8 METAL FORMING PROCESSES

Manufacturing Technology, Vol. 1, Foundry, Forming and Welding - Ch 7

Metal Forming

- METAL FORMING?
- HOT & COLD?
- ROLLING?
- FORGING?
- EXTRUSION?

Introduction to metal-forming

- Mechanical working involves the reduction of the cross section of a material by applying force. The process is essentially done to convert the original cast metal from the initial large section into the final desired small section
- Ex Convert the cast ingots into thin sheets required for car bodies.

Nature of Plastic deformation

When a metal is deformed by “hot working” there are 2 things that takes place:

- 1) The metal piece “changes its shape permanently” because it has crossed the ‘elastic limit’ So, if you apply a force in the vertical direction, the length of the piece increases proportionately (since total volume and weight cannot change).
- 2) The strength, hardness of the piece increases, while it’s ductility reduces. Also the grain size becomes finer.

Forming: Plastic deformation

- 1) The reduction in cross sectional area that occurs is made use of to obtain the final size/shape. For example, a rail section can be obtained from a 100mmx 100mm cross section ingot.
- 2) The increase in strength and hardness is useful for the end product (say a rail section) to have longer life and less wear-out.
- Quite often, a stress-release heat treatment is done on the finished product' Also "finishing" operations are done.

MANUFACTURING PROCESSES - METAL FORMING

CONVERT THE BULK RAW MATERIALS INTO FINISHED FORMS FOR MAKING COMPONENTS

- CASTING
- FORMING
- FABRICATION

- Powder metallurgy; 3D printing

Metal forming:

It is a manufacturing processes in which the material is deformed plastically to take the shape of the die geometry.

The tools used for such deformation are called roll, die, punch etc. depending on the type of process.

Plastic deformation: Stresses beyond yield strength of the workpiece material is applied.

May be HOT or COLD forming

Nature of Plastic Deformation

- When the cast metal is subjected to force in the perpendicular direction its section becomes smaller (as intended) and it correspondingly increases in length. This is called metal working.
- .

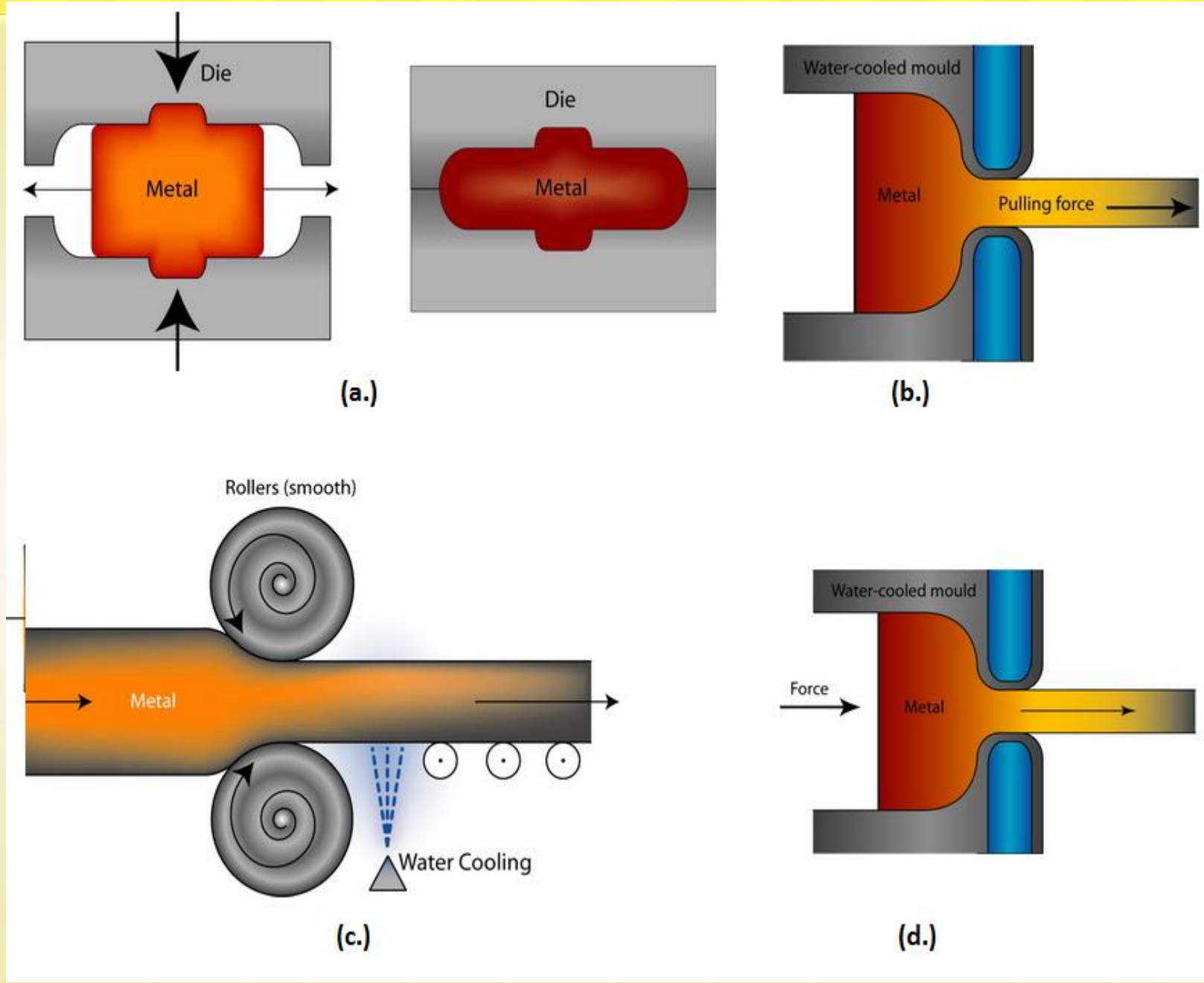
Metal Working Principles

- Metals can be 'worked' in the 'red-hot' condition (called hot working) or at room-temperature (called cold working).

- Usually, there are 2 steps:
- 1 st stage: the cast metal (ingot) is initially subjected to 'hot' working to an intermediate size.
- 2 nd Stage involves 'cold' working to convert the intermediate shape to final (required) shape

Metal Forming

a) Forging –hot & cold
b) Wire Drawing
c) Rolling – hot & cold
d) Extrusion – usually hot



Metal working

- During ‘working’ the crystals or grains of the metal are elongated in the direction of metal flow. This flow of metal can be seen under microscope after polishing and suitable etching of the metal surface. These visible lines are called 'fibre flow lines', some representative specimens of which are presented in Fig 7-1

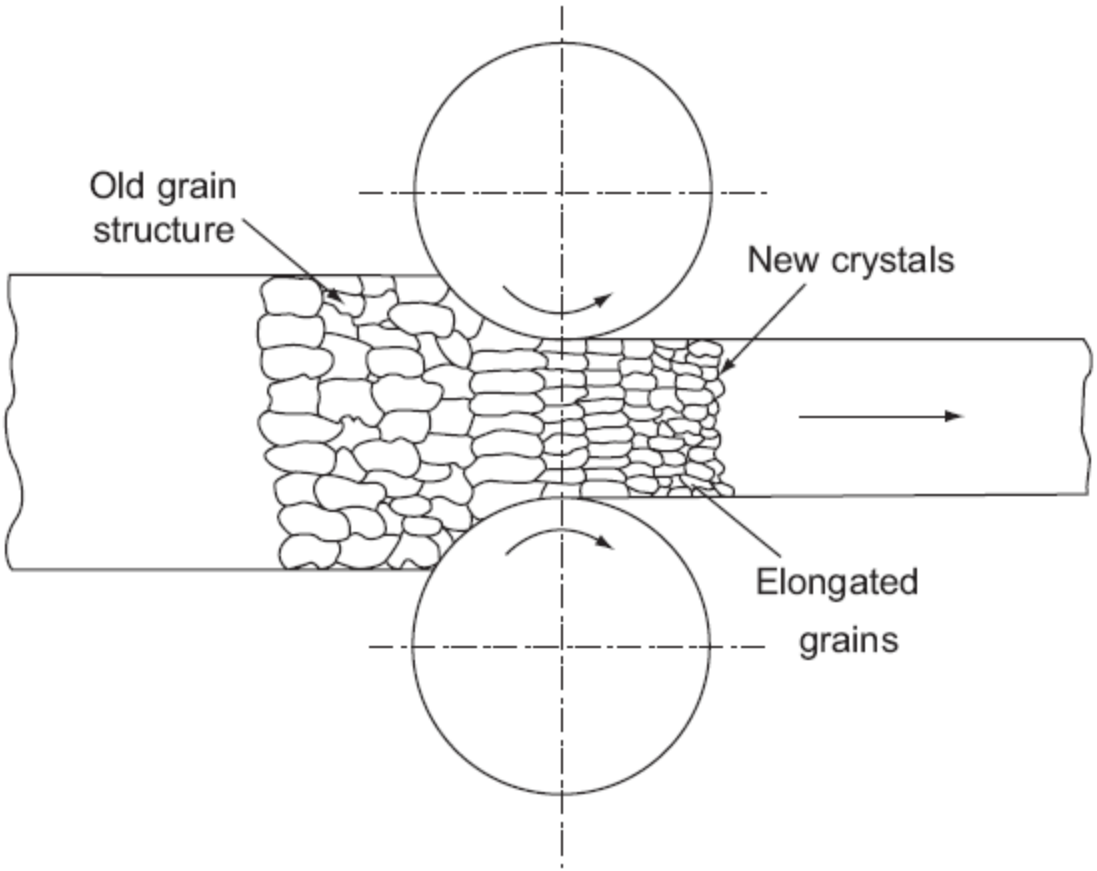


Fig. 7.4 *Grain reformation in hot rolling operation*

Hot Working and Cold Working

- The metal working processes are traditionally divided into hot working and cold working processes.
- Those processes, working above the recrystallisation temperature, are termed as hot working processes whereas those below are termed as cold working processes.

Hot Working

- Any amount of working can be imparted
- There is a limit on the amount of hot working that can be done on a material at a given stage..
- The hot working requires much less force to achieve the necessary deformation.
- When the red hot material becomes cold, it becomes hard and it has to be once again heated (to red hot condition) to further reduce the section
- It is possible to continuously reform the grains in metal working and if the temperature and rate of working are properly controlled, a very favourable grain size could be achieved giving rise to better mechanical properties.

Videos on Metal Forming

- Forging vs Stamping (14 min)

https://www.youtube.com/watch?v=gKz7FFIduYc

Extrusion Process – 3 min

https://www.youtube.com/watch?v=Y75IQksBb0M

Videos on Forming

- Making Steel – Start to Finish 8 min

https://www.youtube.com/watch?v=AfLOnfbXJdI

- Metal Forming Process – explained 18 min

https://www.youtube.com/watch?v=kE6LjkfSWhA

Hot Working

- As the metal in the ‘hot’ condition is ‘worked’ (rolled, forged, extruded, drawn); its cross sectional area reduces.
- However, as the ‘hot’ metal gets worked, its temperature drops and correspondingly its formability reduces. This is called ’work hardening’.
- The metal grains become small and ‘strained’. Any further ‘working’ will result in the metal cracking. Usually every metal has a certain limit of hot working.

Cold Working

- Cold working increases the strength and hardness of the material due to the strain hardening which would be beneficial in some situations.
- Good surface finish is obtained.
- Better dimensional accuracy is achieved.

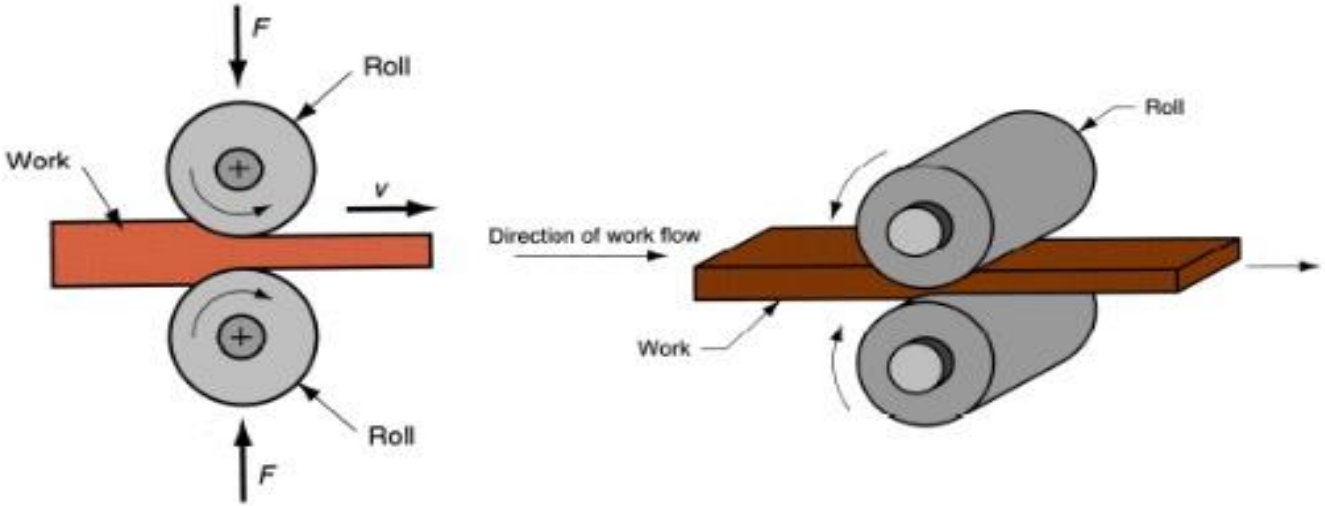
example: is the automobile body, which is made of "cold drawn steel sheet"

Rolling

- Rolling is a process where the metal is compressed between two rotating rolls for reducing its cross-sectional area (Fig 7-5).
- This is one of the most widely used of all the metal working processes, because of its higher productivity and low cost.
- Rolling is normally a hot working process unless specifically mentioned as cold rolling.

Bulk Deformation Processes

Rolling: A compressive deformation process in which the thickness of slab or plate is reduced by two opposing tools "rolls". They rotate to draw the work piece into the gap between them and squeeze it.



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Type of products made in Rolling

- Sheets are the most important type of products made by rolling.
- The sheets are used in bodies and other parts of of Automobiles, 2 wheelers, Aero planes, Trains, cupboards, panels, roofs of houses

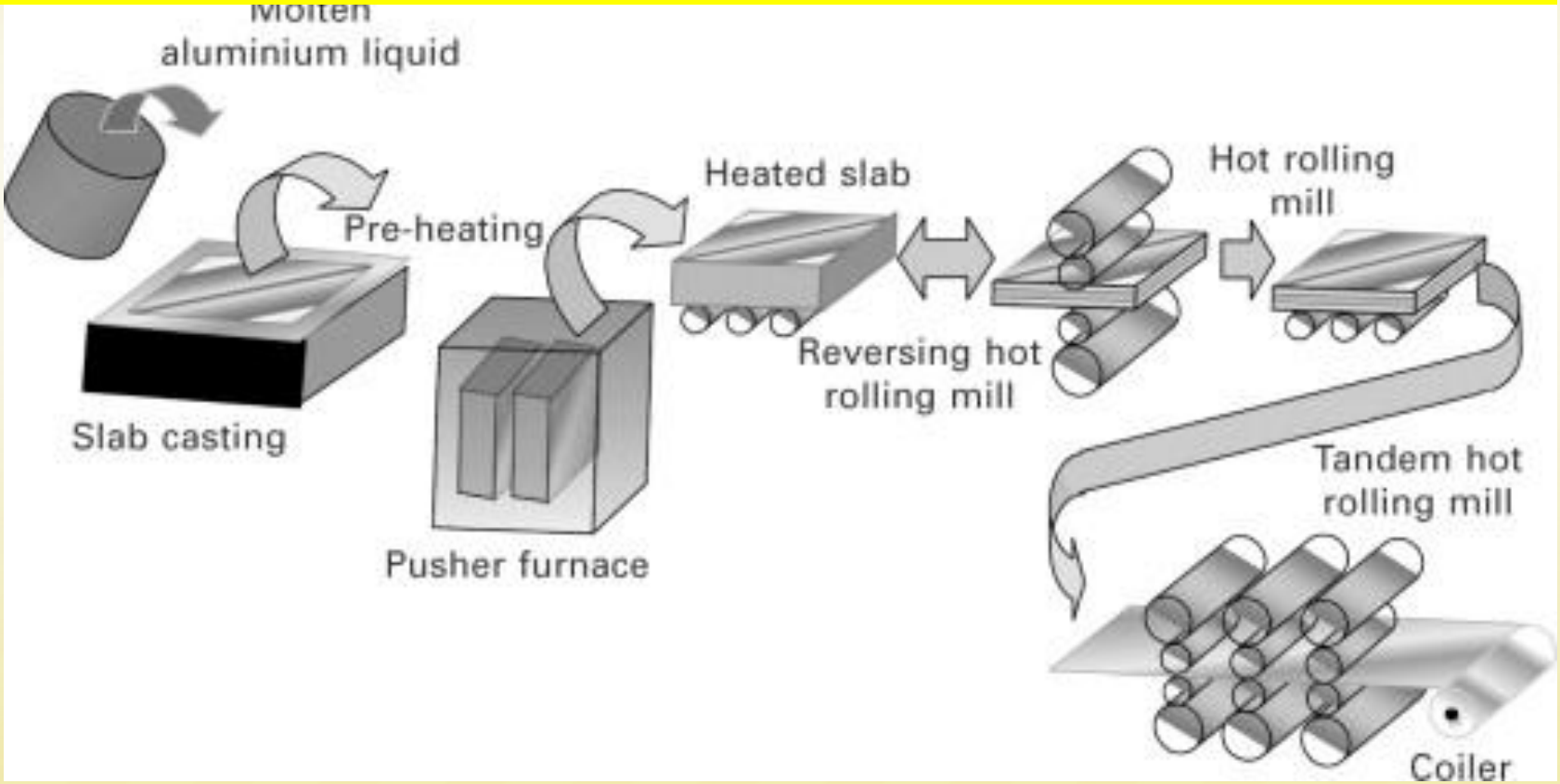
- The sheets are usually made in 2 steps

a) – raw material ingot to Intermediate shape by Hot Rolling

b) - Intermediate shape to finished product shapes by Cold Rolling

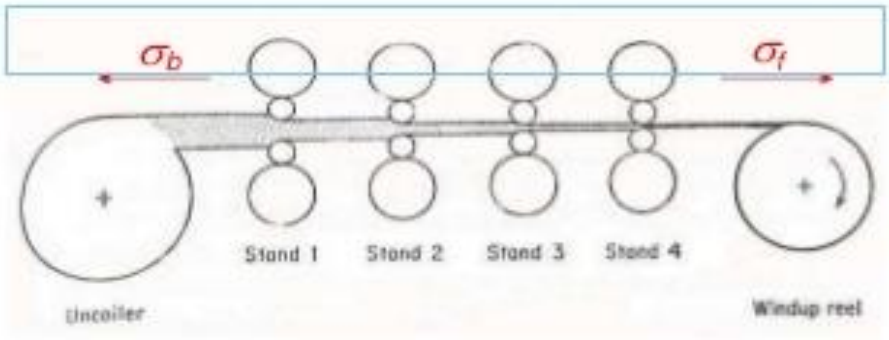
Aluminium Foil Making Process:

1) Aluminium is Smelted in a Refinery to get Auminium Slabs
2) Slabs are heated (above recrystallization temperature) and hot rolled to get intermediate thickness coils.3) These coils are slit to smaller width coils. 4) These coils are annealed. 5) Further these are cold rolled in 4 high rolling mill to get thin foils of required thickness in coil form.



Typical arrangement of rollers for rolling mills

Continuous rolling or tandem mil.

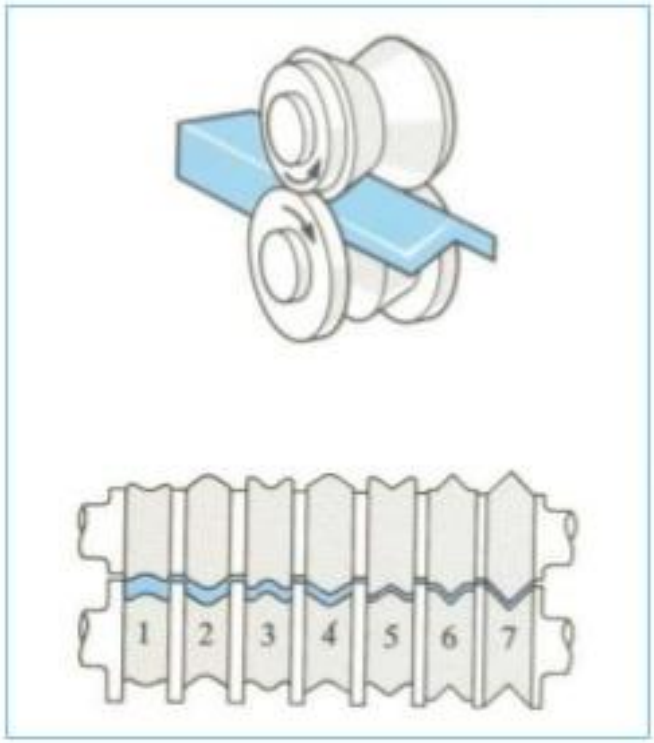


- Use a series of rolling mill and each set is called a *stand*.
- The strip will be moving at *different velocities* at each stage in the mill.

- The speed of each set of rolls is *synchronised* so that the input speed of each stand is equal to the output speed of preceding stand.

- The uncoiler and windup reel not only feed the stock into the rolls and coiling up the final product but also provide *back tension* and *front tension* to the strip.

Shaped rolling or section rolling



- A special type of cold rolling in which flat slap is progressively bent into *complex shapes* by passing it through a series of *driven rolls.*
- No appreciable change in the thickness of the metal during this process.
- Suitable for producing moulded sections such as irregular shaped channels and trim.

Rolled products

Rolling mill products which are most popular are:

Cold Rolled Sheet Steel –automobile body

Steel sheets – Corrugated sheets for roofing

Steel Sections – Railroad tracks

Wire Bars –(Pre-stressed concrete slabs/beams)in Construction

Cold Rolled Wires – Fencing, Nails, Bolts

(Cold drawn) Cable wires – Copper conductors.

Cold Rolled Sheet- Stainless Steel utensils

Products made by Rolling:

Final shape is achieved by use of “Shaped Rolls” Typical application is “Rails” for Traction; Angles for construction.

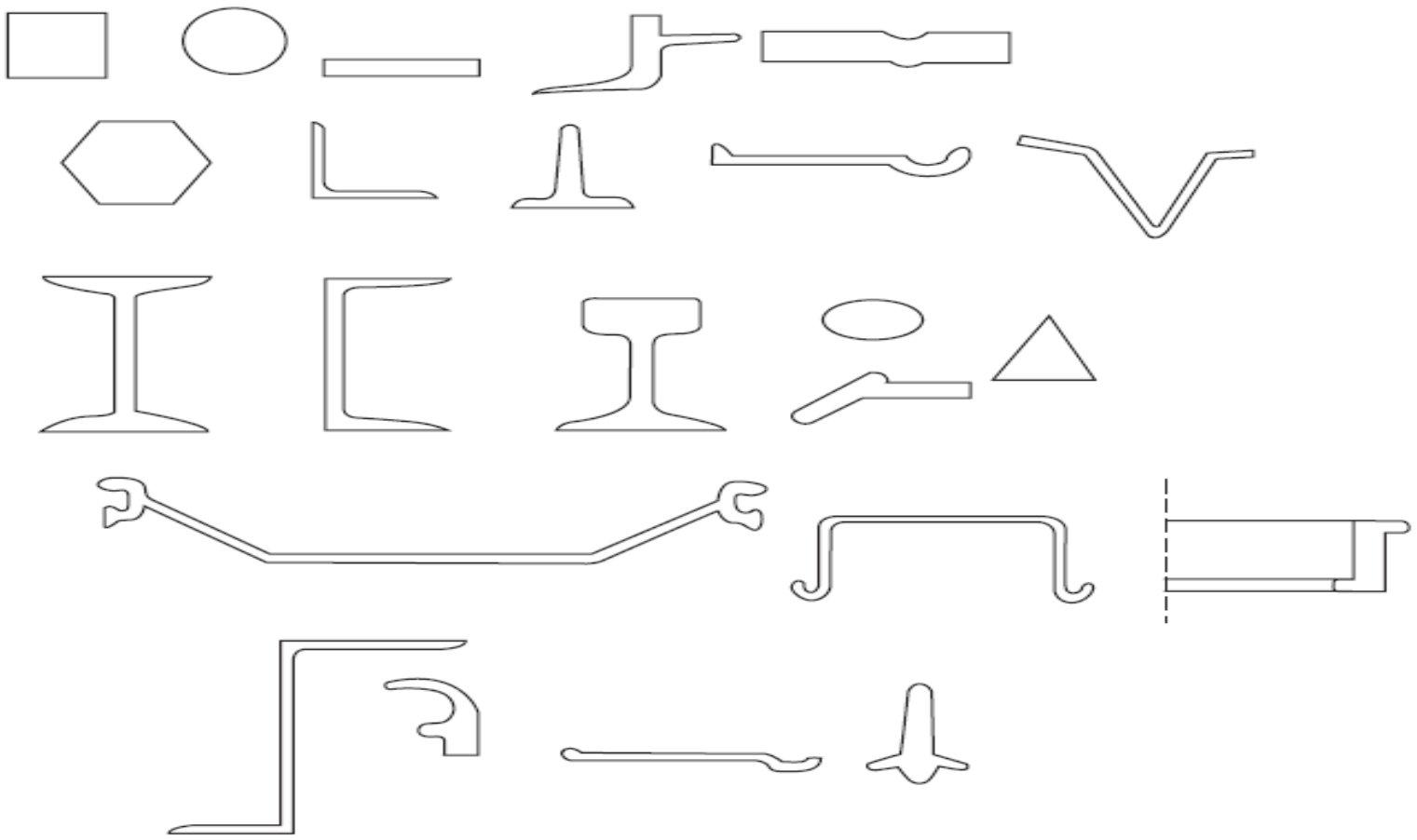


Fig. 7.6 *Typical rolling shapes*

Rolling Defects

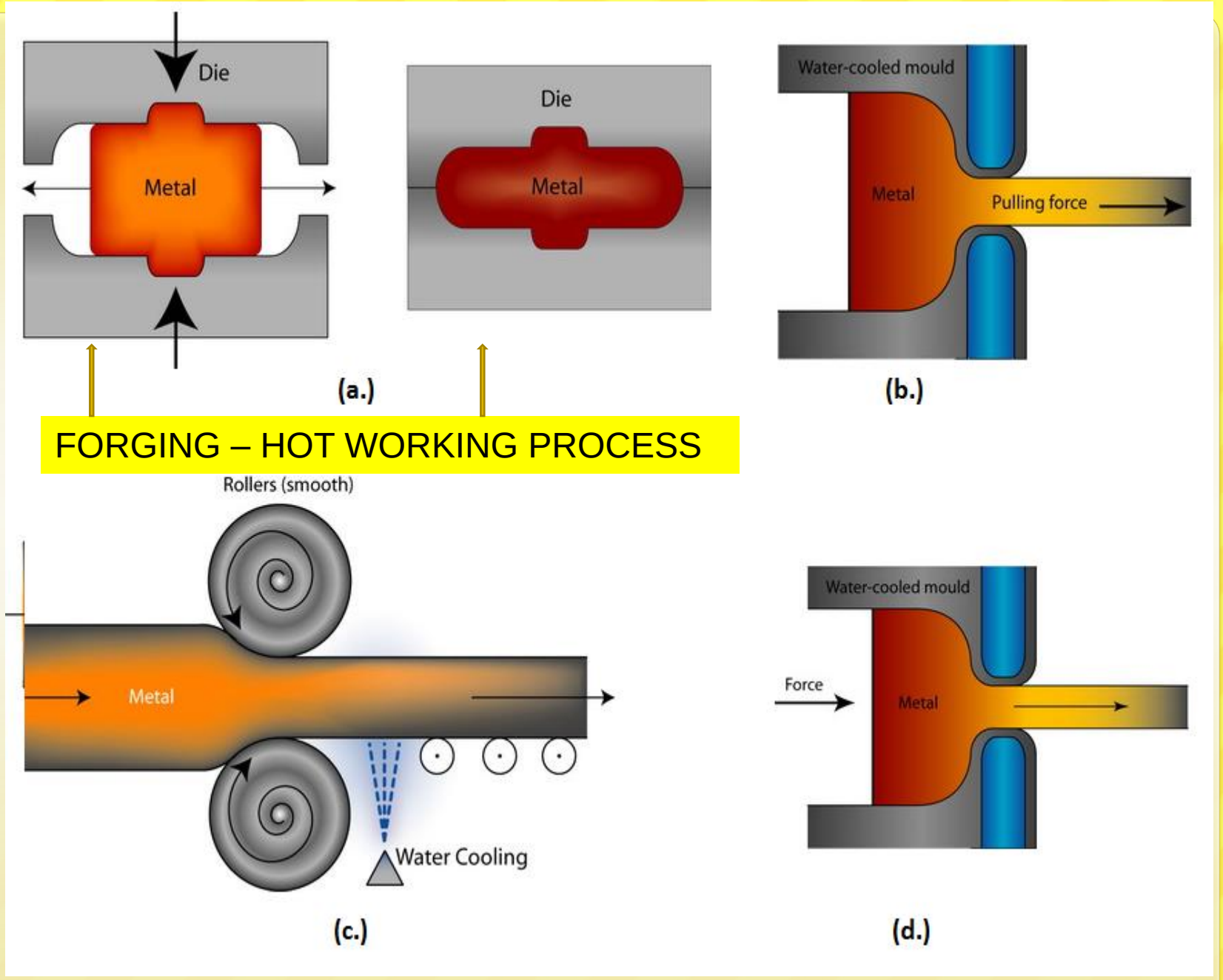
Surface defects

- Lap
- Mill-shearing
- Rolled-in Scale
- Scabs
- Seams
- Silvers

Rolling Defects

Structural defects

- Wavy edges
- Zipper cracks
- Edge cracks
- Laminations



Forging

- Forging is the operation where the metal is heated and then a force is applied to manipulate the metal in such a way that the required final shape is obtained.
- Forging is generally a hot working operation though cold forging is used sometimes.

Forging -Advantages

- Forging provides better mechanical properties, d**uctility** and **fatigue** and impact resistance because this process refines and directs the grain flow according to the shape of the piece. Almost all metals—ferrous and non-ferrous— can be forged. Any kind of steel can be used: carbon, alloy, stainless or superalloy
- Another advantage is the possibility of selective forging to obtain required properties wherever needed

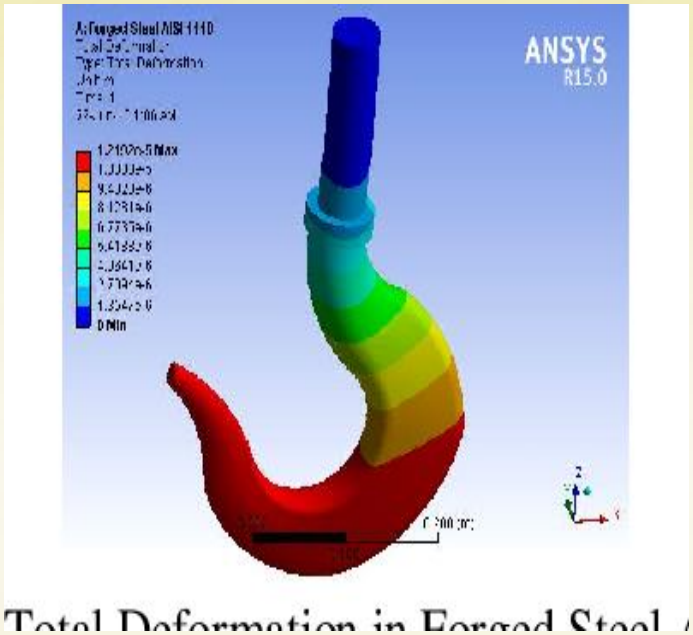
Forging Operations

- **Drawing out:** This is the operation in which the metal gets elongated with a reduction in the cross-sectional area.
  - Force is to be applied in a direction, perpendicular to the length axis.
- **Upsetting:** This is applied to increase the cross-sectional area of the stock at the expense of its length.
  - Force is applied in a direction parallel to the length axis. (Example: Bolts, Rivets)

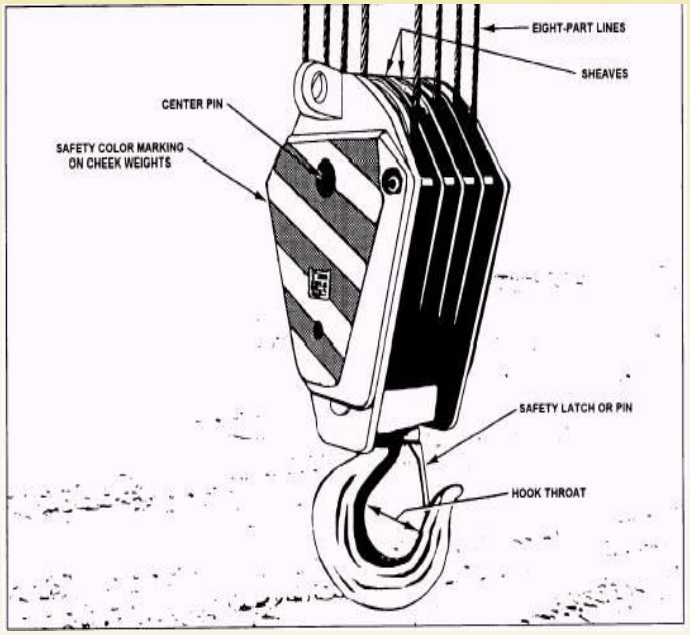
Forging

- Because of the manipulative ability of the forging process, it is possible to closely control the grain flow in the specific direction, such that best mechanical properties can be obtained based on the specific application.
- (example: Hook of Crane)

FORGED HOOK: stress analysis



Total Deformation in Forged Steel



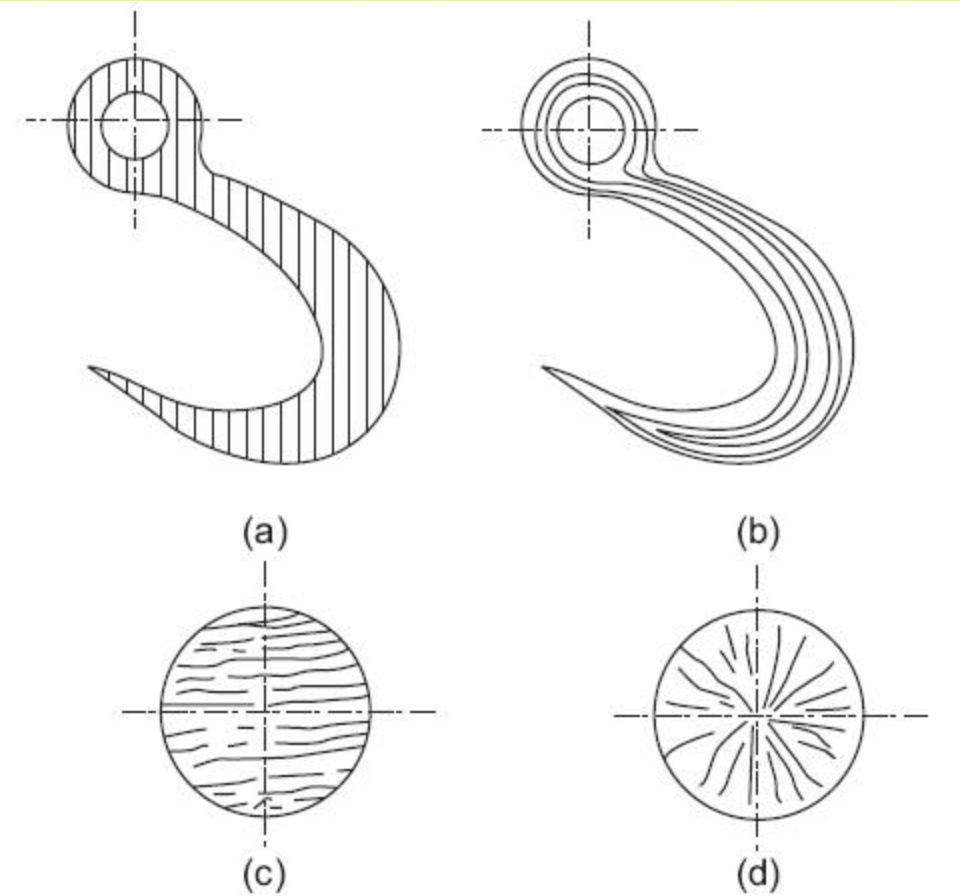


Fig. 7.18 *Grain flow directions obtained in forging*

Forging Types

- **Smith forging** This is the traditional forging operation done openly or in open dies by the village black smith or modern shop floor by manual hammering or by power hammers.
- **Drop forging** This is the operation done in closed impression dies by means of the drop hammers. Here the force for shaping the component is applied in a series of blows.

Forging Types

- **Press forging** Similar to drop forging, the press forging is also done in closed impression dies with the exception that the force is a continuous squeezing type applied by the hydraulic presses.
- **Machine forging** Unlike the drop or press forging where the material is drawn out, in machine forging, the material is only upset to get the desired shape.

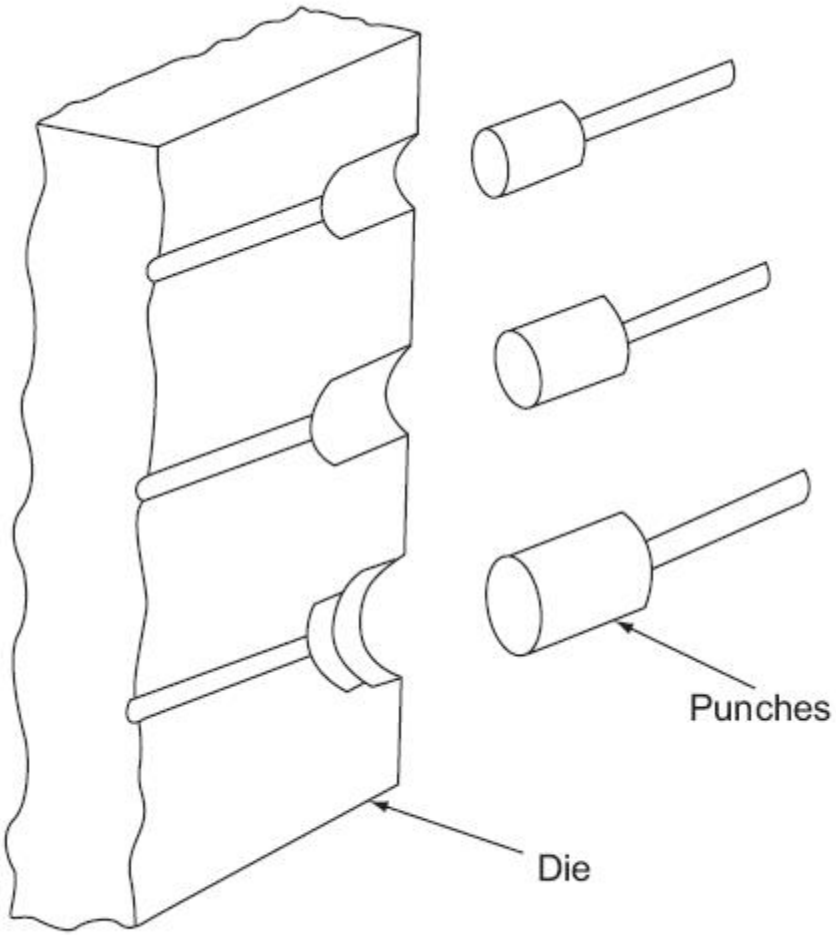
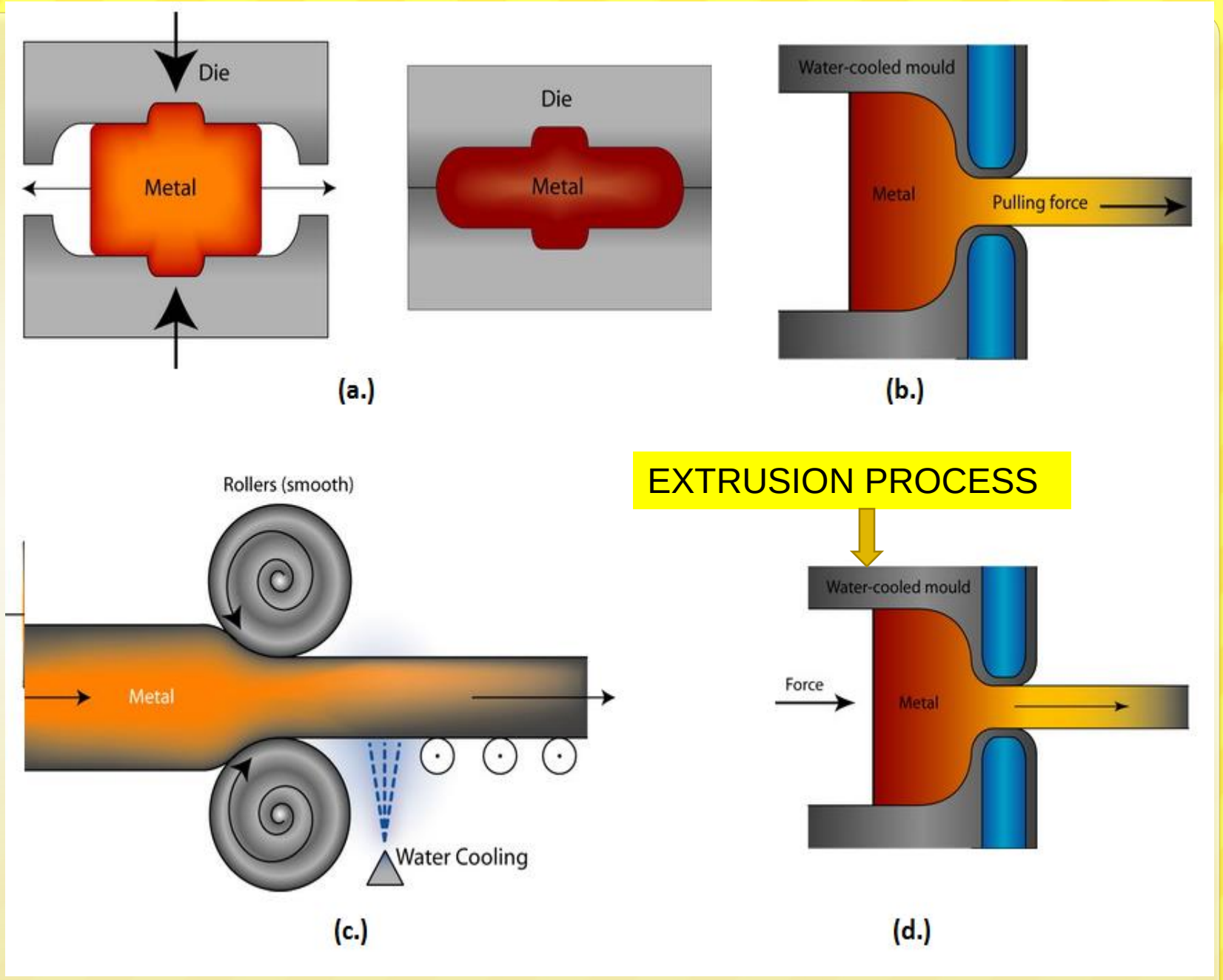


Fig. 7.22 *Upsetting die*

Compare Rolling & Forging

- Forging is a hammering process either by hammer and anvil or in a large forging tool call a drop hammer.
- Rolling involves passing metal between rollers to reduce its thickness to a specific size. Rolling can be done hot or cold with the cold process usually toughening or hardening the metal, also called work hardening. Such a flat surface cannot be obtained in Forging.



Extrusion

- Extrusion is the process of confining the metal in a closed cavity and then pushing it to flow from only one opening so that the metal will take the shape of the opening.
- The operation is identical to the squeezing of tooth paste out of the tooth paste tube.

Extrusion Principle

- The equipment consists of a cylinder or container into which the heated metal billet is loaded.
- On one end of the container, the die plate with the necessary opening is fixed.
- From the other end, a plunger or ram compresses the metal billet against the container walls and the die plate, thus forcing it to flow through the die opening, acquiring the shape of the opening.
- The extruded metal is then carried by the metal handling system as it comes out of the die.

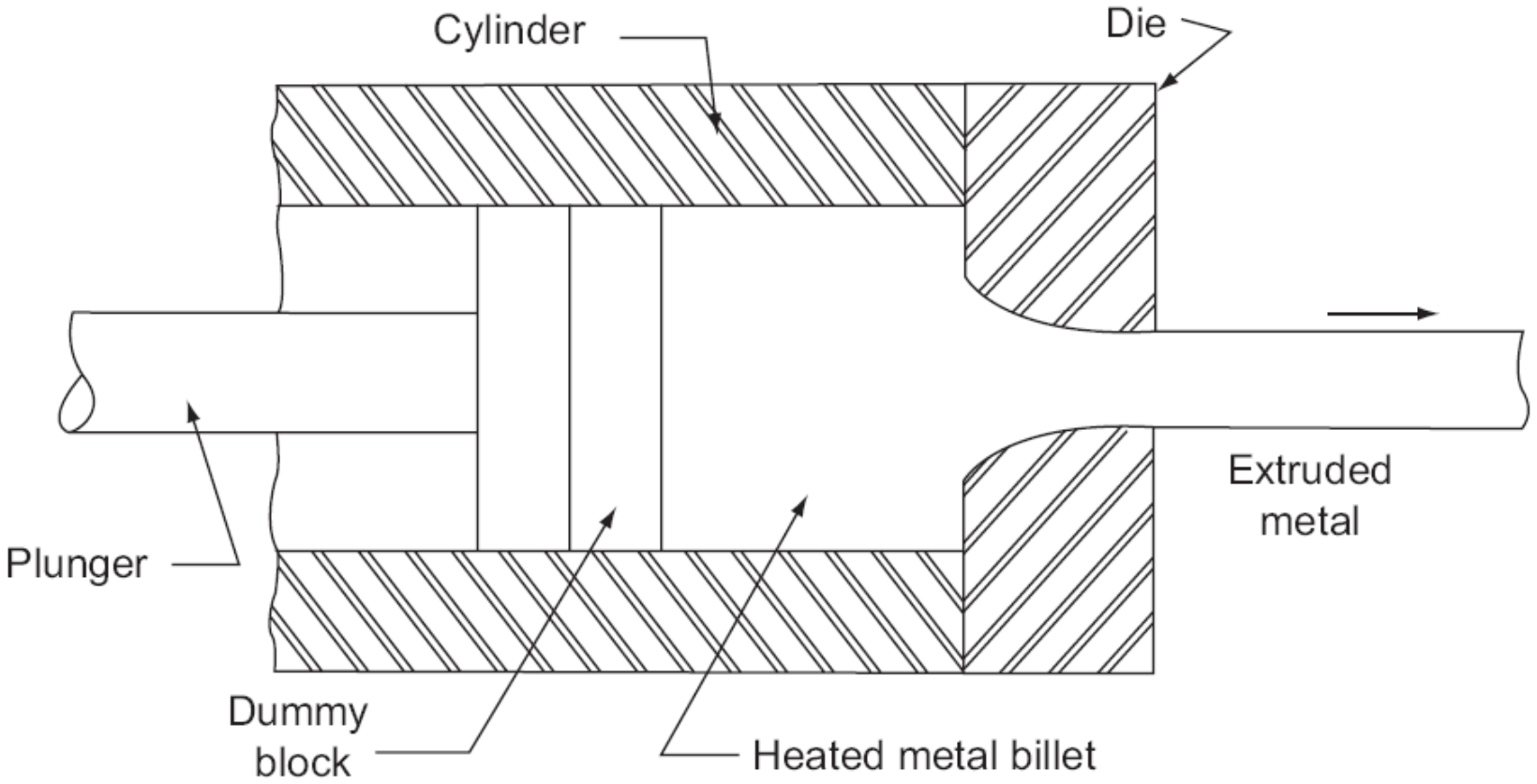


Fig. 7.48 *Typical extrusion set up*

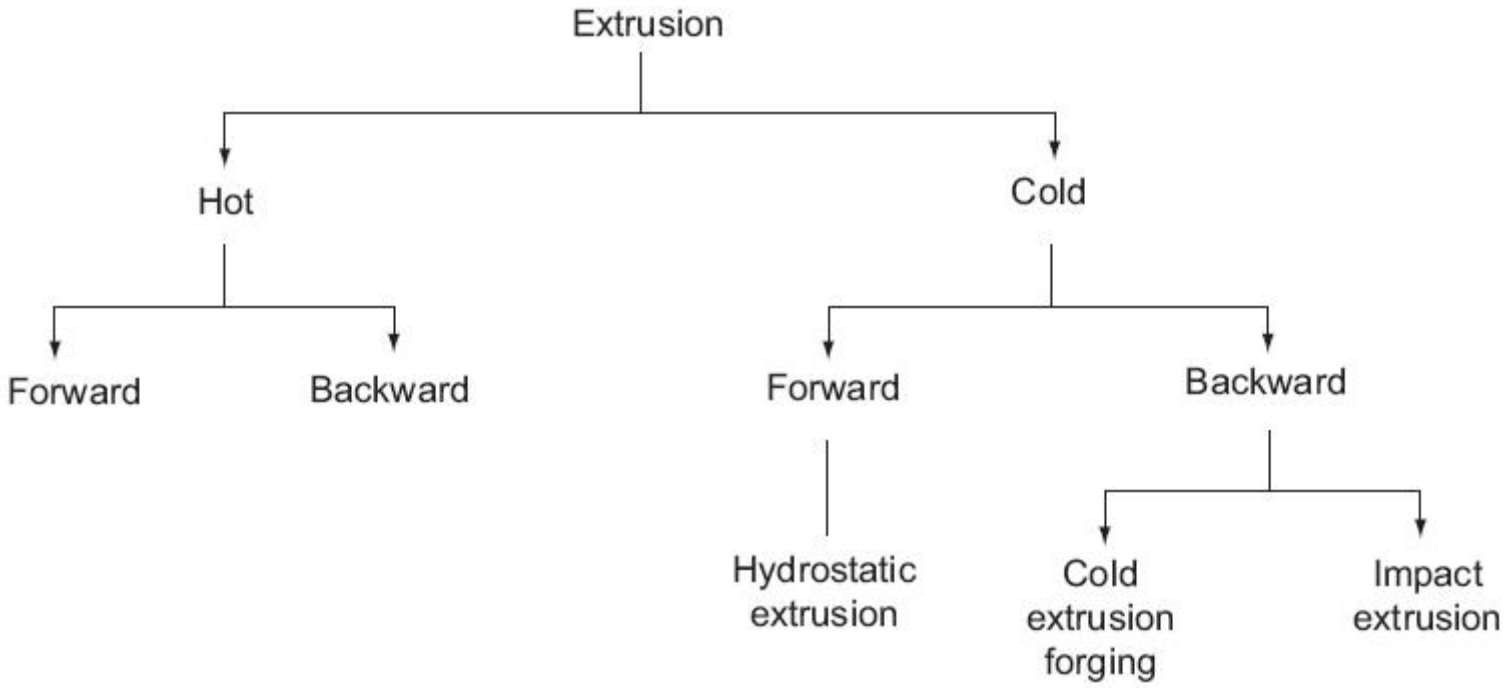


Fig. 7.51 *Classification of extrusion processes*

Summary

- Rolling is a method of producing constant cross section by passing the metal through cylindrical rolls. This is an economical process for producing structural shapes, and by far the largest tonnage of metal is produced using rolling processes
- Forging ensures directional properties be obtained by controlling the fibre flow directions. As a result many engineering components that are required to withstand heavy forces are produced using forging process.
- Extrusion is similar to rolling in producing constant cross-section shapes. However extrusion allows the production of complex shapes by using minimum number of passes.