UNIT: 5
Mechanical Working of Metals, Surface Heat Treatment and Finishing Operations

STRUCTURE

Introduction.

Hot Working Processes.

Advantages and Disadvantages of Hot Working.

Cold Working Processes.

Advantages and Disadvantages of Cold Working.

Surface Heat Treatment processes.

Finishing operations.

Introduction:

The shaping of metals by applying pressures either cold or hot condition is called mechanical working of metals.

Ex: Forging, bending, drawing, squeezing, spinning, shearing etc.

Hot Working Process:

Hot Working:

The plastic deformation of metal above re-crystallization temperature is called hot working. In this new grains are formed.

1. Rolling:

The plastic deformation of metal takes place as it passes through a pair of rolls rotating in opposite direction. This is due to squeezing action of rolls. In this reducing the cross- sectional area takes place. The hot rolling is used to produce bars, plates, sheets, rails and girders.

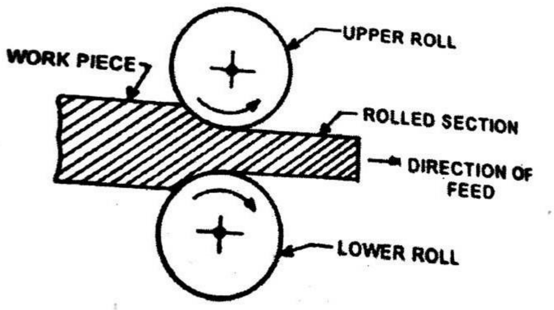

Fig 5.1 Rolling

2. Piercing:

Hot piercing is used to produce seamless tubes. A small hole is made at the end of the heated billet. It is feed between two piercing rolls rotating in the same direction. As a result seamless tube is produced.

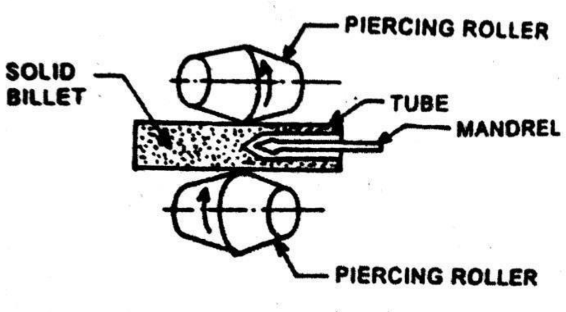

Fig 5.2 Piercing

3. Drawing or Cupping:

Drawing is the process of making cup shaped parts from sheet metal blanks. The blank is first heated then placed in position over the die or cavity. The punch descends through the die to form a cup.

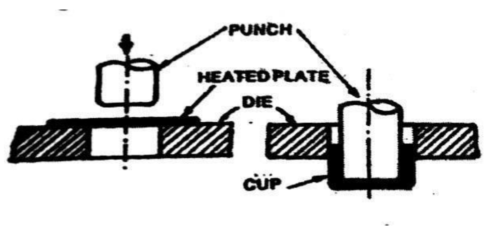

Fig 5.3 Drawing

4. Spinning:

It is the process of shaping thin sheets of metal by pressing against a rotating former. The blank is held between the former and adopter. The blank rotates with the former. A specially shaped tool is pressed against the blank and slowly moved to cover the former.

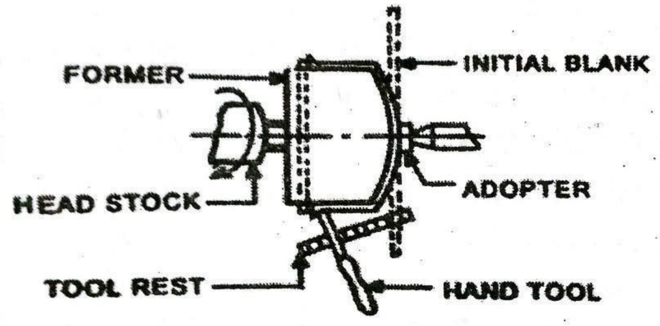

Fig 5.4 Spinning

5. Extrusion:

In this the metal billet is heated to plastic state and placed in a container. The billet is forced through a die by the pressure applied from the ram. The billet moves relative to the container.

Ex: Tubes, cables, air craft parts etc.

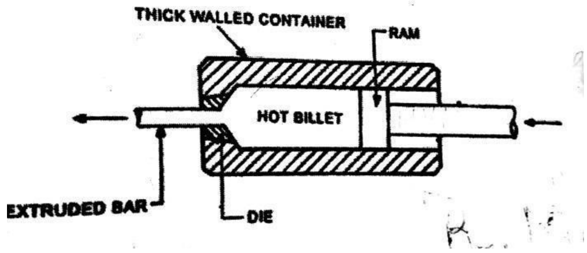

Fig 5.5 Extrusion

Advantages of Hot Working Process:

- The grain structure is refined.
- Less force is enough to shape the metal into desired shape.
- Strength and hardness of metal decreases.
- Porosity of metal eliminated.
- Ductility and toughness increases.
- Energy consumption is less.
- Uni-directional fiber structure is obtained.
- This process is easy and economical.
- Larger deformation is possible with less force.

Disadvantages:

- At high temperature scales are formed, so poor surface finish.
- Close tolerance cannot be maintained.
- Tooling and handling costs are high.
- Tool life is less due to work at high temperature.
- The steel work piece loose carbon, so crakes are developed on the surface of the work piece.

Cold Working Process:

Cold Working:

The plastic deformation of metal below re-crystallization temperature is called cold working.

1. **Rolling:**

In this process the metal is passed through the number of rollers till the required thickness is obtained. For this sheet, bars, rods are used.

Ex: Wrought Iron products.

2. **Bending:**

In this process the metal bars are bending into required shape. For this three rollers are used. Two rollers are in fixed position and other is adjustable. The long metal is passed through them. The rollers bend the metal.

3. **Drawing:**

It is the process to reduce the large diameter of metal into required low diameter. In this die is used. The metal is passed through the die, by applying force the metal comes out from die.

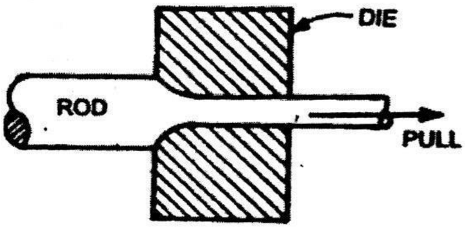

Fig 5.6 Drawing

4. **Spinning:**

It is the process of shaping thin sheet metal by pressing against the form which is rotation. This process is suitable for soft metals.

5. **Extrusion:**

It is the process of pushing the billet of metal through an orifice in the die.

The punch is passed on metal. Then the metal extruded into die shape.

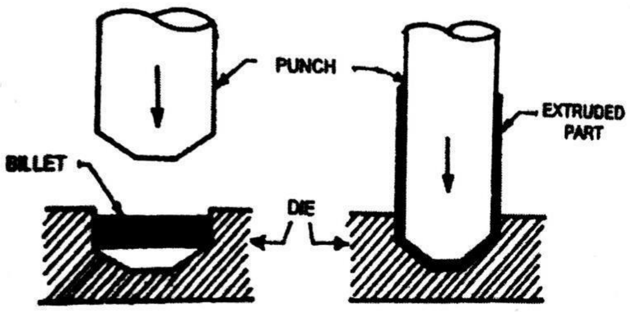

Fig 5.7 Extrusion

6. Squeezing:

It requires large amount of pressure to get required shape. For this a cavity of die and punch are required. Ex: bolts, screws, rivets.

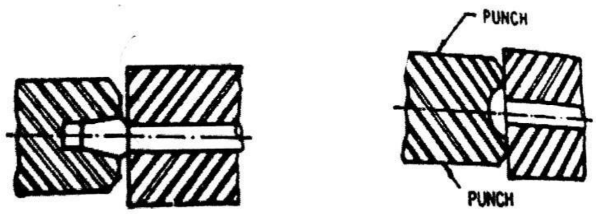

Fig 5.8 Squeezing

7. Reeding:

It is the process of intending large quantities of steel shots into the surface of metal. This is done by air blast. By this indentation compressive stresses are developed at outer layer. Due to this the metal surface is slightly hardened.

Advantages and Disadvantages of Cold Working:

Advantages:

- It improves surface finish.
- It gives scale free and bright surface.
- Strength and hardness are increased.
- They do not require any other finishing operations.
- Physical properties are increases.

Disadvantages:

- A high pressure and heavy equipment are required.
- Only small sized parts are worked. It is limited to ductile materials only.
- It increases the brittleness of the metal.

Surface Heat Treatment Processes:

Heat treatment is the process of heating and cooling metals, using specific predetermined methods to obtain desired properties. Both ferrous as well as non-ferrous metals undergo heat treatment before putting them to use.

Types of Heat Treatment:

There are four basic types of heat treatment in use today: annealing, normalizing, hardening, and tempering.

The following sections describe the techniques used in each process and show how they relate to Steelworkers.

1. Annealing:

The objective of annealing is the opposite of hardening. You anneal metals to relieve internal stresses, soften them, make them more ductile, and refine their grain structures. The process includes all three stages of heat treatment already covered (heat the metal to a specific temperature, hold it at a temperature for a set length of time, cool it to room temperature), but the cooling method will depend on the metal and the properties desired.

You may need to furnace-cool some metals or bury others in ashes, lime, or other insulating materials to achieve the appropriate characteristics.

Under certain job conditions, or without proper preheating, welding can produce areas of molten metal adjacent to other areas at room temperature. Given specific conditions, welding can actually weaken a metal, for as a weld cools, internal stresses occur along with hard spots and brittleness.

Annealing is just one method for correcting these problems and relieving the stresses.

2. Normalizing:

The intent of normalizing is to remove internal stresses that may have been induced by heat treating, welding, casting, forging, forming, or machining. Uncontrolled stress leads to metal failure; therefore, you should normalize steel before hardening it to ensure maximum results.

Normalizing applies to ferrous metals only, and it differs from annealing; the metal is heated to a higher temperature, but then it is removed from the furnace for air cooling.

Low-carbon steels do not usually require normalizing, but if they are normalized, no harmful effects result.

Castings are usually annealed rather than normalized; however, some castings require the normalizing heat treatment.

Normalized steel has a higher strength than annealed steel; it has a relatively high strength and ductility, much tougher than in any other structural condition. Metal parts that will be subjected to impact and those requiring maximum toughness with resistance to external stress are usually normalized.

In normalizing, since the metal is air cooled, the mass of a metal has a significant influence on the cooling rate and hence on the resulting piece's hardness. With normalizing, thin pieces cool faster in the air and are harder than thick ones, whereas with annealing and its associated furnace cooling, the hardness of the thin and thick pieces is about the same.

3. Hardening:

The purpose of hardening is not only to harden steel as the name implies, but also to increase its strength. However, there is a trade off; while a hardening heat treatment does increase the hardness and strength of the steel, it also makes it less ductile, and brittleness increases as hardness increases. To remove some of the brittleness, you should temper the steel after hardening.

Many nonferrous metals can also be hardened and their strength increased by controlled heating and rapid cooling, but for nonferrous metals, the same process is called heat treatment rather than hardening.

For most steels, hardening consists of employing the typical first two stages of heat treatment (slowly heat to temperature and soak to time and temperature), but the third stage is dissimilar. With hardening, you rapidly cool the metal by plunging it into oil, water, or brine. (Note: Most steels require rapid cooling [quenching] for hardening, but a few can be air cooled with the same results.)

4. Case Hardening:

The object of case hardening is to produce a hard, wear-resistant surface (case) over a strong, tough Core. In case hardening, the surface of the metal is chemically changed by the introduction of a high carbide or nitride content, but the Core remains chemically unaffected. When the metal is heat treated, the high-carbon surface responds to hardening and the Core toughens.

Case hardening applies only to ferrous metals. It is ideal for parts that must have a wear-resistant surface yet be internally tough enough to withstand heavy loading. Low- carbon and low-alloy series steels are best suited for case hardening. When high- carbon steels are case hardened, the hardness penetrates beyond the surface resulting in brittleness.

There are three principal processes for case hardening: carburizing, cyaniding, and nit riding.

5. Carburizing:

Carburizing — a case hardening process by which carbon is added to the surface of low-carbon steel.

When the carburized steel is heat treated, the case becomes hardened and the Core remains soft and tough--in other words, it has a high-carbon surface and a low- carbon interior.

There are two methods for carburizing steel:

- Heat the steel in a furnace containing a carbon monoxide atmosphere.
- Place the steel in a container packed with charcoal (or some other carbon- rich material) and heat in a furnace.

The parts can be left in the container and furnace to cool, or they can be removed and air-cooled. In either case, the parts become annealed during the slow cooling. The depth of the carbon penetration depends on the length of the soaking period during heat treatment. Modern methods dictate that carburizing is almost exclusively done by gas atmospheres.

6. Cyaniding:

Cyaniding — a case hardening process by which preheated steel is dipped into a heated cyanide bath and allowed to soak.

The part is then removed, quenched, and rinsed to remove any residual cyanide.

This process is fast and efficient. It produces a thin, hard shell, harder than the shell produced by carburizing, and can be completed in 20 to 30 minutes vice several hours. The major drawback is the use of cyanide; cyanide salts are a deadly poison.

7. Nitriding:

Nitriding – a case hardening process by which individual parts have been heat treated and tempered before being heated in a furnace that has an ammonia gas atmosphere.

This case hardening method produces the hardest surface of any of the hardening processes, and it differs from the other methods in that no quenching is required so there is no worry about warping or other types of distortion.

The nitriding process is used to case harden items such as gears, cylinder sleeves, camshafts, and other engine parts that need to be wear-resistant and operate in high- heat areas.

8. Flame Hardening:

Flame hardening is another process available for hardening the surface of metal parts. In flame hardening, you use an oxyacetylene flame to heat a thin layer of the surface to its critical temperature and then immediately quench it with a water spray. In this case, the cold base metal assists in the quenching since it is not preheated.

Similar to case hardening, this process produces a thin, hardened surface while the internal parts retain their original properties.

The process can be manual or mechanical, but in either case, you must maintain a close watch since an oxyacetylene flame can heat the metal rapidly and temperatures in this method are usually determined visually.

9. Tempering:

After hardening by either case or flame, steel is often harder than needed and too brittle for most practical uses, containing severe internal stresses that were set during the rapid cooling of the process. Following hardening, you need to temper the steel to relieve the internal stresses and reduce brittleness.

Tempering consists of:

- Heating the steel to a specific temperature (below its hardening temperature)
- Holding it at that temperature for the required length of time
- Cooling it, usually in still air.

The annealing, normalizing, and hardening processes all include steps at temperatures above the metal’s upper critical point. Tempering is always conducted at temperatures below the metal’s low-critical point.

Super Finishing Operations:

1. Honing:

Honing is a final finishing operation conducted on a surface, typically of an inside cylinder, such as of an automotive engine block. Abrasive stones are used to remove minute amounts of material in order to tighten the tolerance on cylindricity. Either type applies a slight, uniform pressure to a light abrasive that wipes over the entire surface. Honing is an abrading process for removing stock from metallic and non metallic surface. It is used to correct local irregularities such as ovality waviness of axis or non parallelism of cylindrical features and to develop a particular texture. Honing is the application of bonded abrasive stones (called hones) to a surface. The abrasive particles ($Al2O_3$ or SiC) are held by proper bond in the form of sticks. Honing is employed for grinding internal or external surface.

Mostly honing is done on internal surface or holes such as automobile cylinders. However it cannot correct hole location or perpendicularity. Surface finishes of 0.05 m Ra can be achieved. The hone rotates at 0.5-2.5 m/sec and reciprocates at 0.2-0.5 m/sec. The hole to be honed is flooded with a lubricant like paraffin while the honing sticks are removing metal. A honing machine rotates and reciprocates the hone inside holes being finished.

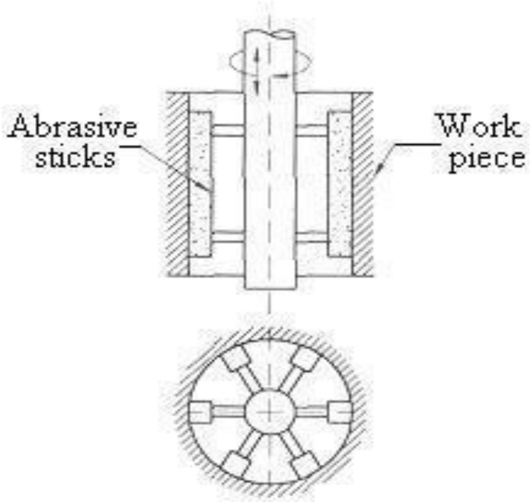

Fig. 5.9 Honing process

2. Lapping:

Lapping is a machining operation, in which two surfaces are rubbed together with an abrasive between them, by hand movement or by way of a machine. A paste of abrasive is rubbed against the surface of the component with certain pressure and with a relative motion. This can take two forms: The first type of lapping (traditionally called grinding), typically involves rubbing a brittle material such as glass against a surface such as iron or glass itself (also known as the "lap" or grinding tool) with an abrasive such as aluminum oxide, emery, silicon carbide, diamond, etc., in between them. This produces microscopically similar fractures as the abrasive rolls between the two surfaces and removes material from both. The other form of lapping involves a softer material for the lap, which is charged with the abrasive. The lap is then used to cut a harder material, which in most cases the work piece. The abrasive embeds within the softer material which holds it and permits it to score across and cut the harder material. Taken to the finer limit, this will produce a polished surface such as with a polishing cloth on an automobile, or a polishing cloth or polishing pitch upon glass or steel. With the aid of accurate interferometry and specialized polishing machines or skilled hand polishing can produce surfaces that are flat to better than 30 nanometers.

3. Buffing

Metal polishing, also termed buffing, it is the smoothing and brightening process of a surface by the rubbing action of fine abrasive in a lubricating binder applied intermittently to a moving wheel of wood cotton fabric felt or a cloth or a felt belt. Buffing is used to give a much more lustrous reflective finish that cannot be obtained by polishing. This gives a smooth finish by forming very thin lines that are not visible to the naked eye.

Buffing wheels are made of felt, pressed and glued layers of duck, or some select cloth and also of leather. The abrasive is mixed with a binder and is applied on either the buffing wheel or on the work. The buffing wheel rotates with a high peripheral speed up to 40 m/sec.

The abrasive may consist of iron oxide, chromium oxide etc. The binder is a paste consisting of wax mixed with grease, paraffin and kerosene or turpentine and other liquids. The stone is given as oscillating motion in the axial direction and simultaneously the job is given a rotary motion about the axis.

Buffing is commonly used in metal polishing of pressure cookers, cookware, and kitchenware. Pipes which are used in pharmaceutical, dairy and water industries are buffed to maintain hygienic conditions and prevent corrosion.

Super Finishing

Super finishing is a type of grinding also known as Micro finishing. An abrasive stick of very fine girt size (400-600 mesh) is retained in a suitable holder and held against the workplace surface under a high spring pressure. The stick is given a feeding and oscillatory motion. The work piece is rotated or reciprocated accordingly to the requirements of the shape being super finished. A lubricant is also fed into the contact surface. An extremely high quality surface with almost no defects is obtained. Holes can also be super-finished.

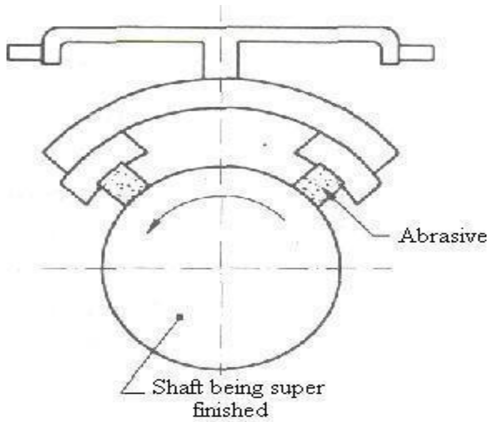

Fig. 5.10 Super Finishing of a shaft

Grinding

Grinding is a finishing process used to improve surface finish, abrade hard materials, and tighten the tolerance on flat and cylindrical surfaces by removing a small amount of material. In grinding, an abrasive material rubs against the metal part and removes tiny pieces of material. The abrasive material is typically on the surface of a wheel or belt and abrades material in a way similar to sanding (or sand grinding). On a microscopic scale, the chip formation in grinding is the same as that found in other machining processes. The abrasive action of grinding generates excessive heat so that flooding of the cutting area with fluid is necessary.

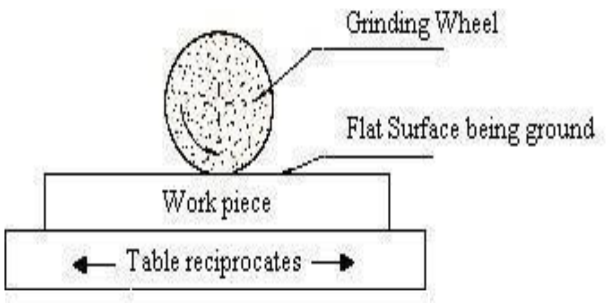

Fig. 5.11 Surface Grinding

Most of the processes, described in the present section involve removal of material with or without introducing or altering the surface stress/strain distribution and they also involve high costs. The only other technique which not only reduces surface roughness, but also introduces beneficial compressive residual stresses is BURNISHING, which process is described in detail in the next section.

Burnishing

Burnishing is considered as a cold-working finishing process, differing from other cold-working, surface treatment processes such as shot peening and sand blasting, etc. In that it produces a good surface finish and also induces residual compressive stresses at the metallic surface layers. Accordingly, burnishing distinguishes itself from chip- forming finishing processes such as grinding, honing, lapping and super-finishing which induce residual tensile stresses at the machined surface layers. Also, burnishing is economically desirable, because it is a simple and economical process, requiring less time and skill to obtain a high-quality surface finish.

The burnishing process can be achieved by applying a highly polished and hard ball or roller onto a metallic surface under pressure. This will cause the peaks of the metallic surface to spread out permanently, when the applied burnishing pressure exceeds the yield strength of the metallic material, to fill the valleys.

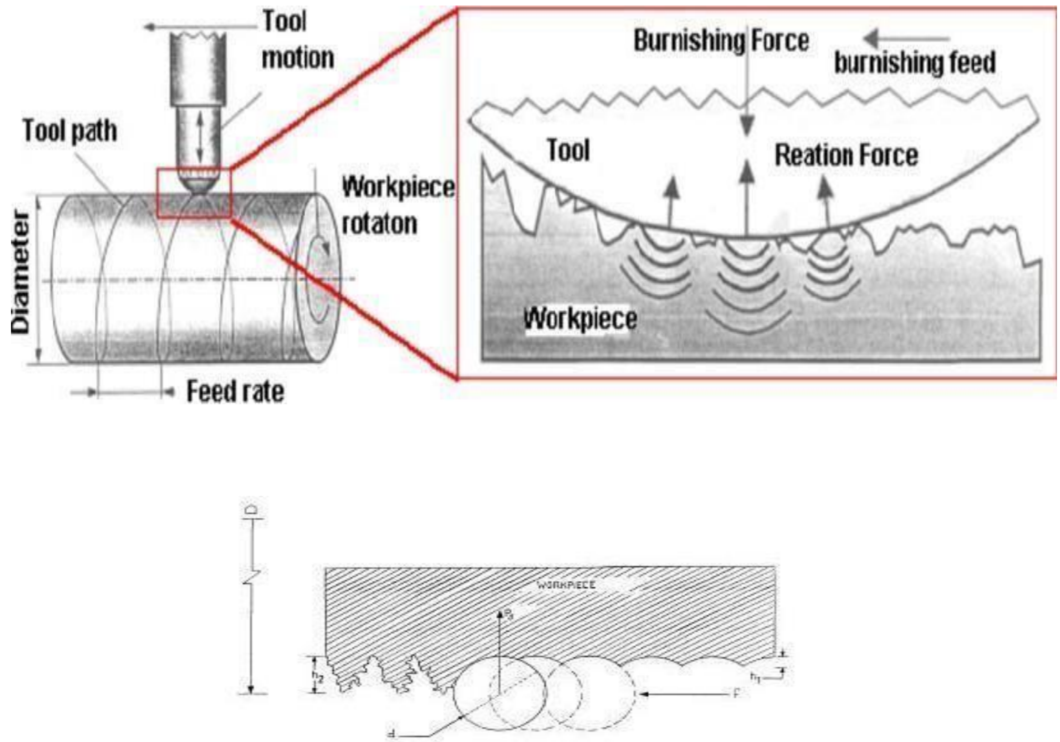

Fig. 5.12 Burnishing Process

The surface of the metallic material will be smoothed out and because of the plastic deformation the surface becomes work hardened, the material being left with a residual stress distribution that is compressive on the surface. The changes in surface characteristics due to burnishing will cause improvements in surface hardness, wear resistance, fatigue resistance, yield and tensile strength and corrosion resistance. It can be seen from this figure that the ball or roller rotates by the effect of frictional engagement between the surface of the ball or roller and the surface of the work piece. This process flattens the roughness peaks by causing plastic flow of the metal. It not only improves surface finish but also imposes favorable compressive residual stresses and raises hardness in functional surfaces, which can lead to long fatigue life and high load bearing capacity, surface finish, hardness, wear-resistance, and corrosion resistance.

The present work is an attempt to study the effects of roller burnishing on the surface roughness and hardness of Ferrous and Non-ferrous materials. The variable burnishing parameters selected for the experimental work were burnishing force, number of burnishing tool passes and other burnishing parameters such as feed- rate, speed, depth of cut etc.

SHORT ANSWER QUESTIONS

1. What is mechanical working of metals and give examples.
2. What is Hot working.
3. What is Cold working.
4. Write advantages and disadvantages of Cold working.

LONG ANSWER QUESTIONS

1. Explain Hot working processes.
2. Explain Heat treatment processes.
3. Explain super finishing operations.
4. Explain Burnishing processes.