CHAPTER 1

Basic Metal Forming Processes and Uses

INTRODUCTION

Metal forming processes, also known as mechanical working processes, are primary shaping processes in which a mass of metal or alloy is subjected to mechanical forces. Under the action of such forces, the shape and size of metal piece undergo a change. By mechanical working processes, the given shape and size of a machine part can be achieved with great economy in material and time.

Metal forming is possible in case of such metals or alloys which are sufficiently malleable and ductile. Mechanical working requires that the material may undergo "plastic deformation" during its processing. Frequently, work piece material is not sufficiently malleable or ductile at ordinary room temperature, but may become so when heated. Thus we have both hot and cold metal forming operations.

Many metal forming processes are suitable for processing large quantities (*i.e.,* bulk) of material, and their suitability depends not only upon the shape and size control of the product but also upon the surface finish produced. There are many different metal forming processes and some processes yield a better geometry (*i.e.*, shape and size) and surface-finish than some others. But, they are not comparable to what can be achieved by machining processes. Also cold working metal forming processes result in better shape, size and surface finish as compared to hot working processes. Hot working results in oxidation and decarburisation of the surface, formation of scales and lack of size control due to contraction of the work piece while it cools to room temperature.

ADVANTAGES OF MECHANICAL WORKING PROCESSES

Apart from higher productivity, mechanical working processes have certain other advantages over other manufacturing processes. These are enumerated below:

1. Mechanical working improves the mechanical properties of material like ultimate tensile strength, wear resistance, hardness and yield point while it lowers ductility. This phenomenon is called "strain hardening".

2. It results in grain flow lines being developed in the part being mechanically worked. The grainflow improves the strength against fracture when the part is in actual use. This is best explained by taking illustration of a crankshaft. If the crankshaft is manufactured by machining from a bar of large

cross-section, the grain flow lines get cut at bends whereas in a crankshaft which is shaped by forging (which is a mechanical working process), the grain flow lines follow the full contour of the crankshaft making it stronger. This is illustrated in Fig. 1.1.

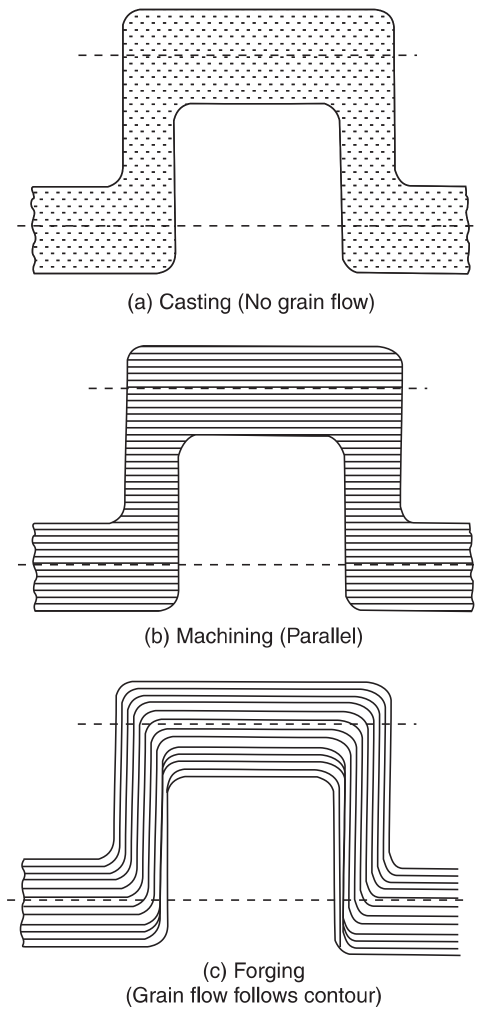

Fig. 1.1 Comparison of grain flow

During mechanical working, the grains of the metal get deformed and lengthen in the direction of metal flow. Hence they offer more resistance to fracture across them. Hence mechanically worked components have better mechanical strength in a certain orientation *i.e.*, across the grain flow.

DIFFERENCE BETWEEN HOT AND COLD WORKING

Cold working (or cold forming, as it is sometimes called) may be defined as plastic deformation of metals and alloys at a temperature below the recrystallisation temperature for that metal or alloy. When this happens, then the strain hardening which occurs as a result of mechanical working, does not get relieved. Infact as the metal or alloys gets progressively strain hardened, more and more force is required to cause further plastic deformation. After sometime, if the effect of strain hardening is not removed, the forces applied to cause plastic deformation may infact cause cracking and failure of material.

Hot working may be explained as plastic deformation of metals and alloys at such a temperature at which recovery and recrystallisation take place simultaneously with the strain hardening. Such a temperature is above recrystallisation temperature. Properly done hot working will leave the metal or alloy in a fine grained recrystallised structure.

A word about recrystallisation temperature will not be out of place here. Recrystallisation temperature is not a fixed temperature but is actually a temperature range. Its value depends upon several factors. Some of the important factors are:

(*i*) **Nature of metal or alloy:** It is usually lower for pure metals and higher for alloys. For pure metals, recrystallisation temperature is roughly one third of its melting point and for alloys about half of the melting temperature.

(*ii*) **Amount of cold work already done:** The recrystallisation temperature is lowered as the amount of strain-hardening done on the work piece increases.

(*iii*) **Strain-rate:** Higher the rate of strain hardening, lower is the recrystallisation temperature.

For mild steel, recrystallisation temperature range may be taken as 550–650°C. Recrystallisation temperature of low melting point metals like lead, zinc and tin, may be taken as room temperature. The effects of strain hardening can be removed by annealing above the recrystallisation temperature.

ADVANTAGES AND DISADVANTAGES OF COLD AND HOT WORKING PROCESSES

(*i*) Since cold working is practically done at room temperature, no oxidation or tarnishing of surface takes place. No scale formation is there, hence there is no material loss. In hot working opposite is true. Besides, hot working of steel also results in partial decarburisation of the work piece surface as carbon gets oxidised as CO_2.

(*ii*) Cold working results in better dimensional accuracy and a bright surface. Cold rolled steel bars are therefore called bright bars, while those produced by hot rolling process are called black bars (they appear greyish black due to oxidation of surface).

(*iii*) In cold working heavy work hardening occurs which improves the strength and hardness of bars, but it also means that high forces are required for deformation increasing energy consumption. In hot working this is not so.

(*iv*) Due to limited ductility at room temperature, production of complex shapes is not possible by cold working processes.

(*v*) Severe internal stresses are induced in the metal during cold working. If these stresses are not relieved, the component manufactured may fail prematurely in service. In hot working, there are no residual internal stresses and the mechanically worked structure is better than that produced by cold working.

(*vi*) The strength of materials reduces at high temperature. Its malleability and ductility improve at high temperatures. Hence low capacity equipment is required for hot working processes. The forces on the working tools also reduce in case of hot working processes.

(*vii*) Sometimes, blow holes and internal porosities are removed by welding action at high temperatures during hot working.

(*viii*) Non-metallic inclusions within the work piece are broken up. Metallic and non-metallic segregations are also reduced or eliminated in hot working as diffusion is promoted at high temperatures making the composition across the entire cross-section more uniform.

Typical Hot Working Temperatures

Steels	650–1050°C
Copper and alloys	600–950°C
Aluminium and alloys	350–485°C

CLASSIFICATION OF METAL FORMING PROCESSES ACCORDING TO TYPE OF STRESS EMPLOYED

Primary metal working processes are those in which the bulk material in the form of ingots, blooms and billets is broken down to required shapes and sizes by processes such as forging, rolling, extrusion etc. These processes can be categorised on the basis of the kind of stress employed in the material, that is:

(*i*) Mainly compression type, (Examples: forging, rolling, extrusion etc.).

(*ii*) Mainly tension type (Example: drawing).

(*iii*) Combined compression and tension type, (Examples : deep drawing, embossing etc.).

Many of these processes are shown schematically in Fig. 1.2.

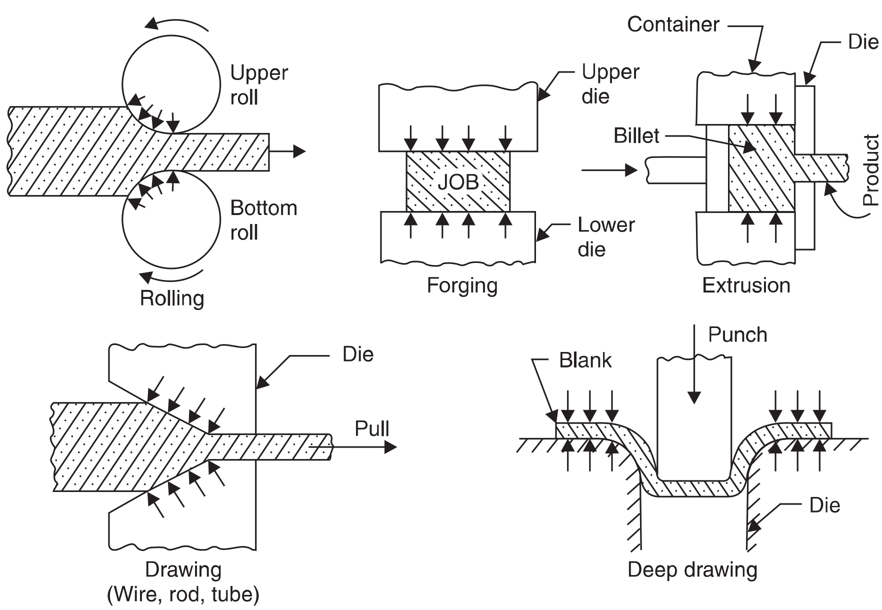

Fig. 1.2 Typical metal working processes

QUESTIONS

1. Explain the meaning of the expression ‘metal forming’. Mention the names of five metal forming processes.

2. What is the difference between hot forming and cold forming ?

3. What is the significance of “recrystallisation” temperature in metal forming ?

4. What do you understand by “grain flow” ? How is it connected with the strength of machine parts ?