



**COURSE: MANUFACTURING PROCESSES
CODE: AMEB05**

**Institute of Aeronautical Engineering
(Autonomous)
Dundigal, Hyderabad – 500 043**

**Prepared by
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9/23/2020

COURSE OBJECTIVES:

The students will try to learn:

- 1. The Importance manufacturing sciences in the day-to-day life, and study the basic manufacturing processes and tools used.**
- 2. The knowledge in thermal, metallurgical aspects during casting and welding for defect free manufacturing components.**
- 3. Design features that make each of these manufacturing process both harder, easier, assess design and manufacturing features on real products**

MODULE-I



CASTING

9/23/2020

MODULE-I

COURSE OUTCOMES (COs):

At the end of the course students are able to:		
Course Outcomes		Knowledge Level (Bloom's Taxonomy)
CO1	Outline the steps involved in making a casting the desired pattern for automotive industry components cylinder heads, engine blocks etc.	Remember
CO2	Design the gating and riser system needed for casting requirements to achieve defect/error free components	Apply

MODULE-I

PROGRAM OUTCOMES (POs):

Program Outcomes (POs)		Strength	Proficiency Assessed by
PO 1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	CIE/Quiz/AAT
PO 2	Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	CIE/Quiz/AAT

THE MANUFACTURE OF A CASTING REQUIRES:

- (a) Preparation of a pattern**
- (b) Preparation of a mould with the help of the pattern**
- (c) Melting of metal or alloy in a furnace**
- (d) Pouring of molten metal into mould cavity**
- (e) Breaking the mould to retrieve the casting**
- (f) Cleaning the casting and cutting off risers, runners etc.,
(this operation is called 'fettling')**
- (g) Inspection of casting.**

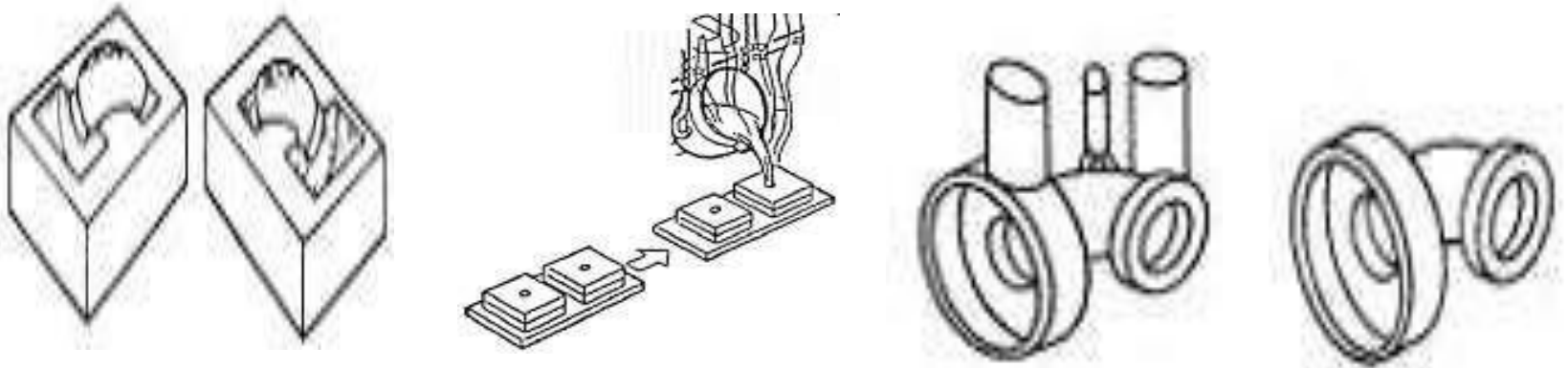
STEPS INVOLVED IN MAKING A CASTING

1. Making mould cavity
2. Material is first liquefied by properly heating it in a suitable furnace.
3. Liquid is poured into a prepared mould cavity - allowed to solidify
4. product is taken out of the mould cavity, trimmed and made to shape.

We should concentrate on the following for successful casting operation:

- (i) Preparation of moulds of patterns
- (ii) Melting and pouring of the liquefied metal
- (iii) Solidification and further cooling to room temperature
- (iv) Defects and inspection

STEPS INVOLVED IN MAKING A CASTING



Refractory mold → pour liquid metal → solidify ,remove → finish

- **VERSATILE:** complex geometry, internal cavities, hollow sections
- **VERSATILE:** small (~10 grams) ☐ very large parts (~1000 Kg)
- **ECONOMICAL:** little wastage (extra metal is re-used)
- **ISOTROPIC:** cast parts have same properties along all directions

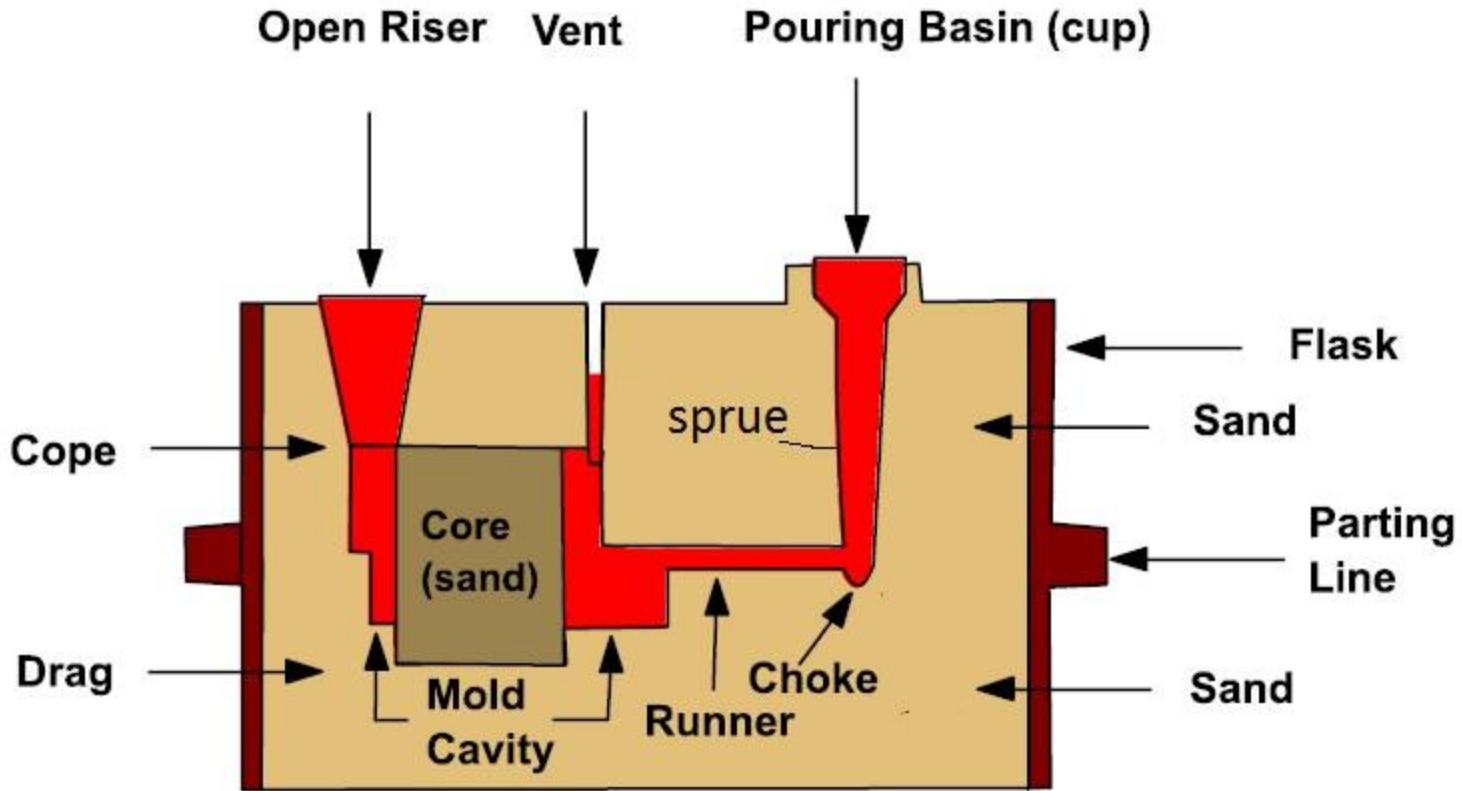
ADVANTAGES

- 1. Molten material can flow into very small sections so that intricate shapes can be made by this process. As a result, many other operations, such as machining, forging, and welding, can be minimized.**
- 2. Possible to cast practically any material: ferrous or non-ferrous.**
- 3. The necessary tools required for casting moulds are very simple and inexpensive. As a result, for production of a small lot, it is the ideal process.**
- 4. There are certain parts (like turbine blades) made from metals and alloys that can only be processed this way. Turbine blades: Fully casting + last machining.**
- 5. Size and weight of the product is not a limitation for the casting process.**

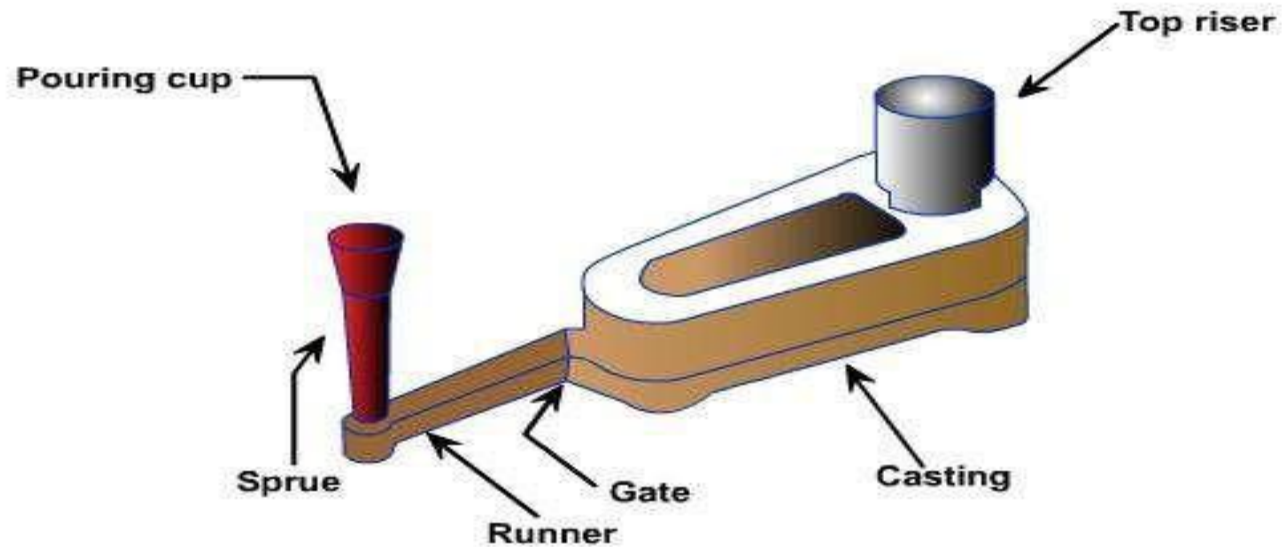
- 1. Dimensional accuracy and surface finish of the castings made by sand casting processes are a limitation to this technique.**
- 2. Many new casting processes have been developed which can take into consideration the aspects of dimensional accuracy and surface finish. Some of these processes are die casting process, investment casting process, vacuum-sealed moulding process, and shell moulding process.**
- 3. Metal casting is a labour intensive process**

1. **Transport : Automobile, aerospace, railways and shipping**
2. **Heavy Equipment : Construction, farming and mining**
3. **Machine Tools : Machining, casting, plastics molding, forging, extrusion and forming**
4. **Plant Machinery : Chemical, petroleum, paper, sugar, textile, steel and thermal plants**
5. **Defense : Vehicles, artillery, munitions, storage and supporting equipment**
6. **Electrical Equipment Machines : Motors, generators, pumps and compressors**
7. **Hardware : Plumbing industry pipes, joints, valves and fittings**
8. **Household : Appliances, kitchen and gardening equipment, furniture and fittings**
9. **Art Objects : Sculptures, idols, furniture, lamp stands and decorative items.....**

TYPICAL SAND MOULD

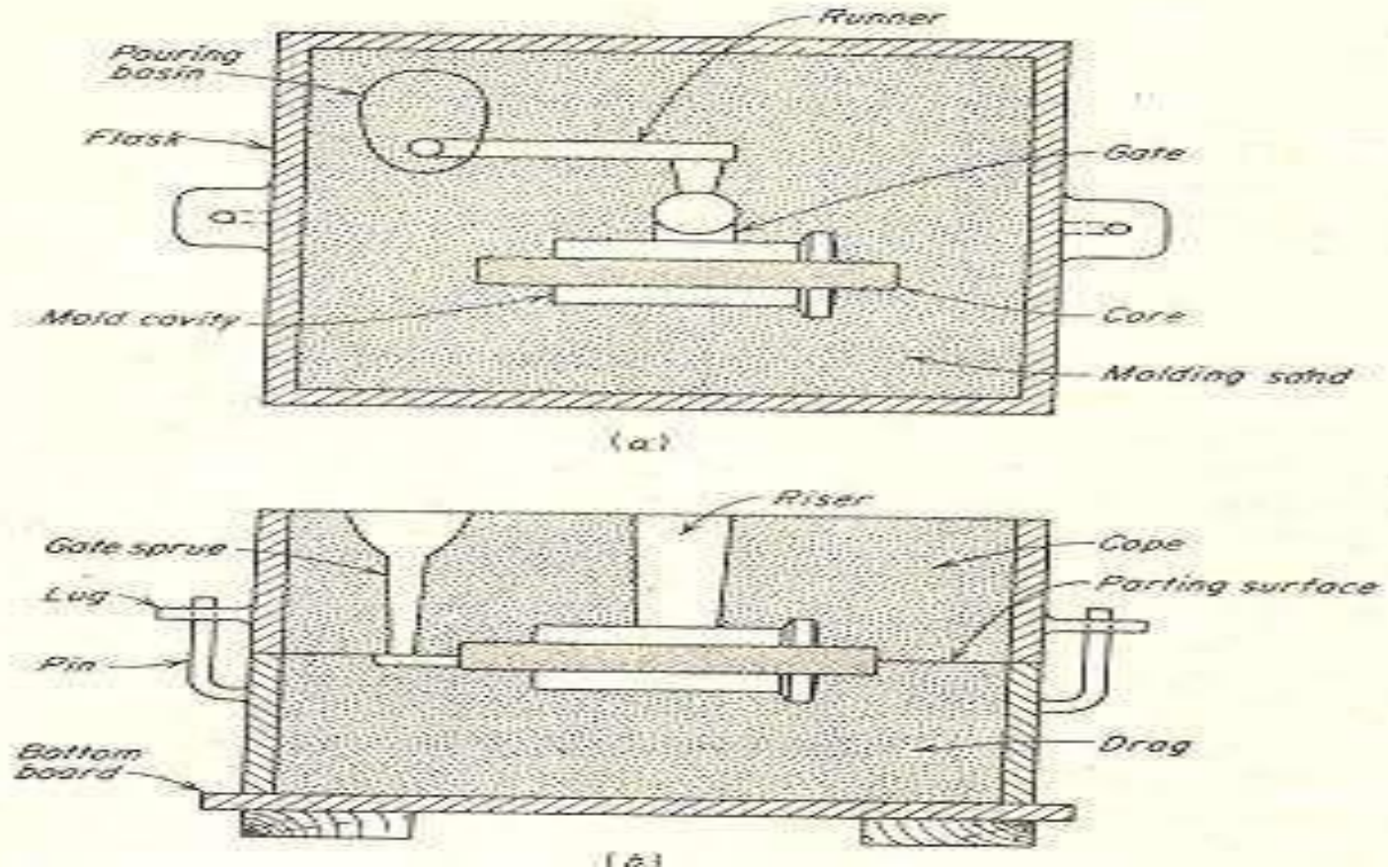


Mould Section And Casting Nomenclature



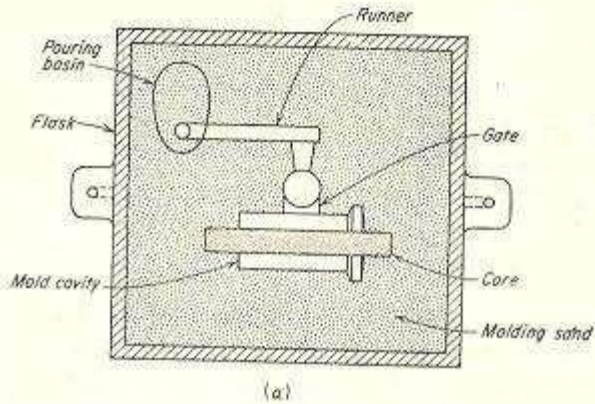
Pattern attached with Gating and Risering system

MOULD SECTION AND CASTING



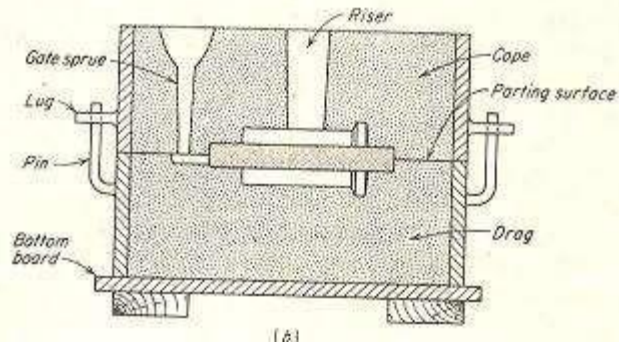
Mould Section and casting nomenclature, (a) top view, (b) front view

IMPORTANT CASTING TERMS



(a)

Flask: A metal or wood frame, without fixed top or bottom, in which the mould is formed. Depending upon the position of the flask in the moulding structure, it is referred to by various names such as drag – lower moulding flask, cope – upper moulding flask, cheek – intermediate moulding flask used in three piece moulding.



(b)

Pattern: It is the replica of the final object to be made. The mould cavity is made with the help of pattern.

Parting line: This is the dividing line between the two moulding flasks that makes

Core: A separate part of the mould, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.

Pouring basin: A small funnel shaped cavity at the top of the mould into which the molten metal is poured.

Sprue: The passage through which the molten metal, from the pouring basin, reaches the mould cavity. In many cases it controls the flow of metal into the mould.

Runner: The channel through which the molten metal is carried from the sprue to the gate.

Gate: A channel through which the molten metal enters the mould cavity.
Chaplets: Chaplets are used to support the cores inside the mould cavity to take care of its own weight and overcome the metallostatic force.

Riser: A column of molten metal placed in the mould to feed the castings as it shrinks and solidifies. Also known as “feed head”.

Vent: Small opening in the mould to facilitate escape of air and gases.

STEPS IN MAKING SAND CASTINGS

The six basic steps in making sand castings are

(i) Pattern making

(ii) Core making

(iii) Molding

(iv) Melting and pouring

(v) Cleaning

Pattern making - Pattern: Replica of the part to be cast and is used to prepare the mould cavity. It is the physical model of the casting used to make the mould. Made of either wood or metal. The mould is made by packing some readily formed aggregate material, such as moulding sand, surrounding the pattern. When the pattern is withdrawn, its imprint provides the mould cavity. This cavity is filled with metal to become the casting.

STEPS IN MAKING SAND CASTINGS

Core making: Cores are placed into a mould cavity to form the interior surfaces of castings. Thus the void space is filled with molten metal and eventually becomes the casting.

Moulding: Moulding is nothing but the mould preparation activities for receiving molten metal. Moulding usually involves: (i) preparing the consolidated sand mould around a pattern held within a supporting metal frame, (ii) removing the pattern to leave the mould cavity with cores.

Melting and Pouring :The preparation of molten metal for casting is referred to simply as melting. The molten metal is transferred to the pouring area where the moulds are filled.

Cleaning: Cleaning involves removal of sand, scale, and excess metal from the casting. Burned-on sand and scale are removed to improved the surface appearance of the casting

PATTERN

A pattern is an element used for making cavities in the mould, into which molten metal is poured to produce a casting.

Requirements of a good pattern, and pattern allowances.

1. Secure the desired shape and size of the casting
2. Simple in design, for ease of manufacture
3. Cheap and readily available Light in mass and convenient to handle
4. Have high strength

PATTERN ALLOWANCES

The pattern and the part to be made are not same. They differ in the following aspects.

Pattern allowance: A pattern is always made larger than the final part to be made. The excess dimension is known as Pattern allowance.

Pattern allowance => shrinkage allowance, machining allowance **Shrinkage**

allowance: will take care of contractions of a casting which occurs as the metal cools to room temperature.

Liquid Shrinkage: Reduction in volume when the metal changes from liquid state to solid state. Riser which feed the liquid metal to the casting is provided in the mould to compensate for this.

Solid Shrinkage: Reduction in volume caused when metal loses temperature in solid state. Shrinkage allowance is provided on the patterns to account for this

PATTERN ALLOWANCES

Shrink rule is used to compensate solid shrinkage depending on the material contraction rate.

Cast iron: One foot (=12 inches) on the 1/8-in-per-foot shrink rule actually measures 12-1/8 inches.

1. So, 4 inch will be 4-1/24 inch for considering shrinkage allowance.

Material	Dimensions	Shrinkage allowance (inch/ft)
Grey Cast Iron	Up to 2 feet	0.125
	2 feet to 4 feet	0.105
	over 4 feet	0.083
Cast Steel	Up to 2 feet	0.251
	2 feet to 6 feet	0.191
	over 6 feet	0.155
Aluminum	Up to 4 feet	0.155
	4 feet to 6 feet	0.143
	over 6 feet	0.125
Magnesium	Up to 4 feet	0.173
	Over 4 feet	0.155

2. The shrinkage allowance depends on the coefficient of thermal expansion of the material (α). A simple relation indicates that higher the value of α , more is the shrinkage allowance.
3. For a dimension ' l ', shrinkage allowance is $\alpha l (\vartheta_f - \vartheta_0)$. Here ϑ_f is the freezing temperature and ϑ_0 is the room temperature.

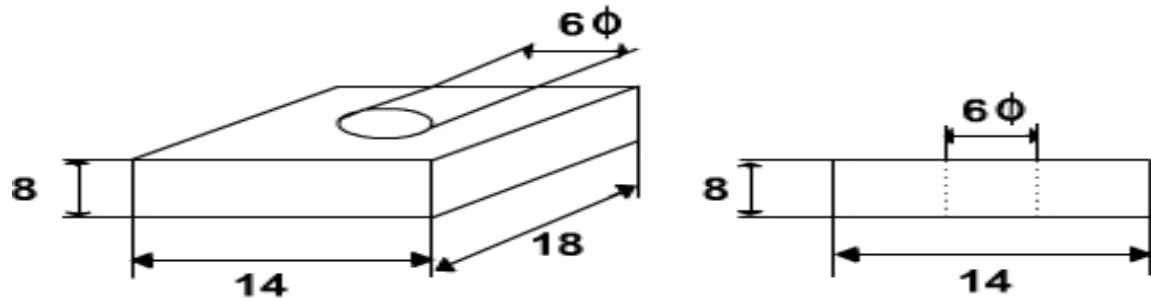
Machining allowance: will take care of the extra material that will be removed to obtain a finished product. In this the rough surface in the cast product will be removed. The machining allowance depends on the size of the casting, material properties, material distortion, finishing accuracy and machining method.

MACHINING ALLOWANCES OF VARIOUS METALS

Metal	Dimension (inch)	Allowance (inch)
Cast iron	Up to 12	0.12
	12 to 20	0.20
	20 to 40	0.25
Cast steel	Up to 6	0.12
	6 to 20	0.25
	20 to 40	0.30
Non ferrous	Up to 8	0.09
	8 to 12	0.12
	12 to 40	0.16

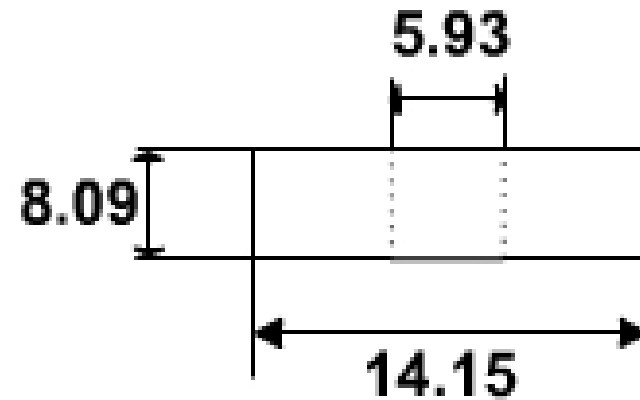
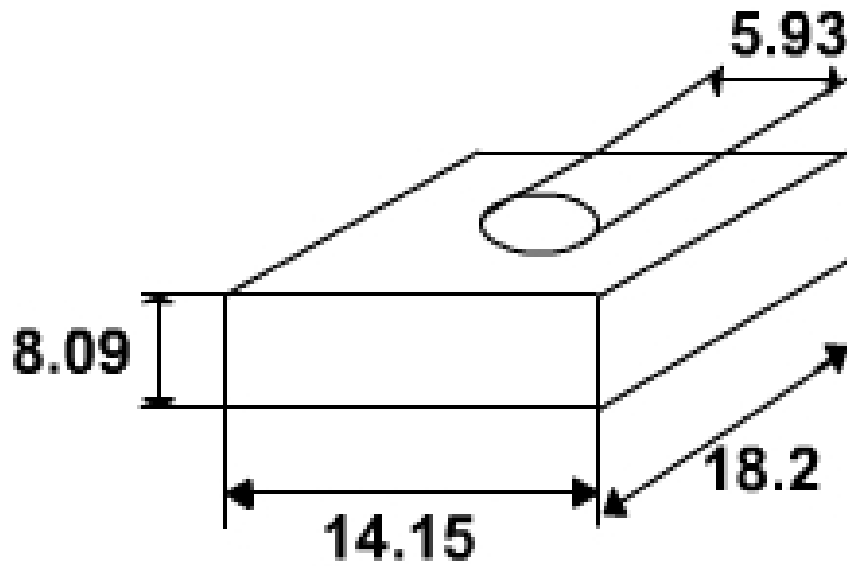
PATTERN ALLOWANCES: PROBLEM

EXAMPLE: The casting shown is to be made in CI using a wooden pattern. Assuming only shrinkage allowance, calculate the dimensions of the pattern. All dimensions are in inches



Material	Dimension	Shrinkage allowance (inch/ft)
Grey Cast Iron	Up to 2 feet	0.125
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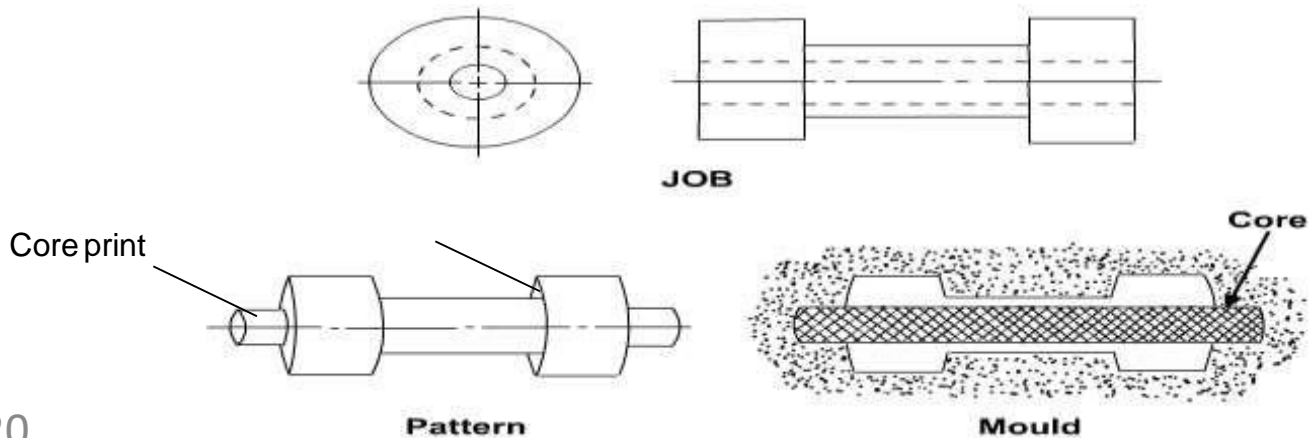
ANSWER



PATTERN ALLOWANCES

Core and core print

1. Cores are used to make holes, recesses etc. in castings
2. So where coring is required, provision should be made to support the core inside the mould cavity. Core prints are used to serve this purpose. The core print is an added projection on the pattern and it forms a seat in the mould on which the sand core rests during pouring of the mould.
3. The core print must be of adequate size and shape so that it can support the weight of the core during the casting operation.



Distortion allowance (camber)

1. Vertical edges will be curved or distorted
2. This is prevented by shaped pattern converge slightly (inward) so that the casting after distortion will have its sides vertical
3. The distortion in casting may occur due to internal stresses. These internal stresses are caused on account of unequal cooling of different sections of the casting and hindered contraction.

Prevention:

1. providing sufficient machining allowance to cover the distortion affect
2. Providing suitable allowance on the pattern, called camber or distortion allowance (inverse reflection)

PATTERN MATERIALS

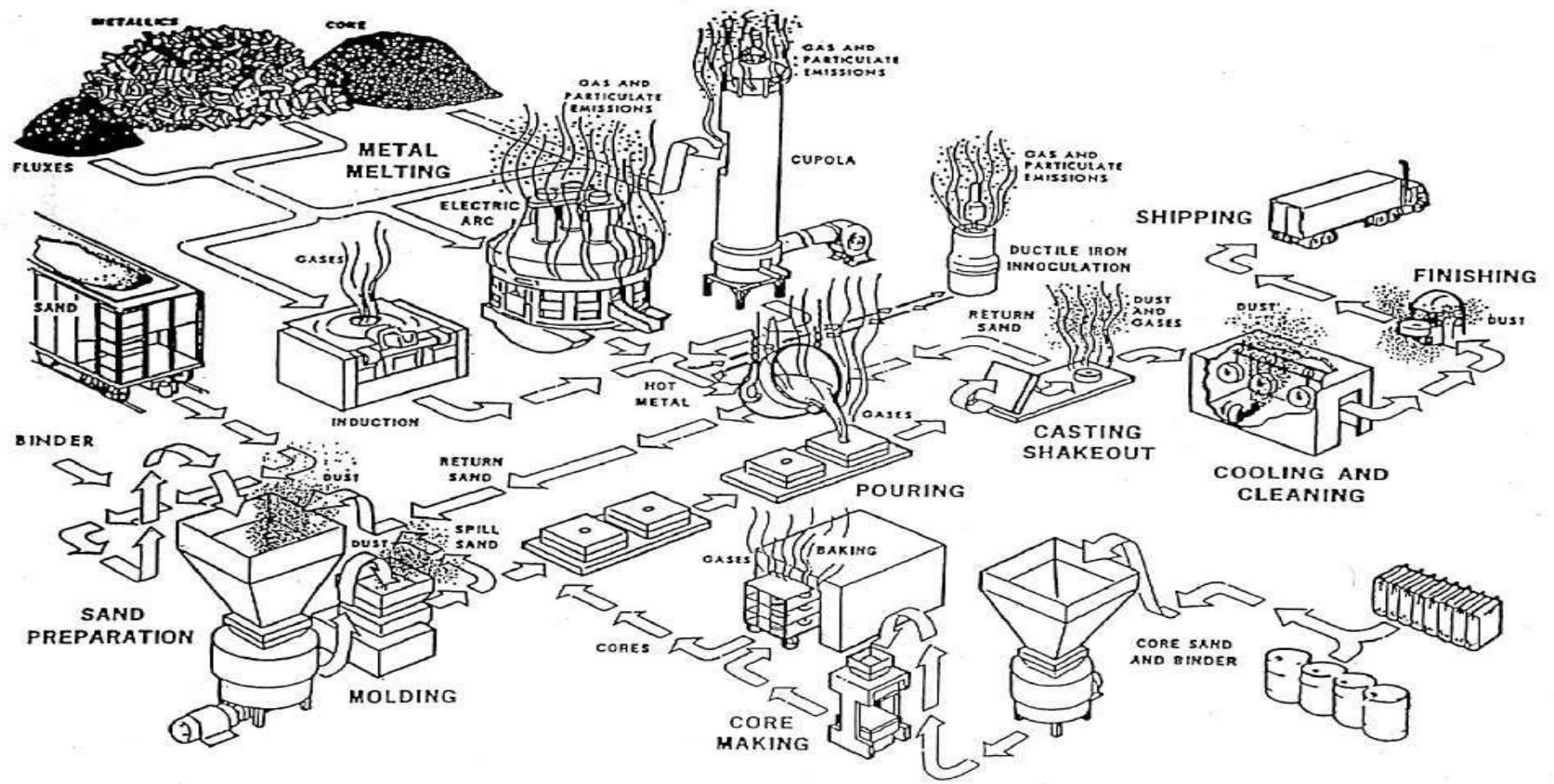
- 1. Patterns for sand castings are subjected to considerable wear and tear due**
- 2. to ramming action that is required and the abrasive action of the sand**
- 3. Should be impervious to moisture because of changing surroundings**
- 4. Made of: wood, metal, plastics, plaster and synthetic materials**
- 5. Woods => white pine, sugar pine; The wood should be straight grain, light,**
- 6. easy to work, little tendency to develop crack and warp.**
- 7. More durable: Mahogany**
- 8. For large castings: metal such as cast iron or aluminum**
- 9. When metal pattern are cast from the wooden master pattern, double shrinkage must be provided on the wooden master pattern**
- 10. Assume metal pattern is made of aluminum and castings are made of CI**

TYPES OF CASTING PROCESSES

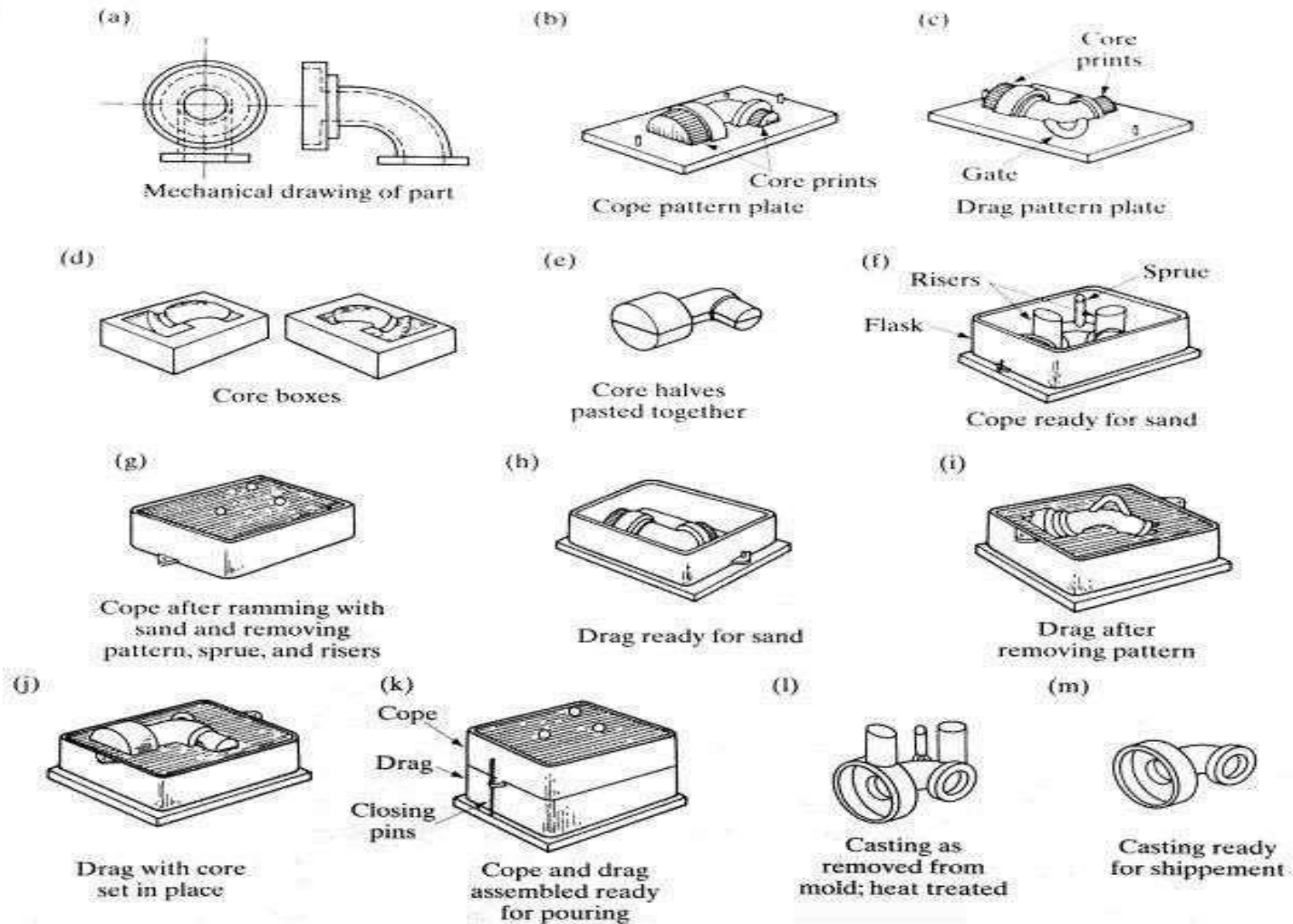
Process	Advantages	Disadvantages	Examples
Sand	many metals, sizes, shapes, cheap	poor finish & tolerance	engine blocks, cylinder heads
Shell mold	better accuracy, finish, higher production rate	limited part size	connecting rods, gear housings
Expendable pattern	Wide range of metals, sizes, shapes	patterns have low strength	cylinder heads, brake components
Plaster mold	complex shapes, good surface finish	non-ferrous metals, low production rate	prototypes of mechanical parts
Ceramic mold	complex shapes, high accuracy, good finish	small sizes	impellers, injection mold tooling
Investment	complex shapes, excellent finish	small parts, expensive	jewellery
Permanent mold	good finish, low porosity, high production rate	Costly mold, simpler shapes only	gears, gear housings
Die	Excellent dimensional accuracy, high production rate	costly dies, small parts, non-ferrous metals	gears, camera bodies, car wheels
Centrifugal	Large cylindrical parts, good quality	Expensive, few shapes	pipes, boilers, flywheels

TYPES OF CASTING PROCESSES

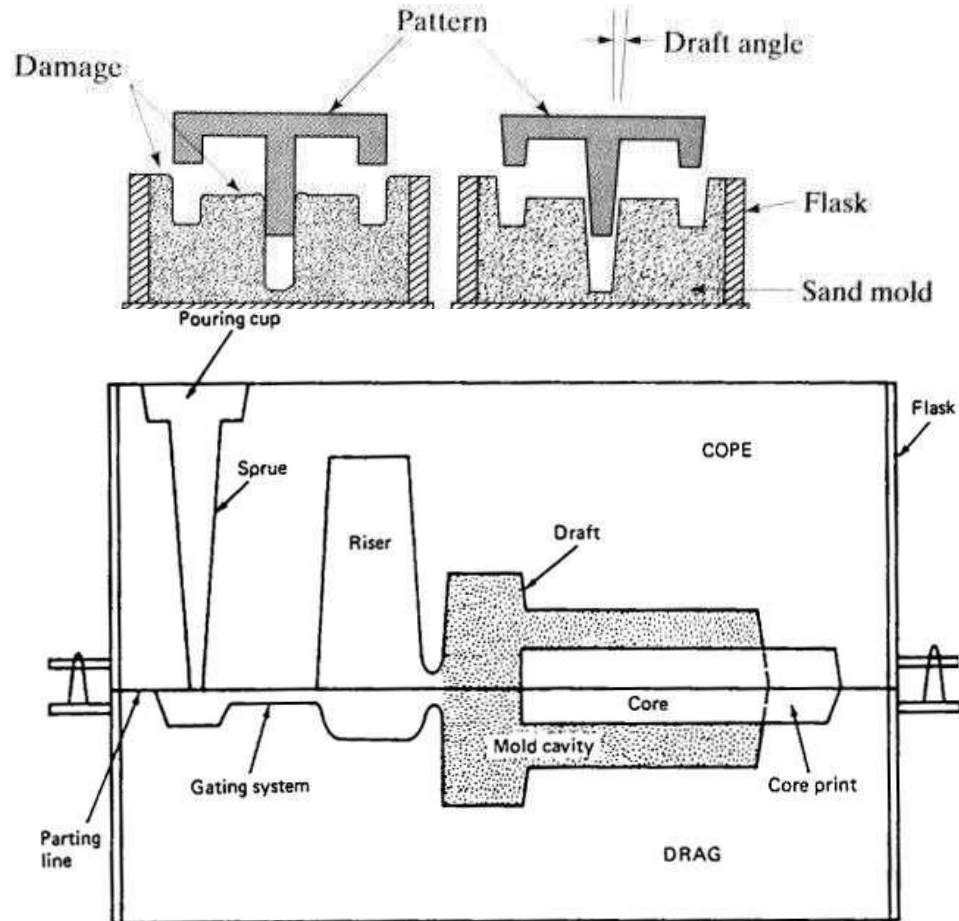
Sand Casting



TYPES OF CASTING PROCESSES

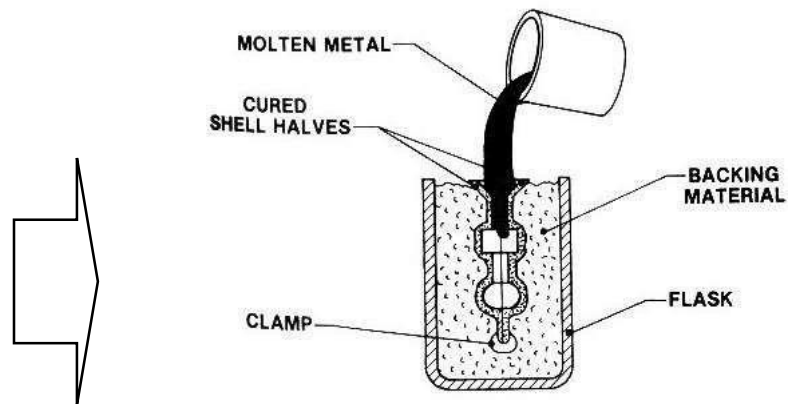
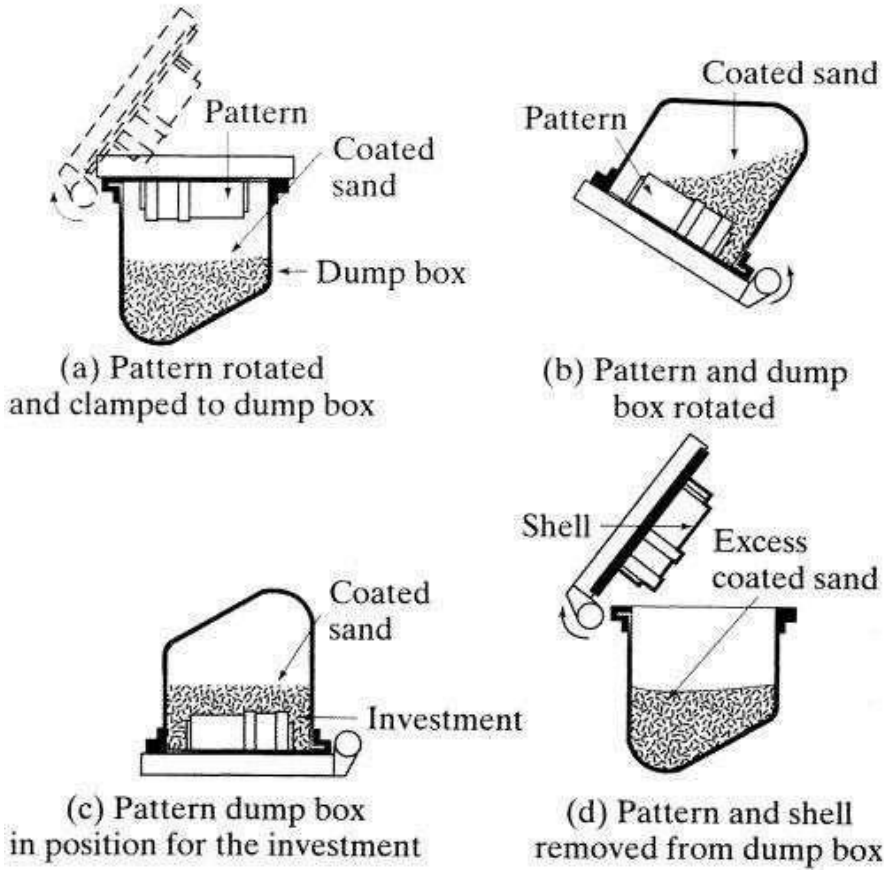


TYPES OF CASTING PROCESSES



TYPES OF CASTING PROCESSES

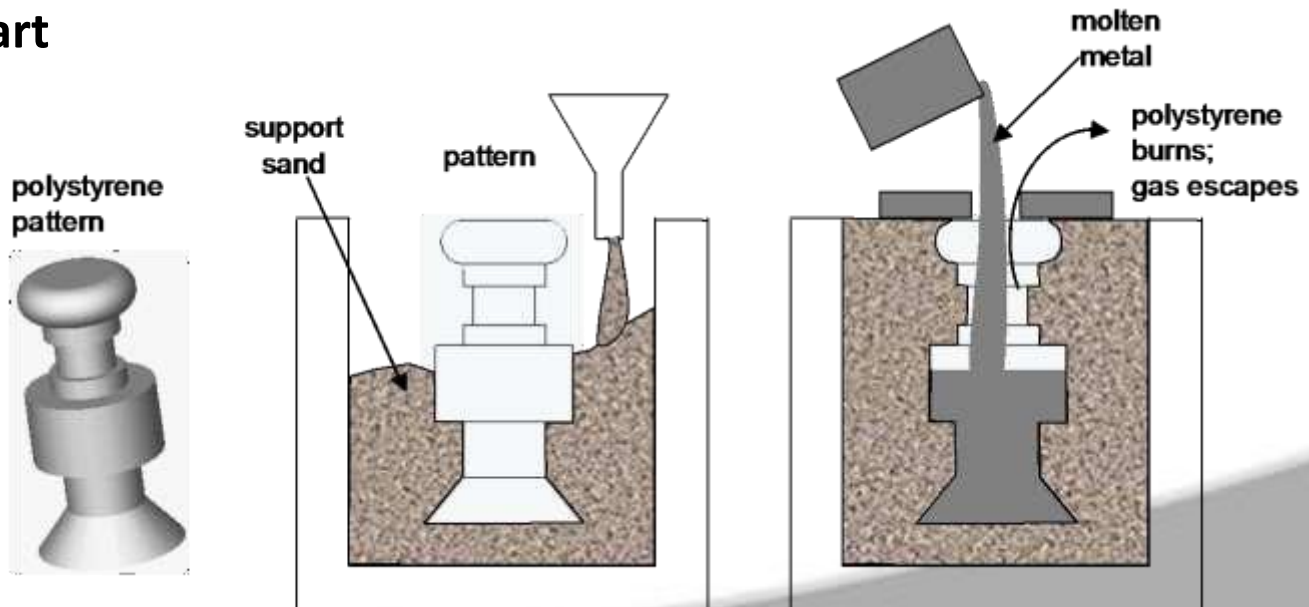
Shell mold casting



TYPES OF CASTING PROCESSES

Expendable Mold Casting

- Styrofoam pattern
- dipped in refractory slurry & dried
- sand (support)
- pour liquid metal
- foam evaporates, metal fills the shell
- cool, solidify
- break shell part



TYPES OF CASTING PROCESSES

Plaster-mold, Ceramic-mold casting

Plaster-mold slurry: *plaster of Paris* (CaSO_4), talc, silica flour

Ceramic-mold slurry: silica, powdered Zircon (ZrSiO_4)

- The slurry forms a shell over the pattern
- Dried in a low temperature oven
- Remove pattern
- Backed by clay (strength), baked (burn-off volatiles)
- cast the metal
- break mold → part

good finish (Why ?)

Plaster-mold:

plaster: low conductivity => low war page, residual stress

low mp metal (Zn, Al, Cu, Mg)

Ceramic-mold:

good finish

high mp metals (steel, ...) => impeller blades, turbines, ...

MODULE-II



WELDING

MODULE-II

COURSE OUTCOMES (COs):

At the end of the course students are able to:		
Course Outcomes		Knowledge Level (Bloom's Taxonomy)
CO3	Categorize various defects and shortcomings during gas welding operation such as TIG, MIG and Spot welding etc. for real time applications.	Understand
CO4	Illustrate the properties and bonding techniques of plastics and various plastic molding techniques.	Understand

MODULE-II

PROGRAM OUTCOMES (POs):

Program Outcomes (POs)		Strength	Proficiency Assessed by
PO 1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	CIE/Quiz/AAT
PO 2	Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	CIE/Quiz/AAT

Welding is defined as an localized coalescence of metals, where in coalescence is obtained by heating to suitable temperature, with or without the application of pressure and with or without the use of filler metal.

OR

Welding is a process of joining similar metals by application of heat with or without application of pressure and addition of filler material

CLASSIFIATION OF WELDING PROCESSES

Welding process can be classified into different categories depending upon the following criteria :

(a)It can be classified as fusion welding or pressure welding depending upon on the application of heat. If application of heat is not required, it is called pressure welding.

(b)In case of fusion welding it can classified low temperature welding and high temperature welding. When heat is generated to develop low temperature it is called low temperature welding like soldering and brazing. Other fusion welding methods are high temperature welding methods.

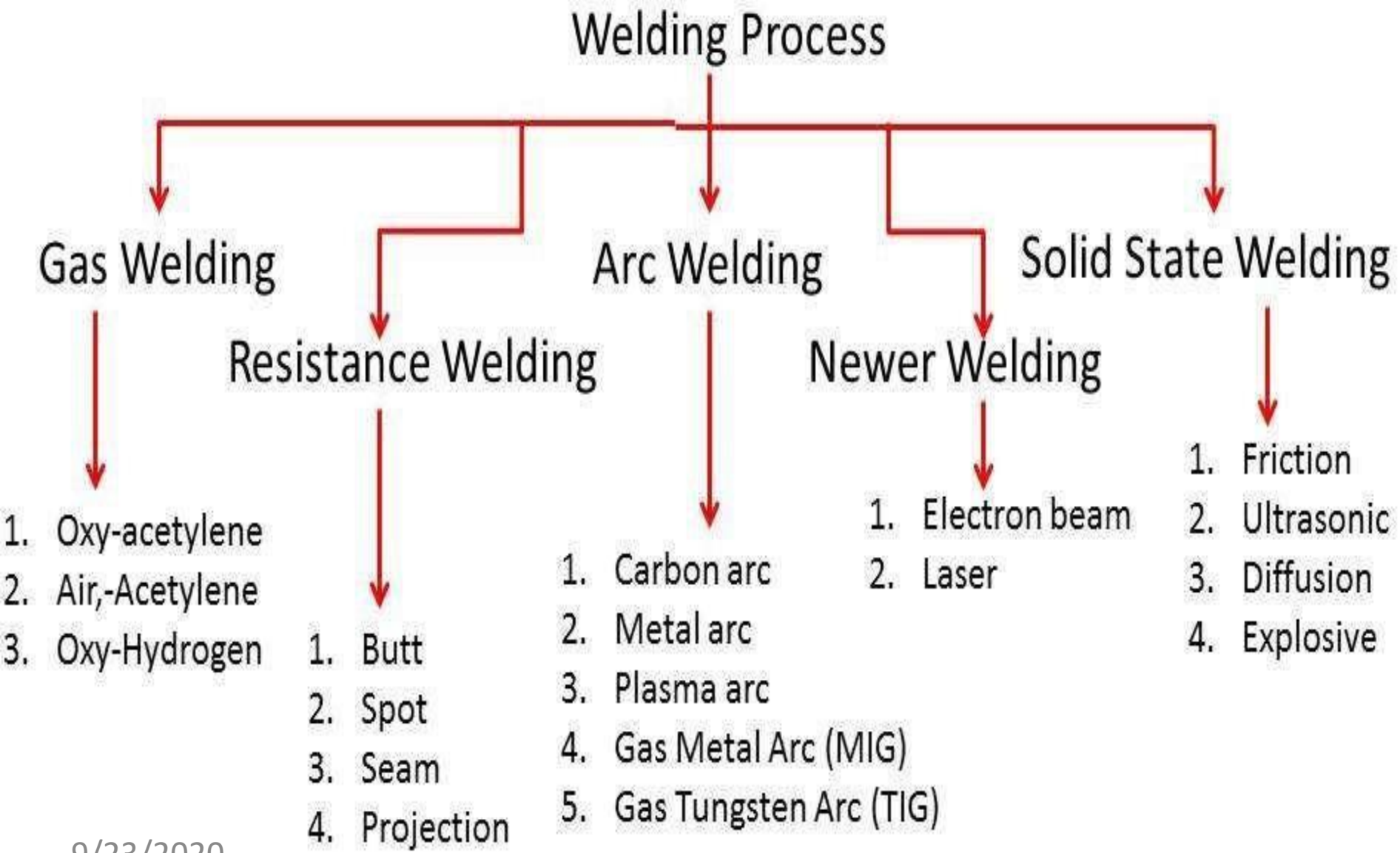
(c)Fusion welding can also be classified on the basis of method of heat generation like gas welding, electric arc welding, resistance welding, thermit welding, etc.

CLASSIFIATION OF WELDING PROCESSES

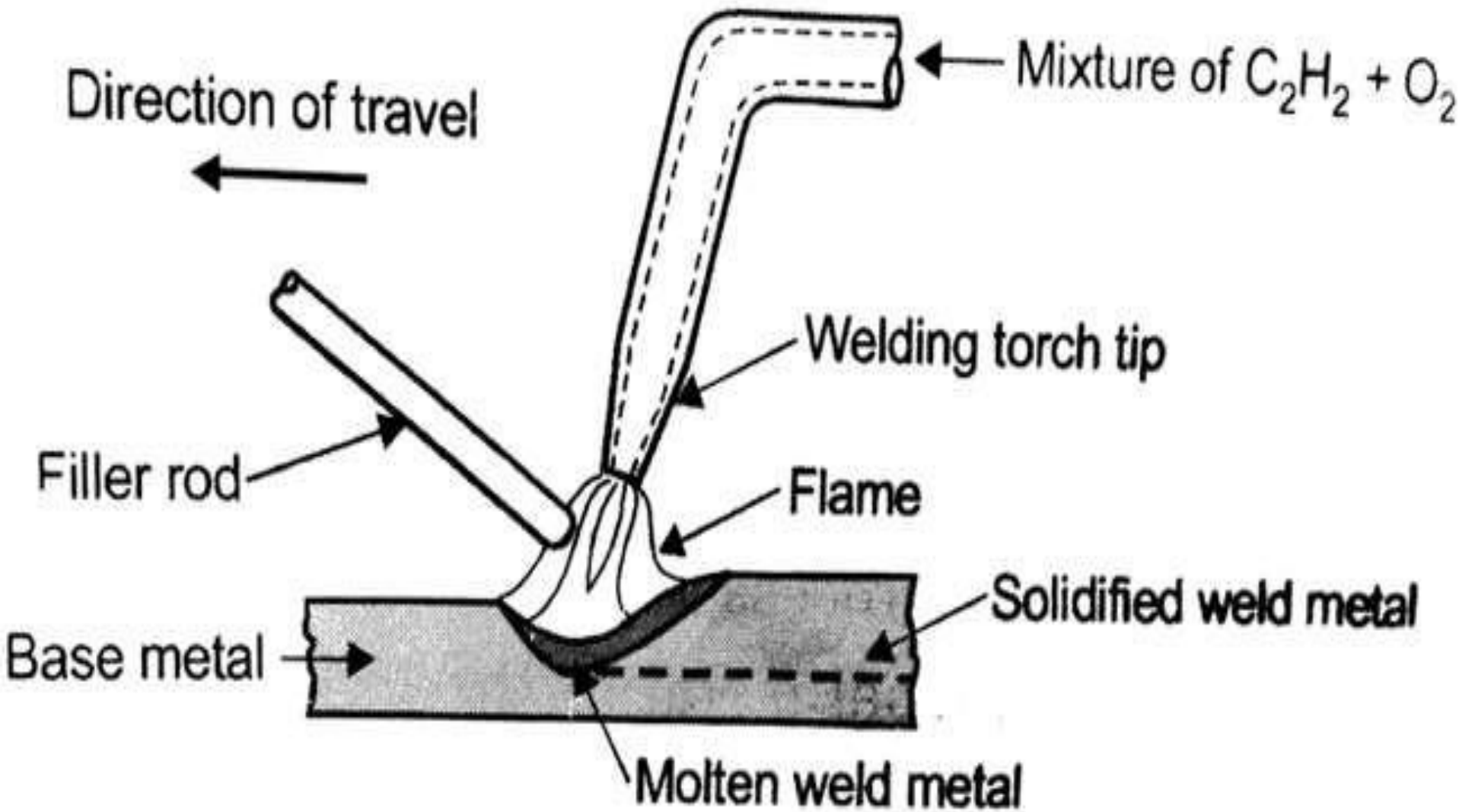
(d) On the basis of the type of joint produced it can be categorized as butt welding, seam welding, spot welding, lap joint welding, etc.

Each of the above type of welding can be further classified depending on other micro level characteristics

CLASSIFICATION OF WELDING PROCESSES



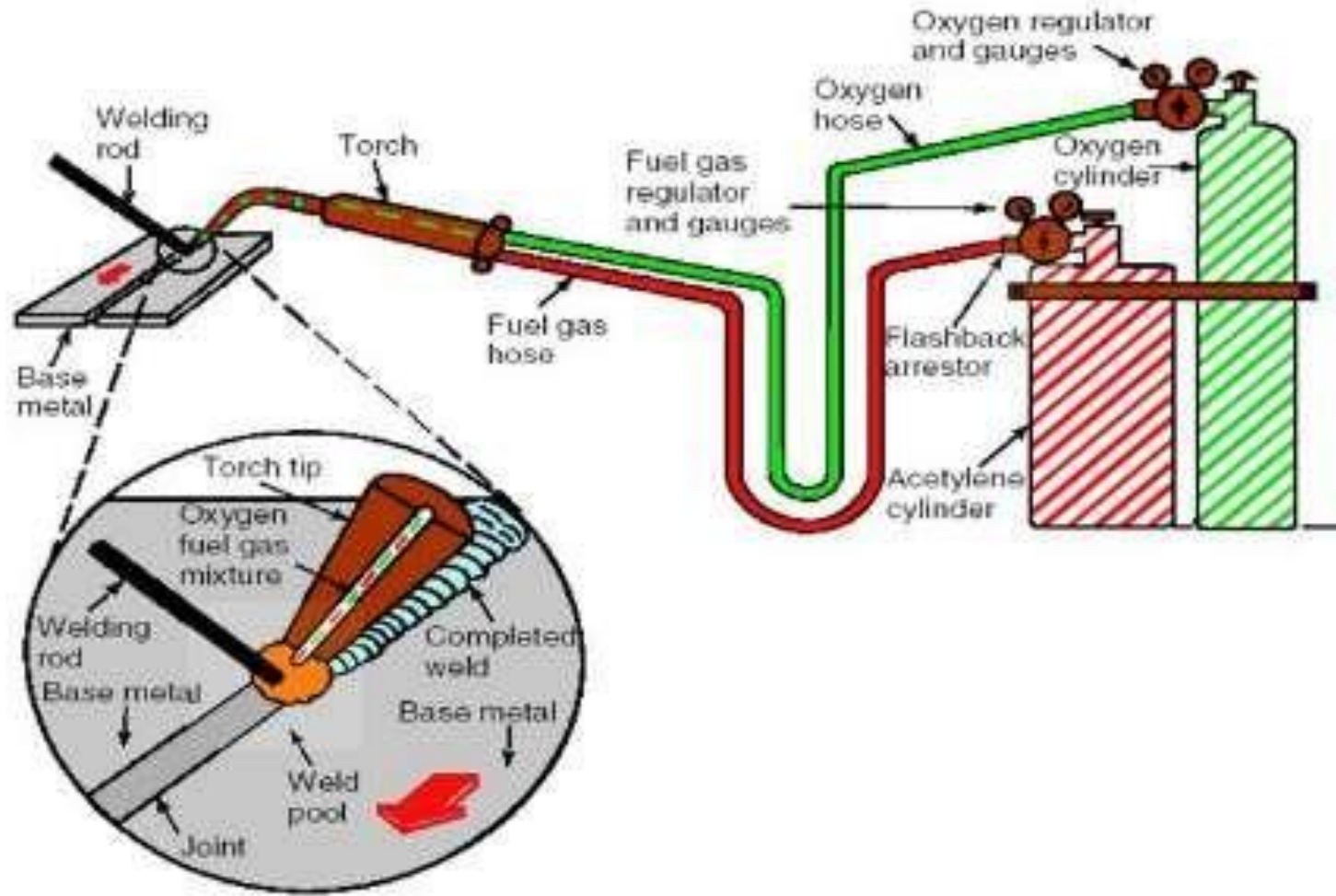
OXY-ACETYLENE PRINCIPLE



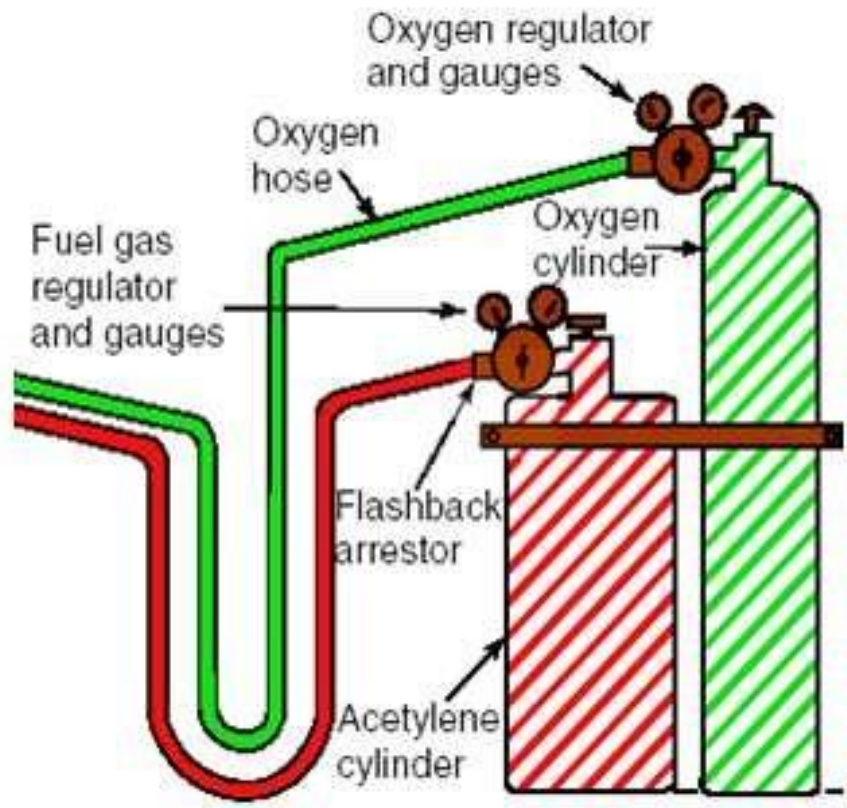
MATERIALS SUITABLE FOR OXY-ACETYLENE

- Plain carbon steel and low –alloy steel.
- Cast iron (best results)
- Stainless steel
- Aluminum and magnesium
- Copper and copper alloys
- Mild steel
- lead

OXY-ACETYLENE WELDING(OAW) STATION



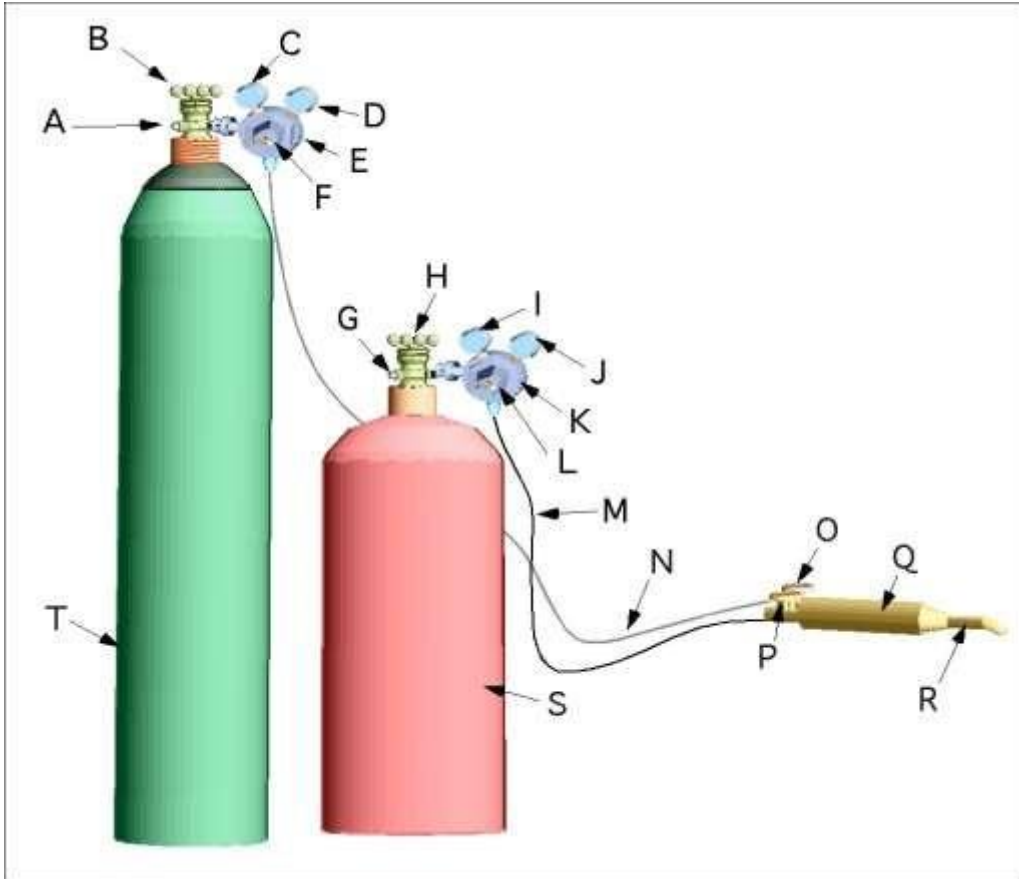
OXY-ACETYLENE WELDING(OAW) STATION



- Hoses are are fabricated from rubber
- Oxygen hoses are green in color and have right hand thread.
- Acetylene hoses are red in color with left hand thread.
- Left hand threads can be identified by a groove in the body of the nut and it may have "ACET" stamped on it

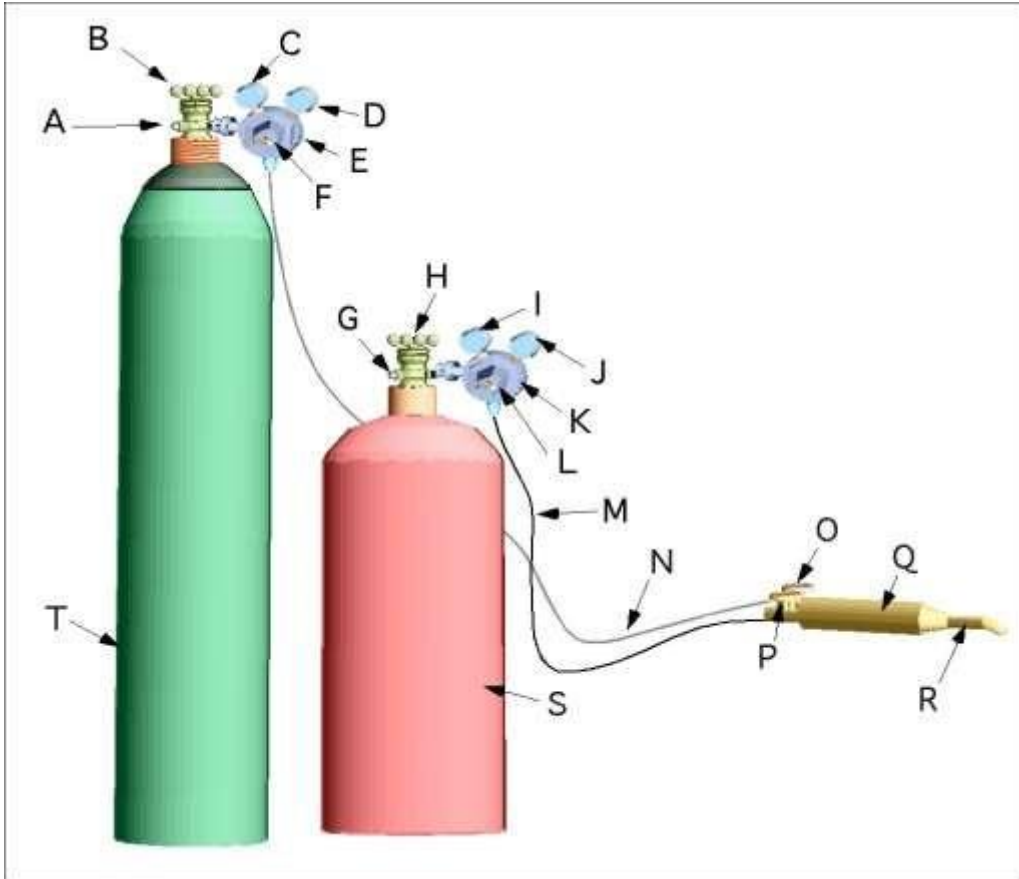
OXY-ACETYLENE WELDING(OAW) EQUIPMENT

- A. Oxygen safety disc
- B. Oxygen cylinder valve
- C. Oxygen cylinder pressure gauge
- D. Oxygen working pressure gauge
- E. Oxygen regulator
- F. Oxygen regulator adjusting screw
- G. Acetylene cylinder safety disc
- H. Acetylene cylinder valve
- I. Acetylene cylinder pressure



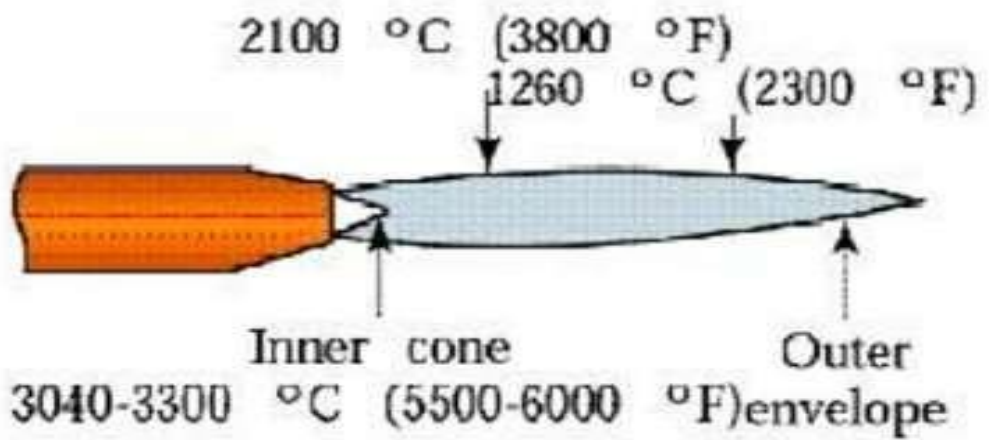
OXY-ACETYLENE WELDING(OAW) EQUIPMENT

- J.Acetylene working pressure gauge
- K.Acetylene regulator
- L.Acetylene regulator adjusting screw
- M.Acetylene hose
- N.Oxygen hose
- O.Oxygen torch valve
- P.Acetylene torch valve
- Q.Torch
- R.Welding tip
- S.Acetylene cylinder
- T.Oxygen cylinder

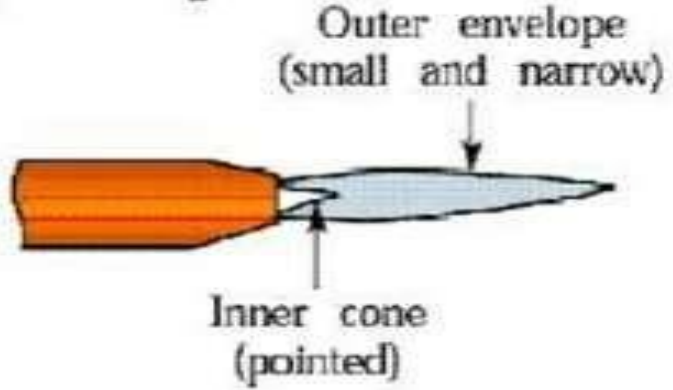


TYPES OF FLAMES USED IN OAW

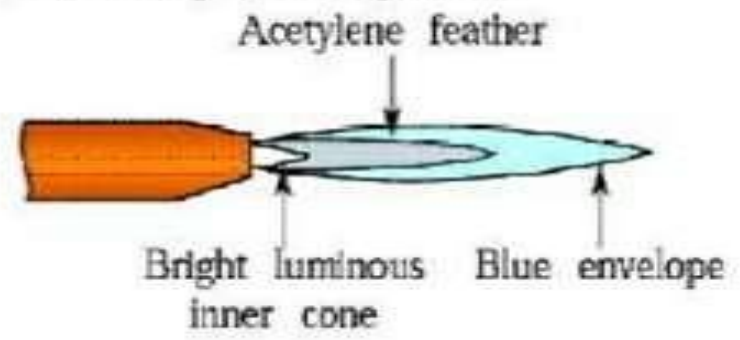
(a) Neutral flame



(b) Oxidizing flame



(c) Carburizing (reducing) flame



FLAMES ADJUSTMENT FOR OAW

METAL	FLAME
MILD STEEL	NEUTRAL
LEAD	NEUTRAL
GREY CAST IRON	SLIGHTLY OXIDISING
ALLOY STEEL	NEUTRAL
ALUMINIUM	SLIGHTLY CARBURIZING
NICKEL ALLOY	SLIGHTLY CARBURIZING
COPPER	NEUTRAL

WELDING PARAMETER FOR WELDING CARBON STEEL

Metal thickness (mm)	Welding tip orifice (mm)	Welding rod diameter (mm)	Oxygen Consumption (m ³ /hr)	Acetylene Consumption (m ³ /hr)	Welding Speed (m/hr)
0.8	0.57	1.6	0.031	0.0283	
1.6	0.75	1.6	0.062	0.0566	
2.4	0.92	1.6/2.4	0.156	0.1420	6.10
3.2	1.09	2.4/3.2	0.280	0.2550	4.88
4.8	1.32	3.2	0.498	0.4530	4.27
6.4	1.61	3.2/4.8	0.778	0.7080	3.66
8	1.85	3.2/4.8	0.935	0.8500	3.05
9.6	2.08	4.8	1.246	1.1330	2.74
12.7	2.37	4.8	1.869	1.6990	2.44

APPLICATIONS

➤ ***Cutting a rail just before renewing the rails***



APPLICATIONS

A CUTTING TORCH IS USED TO CUT A STEEL PIPE



APPLICATIONS

- **Oxygen cutting would be useful only for those materials which readily get oxidized and the oxides have lower melting points than the metals. So it is most widely used for ferrous materials. f**
- **Oxygen cutting is NOT used for materials like aluminum, bronze, stainless steel which resist oxidation. f**
- **Cutting of high carbon steels and cast irons require special attention due to formation of heat affected zone (HAZ) where structural transformation occurs.**

ARC WELDING

The arc welding is a fusion welding process in which the heat required to fuse the metal is obtained from an electric arc between the base metal and an electrode.

The electric arc is produced when two conductors are touches together and then separated by a small gap of 2 to 4 mm, such that the current continues to flow, through the air. The temperature produced by the electric arc is about 4000°C to 6000°C.

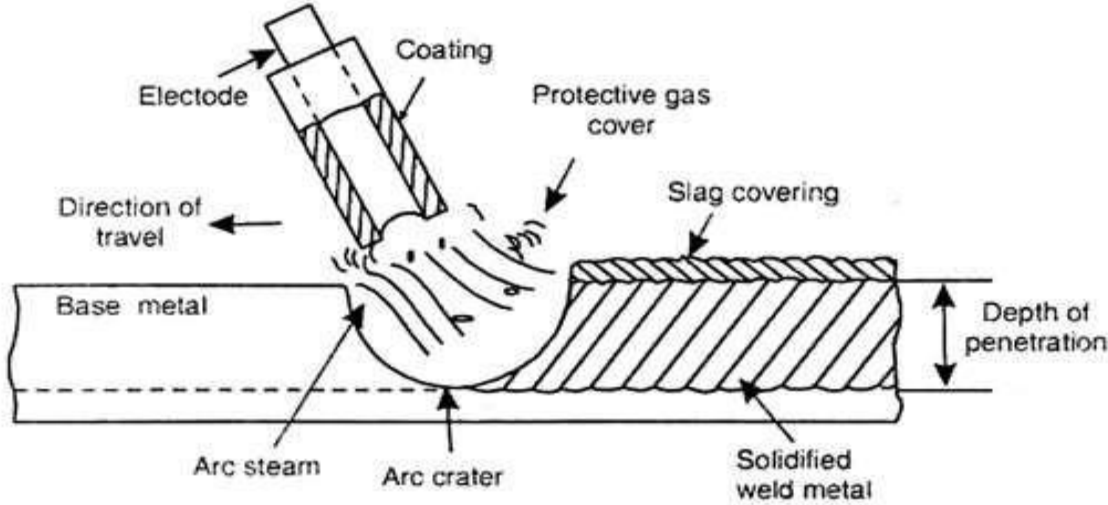


Fig. 7.14. Cut away view of the arc welding with a coated electrode.

ARC WELDING

A metal electrode is used which supplies the filler metal. The electrode may be flux coated or bare. In case of bare electrode, extra flux material is supplied. Both direct current (D.C.) and alternating current (A.C.) are used for arc welding.

The alternating current for arc is obtained from a step down transformer. The transformer receives current from the main supply at 220 to 440 volts and step down to required voltage i.e., 80 to 100 volts. The direct current for arc is usually obtained from a generator driven by either an electric motor, or petrol or diesel engine.

An open circuit voltage (for striking of arc) in case of D.C. welding is 60 to 80 volts while a closed circuit voltage (for maintaining the arc) is 15 to 25 volts

PROCEDURE OF ELECTRIC ARC WELDING ARC WELDING



First of all, metal pieces to be weld are thoroughly cleaned to remove the dust, dirt, grease, oil, etc. Then the work piece should be firmly held in suitable fixtures. Insert a suitable electrode in the electrode holder at an angle of 60 to 80° with the work piece.

Select the proper current and polarity. The spot are marked by the arc at the places where welding is to be done. The welding is done by making contact of the electrode with the work and then separating the electrode to a proper distance to produce an arc.

PROCEDURE OF ELECTRIC ARC WELDING

ARC WELDING

When the arc is obtained, intense heat so produced, melts the work below the arc, and forming a molten metal pool. A small depression is formed in the work and the molten metal is deposited around the edge of this depression. It is called arc crater. The slag is brushed off easily after the joint has cooled. After welding is over, the electrode holder should be taken out quickly to break the arc and the supply of current is switched off.

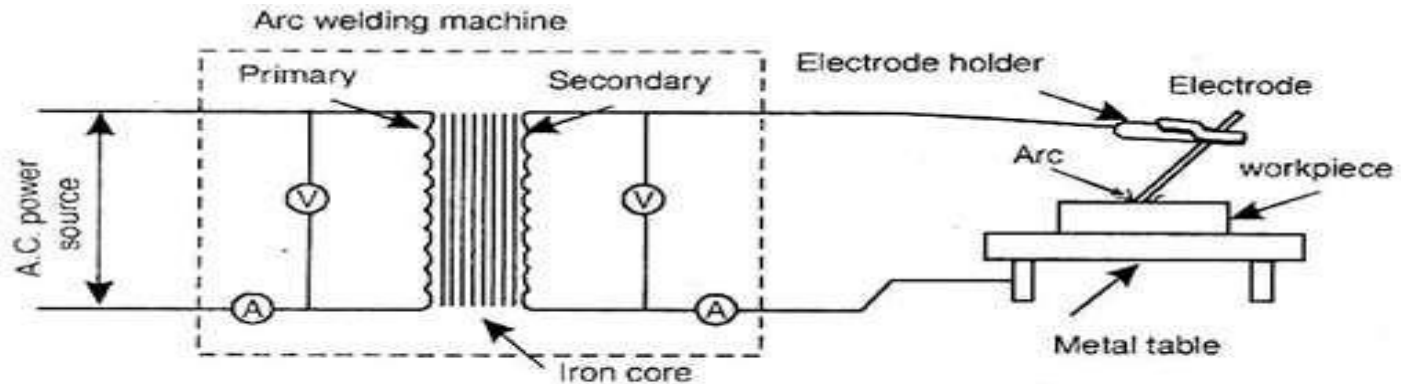


Fig. 7.15. The arc welding setup.

ELECTRIC CURRENT FOR WELDING

Both D.C. (direct current) and A.C. (alternating current) are used to produce an arc in electric arc welding. Both have their own advantages and applications.

The D.C. welding machine obtains their power from an A.C. motor or diesel/petrol generator or from a solid state rectifier.

The capacities of D.C. machine are:

Current:

Up to 600 amperes.

Open Circuit Voltage:

50 to 90 volts, (to produce arc).

Closed Circuit Voltage:

18 to 25 volts, (to maintain arc)

The A.C. welding machine has a step down transformer which receives current from main A.C. supply. This transformer step down the voltage from 220 V-440V to normal open circuit voltage of 80 to 100 volts. The current range available up to 400 amperes in the steps of 50 ampere.

ELECTRIC CURRENT FOR WELDING

The capacities of A.C. welding machine are:

Current Range:

Up to 400 ampere in steps of 50 ampere.

Input Voltage:

220V- 440V

Actual Required Voltage:

80 – 100 volts. **Frequency:** 50/60 HZ.

SIGNIFICANCE OF POLARITY

When D.C. current is used for welding, the following two types of polarity are available:

- (i) **Straight or positive polarity.**
- (ii) **Reverse or negative polarity.**

When the work is made positive and electrode as negative then polarity is called straight or positive polarity.

In straight polarity, about 67% of heat is distributed at the work (positive terminal) and 33% on the electrode (negative terminal). The straight polarity is used where more heat is required at the work. The ferrous metal such as mild steel, with faster speed and sound weld, uses this polarity.

SIGNIFICANCE OF POLARITY

On the other hand, when the work is made negative and electrode as positive then polarity is known as reverse or negative polarity, as shown in Fig. 7.16 (b).

In reverse polarity, about 67% of heat is liberated at the electrode (positive terminal) and 33% on the work (negative terminal).

The reverse polarity is used where less heat is required at the work as in case of thin sheet metal weld. The non-ferrous metals such as aluminum, brass, and bronze nickel are welded with reverse polarity.

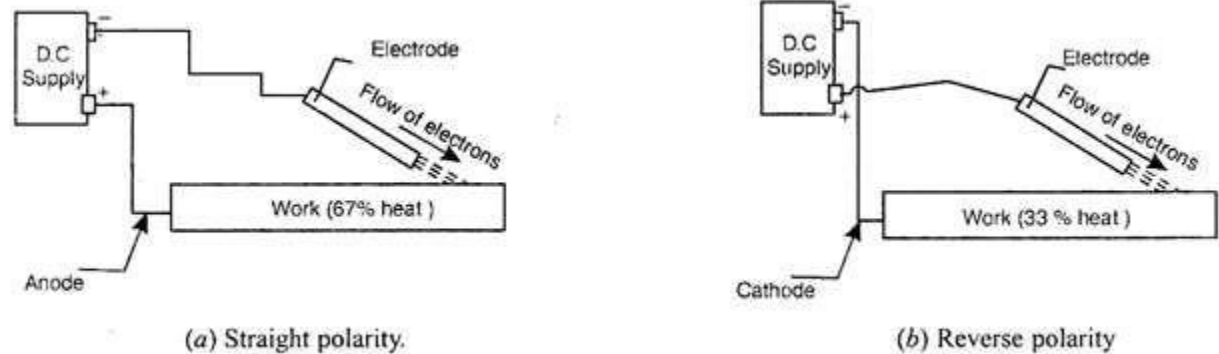


Fig. 7.16. Polarity for D.C. Arc Welding.

Equipments Required for Electric Arc Welding

The various equipments required for electric arc welding are:

1. Welding Machine:

The welding machine used can be A.C. or D.C. welding machine. The A.C. welding machine has a step-down transformer to reduce the input voltage of 220- 440V to 80-100V. The D.C. welding machine consists of an A.C. motor-generator set or diesel/petrol engine-generator set or a transformer-rectifier welding set.

A.C. machine usually works with 50 hertz or 60 hertz power supply. The efficiency of A.C. welding transformer varies from 80% to 85%. The energy consumed per Kg. of deposited metal is 3 to 4 kWh for A.C. welding while 6 to 10 kWh for D.C. welding.

A.C. welding machine usually work with low power factor of 0.3 to 0.4, while motor in D.C. welding has a power factor of 0.6 to 0.7. The following table 7.9 shows the voltage and current used for welding machine.

Equipments Required for Electric Arc Welding

2. Electrode Holders:

The function of electrode holder is to hold the electrode at desired angle. These are available in different sizes, according to the ampere rating from 50 to 500 amperes.

3. Cables or Leads:

The function of cables or leads is to carry the current from machine to the work. These are flexible and made of copper or aluminum. The cables are made of 900 to 2000 very fine wires twisted together so as to provide flexibility and greater strength.

The wires are insulated by a rubber covering, a reinforced fibre covering and further with a heavy rubber coating.

4. Cable Connectors and Lugs:

The functions of cable connectors are to make a connection between machine switches and welding electrode holder. Mechanical type connectors are used; as they can be assembled and removed very easily. Connectors are designed according to the current capacity of the cables used.

5. Chipping Hammer:

The function of chipping hammer is to remove the slag after the weld metal has solidified. It has chisel shape and is pointed at one end.

Equipments Required for Electric Arc Welding

6. Wire Brush, Power Wire Wheel:

The function of wire brush is to remove the slag particles after chipping by chipping hammer. Sometimes, if available a power wire wheel is used in place manual wire brush.

7. Protective Clothing:

The functions of protective clothing's used are to protect the hands and clothes of the welder from the heat, spark, ultraviolet and infrared rays. Protective clothing used are leather apron, cap, leather hand gloves, leather sleeves, etc. The high ankle leather shoes must be wear by the welder.

8. Screen or Face Shield:

The function of screen and face shield is to protect the eyes and face of the welder from the harmful ultraviolet and infrared radiations produced during welding. The shielding may be achieved from head helmet or hand helmet

ARC WELDING ELECTRODES

Arc welding electrodes can be classified into two broad categories:

1. Non-Consumable electrodes.
2. Consumable electrodes.

1. Non-Consumable Electrodes:

These electrodes do not consumed during the welding operation, hence they named, non-consumable electrodes. They are generally made of carbon, graphite or tungsten. Carbon electrodes are softer while tungsten and graphite electrodes are hard and brittle.

Carbon and graphite electrodes can be used only for D.C. welding, while tungston electrodes can be used for both D.C. and A.C. welding. The filler material is added separately when these types of electrodes are used. Since, the electrodes do not consumed, the arc obtained is stable.

2. Consumable Electrodes:

These electrodes get melted during welding operation, and supply the filler material. They are generally made with similar composition as the metal to be welded.

ARC WELDING PROS AND CONS

There are a number of advantages to using arc welding compared with many other formats:

Advantages

Cost – equipment for arc welding is well-priced and affordable, and the process often requires less equipment in the first place because of the lack of gas

Portability – these materials are very easy to transport

Works on dirty metal

Shielding gas isn't necessary – processes can be completed during wind or rain, and spatter isn't a major concern

Disadvantages

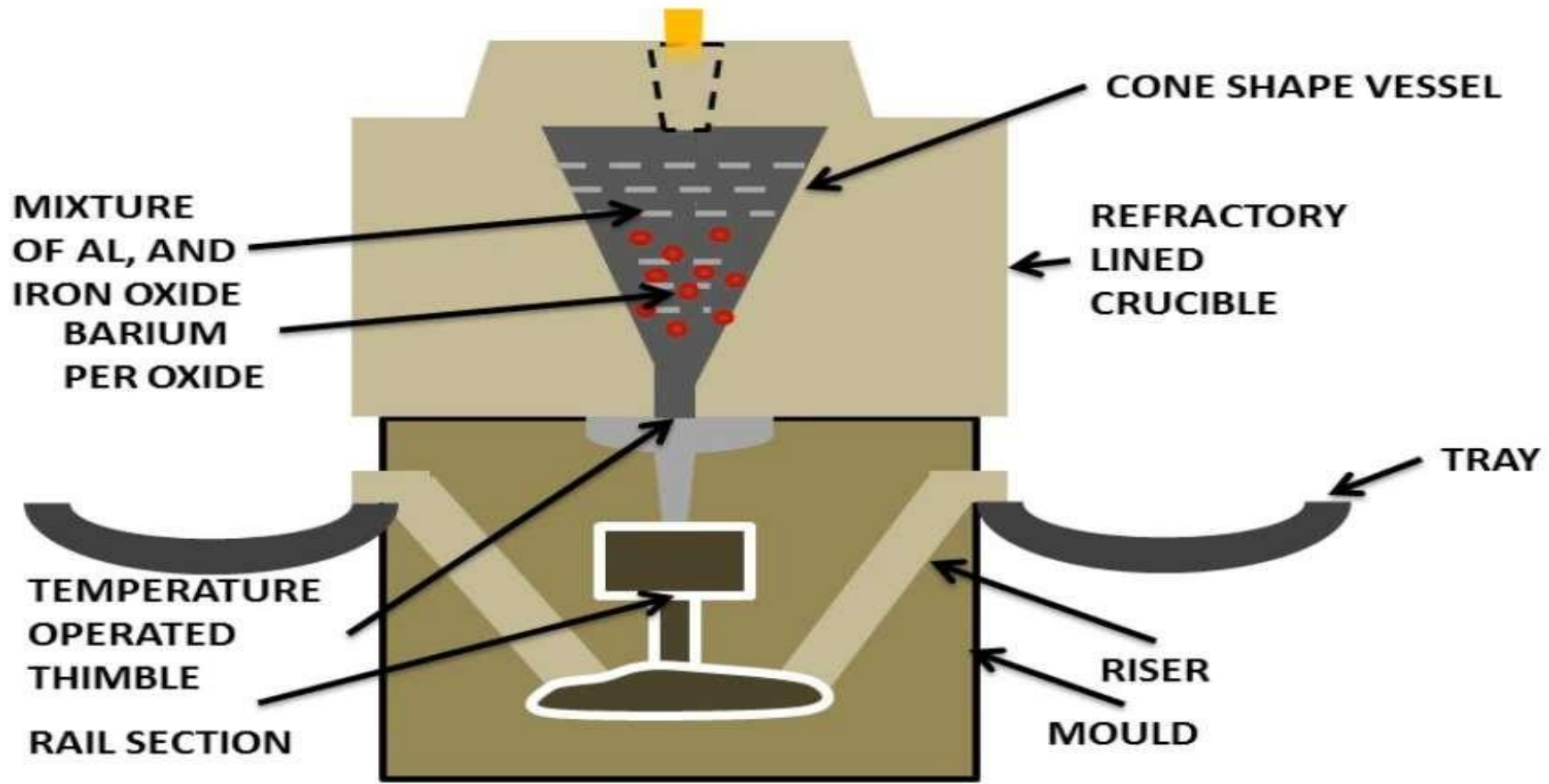
There are a few reasons why some people look to other options beyond arc welding for certain kinds of projects. These downsides can include:

Lower efficiency – more waste is generally produced during arc welding than many other types, which can increase project costs in some cases

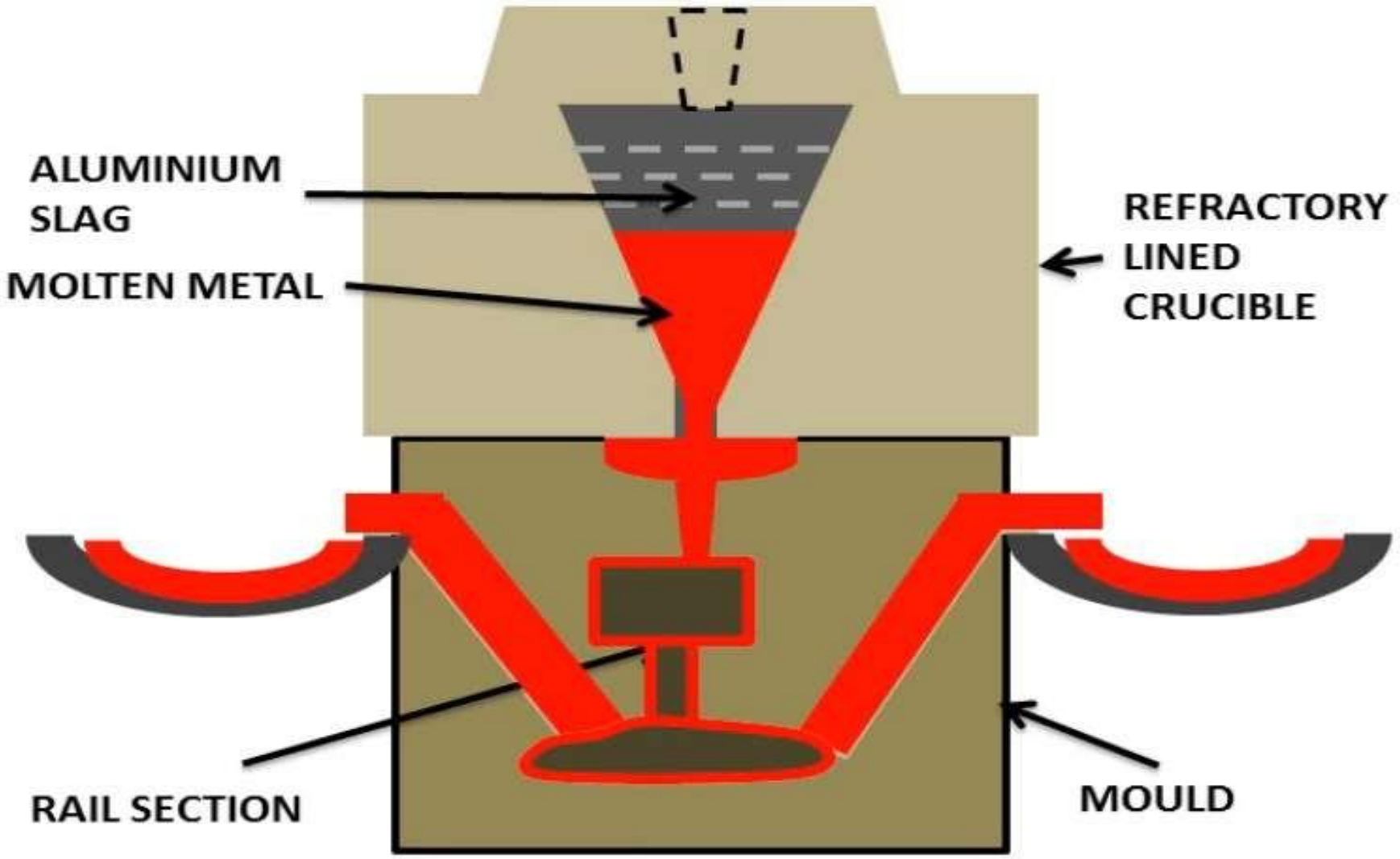
High skill level – operators of arc welding projects need a high level of skill and training, and not all professionals have this

Thin materials – it can be tough to use arc welding on certain thin metals

THERMIT WELDING



THERMIT WELDING



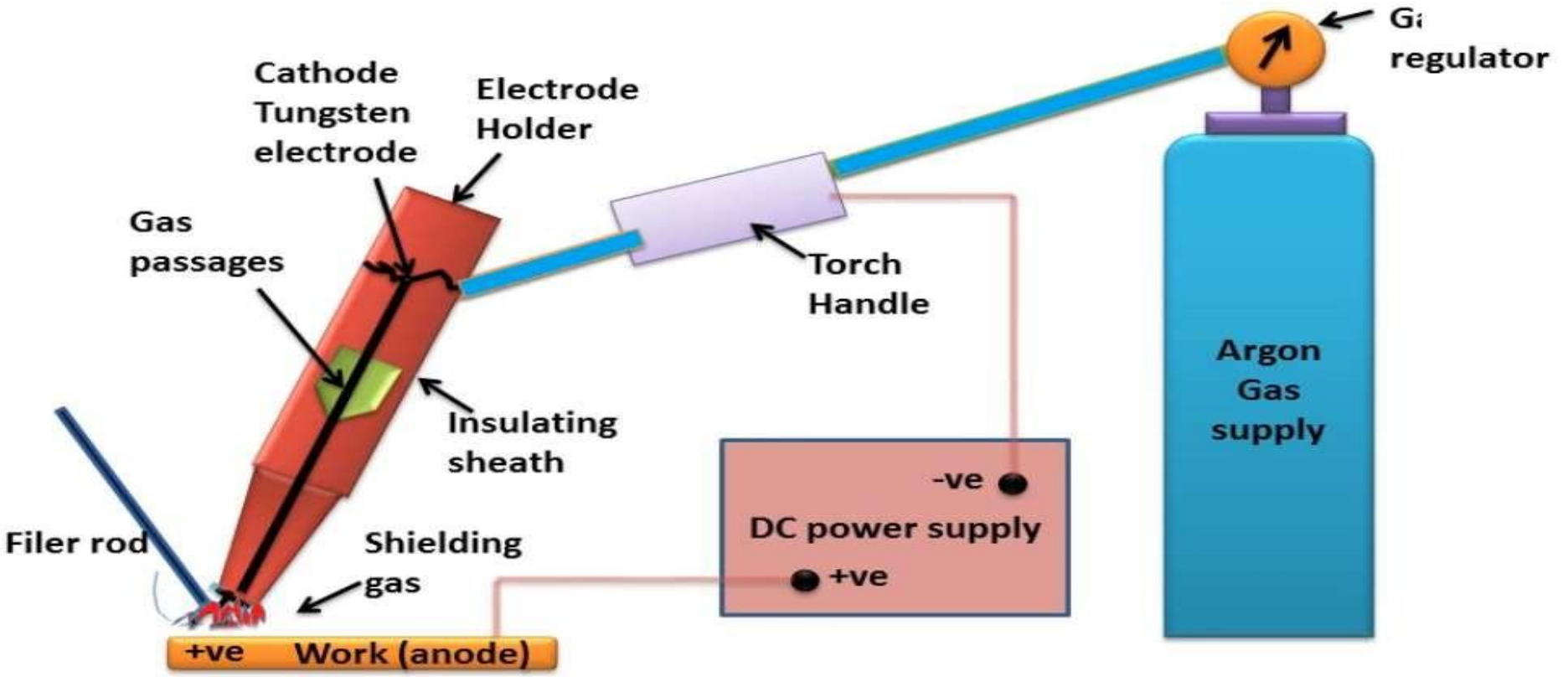
INERT GAS WELDING

Shielding gases are inert or semi-inert gases that are commonly used in several welding processes, most notably gas metal arc welding and gas tungsten arc welding (GMAW and GTAW, more popularly known as MIG (Metal Inert Gas) and TIG (Tungsten Inert Gas), respectively).

Their purpose is to protect the weld area from oxygen, and water vapor. Depending on the materials being welded, these atmospheric gases can reduce the quality of the weld or make the welding more difficult. Other arc welding processes use alternative methods of protecting the weld from the atmosphere as well – shielded metal arc welding, for example, uses an electrode covered in a flux that produces carbon dioxide when consumed, a semi-inert gas that is an acceptable shielding gas for welding steel.

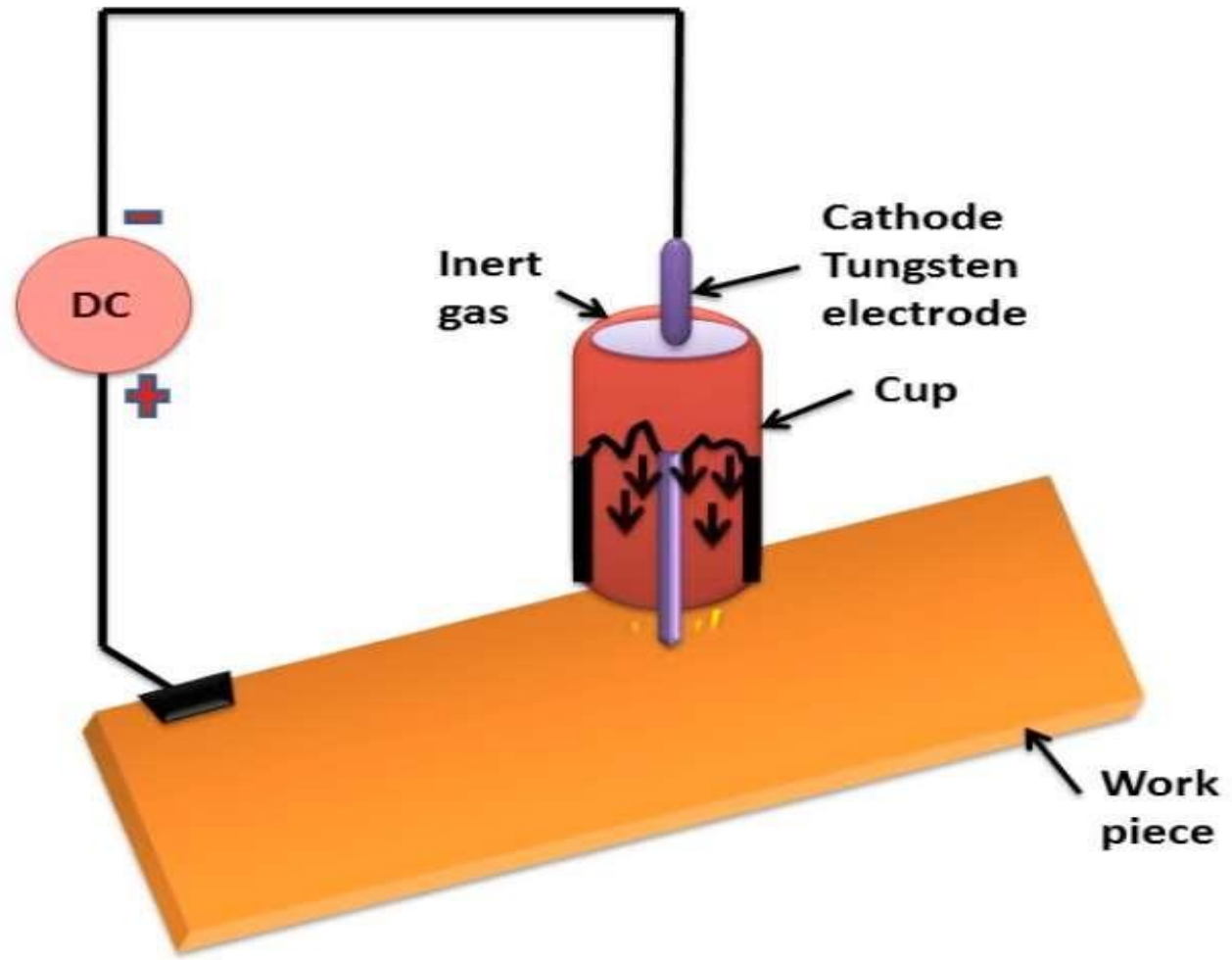
TIG WELDING

TUNGSTEN INERT GAS WELDING (TIG)



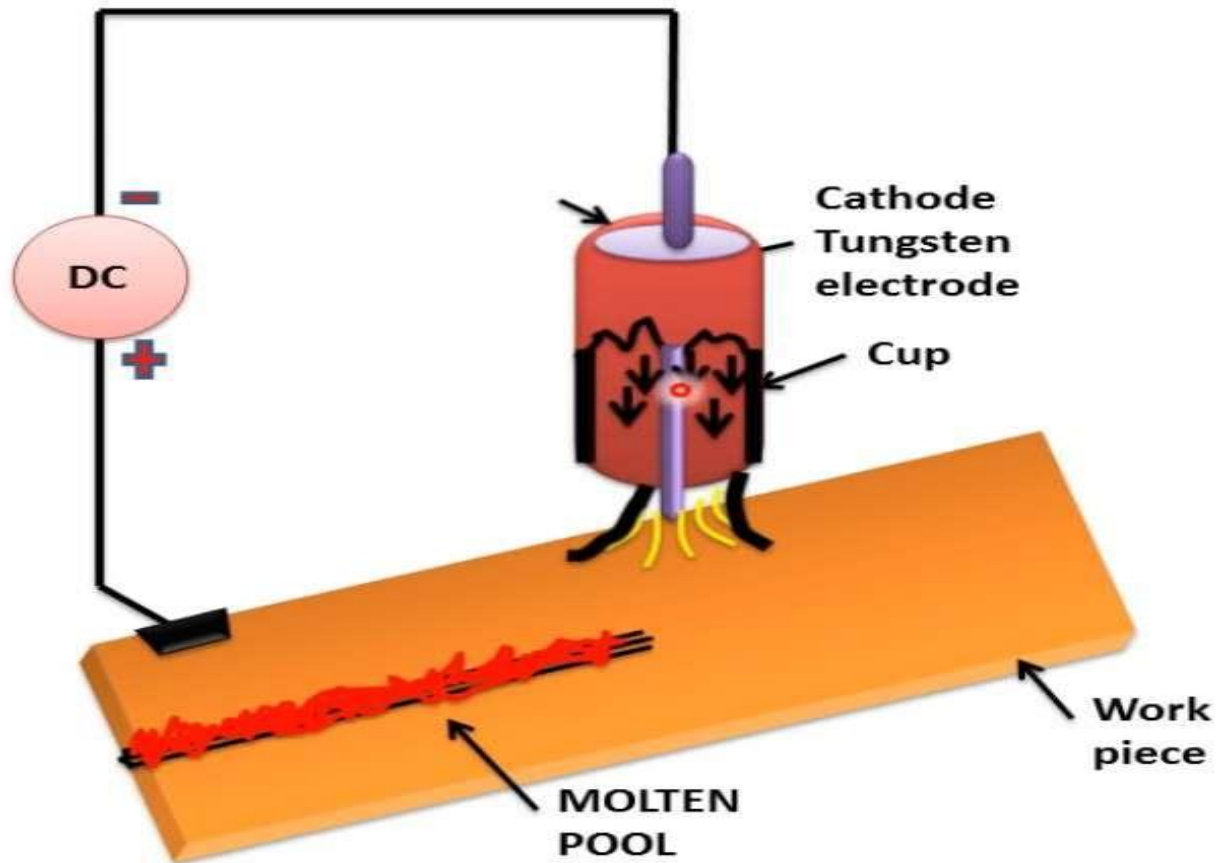
TIG WELDING

TUNGSTEN INERT GAS WELDING (TIG)



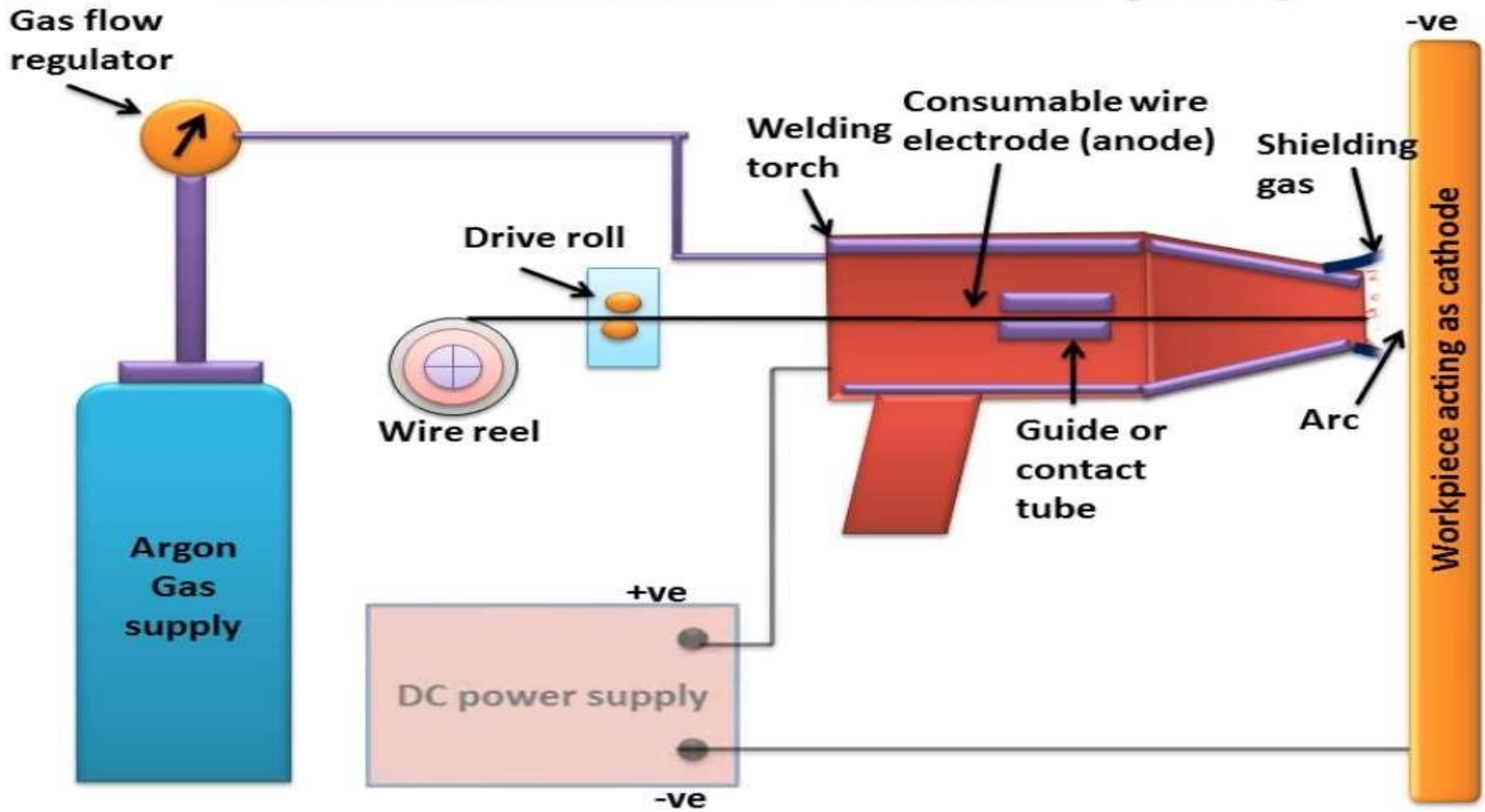
TIG WELDING

TUNGSTEN INERT GAS WELDING (TIG)

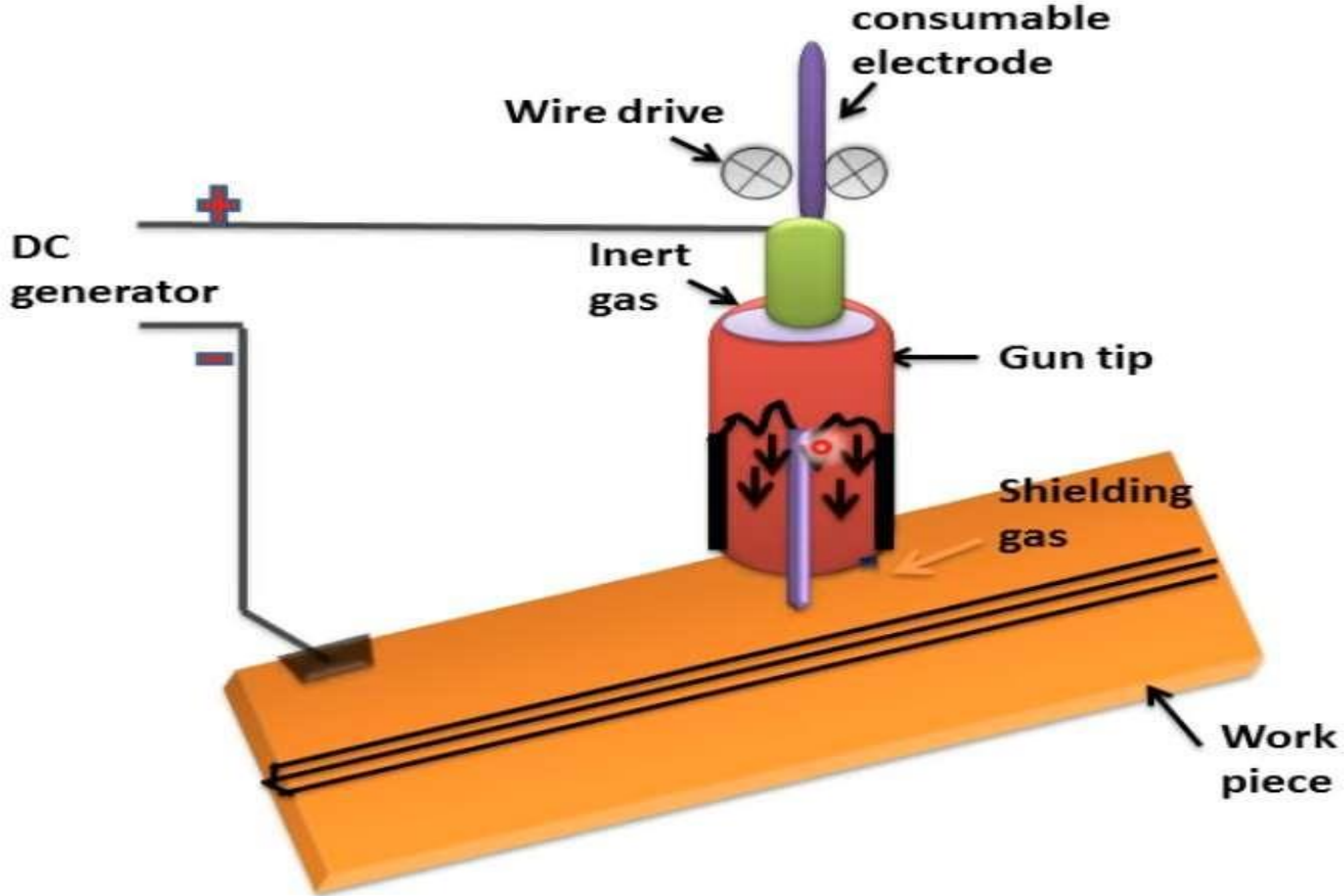


MIG WELDING

METAL INERT GAS WELDING (MIG)



METAL INERT GAS WELDING (MIG)



INDUCTION WELDING



DESTRUCTIVE TEST IN WELDS

It is defined as during testing the metal component is get damage due to which it cannot be reuse again.

1.tensile test

2.compression test

3.hardness test

4.cupping test

5.impact test

6.creep test

7.fatigue test

8.bend test

NON-DESTRUCTIVE TEST IN WELDS

It is defined as during testing the metal component is not damaged or destroyed and can be use for its specific application again.

1. Radiographic test

2. Ultrasonic test

3. Magnetic particle test

4. Dye penetrate test

5. Eddy current test

6. Visual inspection

VISUAL INSPECTION



Fig: Videoscope



Fig: Advanced Videoscope



Fig: Borescopes



Fig. Microscope



Fig: Magnifying glass

METAL FORMING

MODULE-III

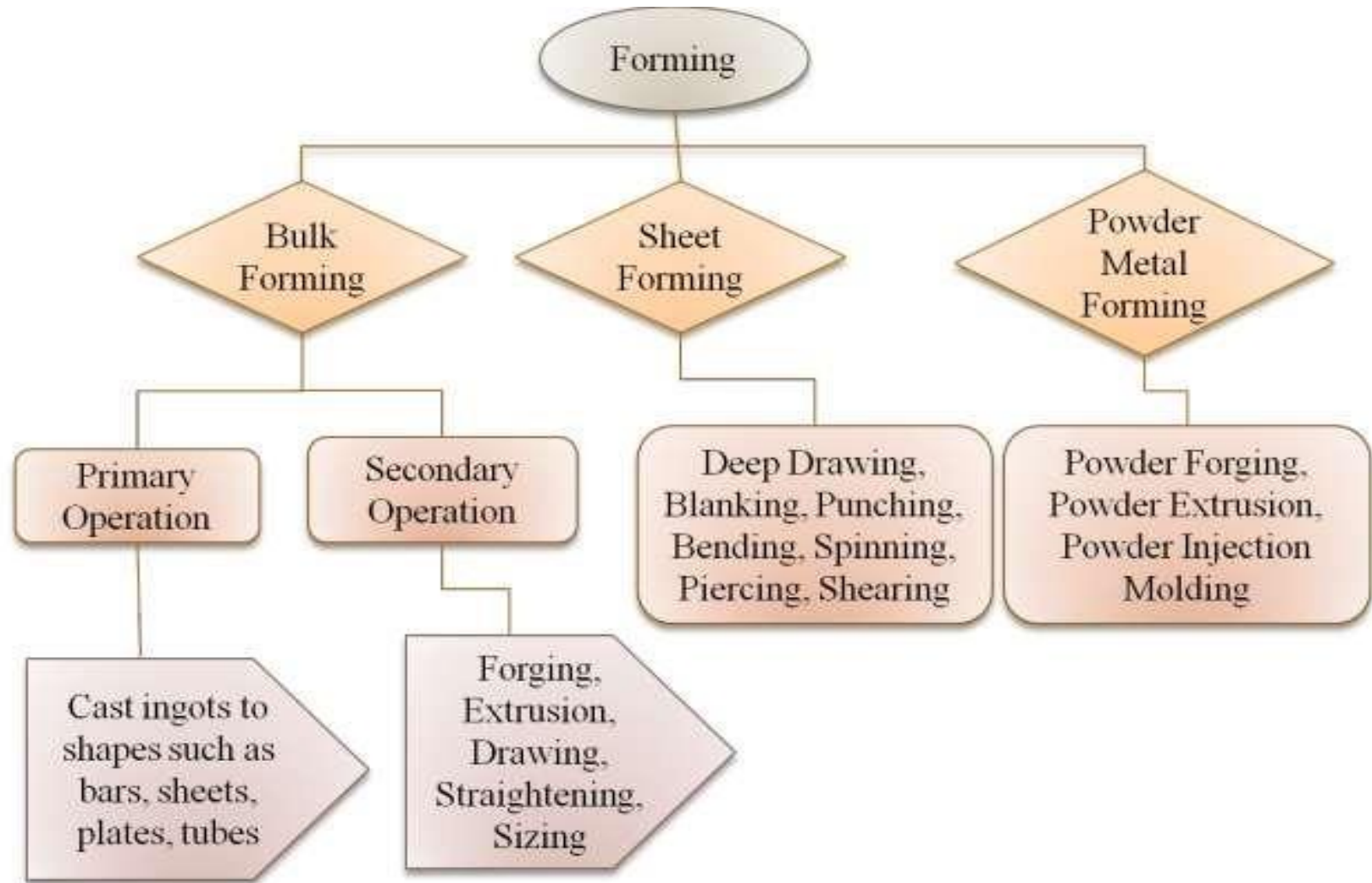
COURSE OUTCOMES (COs):

At the end of the course students are able to:		
Course Outcomes		Knowledge Level (Bloom's Taxonomy)
CO5	Apply the appropriate metal forming techniques, for producing components like hexagonal bolt, nut etc.,	Apply
CO6	Explain the working principle of hot and cold extrusion processes and their application in industries for making of pipes and tubes.	Apply

MODULE-III

PROGRAM OUTCOMES (POs):

Program Outcomes (POs)		Strength	Proficiency Assessed by
PO 2	Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	CIE/Quiz/AAT
PO 3	Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	2	Seminar/ conferences/ Research papers



WHY HOT WORKING?

Capability for substantial plastic deformation of the metal - far more than possible with cold working or warm working **Why?**

1. Strength coefficient is substantially less than at room temperature
2. Strain hardening exponent is zero (theoretically)
3. Ductility is significantly increased

HOT WORKING

Hot working may be explained as plastic deformation of metals and alloys at such a temperature above recrystallization temperature at which recovery and recrystallization take place simultaneously with the strain hardening.

- 1. Deformation at temperatures above recrystallization temperature**
- 2. Recrystallization temperature = about one-half of melting point on absolute scale**
- 3. In practice, hot working usually performed somewhat above $0.5T_m$**
- 4. Metal continues to soften as temperature increases above $0.5T_m$, enhancing advantage of hot working above this level**

HOT WORKING

Advantages of Hot Working Vs Cold Working

1. **Work part shape can be significantly altered**
2. **Lower forces and power required**
3. **Metals that usually fracture in cold working can be hot formed**
4. **Strength properties of product are generally isotropic**
5. **No strengthening of part occurs from work hardening**
6. **Advantageous in cases when part is to be subsequently processed by cold forming**

HOT WORKING

Disadvantages of Hot Working

1. Lower dimensional accuracy
2. Higher total energy required (due to the thermal energy to heat the workpiece)
3. Work surface oxidation (scale), poorer surface finish
4. Shorter tool life

COLD WORKING

Cold working may be defined as plastic deformation of metals and alloys at a temperature below the recrystallization temperature for that metal or alloy. In cold working process the strain hardening which occurs as a result of mechanical working, does not get relieved. In fact 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 cause cracking and failure of material.

Performed at temperatures above room temperature but below recrystallization temperature. Dividing line between cold working and warm working often expressed in terms of melting point: $0.3T_m$, where T_m = melting point (absolute temperature) for metal

COLD WORKING

Cold working of a metal is carried out below its recrystallisation temperature. Although normal room temperatures are ordinarily used for cold working of various types of steel, temperatures up to the recrystallisation range are sometimes used. In cold working, recovery processes are not effective.

PURPOSE OF COLD WORKING

The common purpose of cold working is given as under

- 1.Cold working is employed to obtain better surface finish on parts.**
- 2.It is commonly applied to obtain increased mechanical properties.**
- 3.It is widely applied as a forming process of making steel products using pressing and spinning.**
- 4.It is used to obtain thinner material.**

COLD WORKING

CHARACTERISTICS OF COLD WORKING

The main characteristics of cold working are given as under.

1. Cold working involves plastic deformation of a metal, which results in strain hardening.
2. It usually involves working at ordinary (room) temperatures, but, for high melting point metals, e.g., tungsten, the cold working may be carried out at a red heat.
3. The stress required for deformation increases rapidly with the amount of deformation.
4. The amount of deformation, which can be performed without introducing other treatment, is limited.
5. Cold rolling process generally distorts grain structure.
6. Good surface finish is obtained in cold rolling.

COLD WORKING

CHARACTERISTICS OF COLD WORKING

- 7. The upper temperature limit for cold working is the maximum temperature at which strain hardening is retained. Since cold working takes place below the recrystallisation temperature, it produces strain hardening.**
- 8. Excessive cold working gives rise to the formation and propagation of cracks in the metal.**
- 9. The loss of ductility during cold working has a useful side effect in machining.**
- 10. With less ductility, the chips break more readily and facilitate the cutting operation.**
- 11. Heating is sometimes required.**

COLD WORKING

LIMITATIONS OF COLDWORKING

- 1. The cold worked process possesses less ductility.**
- 2. Imparted directional properties may be detrimental**
- 3. Strain hardening occurs.**
- 4. Metal surfaces must be clean and scale free before cold working.**
- 5. Hot worked metal has to be pickled in acid to remove scale, etc.**
- 6. Higher forces are required for deformation than those in hot working.**
- 7. More powerful and heavier equipments are required for cold working.**

COLD WORKING

ADVANTAGES OF COLD WORKING

- 1. In cold working processes, smooth surface finish can be easily produced.**
- 2. Accurate dimensions of parts can be maintained.**
- 3. Strength and hardness of the metal are increased but ductility decreased.**
- 4. Since the working is done in cold state, no oxide would form on the surface and consequently good surface finish is obtained.**
- 5. Cold working increases the strength and hardness of the material due to the strain hardening which would be beneficial in some situations.**
- 6. There is no possibility of decarburization of the surface**
- 7. Better dimensional accuracy is achieved.**
- 8. It is far easier to handle cold parts and it is also economical for smaller sizes.**

COMPARISON OF HOT WORKING WITH COLD WORKING

S. No.	Hot Working	Cold Working
1.	<p>Hot working is carried out above the recrystallisation temperature and below the melting point. Hence the deformation of metal and recovery take place simultaneously.</p>	<p>Cold working is carried out below the recrystallisation temperature. As such, there is no appreciable recovery.</p>
2.	<p>No internal or residual stresses are set-up in the metal in hot working.</p>	<p>In this process internal or residual stresses are set-up in the metal.</p>
3.	<p>It helps in irradiating irregularities in metal composition breaking up the non metallic impurities in to tiny fragments and dispersing them through out the metal and thus facilitate uniformity of composition in the metal</p>	<p>It results in loss of uniformity of metal composition and thus affects the metal properties.</p>

COMPARISON OF HOT WORKING WITH COLD WORKING

4. Close tolerance can not be maintained
5. Surface finish of this process is comparatively not good
6. It results in improvements of properties like impact strength and elongation
7. Due to re-crystallisation and recovery no or very negligible hardening of metal takes place.
8. Due to higher deformation temperatures, the stress required for deformation is much less.
9. Hot working refines metal grains resulting in improved mechanical properties.

Better tolerance can be easily maintained.
 Surface finish of this process is better.

It results in improvements of properties like impact strength and elongation.
 Since this is done below re-crystallisation temperature the metal gets work hardened.

The stress required to cause deformation is much higher.

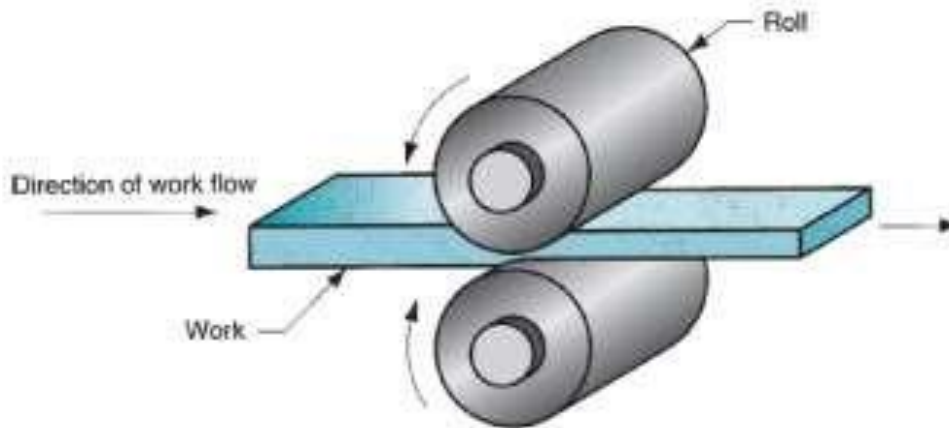
Most of the cold working processes lead to distortion of grains.

ROLLING FUNDAMENTALS

Rolling is the process of reducing the thickness or changing the cross section of a long work piece by compressive forces applied through a set of rolls.

Most rolling is carried out by hot working, called hot rolling, owing to the large amount of deformation required. Hot-rolled metal is generally free of residual stresses, and its properties are isotropic. Disadvantages of hot rolling are that the product cannot be held to close tolerances, and the surface has a characteristic oxide

scale.

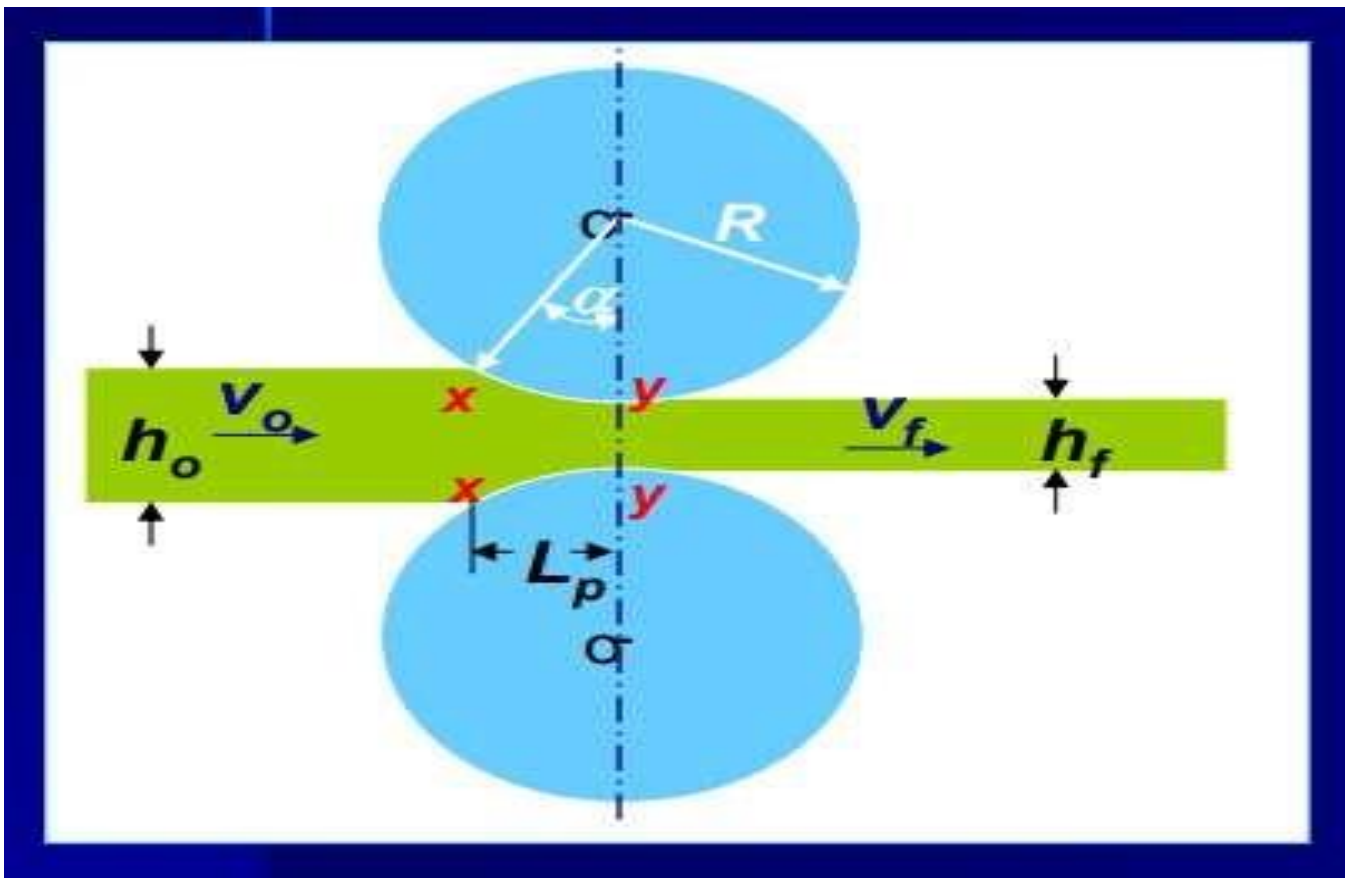


ROLLING FUNDAMENTALS

Fundamental concept of metal rolling

- 1) The arc of contact between the rolls and the metal is a part of a circle.
- 2) The coefficient of friction, μ , is constant in theory, but in reality μ varies along the arc of contact.
- 3) The metal is considered to deform plastically during rolling.
- 4) The volume of metal is constant before and after rolling. In practical the volume might decrease a little bit due to close-up of pores.
- 5) The velocity of the rolls is assumed to be constant.
- 6) The metal only extends in the rolling direction and no extension in the width of the material.
- 7) The cross sectional area normal to the rolling direction is not distorted.

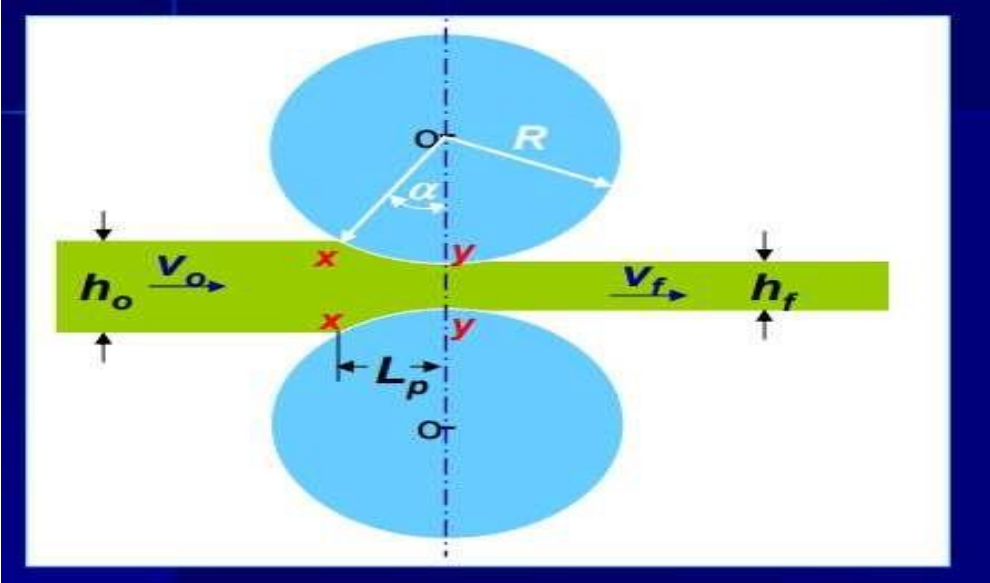
ROLLING FUNDAMENTALS



FORCES AND GEOMETRICAL RELATIONSHIPS IN ROLLING

A metal sheet with a thickness h_o enters the rolls at the entrance plane xx with a velocity v_o . It passes through the roll gap and leaves the exit plane yy with a reduced thickness h_f and at a velocity v_f . Given that there is no increase in width, the vertical compression of the metal is translated into an elongation in the rolling direction.

Where b is the width of the sheet v is the velocity at any thickness h intermediate between h_o and h_f .



$$bh_o v_o = bhv = bh_f v_f$$

FLAT ROLLING AND ITS ANALYSIS:

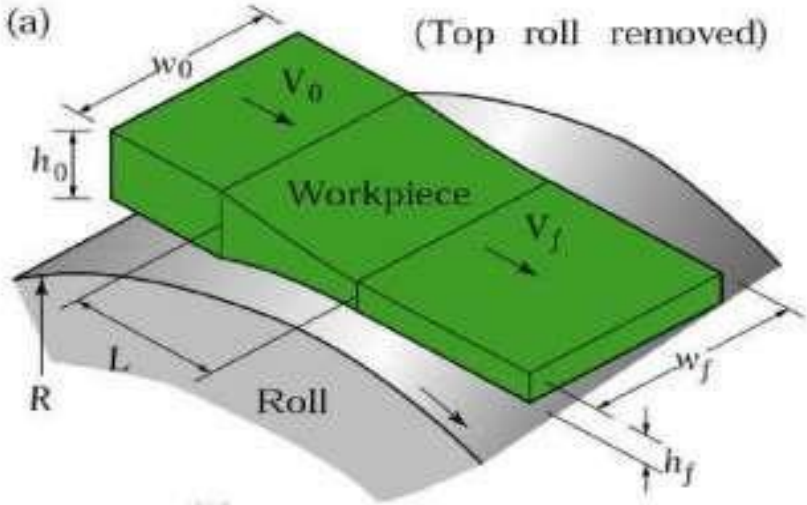
Flat rolling it involves the rolling of slabs, strips, sheets, and plates work parts of rectangular cross section in which the width is greater than the thickness. In flat rolling, the work is squeezed between two rolls so that its thickness is reduced by an amount called the draft

$$d = h_o - h_f = 2R (1 - \cos\alpha)$$

Where d = draft, mm (in); h_o = starting thickness, mm (in); and h_f = final thickness, mm (in). R = roll radius in mm and (α) = bite angle in degree. Draft is sometimes expressed as a fraction of the starting stock thickness, called the reduction

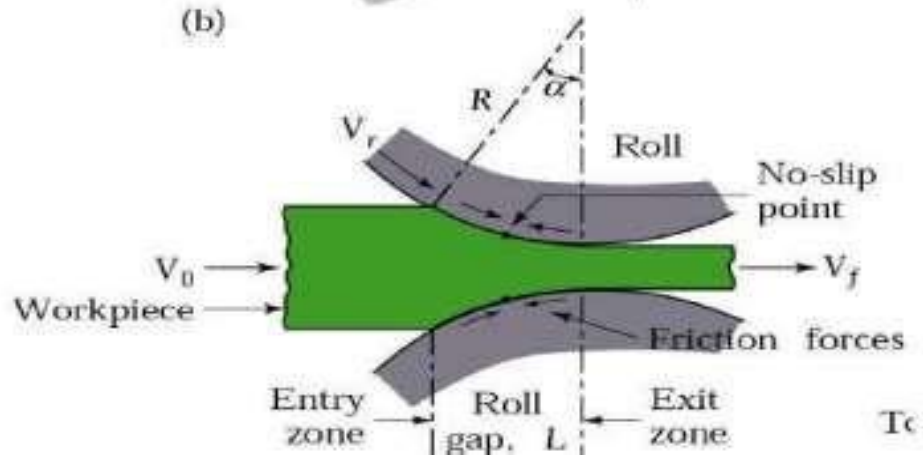
$$r = \frac{d}{h_o}$$

THEORY OF ROLLING :



To keep constant the volume rate of the material, the velocity of the strip must increase as it moves through the roll gap

$$V_f = V_0 \left(\frac{h_0}{h_f} \right)$$



NEUTRAL POINT:
point in the arc of contact where the roll velocity and the strip velocity are the same

$$\text{Forward slip} = \frac{V_f - V_r}{V_r}$$

THEORY OF ROLLING :

Because the surface speed of the rigid roll is constant, there is relative sliding between the roll and the strip along the arc of contact in the roll gap, L.

At one point along the contact length (called the neutral point or no-slip point) the velocity of the strip is the same as that of the roll.

On either side of this point, slipping and friction occur between roll and work. The amount of slip between the rolls and the work can be measured by means of the forward slip, a term used in rolling that is defined Where s = forward slip; v_f = final (exiting) work velocity, m/s (ft/sec); and v_r = roll speed, m/s (ft/sec).

$$s = \frac{v_f - v_r}{v_r}$$

ROLLING MILLS:

Two-High Rolling Mill

Four-High Rolling Mill

Cluster Mill

Three-High Rolling Mill

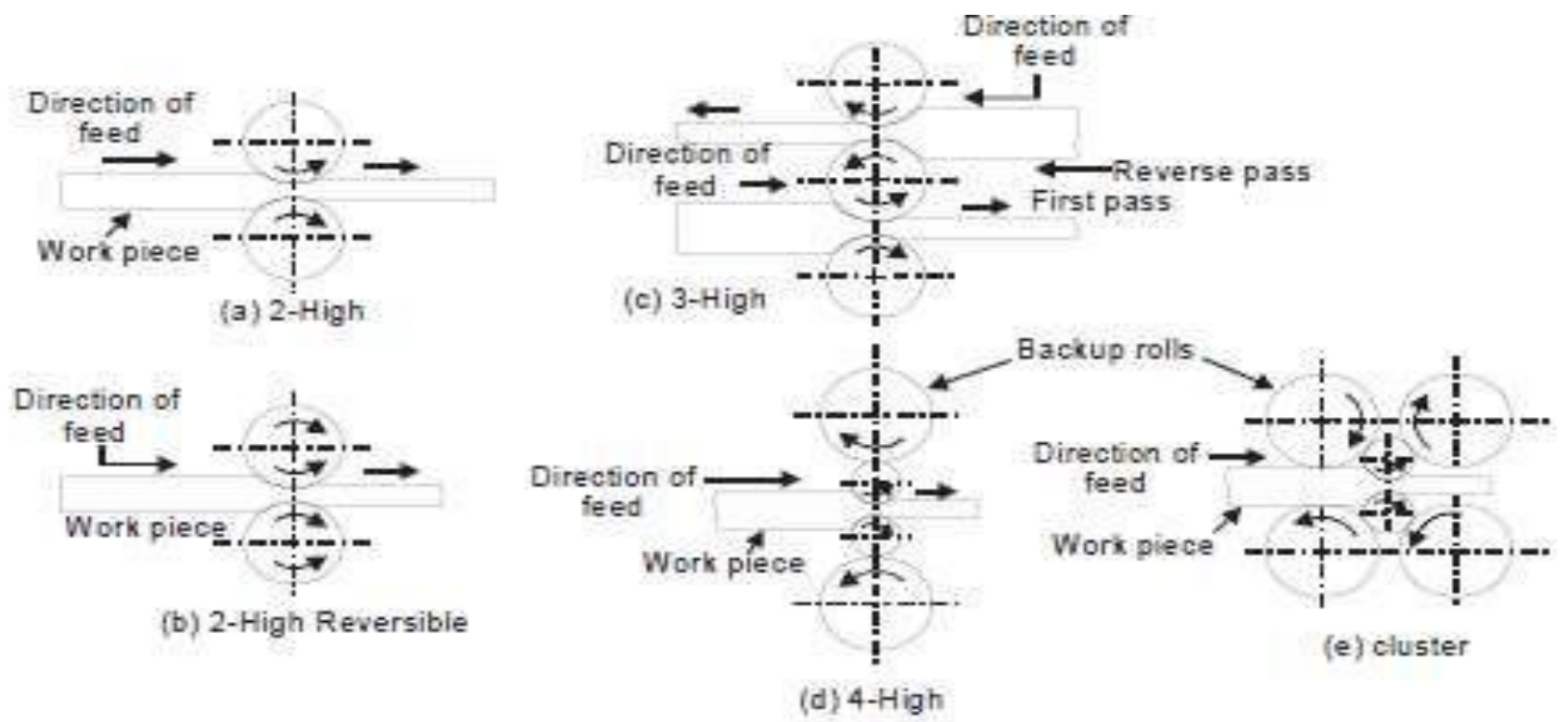


Fig. 15.2 Hot rolling stand arrangements

EXTRUSION AND RAPID PROTOTYPING

MODULE-IV

COURSE OUTCOMES (COs):

At the end of the course students are able to:		
Course Outcomes		Knowledge Level (Bloom's Taxonomy)
CO7	Analyze the manufacturing defects as well as material characterization and its application.	Apply
CO8	Classify the various forging techniques based on functionality, cost and time in development of critical products.	Understand

MODULE-IV

PROGRAM OUTCOMES (POs):

Program Outcomes (POs)		Strength	Proficiency Assessed by
PO 2	Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	CIE/Quiz/AAT
PO 3	Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	2	Seminar/ conferences/ Research papers

EXTRUSION

Compression forming process in which the work metal is forced to flow through a die opening to produce a desired cross-sectional shape

1.Process is similar to squeezing toothpaste out of a toothpaste tube

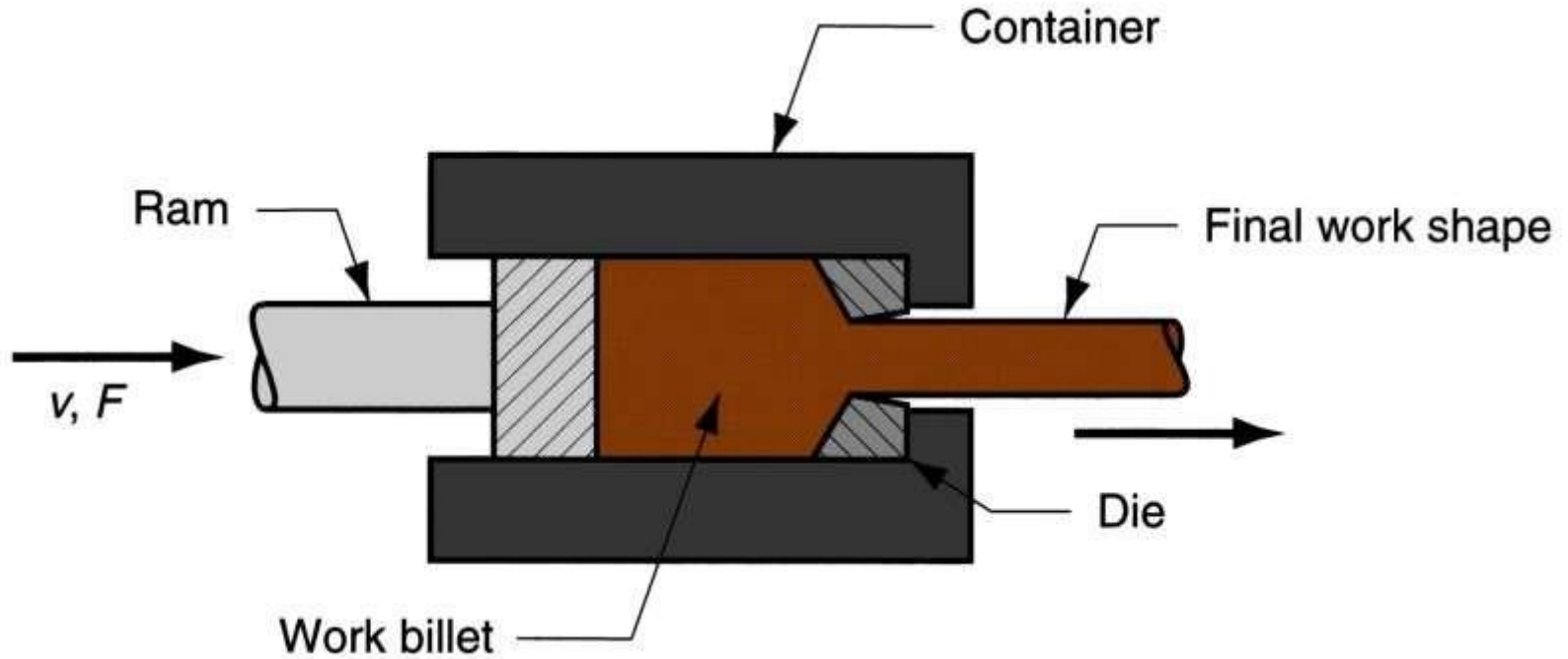
2.In general, extrusion is used to produce long parts of uniform cross-sections

Extrusion – It is a process where a billet is forced through a die. Parts have constant cross-section
Typical Products of Extrusion – Sliding Doors, tubing having various cross-sections, structural and architectural shapes and door and window frames.

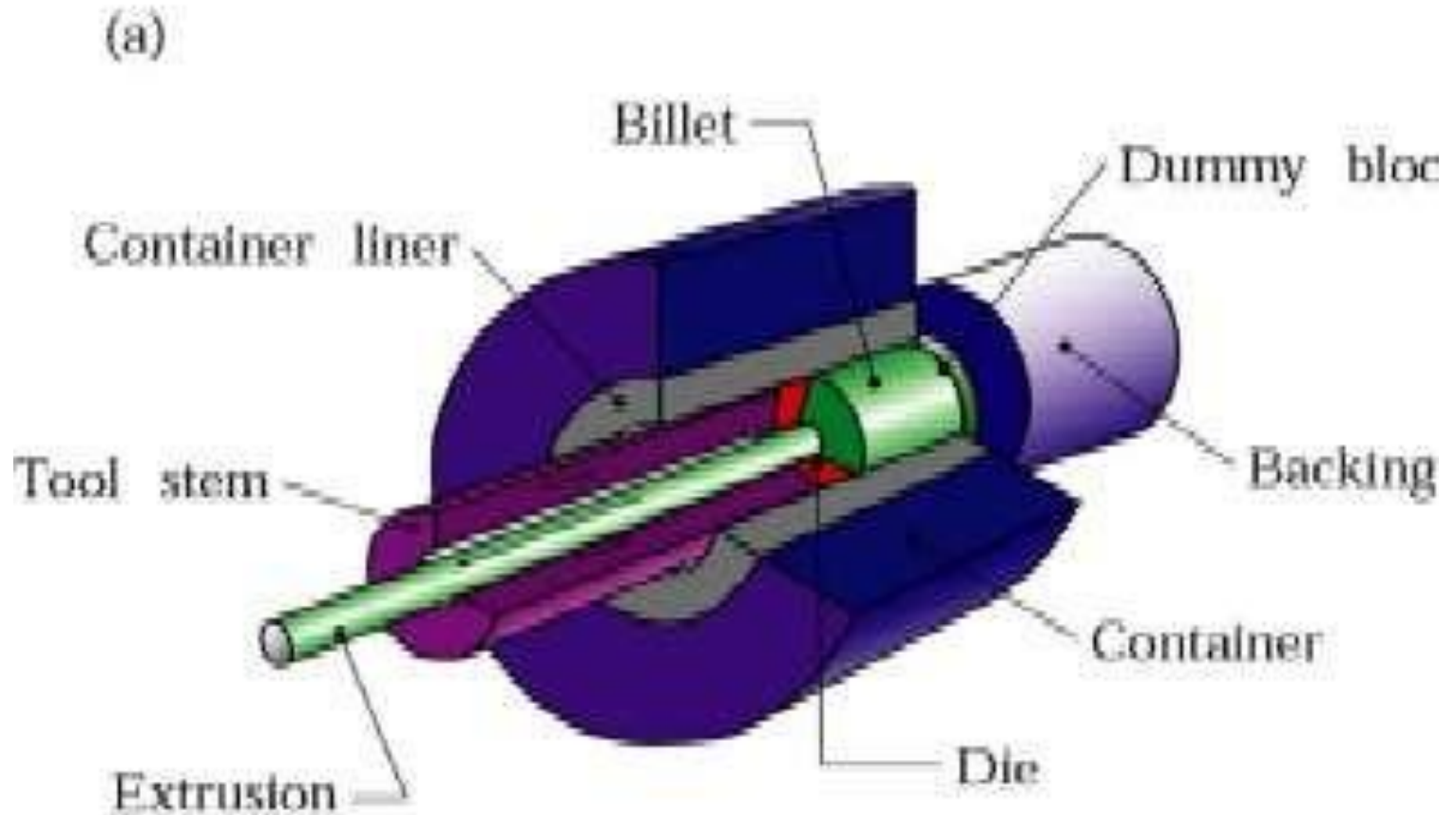
Drawing – It is a process where a cross-section of solid rod, wire, or tubing is reduced or changed in shape by pulling it through a die.

- 1. Direct Extrusion (or) Forward Extrusion – Billet is placed in a chamber and forced through a die opening by a hydraulically-driven ram or pressing stem.**
- 2. Indirect Extrusion (or) Backward Extrusion – Die moves towards the billet.**
- 3. Hydrostatic Extrusion – The billet is smaller in diameter than the chamber, which is filled with a fluid, and the pressure is transmitted to the billet by a ram.**

DIRECT EXTRUSION



INDIRECT EXTRUSION



GENERAL ADVANTAGES OF EXTRUSION

- 1. Variety of shapes possible, especially in hot extrusion**
- 2. Grain structure and strength enhanced in cold and warm extrusion**
- 3. Close tolerances possible, especially in cold extrusion**
- 4. In some operations, little or no waste of material**

HOT VS. COLD EXTRUSION

- 1. Hot extrusion - prior heating of billet to above its recrystallization temperature**
- 2. This reduces strength and increases ductility of the metal, permitting more size reductions and more complex shapes**
- 3. Cold extrusion - generally used to produce discrete parts**
- 4. The term impact extrusion is used to indicate high speed cold extrusion**

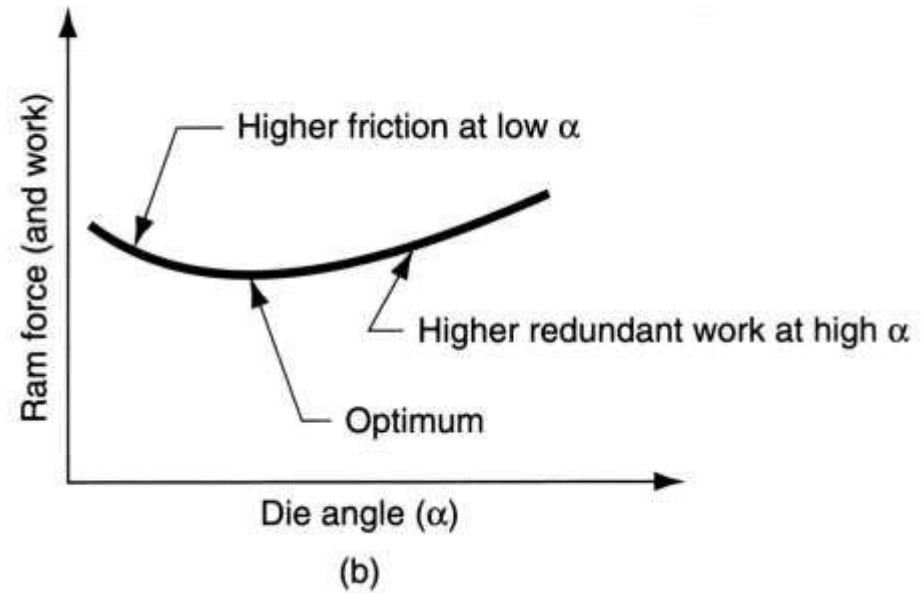
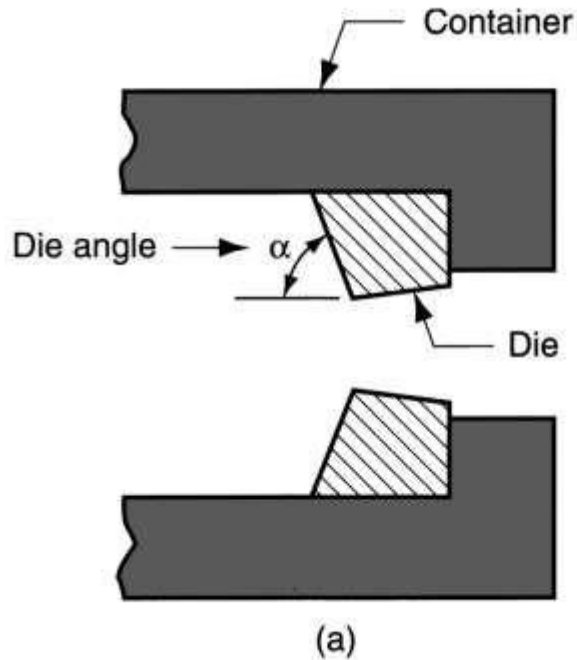
EXTRUSION RATIO

1. Also called the reduction ratio, it is defined as:

$$r_x = \frac{A_o}{A_f}$$

where r_x = extrusion ratio; A_o = cross-sectional area of the starting billet; and A_f = final cross-sectional area of the extruded section

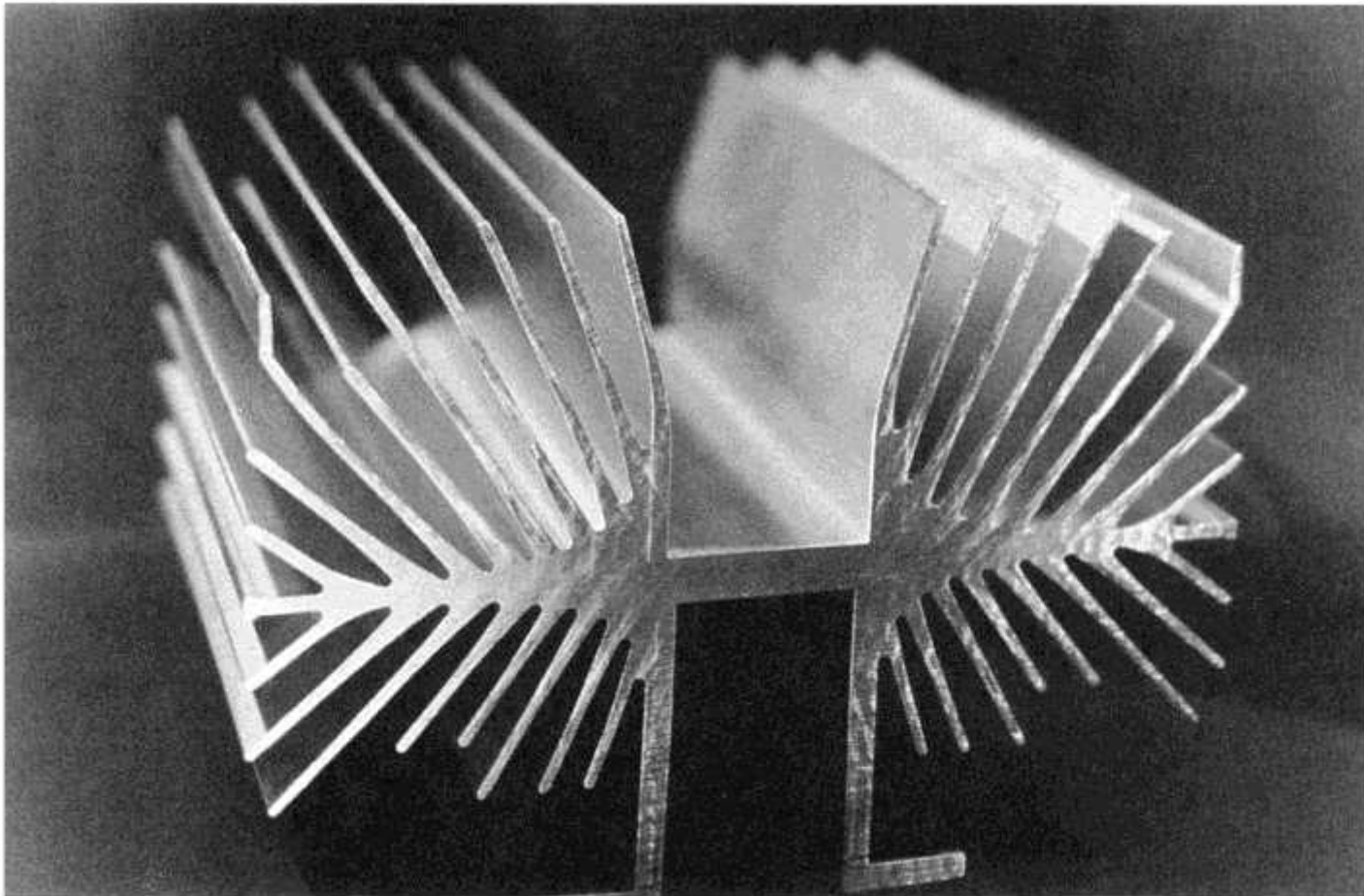
2. Applies to both direct and indirect extrusion



(a) Definition of die angle in direct extrusion;
(b) effect of die angle on ram force

COMMENTS ON DIE ANGLE

- 1. Low die angle - surface area is large, leading to increased friction at die-billet interface**
- 2. Higher friction results in larger ram force**
- 3. Large die angle - more turbulence in metal flow during reduction**
- 4. Turbulence increases ram force required**
- 5. Optimum angle depends on work material, billet temperature, and lubrication**



A complex extruded cross-section for a heat sink (photo courtesy of Aluminum Company of America)

EXTRUSION PRESSES

- 1. Either horizontal or vertical**
 - Horizontal more common
- 2. Extrusion presses - usually hydraulically driven, which is especially suited to semi-continuous direct extrusion of long sections**
- 3. Mechanical drives - often used for cold extrusion of individual parts**

HYDROSTATIC EXTRUSION

- 1. The pressure required for extrusion is supplied through and incompressible fluid medium surrounding the billet**
- 2. Usually carried at room temperature, typically using vegetable oils as the fluid**
- 3. Brittle materials are extruded generally by this method**
- 4. It increases ductility of the material**
- 5. It has complex nature of the tooling**

WIRE AND BAR DRAWING

- 1. Cross-section of a bar, rod, or wire is reduced by pulling it through a die opening**
- 2. Similar to extrusion except work is pulled through die in drawing (it is pushed through in extrusion)**
- 3. Although drawing applies tensile stress, compression also plays a significant role since metal is squeezed as it passes through die opening**

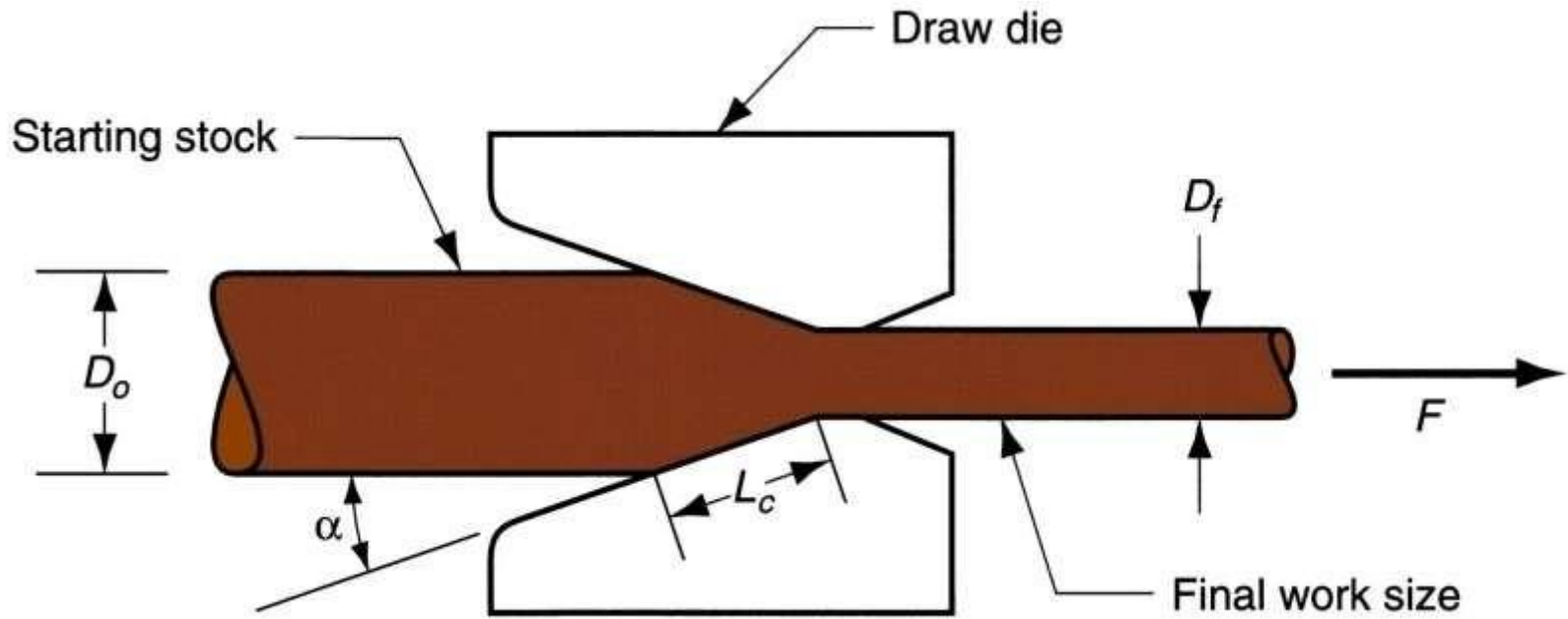


Figure :Drawing of bar, rod, or wire

AREA REDUCTION IN DRAWING

Change in size of work is usually given by area reduction:

$$r = \frac{A_o - A_f}{A_o}$$

where r = area reduction in drawing; A_o = original area of work; and A_f = final work

WIRE DRAWING VS. BAR DRAWING

- 1. Difference between bar drawing and wire drawing is stock size**
- 2. Bar drawing - large diameter bar and rod stock**
- 3. Wire drawing - small diameter stock - wire sizes down to 0.03 mm (0.001in.) are possible**
- 4. Although the mechanics are the same, the methods, equipment, and even terminology are different**

DRAWING PRACTICE AND PRODUCTS

1. Drawing practice:

Usually performed as cold working

Most frequently used for round cross-sections

2. 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

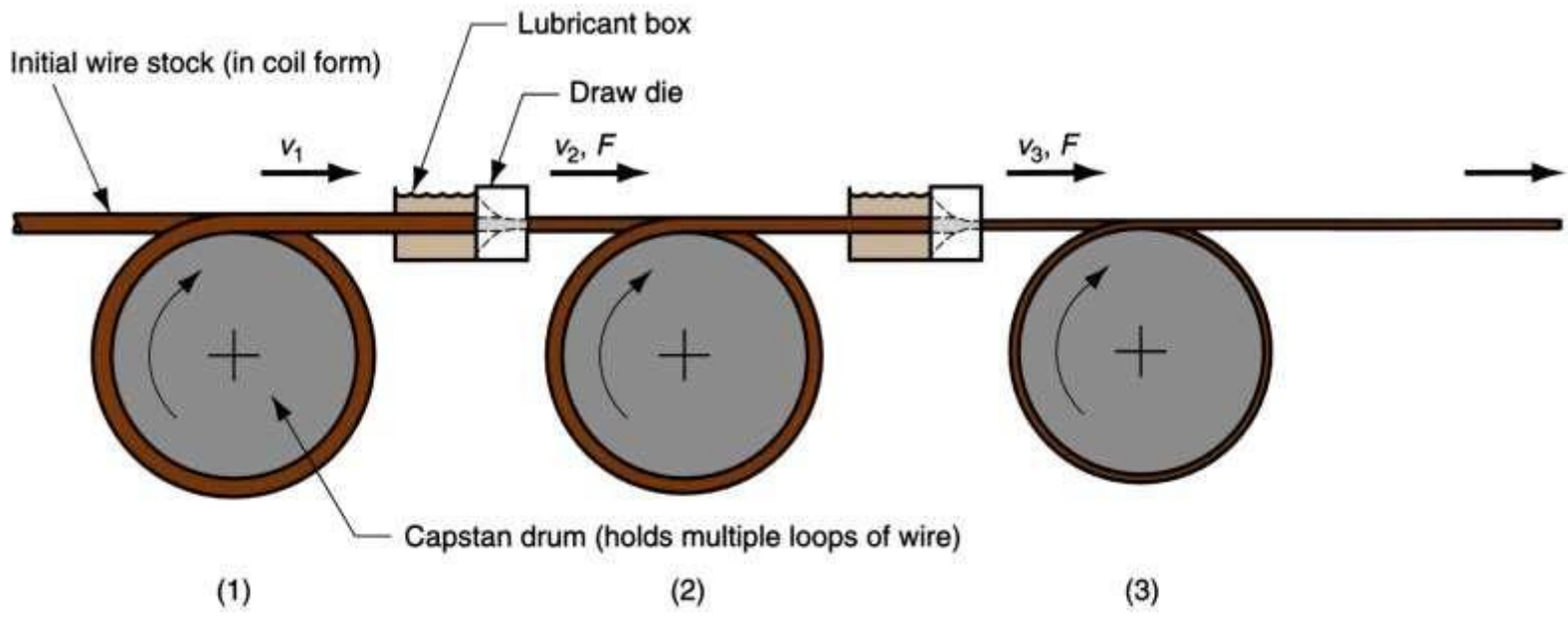
Accomplished as a *single draft* operation - the stock is pulled through one die opening

Beginning stock has large diameter and is a straight cylinder

This necessitates a batch type operation

BAR DRAWING

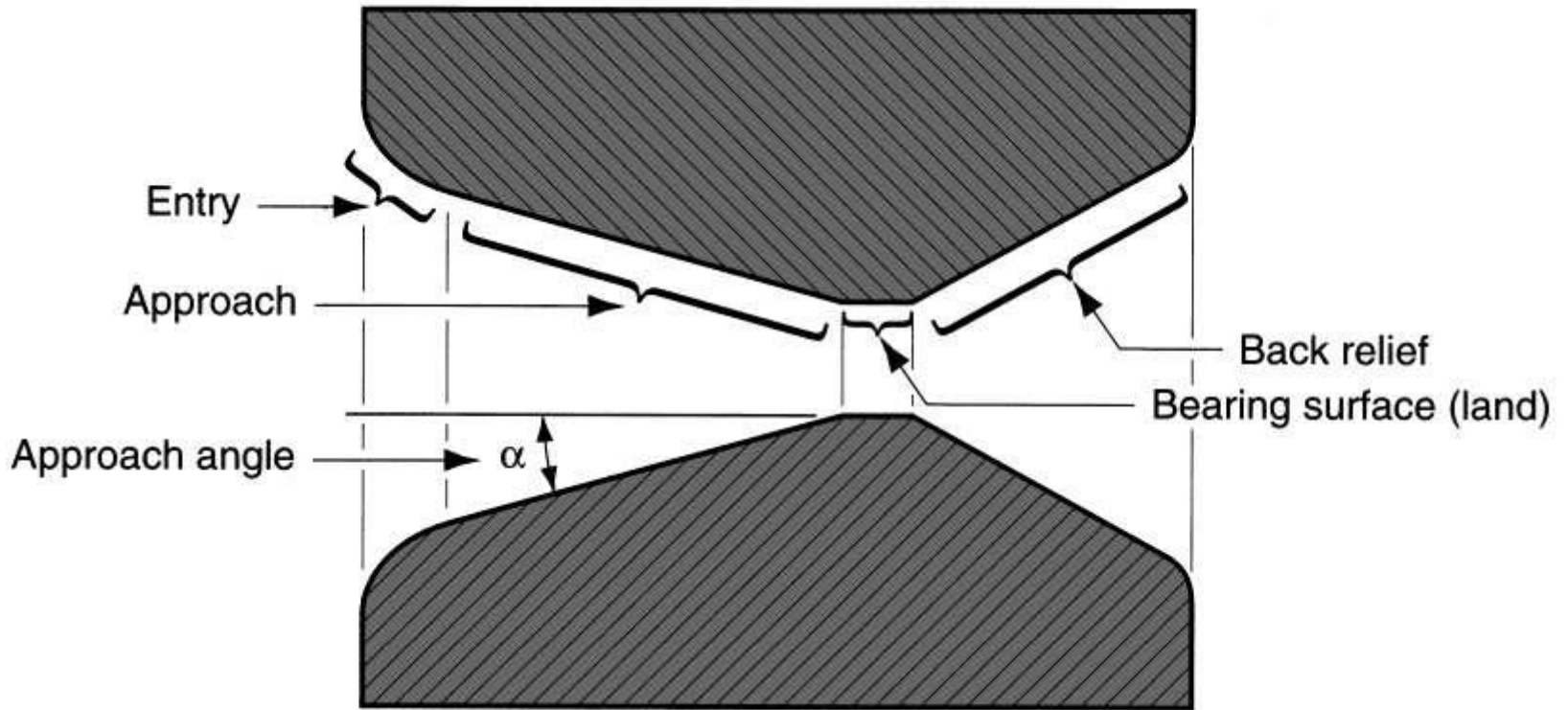
1. Accomplished as a *single-draft* operation - the stock is pulled through one die opening
2. Beginning stock has large diameter and is a straight cylinder
3. This necessitates a batch type operation



Continuous drawing of wire

FEATURES OF A DRAW DIE

- 1. Entry region - funnels lubricant into the die to prevent scoring of work and die**
- 2. Approach - cone shaped region where drawing occurs**
- 3. Bearing surface - determines final stock size**
- 4. Back relief - exit zone - provided with a back relief angle (half angle) of about 30°**
- 5. Die materials: tool steels or cemented carbides**

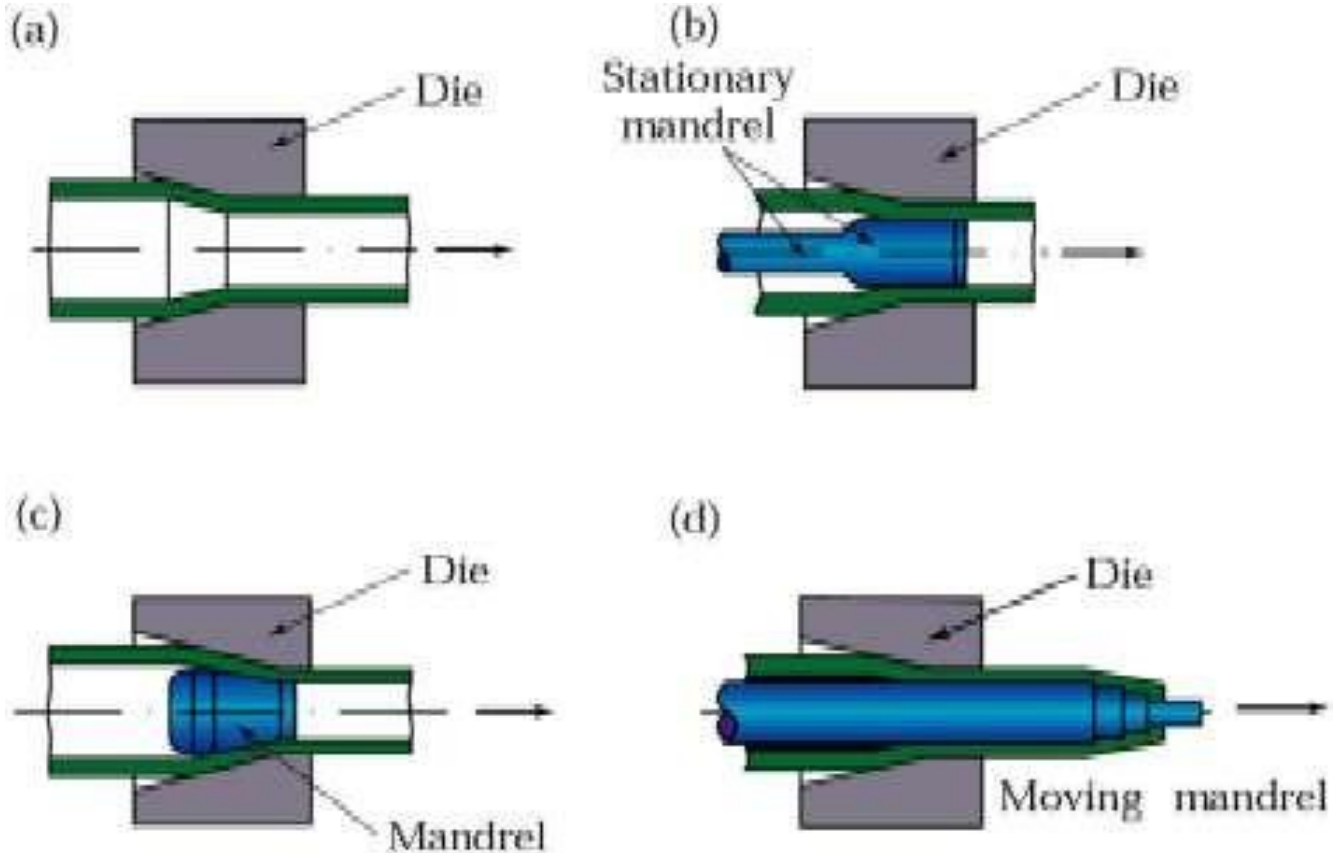


Draw die for drawing of round rod or wire

Preparation of the Work for Wire or Bar Drawing

1. ***Annealing*** – to increase ductility of stock
2. ***Cleaning*** - to prevent damage to work surface and draw die
3. ***Pointing*** – to reduce diameter of starting end to allow insertion through draw die

TUBE DRAWING OPERATIONS



Examples of tube-drawing operations, with and without internal mandrel. Note that a variety of diameters and wall thickness can be produced from the same initial tube stock (which had been made by other processes).

RAPID PROTOTYPING

A family of fabrication processes developed to make engineering prototypes in minimum lead time based on a CAD model of the item

1. Traditional method is machining

- Can require significant lead-times – several weeks, depending on part complexity and difficulty in ordering materials**

2. RP allows a part to be made in hours or days, given that a computer model of the part has been generated on a CAD system

RP – TWO BASIC CATEGORIES

- 1. Material removal RP - machining, using a dedicated CNC machine that is available to the design department on short notice**
 - Starting material is often wax
 - Easy to machine
 - Can be melted and re solidified
 - The CNC machines are often small - called desktop machining
- 2. Material addition RP - adds layers of material one at a time to build the solid part from bottom to top**

STARTING MATERIALS IN MATERIAL ADDITION RP

- 1. Liquid monomers that are cured layer by layer into solid polymers**
- 2. Powders that are aggregated and bonded layer by layer**
- 3. Solid sheets that are laminated to create the solid part**

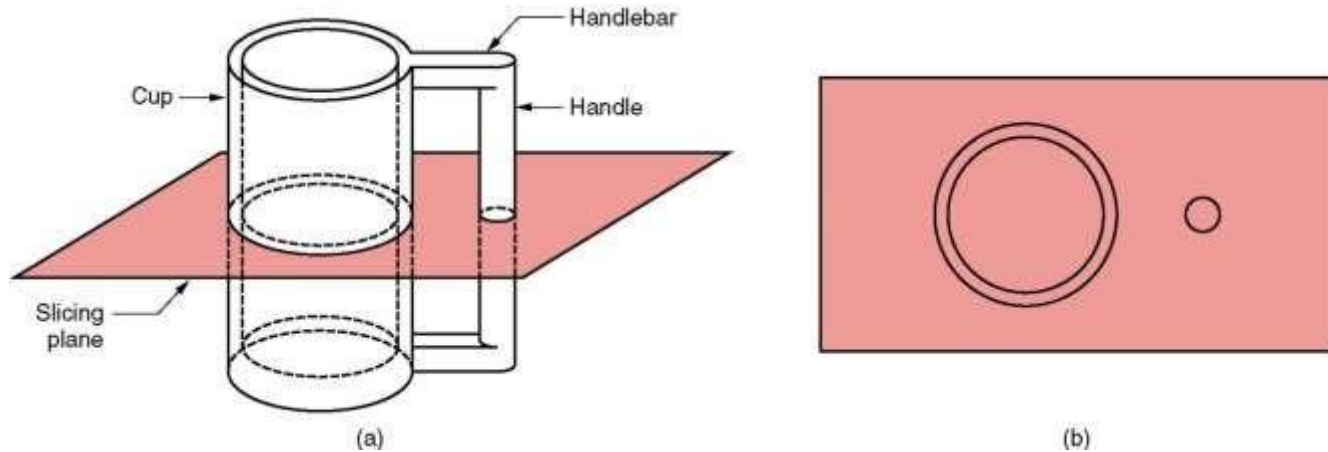
Additional Methods

- In addition to starting material, the various material addition RP technologies use different methods of building and adding layers to create the solid part**
- There is a correlation between starting material and part building techniques**

STEPS TO PREPARE CONTROL INSTRUCTIONS

- 1. Geometric modeling - model the component on a CAD system to define its enclosed volume**
- 2. Tessellation of the geometric model - the CAD model is converted into a computerized format that approximates its surfaces by facets (triangles or polygons)**
- 3. Slicing of the model into layers - computerized model is sliced into closely-spaced parallel horizontal layers**

SOLID MODEL TO LAYERS



Conversion of a solid model of an object into layers (only one layer is shown).

CLASSIFICATION OF RP TECHNOLOGIES

- 1. There are various ways to classify the RP techniques that have currently been developed**
- 2. The RP classification used here is based on the form of the starting material:**
 - 1. Liquid-based**
 - 2. Solid-based**
 - 3. Powder-based**

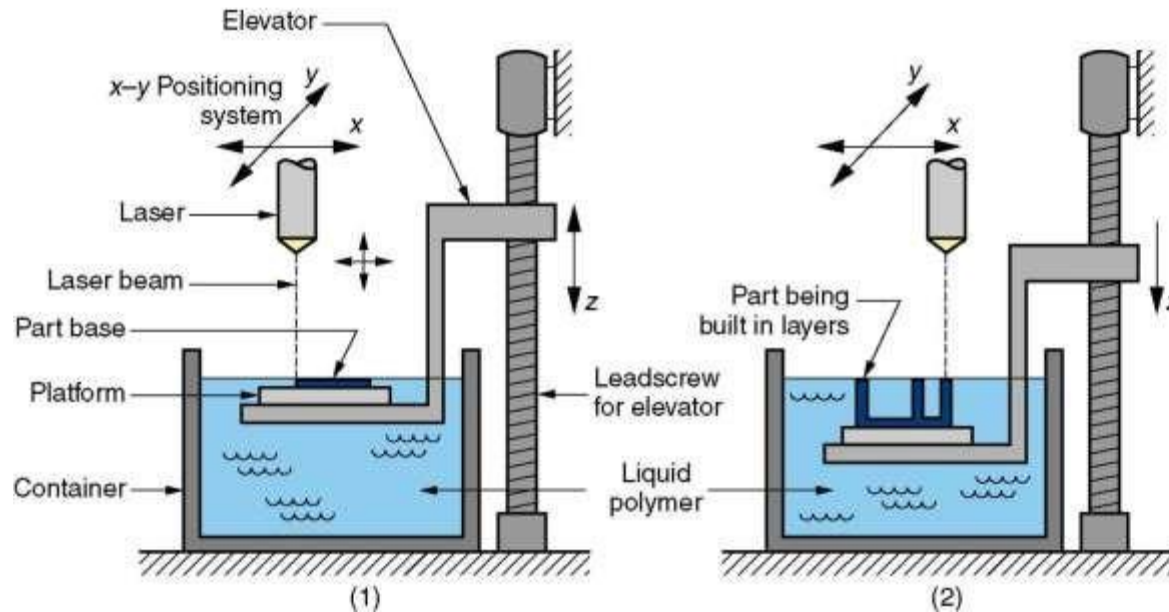
LIQUID-BASED RAPID PROTOTYPING SYSTEMS

- 1. Starting material is a liquid**
- 2. About a dozen RP technologies are in this category**
- 3. Includes the following processes:**
- 4. Stereolithography**
- 5. Solid ground curing**
- 6. Droplet deposition manufacturing**

STEREOLITHOGRAPHY (STL)

- 1. RP process for fabricating a solid plastic part out of a photosensitive liquid polymer using a directed laser beam to solidify the polymer**
- 2. Part fabrication is accomplished as a series of layers - each layer is added onto the previous layer to gradually build the 3-D geometry**
- 3. The first addition RP technology - introduced 1988 by 3D Systems Inc. based on the work of Charles Hull**
- 4. More installations than any other RP method**

STEREOLITHOGRAPHY

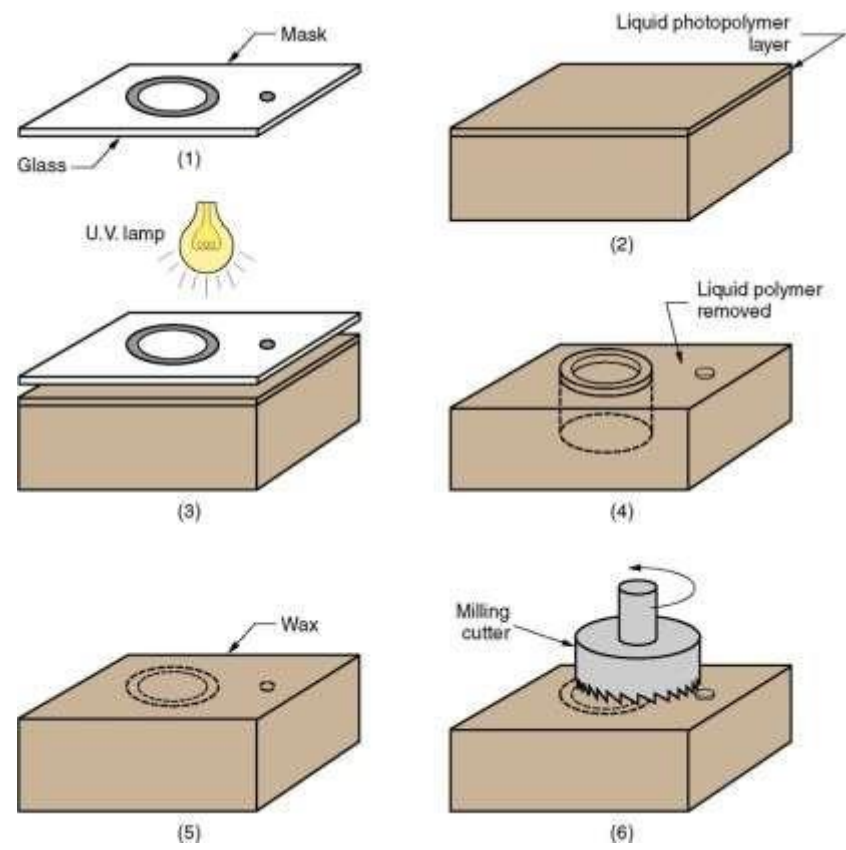


- 1. Stereolithography: (1) at the start of the process, in which the initial layer is added to the platform; and (2) after several layers have been added so that the part geometry gradually takes form.**

SOLID GROUND CURING (SGC)

- 1. Like stereolithography, SGC works by curing a photosensitive polymer layer by layer to create a solid model based on CAD geometric data**
- 2. Instead of using a scanning laser beam to cure a given layer, the entire layer is exposed to a UV source through a mask above the liquid polymer**
- 3. Hardening takes 2 to 3 s for each layer**

SOLID GROUND CURING



SGC steps for each layer: (1) mask preparation, (2) applying liquid photopolymer layer, (3) mask positioning and exposure of layer, (4) uncured polymer removed from surface, (5) wax filling, (6) milling for flatness and thickness.

FACTS ABOUT SGC

- 1. Sequence for each layer takes about 90 seconds**
- 2. Time to produce a part by SGC is claimed to be about eight times faster than other RP systems**
- 3. The solid cubic form created in SGC consists of solid polymer and wax**
- 4. The wax provides support for fragile and overhanging features of the part during fabrication, but can be melted away later to leave the free-standing part**

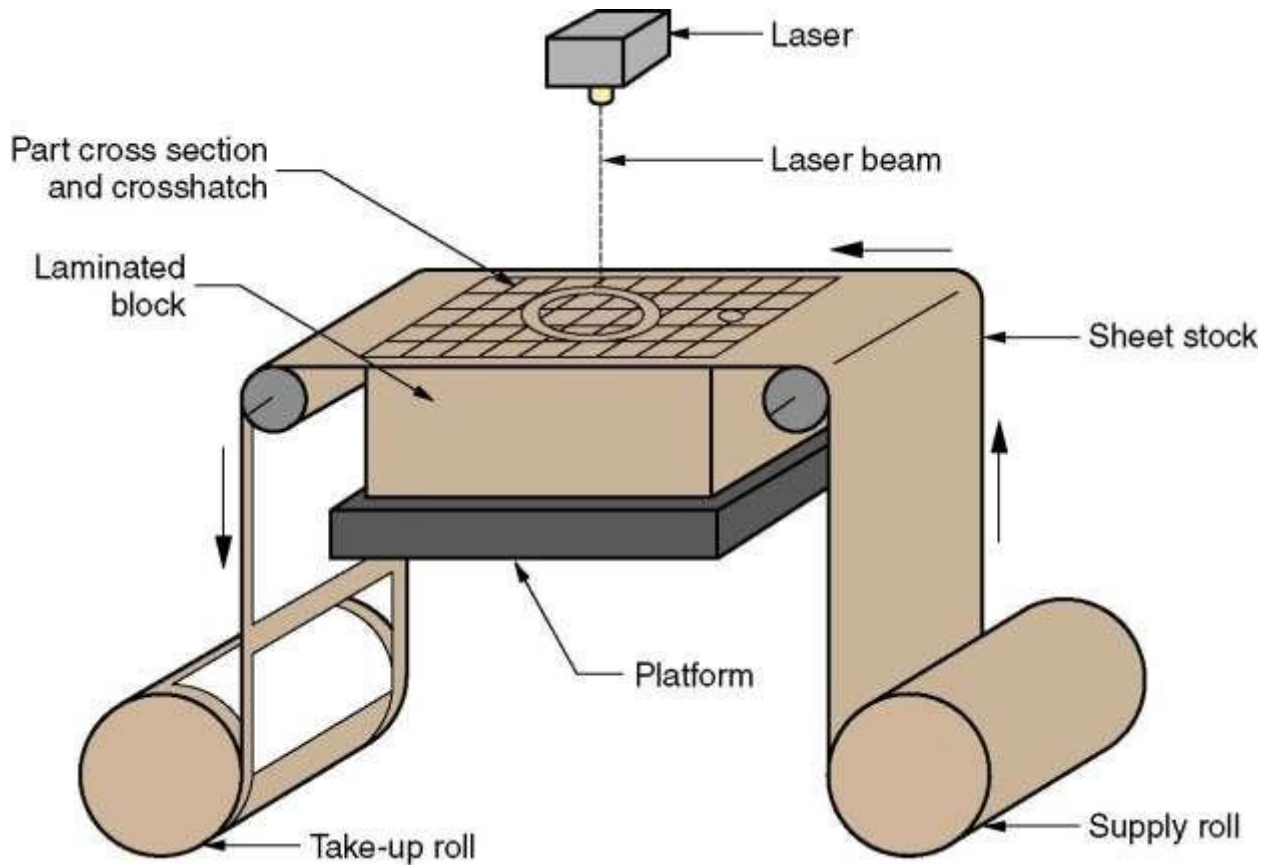
Droplet Deposition Manufacturing (DDM)

- 1. Starting material is melted and small droplets are shot by a nozzle onto previously formed layer**
- 2. Droplets cold weld to surface to form a new layer**
- 3. Deposition for each layer controlled by a moving x-y nozzle whose path is based on a cross section of a CAD geometric model that is sliced into layers**
- 4. Work materials include wax and thermoplastics**
 - Starting material is a solid**
 - Solid-based RP systems include the following processes:**
 - Laminated object manufacturing**
 - Fused deposition modeling**

Laminated Object Manufacturing (LOM)

- 1. Solid physical model made by stacking layers of sheet stock, each an outline of the cross-sectional shape of a CAD model that is sliced into layers**
- 2. Starting sheet stock includes paper, plastic, cellulose, metals, or fiber-reinforced materials**
- 3. The sheet is usually supplied with adhesive backing as rolls that are spooled between two reels**
- 4. After cutting, excess material in the layer remains in place to support the part during building**

Laminated Object Manufacturing



SELECTIVE LASER SINTERING (SLS)

- 1. Moving laser beam sinters heat-fusible powders in areas corresponding to the CAD geometry model one layer at a time to build the solid part**
- 2. After each layer is completed, a new layer of loose powders is spread across the surface**
- 3. Layer by layer, the powders are gradually bonded by the laser beam into a solid mass that forms the 3-D part geometry**
- 4. In areas not sintered, the powders are loose and can be poured out of completed part**

THREE DIMENSIONAL PRINTING

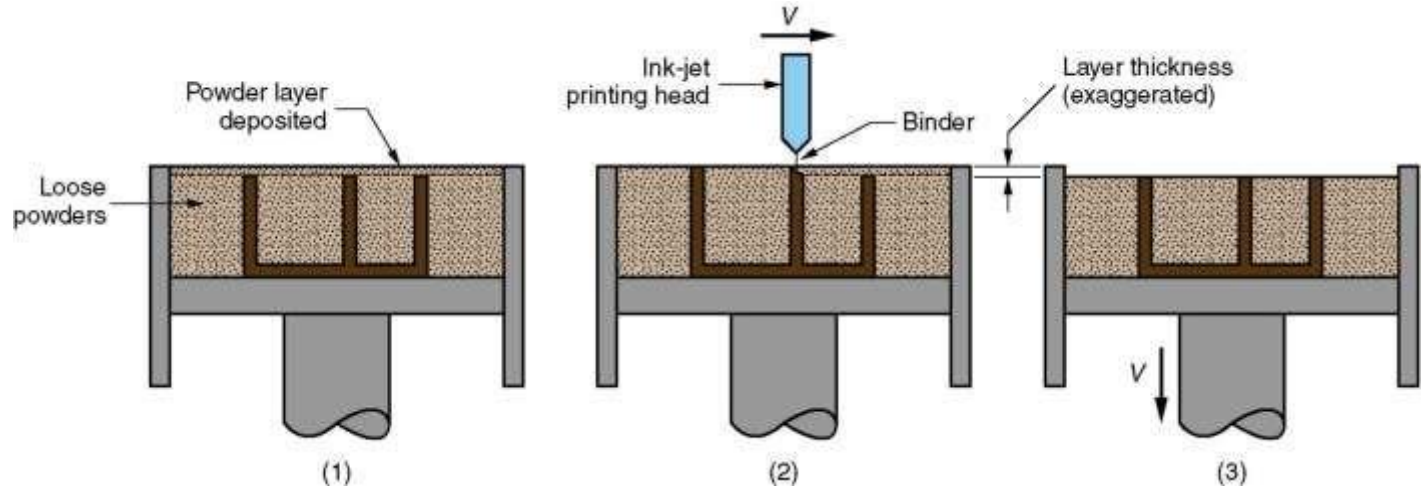


Figure 34.6 Three dimensional printing: (1) powder layer is deposited, (2) ink-jet printing of areas that will become the part, and (3) piston is lowered for next layer (key: v = motion).

RP APPLICATIONS

- 1. Applications of rapid prototyping can be classified into three categories:**
 - 1. Design**
 - 2. Engineering analysis and planning**
 - 3. Tooling and manufacturing**

DESIGN APPLICATIONS

- **Designers are able to confirm their design by building a real physical model in minimum time using RP**
- **Design benefits of RP:**
 - **Reduced lead times to produce prototypes**
 - **Improved ability to visualize part geometry**
 - **Early detection of design errors**
 - **Increased capability to compute mass properties**

PROBLEMS WITH RAPID PROTOTYPING

- **Part accuracy:**
 - **Staircase appearance for a sloping part surface due to layering**
 - **Shrinkage and distortion of RP parts**
- **Limited variety of materials in RP**
 - **Mechanical performance of the fabricated parts is limited by the materials that must be used in the RP process**

RAPID PROTOTYPING

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CLASSIFICATION OF RP TECHNOLOGIES

- 1.
2. **The RP classification used here is based on the form of the starting material:**
Liquid-based Solid-based Powder-based

RAPID PROTOTYPING

Applications of rapid prototyping can be classified into three categories:

- 1. Design**
- 2. Engineering analysis and planning**
- 3. Tooling and manufacturing**

FORGING

MODULE-V

COURSE OUTCOMES (COs):

At the end of the course students are able to:		
	Course Outcomes	Knowledge Level (Bloom's Taxonomy)
CO8	Classify the various forging techniques based on functionality, cost and time in development of critical products.	Understand
CO9	Evaluate the appropriate manufacturing process parameters, for effective optimization of prototype / products.	Apply

MODULE-V

PROGRAM OUTCOMES (POs):

Program Outcomes (POs)		Strength	Proficiency Assessed by
PO 2	Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	CIE/Quiz/AAT
PO 3	Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	2	Seminar/ conferences/ Research papers

FORGING

Forging may be defined as a metal working process by which metals and alloys are plastically deformed to desired shapes by the application of compressive force. Forging may done either hot or cold.

- **Forging - defined as metal working process by which metals and alloys are plastically deformed to the desired shapes by the application of compressive forces.**

- **Classification:**

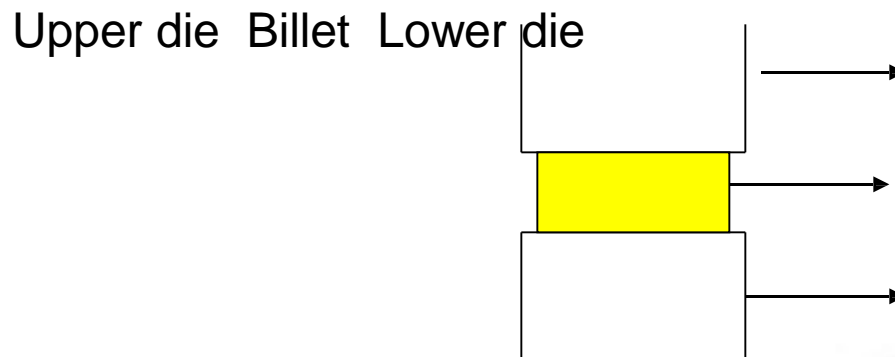
- **Open Die Forging**

- **Impression / closed die forging**

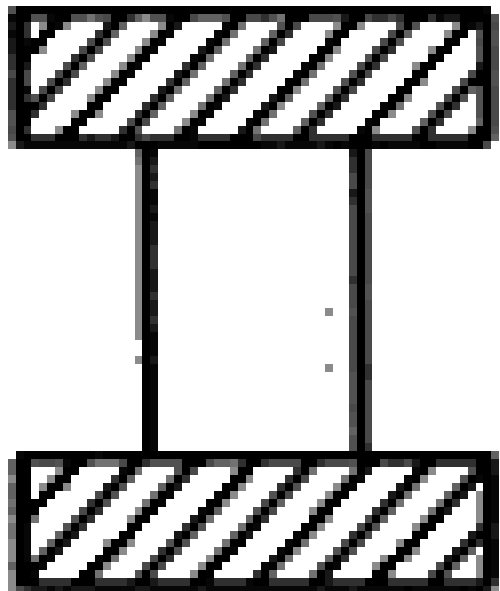
OPEN DIE FORGING

1. Open die forging is performed between flat dies with no precut profiles in the dies.
2. Larger parts over 200,000 lbs. and 80 feet in length can be hammered or pressed into shape this way.

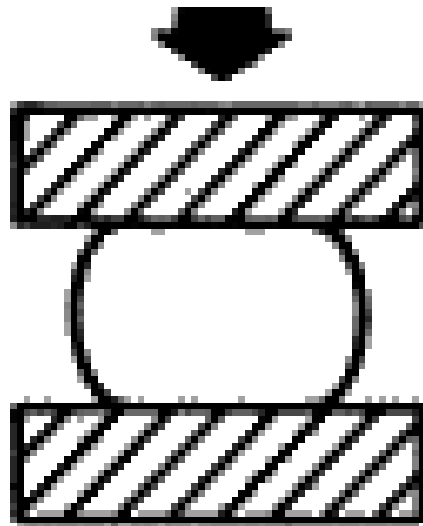
1. It is used
2. Number of components to be forged is too small
3. Size of the component is too large



STARTING STOCK



PRELIMINARY UPSETTING



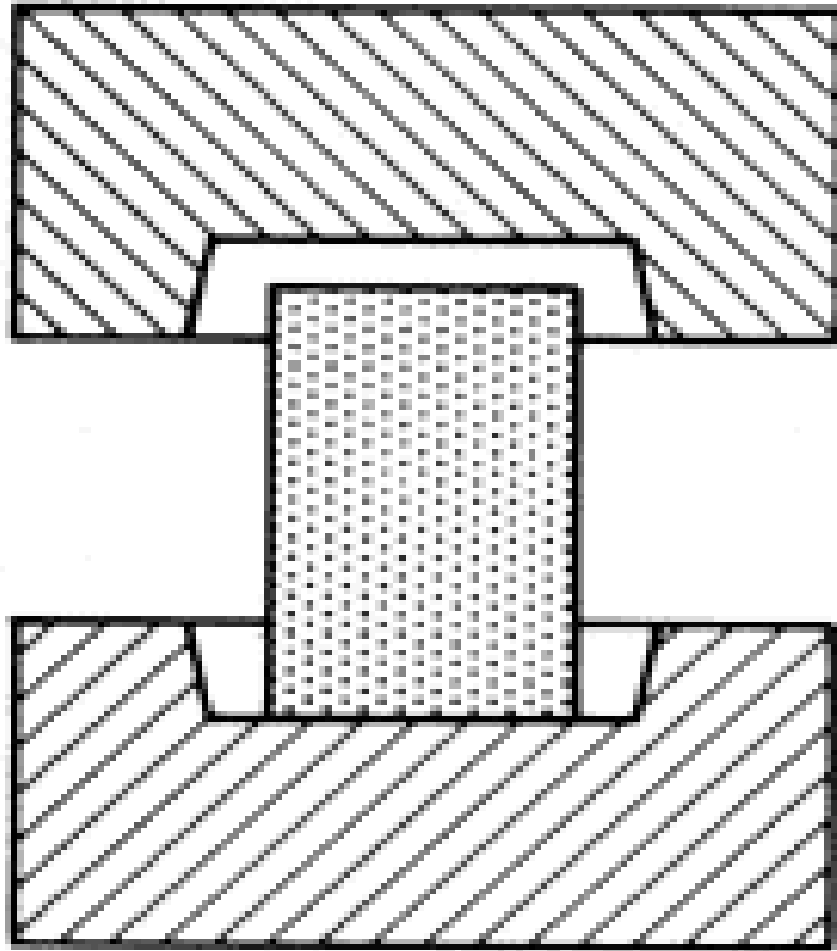
IMPRESSION DIE FORGING

- 1. Impression die forging presses metal between two dies (called tooling) that contain a precut profile of the desired part.**
- 2. It produces closed dimensional tolerances**
- 3. Parts from a few ounces to 60,000 lbs. can be made using this process.**
- 4. Some of the smaller parts are actually forged cold.**

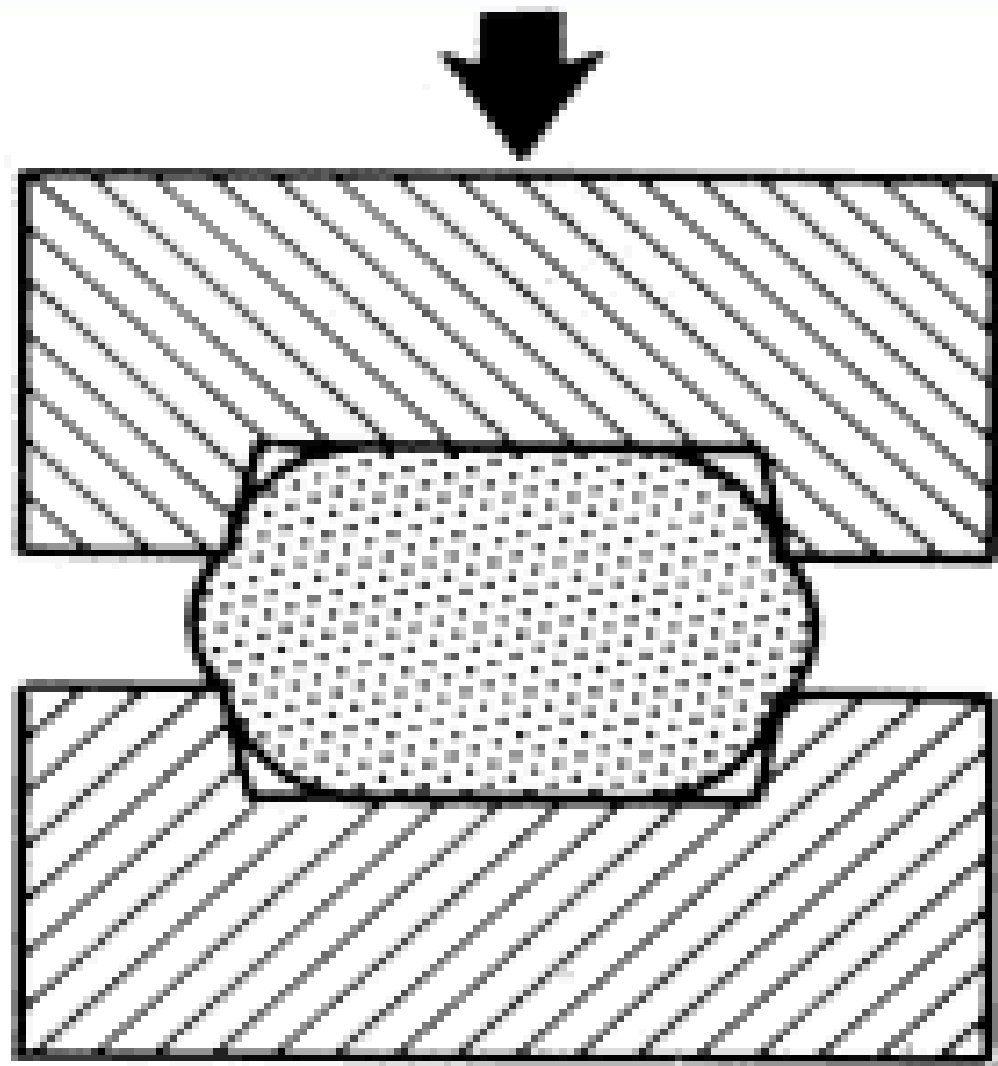
IMPRESSION DIE FORGING

- 1. Impression Die Forging Process Operations.**In impression die forging, two dies are brought together and the work piece undergoes plastic deformation until its enlarged sides touch the side walls of the die. Then, a small amount of material begins to flow outside the die impression forming flash that is gradually thinned.
- 2. The flash cools rapidly and presents increased resistance to deformation and helps build up pressure inside the bulk of the work piece that aids material flow into unfilled impressions.**

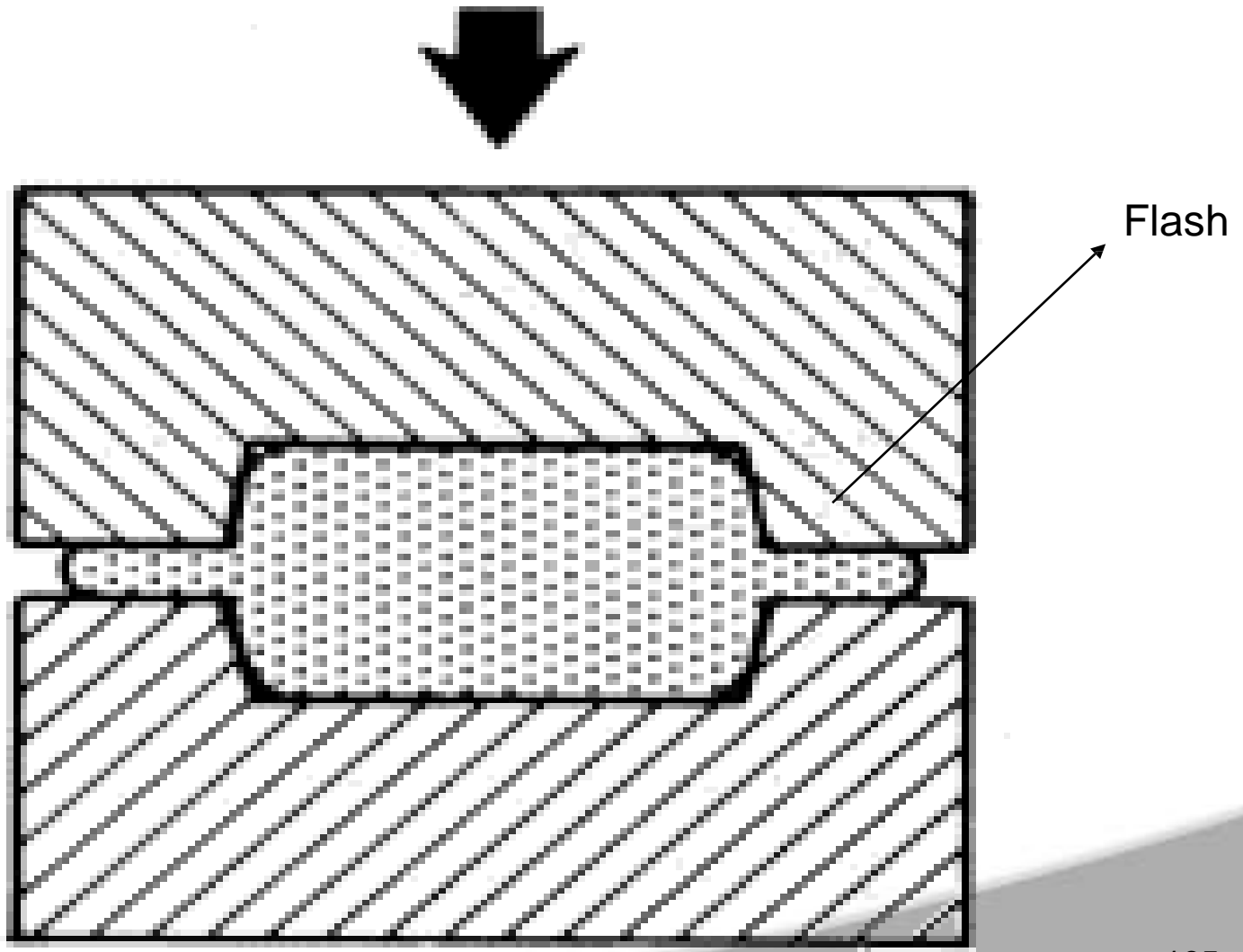
IMPRESSION DIE FORGING



IMPRESSION DIE FORGING



IMPRESSION DIE FORGING



FORGING DEFECTS

1. **Incomplete forging penetration (Dendritic structure will not be broken at the interior surface)**
2. **Surface crack**
3. **High sulphur concentration in the furnace atmosphere can produce HOT SHORTNESS in Steel & Nickel**
4. **Crack at Flash**
5. **Cold shut**
6. **Loose Scale or lubricant may accumulate in deep recess of the die**
7. **Incomplete descaling of work piece**
8. **Internal cracks can develop during upsetting**
9. **Laps (Metal Fold)**
10. **Mismatch**

FORGING OPERATION

1. UPSETTING
2. HEADING
3. FULLERING
4. FLATTENING
5. EDGING
6. DRAWING OR NECKING
7. SETTING DOWN
8. SWAGING
9. PUNCHING
10. PIERCING
11. BENDING

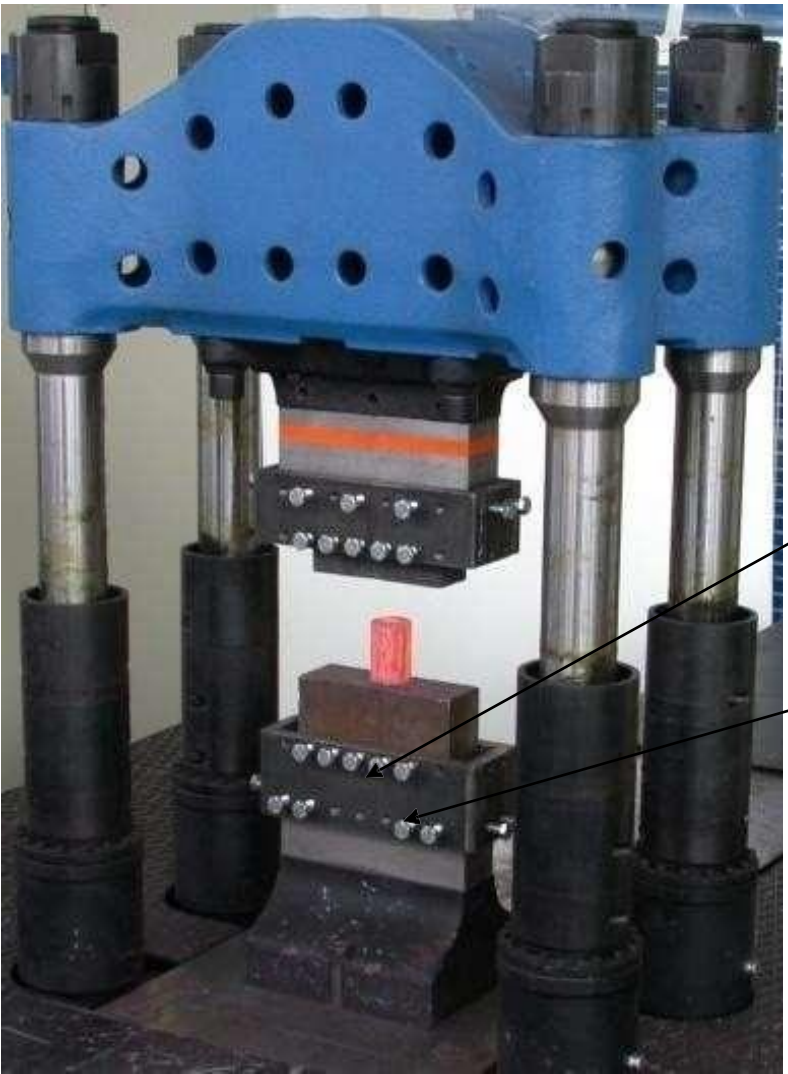
FORGING DEFECTS

- 1. Flash is to be removed**
- 2. Punched holes may be needed**
- 3. Improved surface finish or closer dimensional accuracy may be desired.**
- 4. Trimming Flash is trimmed before the forging is ready for shipping.**
- 5. Coining and ironing are essentially sizing operations with pressure applied to critical surfaces to improve tolerances, smoothen surfaces, or eliminate draft. Little metal flow is involved in either operation and flash is not formed.**
- 6. Coining is usually done on surfaces parallel to the parting line.**
- 7. Ironing is typified by the forcing of a cup-shaped component through a ring to size on outer diameter.**

SWAGING

Swaging--This operation is related to the open die forging process whereby the stock is drawn out between flat, narrow dies. But instead of the stock, the hammer is rotated to produce multiple blows, sometimes as high as 2,000 per minute. It is a useful method of primary working, although in industrial production its role is normally that of finishing. Swaging can be stopped at any point in the length of stock and is often used for pointing tube and bar ends and for producing stepped columns and shafts of declining diameter.

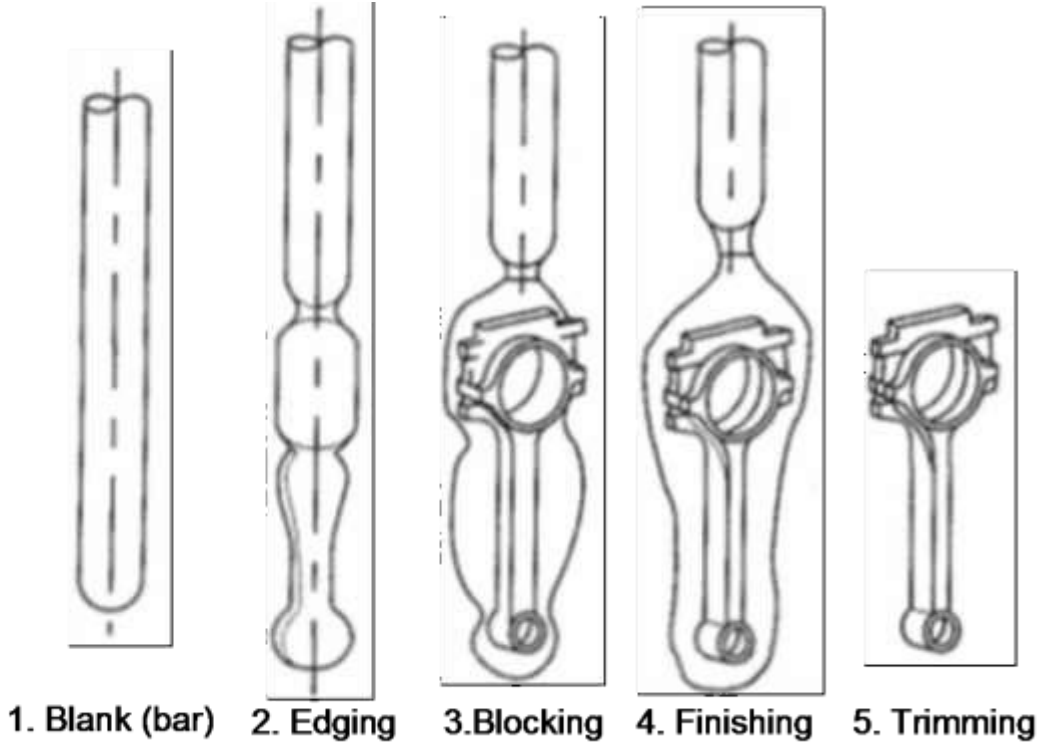
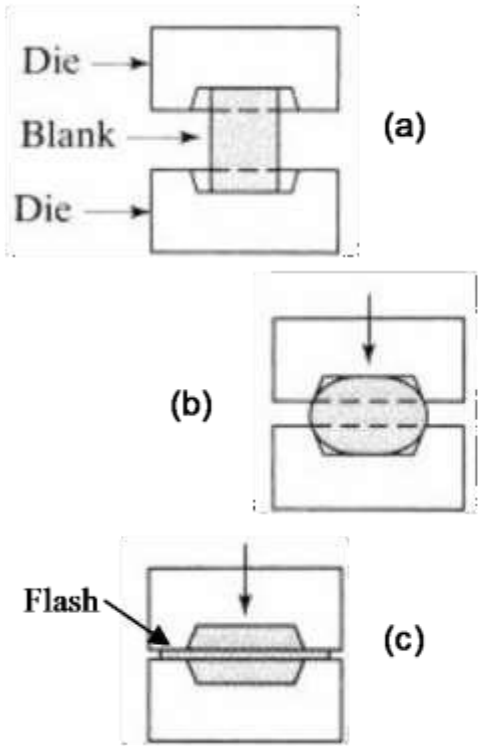
FORGING METHODS



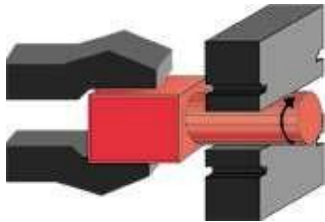
Hot forging,

open-die

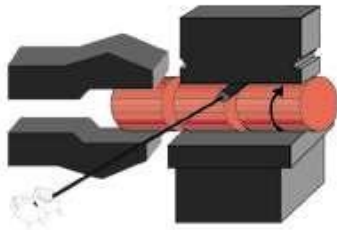
FORGING METHODS



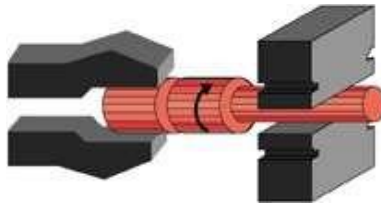
FORGING METHODS



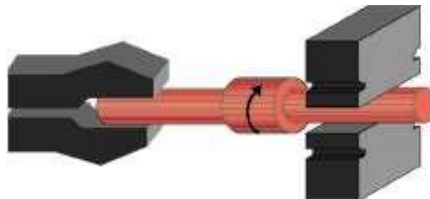
(a) forge hot billet to max diameter



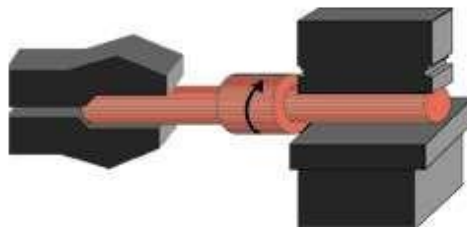
(b) “fuller: tool to mark step-locations



(c) forge right side

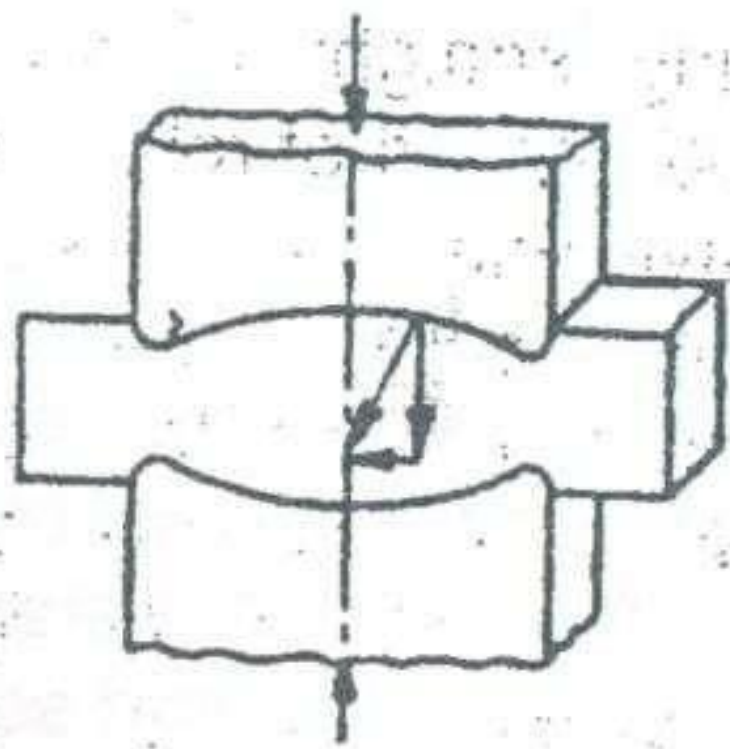


(d) reverse part, forge left side

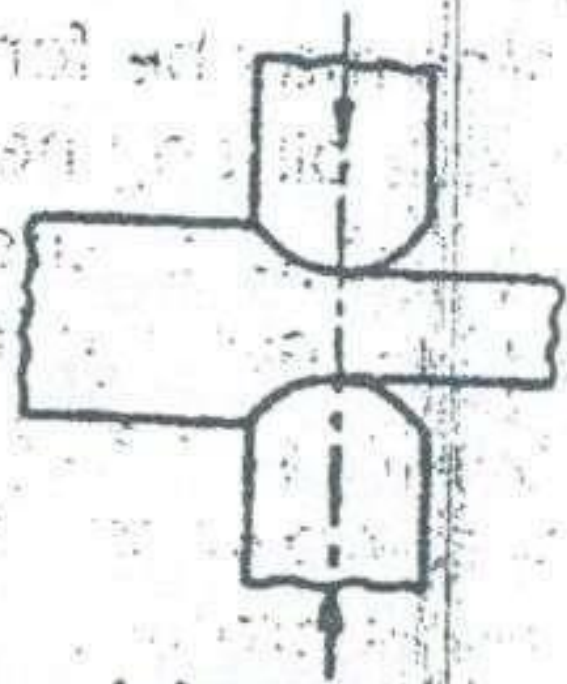


(e) finish (dimension control)

FORGING METHODS

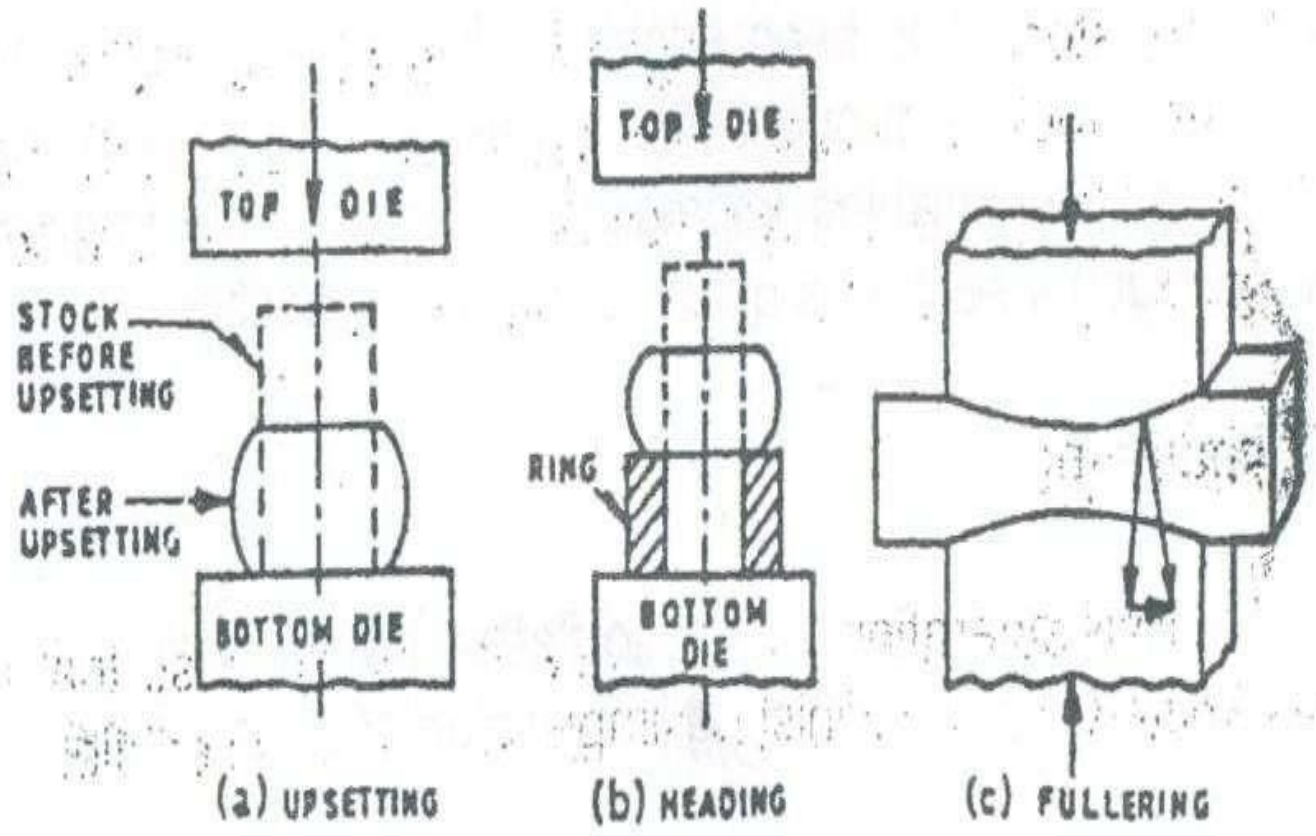


(d) EDGING



(e) DRAWING DOWN

FORGING METHODS





Thank you