewise approximated by a series of triangles (figure 2) and co-ordinate of vertices of triangles and their surface normals are listed. The number and size of triangles are decided by facet deviation or chordal error as shown in figure 2. These STL files are checked for defects like flip triangles, missing facets, overlapping facets, dangling edges or faces etc. and are repaired if found faulty. Defect free STL files are used as an input to various slicing softwares. At this stage choice of part deposition orientation is the most important factor as part building time, surface quality, amount of support structures, cost etc. are influenced. Once part deposition orientation is decided and slice thickness is selected, tessellated model is sliced and the generated data in standard data formats like SLC (stereolithography contour) or CLI (common layer interface) is stored. This information is used to move to step 2, i.e., generation of physical model. The software that operates RP systems generates laser-scanning paths (in processes like Stereolithography, Selective Laser Sintering etc.) or material deposition paths (in processes like Fused Deposition Modeling). This step is different for different processes and depends on the basic deposition principle used in RP machine. Information computed here is used to deposit the part layer-by-layer on RP system platform.



TESSELLATION OF A TYPICAL SURFACE OF CAD MODEL

The final step in the process chain is the post-processing task. At this stage, generally some manual operations are necessary therefore skilled operator is required. In cleaning, excess elements adhered with the part or support structures are removed. Sometimes the surface of the model is finished by sanding, polishing or painting for better surface finish or aesthetic appearance. Prototype is then tested or verified and suggested engineering changes are once again incorporated during the solid modeling stage.

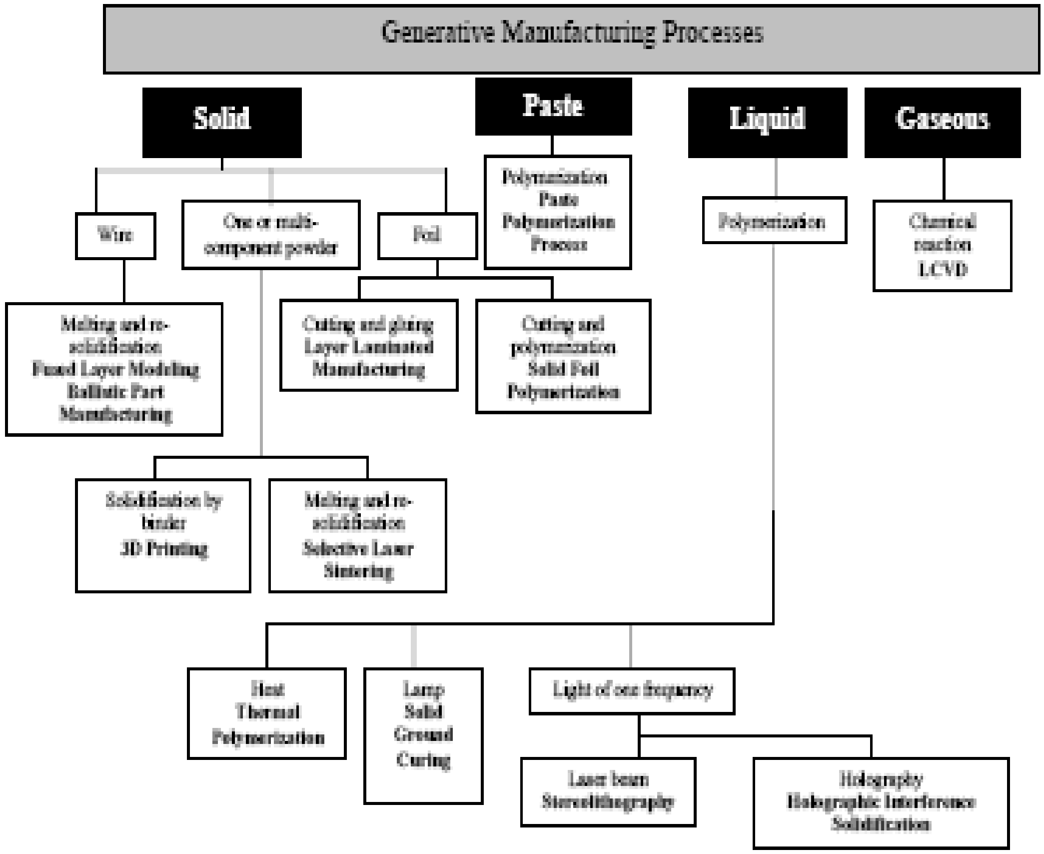


GENERALIZED ILLUSTRATION OF DATA FLOW IN RP

5.16 RAPID PROTOTYPING PROCESSES:

The professional literature in RP contains different ways of classifying RP processes. However, one representation based on German standard of production processes classifies

RP processes according to state of aggregation of their original material

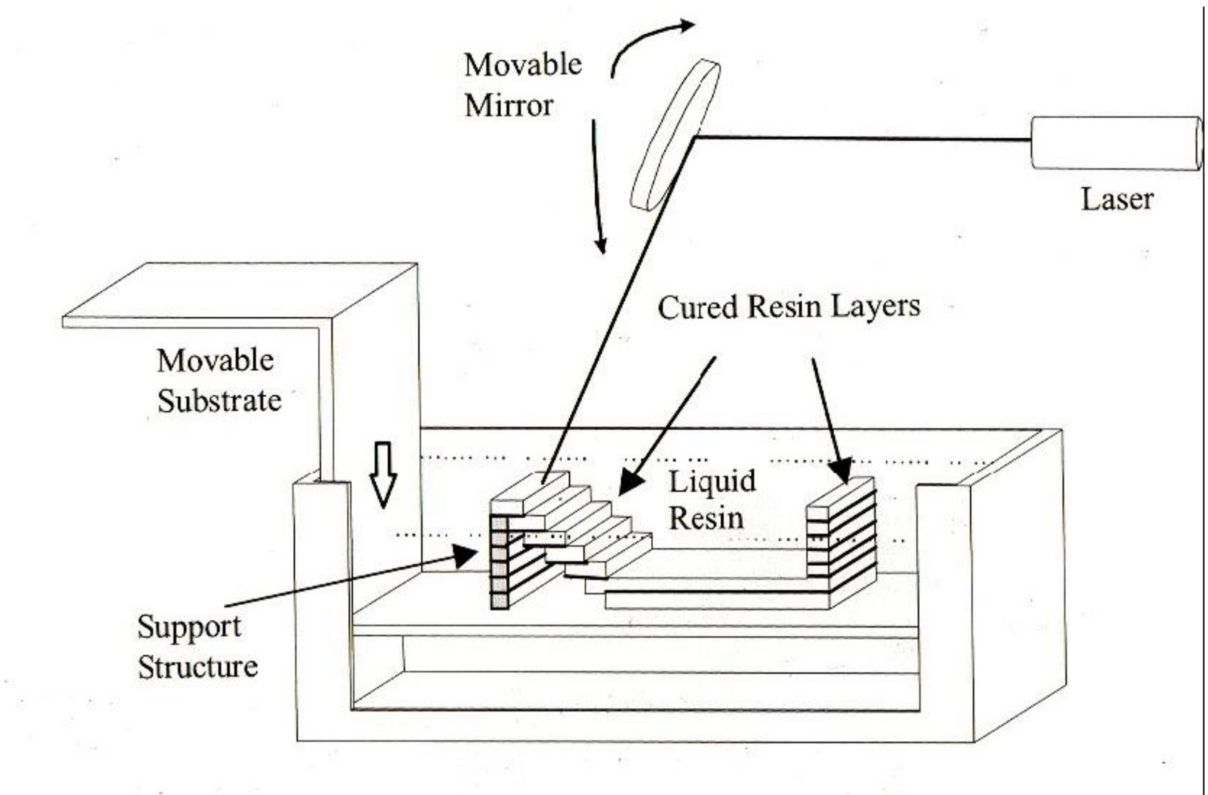


CLASSIFICATION OF RP PROCESSES

5.17 STEREOLOGRAPHY FUSED DEPOSITION MODELING:

In this process photosensitive liquid resin which forms a solid polymer when exposed to ultraviolet light is used as a fundamental concept. Due to the absorption and scattering of beam, the reaction only takes place near the surface and voxels of solid polymeric resin are formed. A SL machine consists of a build platform (substrate), which is mounted in a vat of resin and a UV Helium-Cadmium or Argon ion laser. The laser scans the first layer and platform is then lowered equal to one slice thickness and left for short time (dip-delay) so that liquid polymer settles to a flat and even surface and inhibit bubble formation. The new Generative Manufacturing Processes slice is then scanned. Schematic diagram of a typical Stereolithography apparatus is shown in figure 5.

In new SL systems, a blade spreads resin on the part as the blade traverses the vat. This ensures smoother surface and reduced recoating time. It also reduces trapped volumes which are sometimes formed due to excessive polymerization at the ends of the slices and an island of liquid resin having thickness more than slice thickness is formed (Pham and Demov, 2001). Once the complete part is deposited, it is removed from the vat and then excess resin is drained. It may take long time due to high viscosity of liquid resin. Thegreen part is then post-cured in an UV oven after removing support structures.

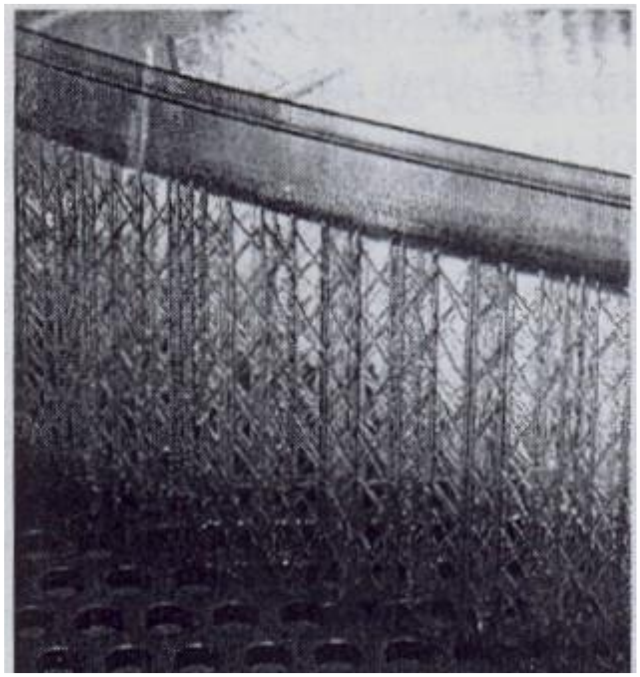


STEREOLITHOGRAPHY

Stability and strength. These overhangs etc. are supported if they exceed a certain size or angle, i.e., build orientation. The main functions of these structures are to support projecting parts and also to pull other parts down which due to shrinkage tends to curl up (Gebhardt, 2003). These support structures are generated during data processing and due to these data grows heavily specially with STL files, as cuboid shaped support element need information about at least twelve triangles. A solid support is very difficult to remove later and may damage the model. Therefore a new support structure called fine point was developed by 3D Systems (figure 6) and is company s trademark.

Build strategies have been developed to increase build speed and to decrease amount of resin by depositing the parts with a higher proportion of hollow volume.

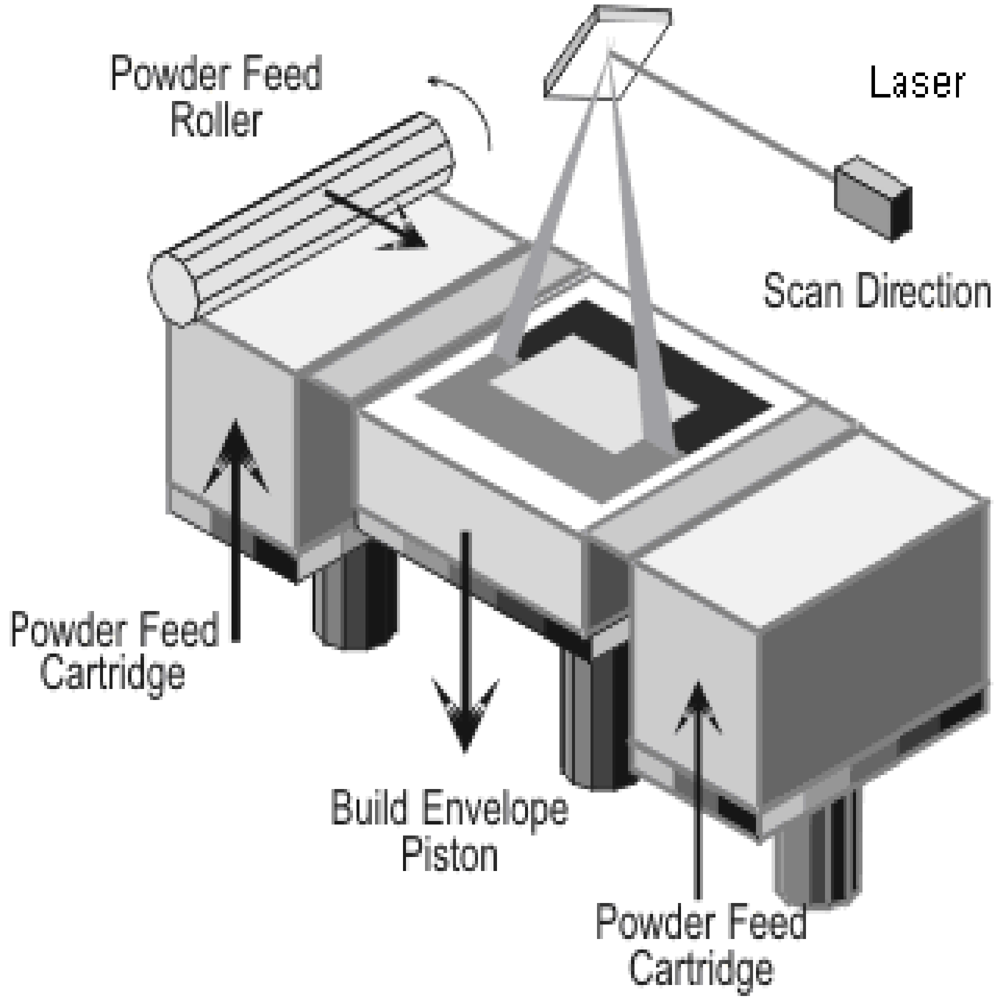
These strategies are devised as these models are used for making cavities for precision castings. Here walls are designed hollow connected by rod-type bridging elements and skin is introduced that close the model at the top and the bottom. These models require openings to drain out uncured resin.



Fine point structure for Stereolithography

5.20 Selective Laser Sintering:

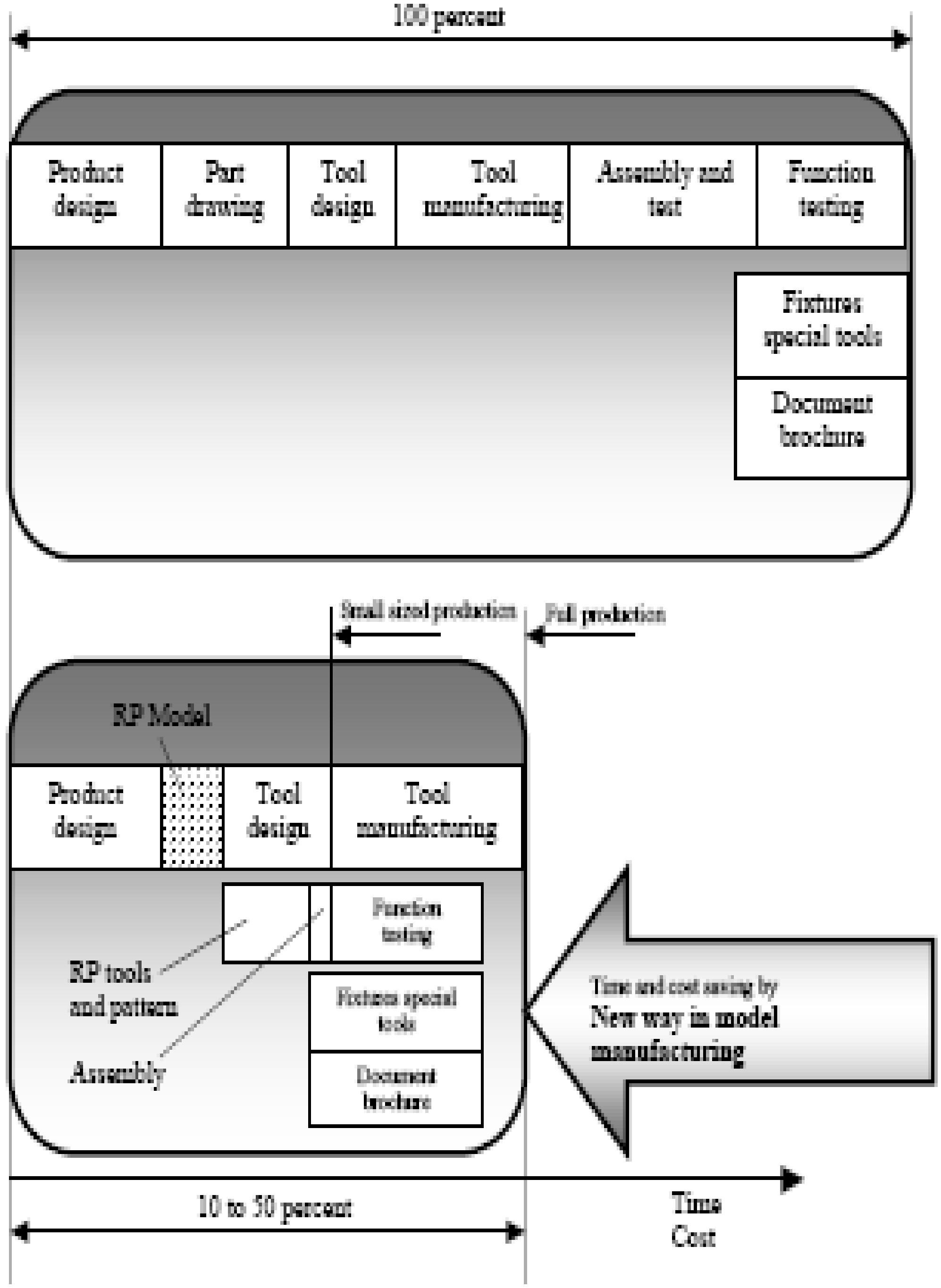
In Selective Laser Sintering (SLS) process, fine polymeric powder like polystyrene, polycarbonate or polyamide etc. (20 to 100 micrometer diameter) is spread on the substrate using a roller. Before starting CO2 laser scanning for sintering of a slice the temperature of the entire bed is raised just below its melting point by infrared heating in order to minimize thermal distortion (curling) and facilitate fusion to the previous layer. The laser is modulated in such away that only those grains, which are in direct contact with the beam, are affected (Pham and Demov, 2001). Once laser scanning cures a slice, bed is lowered and powder feed chamber is raised so that a covering of powder can be spread evenly over the build area by counter rotating roller. In this process support structures are not required as the unsintered powder remains at the places of support structure. It is cleaned away and can be recycled once the model is complete.



SELECTIVE LASER SINTERING SYSTEM

5.21 APPLICATIONS OF RP TECHNOLOGIES:

RP technology has potential to reduce time required from conception to market up to 10-50 percent (Chua and Leong, 2000) as shown in figure 10. It has abilities of enhancing and improving product development while at the same time reducing costs due to major Breakthrough in manufacturing (Chua and Leong, 2000). Although poor surface finish, limited strength and accuracy are the limitations of RP models, it can deposit a part of any degree of complexity theoretically. Therefore, RP technologies are successfully used by various industries like aerospace, automotive, jewelry, coin making, tableware, saddletrees, biomedical etc. It is used to fabricate concept models, functional models, patterns for investment and vacuum casting, medical models and models for engineering analysis.



RESULT OF INTRODUCTION OF RP IN DESIGN CYCLE