UNIT III

BULK DEFORMATION PROCESS

Hot Working of Metals

- **Hot working** is defined as the process of altering the shape or size of a metal by plastic deformation with the temperature above the recrystallisation point.
- Being above the recrystallization temperature allows the material to recrystallize during deformation.
- This is important because recrystallization keeps the materials from strain hardening, which ultimately keeps the yield strength and hardness low and ductility high.

Methods of Hot Working

1. Rolling
2. Forging
3. Piercing
4. Drawing
5. Spinning
6. Extruding

Cold Working

- **Cold working** is the process of altering the shape or size of a metal by plastic deformation with the temperature below the recrystallisation point.
- Processes include rolling, drawing, pressing, spinning, extruding and heading, it is carried out below the recrystallisation point usually at room temperature.
- Hardness and tensile strength are increased with the degree of cold work whilst ductility and impact values are lowered.
- The cold rolling and cold drawing of steel significantly improves surface finish.
Forging Processes

• **Forging** is the term for shaping metal by using localized compressive forces.

• **Cold forging** is done at room temperature or near room temperature.

• **Hot forging** is done at a high temperature, which makes metal easier to shape and less likely to fracture.

• **Warm forging** is done at intermediate temperature between room temperature and hot forging temperatures.

• Forged parts can range in weight from less than a kilogram to 170 metric tons.

• Forged parts usually require further processing to achieve a finished part.

**Advantages of forging**

Some common advantages of forging are given as under.

1. Forged parts possess high ductility and offers great resistance to impact and fatigue loads.

2. Forging refines the structure of the metal.

3. It results in considerable saving in time, labor and material as compared to the production of similar item by cutting from a solid stock and then shaping it.

4. Forging distorts the previously created unidirectional fiber as created by rolling and increases the strength by setting the direction of grains.

5. Because of intense working, flaws are rarely found, so have good reliability.

6. The reasonable degree of accuracy may be obtained in forging operation.

7. The forged parts can be easily welded.

Few dis-advantages of forging are given as under.

1. Rapid oxidation in forging of metal surface at high temperature results in scaling which wears the dies.

2. The close tolerances in forging operations are difficult to maintain.

3. Forging is limited to simple shapes and has limitation for parts having undercuts etc.

4. Some materials are not readily worked by forging.

5. The initial cost of forging dies and the cost of their maintenance is high.

6. The metals gets cracked or distorted if worked below a specified temperature limit.

7. The maintenance cost of forging dies is also very high.
Characteristics of Forged Parts

(i) Forged parts have directional properties and hence have good strength.
(ii) Mechanical properties of materials such as percentage elongation, resistance to stock and vibrations are improved.
(iii) Forging process confines the structure of metal by closing up the cavities.
(iv) Cracks and blow-holes are minimized in forged parts.

Tools used in Forging Operation

1. Tongs
2. Flatter
3. Swage
4. Fuller
5. Punch
6. Rivet header
7. Hot chisel
8. Hammers
9. Anvil
10. Swage block
11. Drift
12. Set-hammer
13. Brass scale
14. Brass
15. Black smith's gauge
16. Heading tool
Types of Forging

1. Impression Die Forging
2. Cold Forging
3. Open Die Forging
4. Seamless Rolled Ring Forging

Open Die Forging

- Open die forging involves the shaping of heated metal parts between a top die attached to a ram and a bottom die attached to a hammer anvil or press bed.

- Metal parts are worked above their recrystallization temperatures-ranging from 1900°F to 2400°F for steel-and gradually shaped into the desired configuration through the skillful hammering or pressing of the work piece.

- Although the open die forging process is often associated with larger, simpler-shaped parts such as bars, blanks, rings, hollows or spindles, in fact it can be considered the ultimate option in "custom-designed" metal components.

- High-strength, long-life parts optimized in terms of both mechanical properties and structural integrity are today produced in sizes that range from a few pounds to hundreds of tons in weight.
Steps

4" x 4" Billet
(100 x 100 mm)

Impression Die Forging

• Impression-die forging is also called closed-die forging.

• In impression-die work metal is placed in a die resembling a mold, which is attached to the anvil.

• Usually the hammer die is shaped as well.

• The hammer is then dropped on the work piece, causing the metal to flow and fill the die cavities.

• The hammer is generally in contact with the work piece on the scale of milliseconds. Depending on the size and complexity of the part the hammer may be dropped multiple times in quick succession.

• Excess metal is squeezed out of the die cavities; this is called flash. The flash cools more rapidly than the rest of the material; this cool metal is stronger than the metal in the die so it helps prevent more flash from forming.
• This also forces the metal to completely fill the die cavity. After forging the flash is trimmed off.

Benefits of the Closed Die Forging Process

• Three-dimensional shapes
• High strength
• Soundness
• Homogeneity
• Enhanced density
• Production of intricate and difficult geometries
Cold Forging Process

1. Forward extrusion reduces slug diameter and increases its length to produce parts such as stepped shafts and cylinders.

2. In backward extrusion, the steel flows back and around the descending punch to form cup-shaped pieces.

3. Upsetting, or heading, a common technique for making fasteners, gathers steel in the head and other sections along the length of the part.

Types of Forging Machines

1. Drop Hammers

2. Spring Hammers

3. Pneumatic Power Hammer

4. High Velocity forging Machine
Spring Hammer

Power Hammer
Typical Forging Operations

1. Upsetting
2. Drawing Down
3. Bending
4. Punching and Drifting
5. Swaging
6. Fullering and Flattening
7. Forge Welding
8. Cutting
1. Upsetting


2. Drawing-down

3. Bending

- Bending operation is carried out by keeping the work-piece on the edge of the anvil face.
- A thin bar can be bent by inserting one end of the bar in the hole and bend it with the help of wrench or tong.

4. Punching and Drifting

- Punching operation is used to produce or enlarge the hole in the metallic work-piece by hammering a tool called punch.
- Drifting operation is to cut a slit in the work and the tool used is called drift.
5. Swaging

- **Swaging** is a process that is used to reduce or increase the diameter of tubes and/or rods.

- This is done by placing the tube or rod inside a die that applies compressive force by hammering radially. This can be further expanded by placing a mandrel inside the tube and applying radial compressive forces on the outer diameter. Thus, the inner diameter can be a different shape, for example a hexagon, and the outer is still circular.

6. Fullering and Flattening

- Fullering operation uses Fullering tool to reduce the thickness of the heated work-piece.

- The fuller is used mainly to spread the metal. The fuller is placed against the metal stock, and then either the fuller (for an upper fuller) or the stock (for a lower fuller) is struck with a hammer. The rounded nose of the fuller spreads the metal more efficiently than the flat face of the hammer. The process leaves ridges in the stock, which may then be flattened out later with the hammer or other tools.

7. Forger-welding

- **Forge welding** is a welding process of heating two or more pieces of metal and then hammering them together. The process is one of the simplest methods of joining metals and has been used since ancient times. Forge welding is versatile, being able to join a host of similar and dissimilar metals.

- With the invention of electrical and gas welding methods during the Industrial Revolution, forge welding has been largely replaced.

8. Cutting

It is sometimes termed as hot cutting or chiseling by the use of hot chisels.
Rolling

- The process of shaping metal by passing it between rolls revolving at the same peripheral speed and in opposite directions.

- In steel there are a number of different types of rolling mill for processing the ingot to its finished shape.

- These are variously known as Cogging mills, Slabbing mills, Billet mills, Bar mills and Strip mills, which produce plate, sections, bars, sheet and strip.

- Cold rolling of previously hot rolled strip is carried out to produce strip that is accurate to size and with a smooth bright polished surface.

Types of Rolling Mills

1. Two High Rolling Mill
2. Three High Rolling Mill
3. Four high Rolling Mill
4. Multi-roll rolling Mill
5. Universal Rolling Mill
Two High Rolling Mill

Three High Rolling Mill

Driver rolls
Rotates by friction

Four High Rolling Mill

Top working roll
Top backup roll
Bottom working roll
Bottom backup roll
Multi high Rolling Mill or cluster Roll Mill

Defects in Rolled parts

1. Rolling frequently involve non-uniform deformation
2. Fins may be formed on the rolled bars if the metal forces itself into the clearance between the rolls.
3. When the metal is hot rolled, its surface is not smooth and it has scale formed over the same.
4. Cracks may form during cold rolling if the metal becomes too much work-hardened during the process.
Cold Rolling

- **Cold rolling** is a metalworking process in which metal is deformed by passing it through rollers at a temperature below its recrystallization temperature. Cold rolling increases the yield strength and hardness of a metal by introducing defects into the metal's crystal structure.

Hot rolling

- Hot rolling is a hot working metalworking process where large pieces of metal, such as slabs or billets, are heated above their recrystallization temperature and then deformed between rollers to form thinner cross sections.
- Hot rolling produces thinner cross sections than cold rolling processes with the same number of stages.
- Hot rolling, due to recrystallization, will reduce the average grain size of a metal while maintaining an equiaxed microstructure where as cold rolling will produce a hardened microstructure.
Wire drawing

- **Wire drawing** is a metalworking process used to reduce the diameter 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, tension-loaded 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 a cold working process, but it may be performed at elevated temperatures for large wires to reduce forces.
Tube sinking, also known as free tube drawing, reduces the diameter of the tube without a
mandrel inside the tube. The inner diameter (ID) is determined by the inner and outer diameter of the
stock tube, the outer diameter of the final product, the length of the die landing, the amount of back
tension, and the friction between the tube and the die. This type of drawing operation is the most
economical, especially on thick-walled tubes and tubes smaller than 12 mm (0.47 in) in diameter, but
does not give the best surface finish. As the tube thickness increases the surface finish quality decreases. This process is often used for the tubing on low cost lawn furniture.

- **Rod drawing**

Rod drawing is the process that draws the tube with a mandrel inside the tube; the mandrel is drawn with the tube. The advantage to this process is that the mandrel defines the ID and the surface finish and has a quick setup time for short runs. The disadvantages are that lengths are limited by the length of the mandrel, usually no more than 100 feet (30 m), and that a second operation is required to remove the mandrel, called reeling. This type of process is usually used on heavy walled or small ID tubes. Common applications include super-high pressure tubing and hydraulic tubing (with the addition of a finishing tube sinking operation). This process is also used for precision manufacturing of trombone hand slides.

- **Fixed plug drawing**

Fixed plug drawing, also known as stationary mandrel drawing, uses a mandrel at the end of the die to shape the ID of the tube. This process is slow and the area reductions are limited, but it gives the best inner surface finish of any of the processes. This is the oldest tube drawing method.

- **Floating plug drawing**

Floating plug drawing, also known as floating mandrel drawing, uses a mandrel that is not anchored whatsoever to shape the ID of the tube. The mandrel is held in by the friction forces between the mandrel and the tube. This axial force is given by friction and pressure. This greatest advantage of this is that it can be used on extremely long lengths, sometimes up to 1,000 feet (300 m). The disadvantage is it requires a precise design otherwise it will give inadequate results. This process is often used for oil-well tubing.
Tethered plug drawing

Tethered plug drawing, also known as semi-floating mandrel drawing, is a mix between floating plug drawing and fixed plug drawing. The mandrel is allowed to float, but it still anchored via a tether. This process gives similar results to the floating plug process, except that it is designed for straight tubes. It gives a better inner surface finish than rod drawing.

Extrusion

- **Extrusion** is a process used to create objects of a fixed cross-sectional profile. A material is pushed or drawn through a die of the desired cross-section.

- The two main advantages of this process over other manufacturing processes is its ability to create very complex cross-sections and work materials that are brittle, because the material only encounters compressive and shear stresses.

Types of Extrusion

1. **Hot Extrusion**
   a) Forward Extrusion
   b) Backward Extrusion

2. **Cold Extrusion**
   a) Forward Extrusion
* Hydrostatic extrusion

b) Backward Extrusion

*Impact Extrusion

*Cold extrusion Forging

**Hot Extrusion**
Generally done at fairly high temperatures, approximately at 50 to 75% of the melting point of the metal. The pressures range from 35-700 MPa (5076 - 101,525 psi). To cool down the high temperatures and pressures and its adverse effect on the die life as well as other components, good lubrication is a must. Oil graphite and glass powder is preferred as lubricants.

**Application of Hot Extrusion:**
Aluminium, copper with their alloys are successfully used to manufacture products using hot extrusion process. Electrical wires, bars and tubes are some of the items produced.

**Cold Extrusion**
Cold extrusion takes place at room temperature or slightly elevated temperatures. This process is useful for withstanding the stresses created by extrusion.

**The advantages of cold extrusion are:**
No oxidation process.

- Good mechanical properties provided the temperatures created are below the re-crystallization temperature. Good surface finish.

**Application of Cold Extrusion:**
Examples of the metals that can be extruded are copper, lead, tin, aluminum alloys, titanium, molybdenum, vanadium, steel. Which are used to make parts like collapsible tubes, gear blanks, aluminum cans, cylinders etc.

In automobile sector they have found wide applications in Injection technology; Engine control; Fuel supply; Automatic transmissions Seat technology; Safety systems (restraint systems).