MANUFACTURING TECHNOLOGY I

UNIT I METAL CASTING PROCESSES

Sand casting – Sand moulds - Type of patterns – Pattern materials – Pattern allowances – Types of
Moulding sand – Properties – Core making – Methods of Sand testing – Moulding machines – Types
of moulding machines - Melting furnaces – Working principle of Special casting processes – Shell –
investment casting – Ceramic mould – Lost Wax process – Pressure die casting – Centrifugal casting –
CO_2 process – Sand Casting defects.

UNIT II JOINING PROCESSES

Fusion welding processes – Types of Gas welding – Equipments used – Flame characteristics – Filler
and Flux materials - Arc welding equipments - Electrodes – Coating and specifications – Principles of
Resistance welding – Spot/butt – Seam – Projection welding – Percusion welding – GS metal arc welding – Flux cored – Submerged arc welding – Electro slag welding – TIG welding– Principle and
application of special welding processes – Plasma arc welding – Thermit welding – Electron beam
welding – Friction welding – Diffusion welding – Weld defects – Brazing – Soldering process – Methods and process capabilities – Filler materials and fluxes – Types of Adhesive bonding.

UNIT III BULK DEFORMATION PROCESSES

Hot working and cold working of metals – Forging processes – Open impression and closed die forging – Characteristics of the process – Types of Forging Machines – Typical forging operations –
Rolling of metals – Types of Rolling mills – Flat strip rolling – Shape rolling operations – Defects in

rolled parts – Principle of rod and wire drawing – Tube drawing – Principles of Extrusion – Types of
Extrusion – Hot and Cold extrusion – Equipments used.

UNIT IV SHEET METAL PROCESSES

Sheet metal characteristics – Typical shearing operations – Bending – Drawing operations – Stretch forming operations –– Formability of sheet metal – Test methods – Working principle and application of special forming processes – Hydro forming – Rubber pad forming – Metal spinning – Introduction to Explosive forming – Magnetic pulse forming – Peen forming – Super plastic forming.

UNIT V MANUFACTURING OF PLASTIC COMPONENTS

Types of plastics – Characteristics of the forming and shaping processes – Moulding of Thermoplastics – Working principles and typical applications of – Injection moulding – Plunger and screw machines – Compression moulding – Transfer moulding – Typical industrial applications –Introduction to Blow moulding – Rotational moulding – Film blowing – Extrusion – Thermoforming –Bonding of Thermoplastics.

TEXT BOOKS

1. Hajra Choudhury, “Elements of Workshop Technology, Vol. I and II”, Media Promotors Pvt Ltd., 2001

2. S.Gowri, P.Hariharan, and A.Suresh Babu, “Manufacturing Technology I”, Pearson Education,2008.

REFERENCES

1. B.S. Magendran Parashar & R.K. Mittal, “Elements of Manufacturing Processes”, Prentice Hall of India, 2003.

2. P.N. Rao, “Manufacturing Technology”, 2nd Edition, Tata McGraw-Hill Publishing Limited, 2002.

3. P.C. Sharma, “A Text Book of Production Technology”, 4th Edition, S. Chand and Company, 2003.

<u>**UNIT I**</u>

<u>**Metal Casting Process**</u>

Manufacturing

- Manufacturing in its broadest sense is the process of converting raw materials into useful products.
- It includes

i) Design of the product

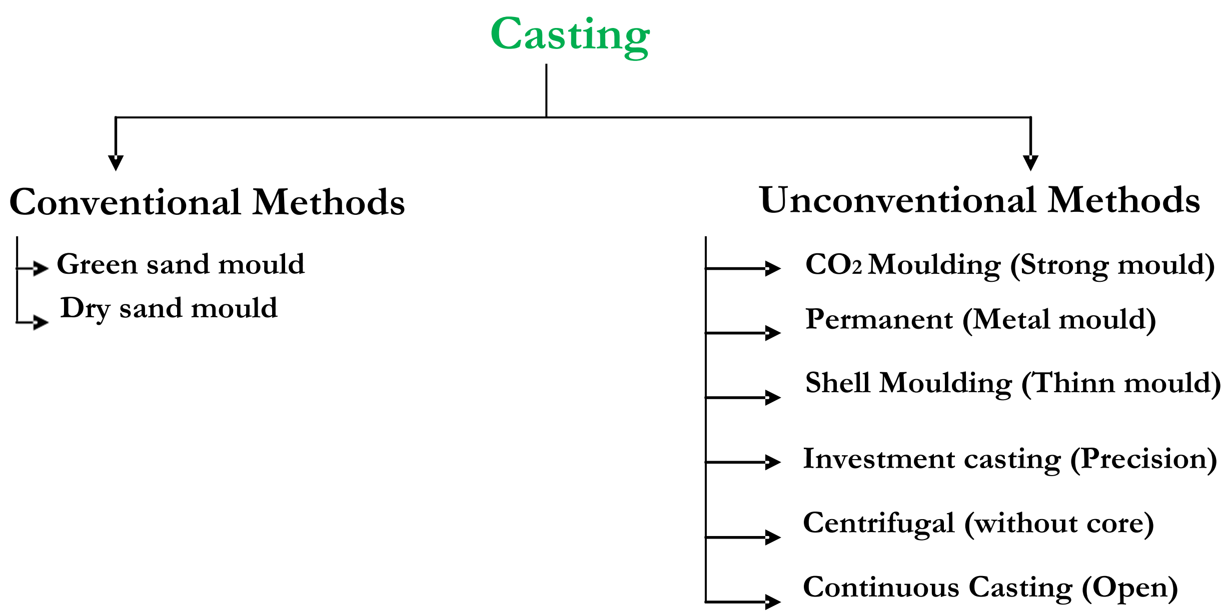
ii) Selection of raw materials and

iii) The sequence of processes through which the product will be manufactured.

Casting

Casting is the process of producing metal parts by pouring molten metal into the mould cavity of the required shape and allowing the metal to solidify. The solidified metal piece is called as "casting".

Types of casting



Advantages

- Design flexibility
- Reduced costs
- Dimensional accuracy
- Versatility in production

Disadvantages

- Lot of molten metal is wasted in riser & gating
- Casting may require machining to remove rough surfaces

Sand Casting

Sand Casting is simply melting the metal and pouring it into a preformed cavity, called mold, allowing (the metal to solidify and then breaking up the mold to remove casting. In sand casting expandable molds are used. So for each casting operation you have to form a new mold.

• Most widely used casting process.
• Parts ranging in size from small to very large
• Production quantities from one to millions
• Sand mold is used.
• Patterns and Cores
    – Solid, Split, Match-plate and Cope-and-drag Patterns
    – Cores – achieve the internal surface of the part

Molds

- Sand with a mixture of water and bonding clay
- Typical mix: 90% sand, 3% water, and 7% clay
- to enhance strength and/or permeability

Sand – Refractory for high temperature

Size and shape of sand

Small grain size -> better surface finish
Large grain size -> to allow escape of gases during pouring
Irregular grain shapes -> strengthen molds due to interlocking but to reduce permeability

Types of sand

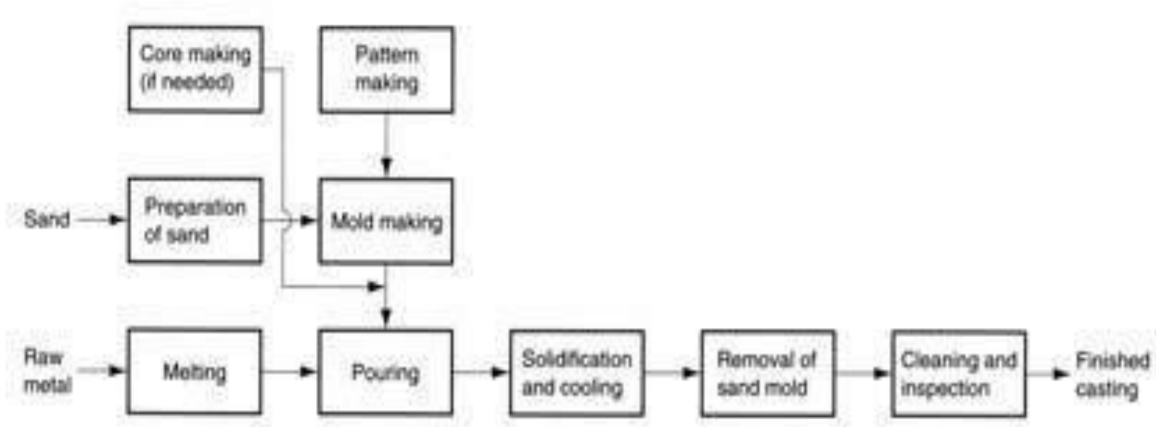
a) Green-sand molds - mixture of sand, clay, and water; "Green" means mold contains moisture at time of pouring.
b) Dry-sand mold - organic binders rather than clay and mold is baked to improve strength
c) Skin-dried mold - drying mold cavity surface of a green-sand
- mold to a depth of 10 to 25 mm, using torches or heating

Steps in Sand Casting

The cavity in the sand mold is formed by packing sand around a pattern, separating the mold into two halves

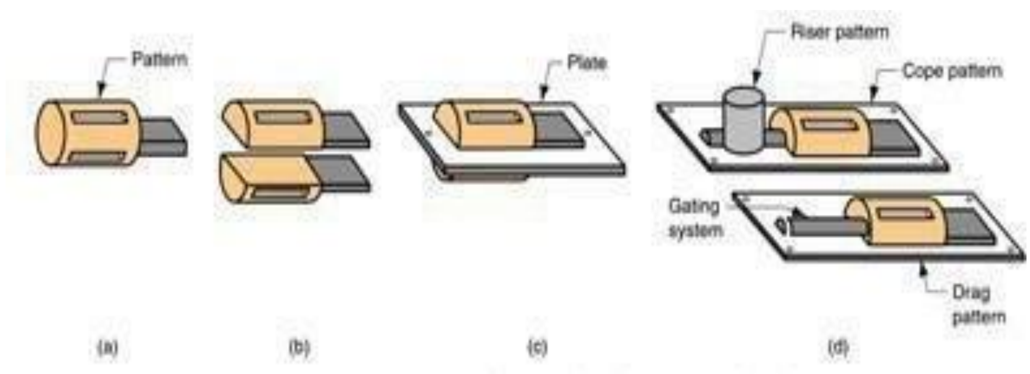
- The mold must also contain gating and riser system
- For internal cavity, a core must be included in mold
- A new sand mold must be made for each part

1. Pour molten metal into sand mold
2. Allow metal to solidify
3. Break up the mold to remove casting
4. Clean and inspect casting
5. Heat treatment of casting is sometimes required to improve metallurgical properties



Types of patterns used in sand casting

(a) solid pattern
(b) split pattern
(c) match-plate pattern
(d) cope and drag pattern



Pattern Allowances

Five types of allowances were taken into consideration for various reasons. They are described as follows:

1. Shrinkage allowance
2. Draft allowance
3. Finish allowance
4. Shake allowance
5. Distortion allowance

Desirable Mold Properties and Characteristics

• Strength - to maintain shape and resist erosion
• Permeability - to allow hot air and gases to pass through voids in sand
• Thermal stability - to resist cracking on contact with molten metal
• Collapsibility - ability to give way and allow casting to shrink without cracking the casting
• Reusability - can sand from broken mold be reused to make other molds.

Testing of Mould & Core sand

1) Preparation of standard test specimen
2) Mould hardness test
3) Core hardness test
4) Moisture content test on foundry sand
5) Sieve analysis
6) Clay content test
7) Permeability test
8) Compression, shear test

Other Expendable Mold Casting

- Shell Molding
- Vacuum Molding
- Expanded Polystyrene Process
- Investment casting
- Plaster and Ceramic Mold casting

Steps in shell-molding

Shell-mold casting yields better surface quality and tolerances. The process is described as follows:

The 2-piece pattern is made of metal (e.g. aluminum or steel), it is heated to between 175°C- 370°C, and coated with a lubricant, e.g. silicone spray.

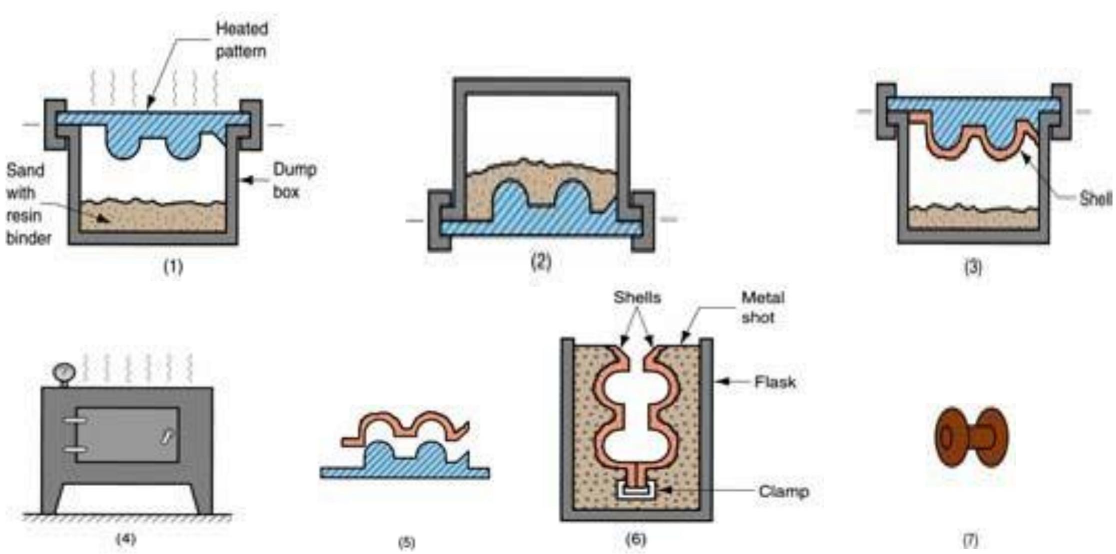
Each heated half-pattern is covered with a mixture of sand and a thermoset resin/epoxy binder.

The binder glues a layer of sand to the pattern, forming a shell. The process may be repeated to get a thicker shell.

The assembly is baked to cure it.

The patterns are removed, and the two half-shells joined together to form the mold; metal is poured into the mold.

When the metal solidifies, the shell is broken to get the part.



Advantages

- Smoother cavity surface permits easier flow of molten metal and better surface finish on casting
- Good dimensional accuracy
- Machining often not required
- Mold collapsibility usually avoids cracks in casting
- Can be mechanized for mass production

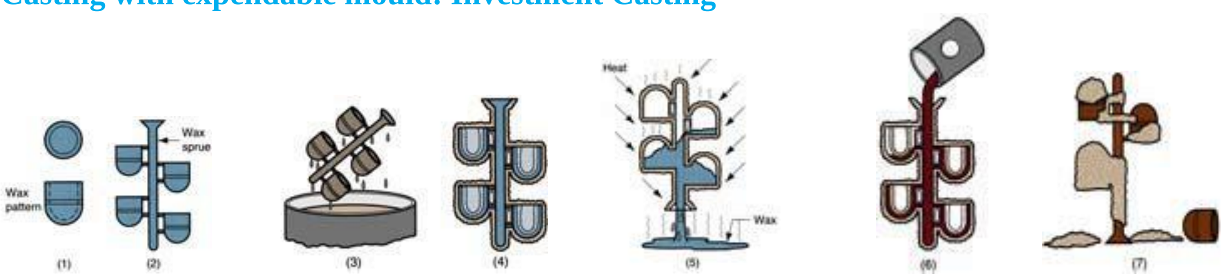
Disadvantages

- More expensive metal pattern
- Difficult to justify for small quantities

Investment Casting

- Investment casting produces very high surface quality and dimensional accuracy.
- Investment casting is commonly used for precision equipment such as surgical equipment, for complex geometries and for precious metals.
- This process is commonly used by artisans to produce highly detailed artwork.
- The first step is to produce a pattern or replica of the finished mould. Wax is most commonly used to form the pattern, although plastic is also used.
- Patterns are typically mass-produced by injecting liquid or semi-liquid wax into a permanent die.
- Prototypes, small production runs and specialty projects can also be undertaken by carving wax models.
- Cores are typically unnecessary but can be used for complex internal structures. Rapid prototyping techniques have been developed to produce expendable patterns.
- Several replicas are often attached to a gating system constructed of the same material to form a tree assembly. In this way multiple castings can be produced in a single pouring.

Casting with expendable mould: Investment Casting



Advantages

– Parts of great complexity and intricacy can be cast
– Close dimensional control and good surface finish
– Wax can usually be recovered for reuse
– Additional machining is not normally required - this is a net shape process

Disadvantages

– Many processing steps are required
– Relatively expensive process

Plaster Molding

• Similar to sand casting except mold is made of plaster of Paris (gypsum - $CaSO_4 \cdot 2H_2O$)
• Plaster and water mixture is poured over plastic or metal pattern to make a mold

Advantages

– Good dimensional accuracy and surface finish
– Capability to make thin cross-sections in casting

Disadvantages

- Moisture in plaster mold causes problems:
- Mold must be baked to remove moisture
- Mold strength is lost when is over-baked, yet moisture content can cause defects in product
- Plaster molds cannot stand high temperatures

Permanent Mold Casting

Basic Permanent Mold Process
– Uses a metal mold constructed of two sections designed for easy, precise opening and closing
– Molds for lower melting point alloys: steel or cast iron and Molds for steel: refractory material, due to the very high pouring temperatures

Permanent Mold Casting Process

- The two halves of the mold are made of metal, usually cast iron, steel, or refractory alloys. The cavity, including the runners and gating system are machined into the mold halves.
- For hollow parts, either permanent cores (made of metal) or sand-bonded ones may be used, depending on whether the core can be extracted from the part without damage after casting.
- The surface of the mold is coated with clay or other hard refractory material – this improves the life of the mold. Before molding, the surface is covered with a spray of graphite or silica, which acts as a lubricant. This has two purposes – it improves the flow of the liquid metal, and it allows the cast part to be withdrawn from the mold more easily.
- The process can be automated, and therefore yields high throughput rates.
- It produces very good tolerance and surface finish.
- It is commonly used for producing pistons used in car engines; gear blanks, cylinder heads, and other parts made of low melting point metals, e.g. copper, bronze, aluminum, magnesium, etc.

Advantage

- Good surface finish and dimensional control and Fine grain due to rapid solidification.

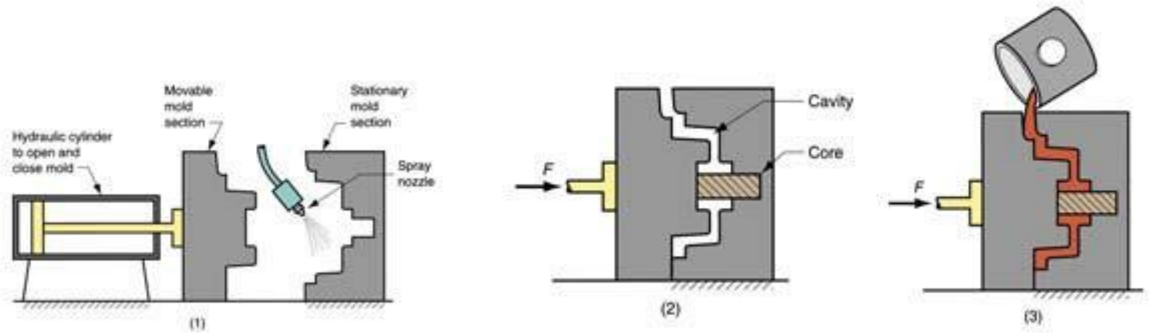
Disadvantage

- Simple geometric part, expensive mold.

Example

It is commonly used for producing pistons used in car engines; gear blanks, cylinder heads, and other parts made of low melting point metals, e.g. copper, bronze, aluminum, magnesium, etc.

Basic Permanent Mold Process



Advantages

– Good dimensional control and surface finish
– More rapid solidification caused by the cold metal mold results in a finer grain structure, so stronger castings are produced

Limitations

- Generally limited to metals of lower melting point
- Simple part geometries compared to sand casting because of the need to open the mold
- High cost of mold
- Due to high mold cost, process is best suited to automated high volume production

Testing of Mould & Core sand

1) Preparation of standard test specimen
2) Mould hardness test
3) Core hardness test
4) Moisture content test on foundry sand
5) Sieve analysis
6) Clay content test
7) Permeability test
8) Compression, shear test

Die Casting

• Die casting is a very commonly used type of permanent mold casting process.
• It is used for producing many components of home appliances (e.g rice cookers, stoves, fans, washing and drying machines, fridges), motors, toys and hand-tools
• The molten metal is injected into mold cavity (die) under high pressure (7-350MPa). Pressure maintained during solidification.
• Hot Chamber (Pressure of 7 to 35MPa)
• The injection system is submerged under the molten metals (low melting point metals such as lead, zinc, tin and magnesium)
• Cold Chamber (Pressure of 14 to 140MPa)
• External melting container (in addition aluminum, brass and magnesium)
Molds are made of tool steel, mold steel, maraging steel, tungsten and molybdenum.
• Single or multiple cavity
• Lubricants and Ejector pins to free the parts

• Venting holes and passageways in die
• Formation of flash that needs to be trimmed

Properties of die-casting

1) Huge numbers of small, light castings can be produced with great accuracy.
2) Little surface finishing is required.
3) Permanent mold (dies can be used over and over)

Advantages

– High production, Economical, close tolerance, good surface finish, thin sections, rapid cooling

Hot-Chamber Die Casting

In a hot chamber process (used for Zinc alloys, magnesium) the pressure chamber connected to the die cavity is filled permanently in the molten metal.

The basic cycle of operation is as follows:

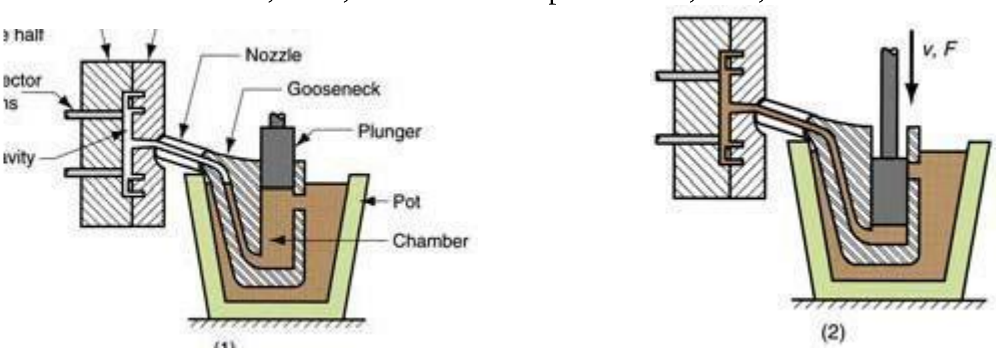
(i) die is closed and gooseneck cylinder is filled with molten metal;

(ii) plunger pushes molten metal through gooseneck passage and nozzle and into the die cavity; metal is held under pressure until it solidifies;

(iii) die opens and cores, if any, are retracted; casting stays in ejector die; plunger returns, pulling molten metal back through nozzle and gooseneck;

(iv) ejector pins push casting out of ejector die. As plunger uncovers inlet hole, molten metal refills gooseneck cylinder.

The hot chamber process is used for metals that (a) have low melting points and (b) do not alloy with the die material, steel; common examples are tin, zinc, and lead.



Cold Chamber Die Casting

In a cold chamber process, the molten metal is poured into the cold chamber in each cycle. The operating cycle is

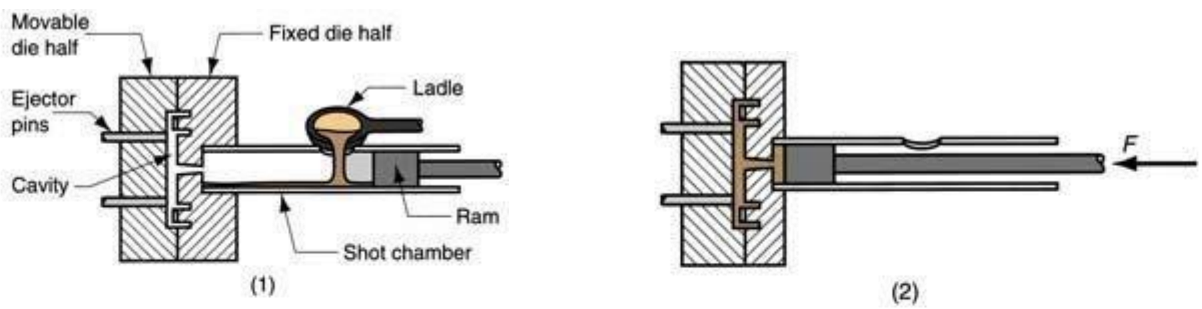
(i) Die is closed and molten metal is ladled into the cold chamber cylinder;

(ii) plunger pushes molten metal into die cavity; the metal is held under high pressure until it solidifies;

(iii) die opens and plunger follows to push the solidified slug from the cylinder, if there are cores, they are retracted away;

(iv) ejector pins push casting off ejector die and plunger returns to original position

This process is particularly useful for high melting point metals such as Aluminum, and Copper (and its alloys).



Advantages

– Economical for large production quantities
– Good dimensional accuracy and surface finish
– Thin sections are possible
– Rapid cooling provides small grain size and good strength to casting

Disadvantages

– Generally limited to metals with low metal points
– Part geometry must allow removal from die cavity

Centrifugal casting

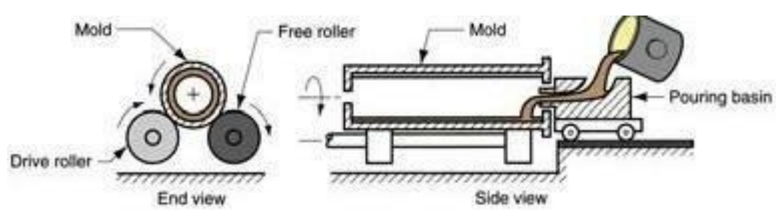
Centrifugal casting uses a permanent mold that is rotated about its axis at a speed between 300 to 3000 rpm as the molten metal is poured.

Centrifugal forces cause the metal to be pushed out towards the mold walls, where it solidifies after cooling.

Centrifugal casting has greater reliability than static castings. They are relatively free from gas and shrinkage porosity.

Surface treatments such as case carburizing, flame hardening and have to be used when a wear resistant surface must be combined with a hard tough exterior surface.

One such application is bimetallic pipe consisting of two separate concentric layers of different alloys/metals bonded together.



Carbon Dioxide Moulding

- This sand is mixed with 3 to 5 % sodium silicate liquid base binder in muller for 3 to 4 minutes. Additives such as coal powder, wood flour sea coal, dextrine may be added to improve its properties.
- Aluminium oxide Kaolin clay may also added to the sand .

- Patterns used in this method may be coated with Zinc of 0.05 mm to 0.13 mm and then spraying a layer of aluminium or brass of about 0.25 mm thickness for good surface finish and good results.

Advantages

- Operation is speedy since we can use the mould and cores immediately after processing.
- Heavy and rush orders
- Floor space requirement is less
- Semi skilled labour may be used.

Disadvantages

Difficult in reusing the moulding sand.

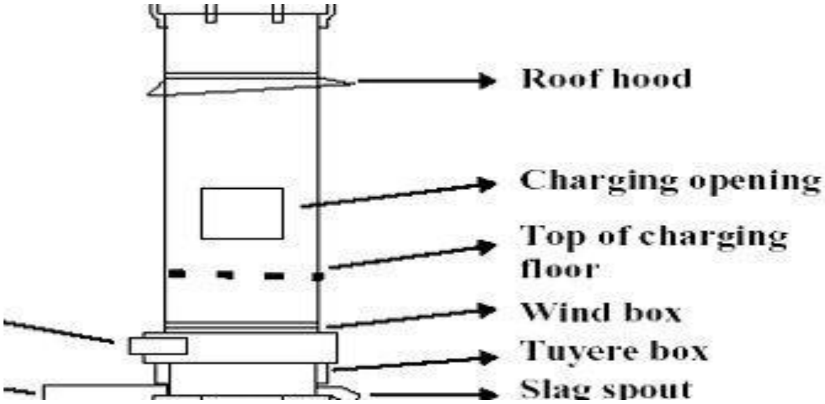
Process	Advantages	Disadvantages	Examples
Sand	Wide range of metals, sizes, shapes, low cost	poor finish, wide tolerance	engine blocks, cylinder heads
Shell mold	better accuracy, finish, higher production rate	limited part size	connecting rods, gear housings
Expendable pattern	Wide range of metals, sizes, 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	precision gears, camera bodies, car wheels
Centrifugal	Large cylindrical parts, good quality	Expensive, limited shapes	pipes, boilers, flywheels

Furnaces

Cupola Furnace

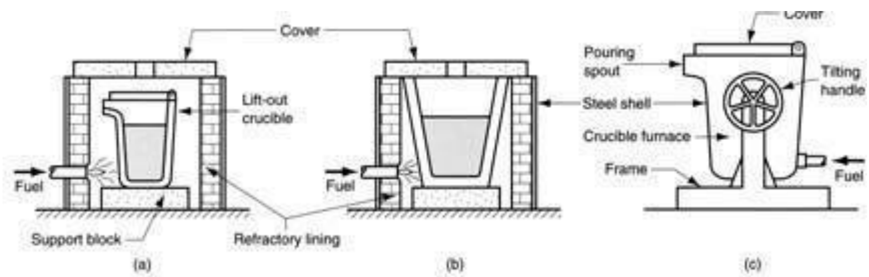
- A continuous flow of iron emerges from the bottom of the furnace.
- Depending on the size of the furnace, the flow rate can be as high as 100 tonnes per hour.

At the metal melts it is refined to some extent, which removes contaminants. This makes this process more suitable than electric furnaces for dirty charges.

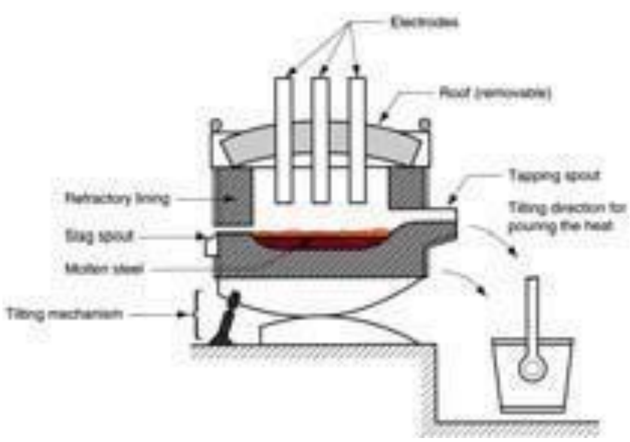


Direct Fuel-fired furnace

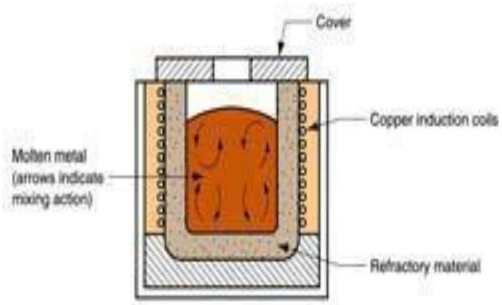
–Crucible Furnace
– Electric-arc Furnace
– Induction Furnace
• Pouring with ladle
• Solidification – watch for oxidation
• Trimming, surface cleaning, repair and heat treat, inspection



Three types: (a) lift-out crucible, (b) stationary pot, from which molten metal must be ladled, and (c) tilting-pot furnace



Induction Furnace:



Casting defects

Defects may occur due to one or more of the following reasons:

- Fault in design of casting pattern
- Fault in design on mold and core
- Fault in design of gating system and riser
- Improper choice of moulding sand
- Improper metal composition
- Inadequate melting temperature and rate of pouring

Some common defects in castings:

a) Misruns b) Cold Shut c) Cold Shot d) Shrinkage Cavity e) Microporosity f) Hot Tearing
Misruns:

a) Misruns

It is a casting that has solidified before completely filling the mold cavity.

Typical causes include
1) Fluidity of the molten metal is insufficient,
2) Pouring Temperature is too low,
3) Pouring is done too slowly and/or
4) Cross section of the mold cavity is too thin.

b) Cold Shut

A cold shut occurs when two portion of the metal flow together, but there is lack of fusion between them due to premature freezing, Its causes are similar to those of a Misruns.

c) Cold Shots

When splattering occurs during pouring, solid globules of the metal are formed that become entrapped in the casting. Poring procedures and gating system designs that avoid splattering can prevent these defects.

d) Shrinkage Cavity

This defects is a depression in the surface or an internal void in the casting caused by solidification shrinkage that restricts the amount of the molten metal available in the last region to freeze.

e) Microporosity

This refers to a network of a small voids distributed throughout the casting caused by localized solidification shrinkage of the final molten metal in the dendritic structure.

f) Hot Tearing

This defect, also called hot cracking, occurs when the casting is restrained or early stages of cooling after solidification.

QUESTION BANK

Manufacturing Technology-I

UNIT- I

PART – A (2 Marks)

1. How special forming process is defined?

1. What is metal spinning process? Define casting?

2. When do you make core (or) what is function of core in moulding sand?

3. Explain the core making process?

4. Mention the specific advantages of carbon di oxide process?

5. Write the composition of good moulding sand?

6. What are chaplets?

7. List the factors to be considered in the choice of metal melting furnace?

8. What are the reasons for the casting defects of cold shuts and misrun?

9. Name four different casting defects.

10. How casting defects are identified?

Part-B (16 Marks)

1. What are the pattern allowances? Explain briefly each. (16)

2. Discuss the properties of moulding sand. (16)

3. Explain the **CO**2 process of core making state its advantages and applications. (16)

4. State the different type of mould. Write a short note on „Green sand mould‟ and shell moulding (16)

5. Write a neat sketch of a cupola, Explain its operate. (16)

6. Explain with a simple sketch how metal is melted in a Electric arc furnace. (16)

7. What are the different types of furnace used in foundry? Describe in detail with neat sketches any one of them. (16)

8. Explain briefly the various moulding method used in foundries. (16)

9. Enumerate the continuous casting defects and suggest suitable remedies. (16)

10. Explain the various non –destructive inspection methods of cast products. (16)

Unit II JOINING PROCESSES

Welding

Welding is a materials joining process which produces coalescence of materials by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone, and with or without the use of filler material.

Welding is used for making permanent joints.

It is used in the manufacture of automobile bodies, aircraft frames, railway wagons, machine frames, structural works, tanks, furniture, boilers, general repair work and ship building.

Classification of welding processes

(i) Arc welding

- Carbon arc
- Metal arc
- Metal inert gas
- Tungsten inert gas
- Plasma arc
- Submerged arc
- Electro-slag

(ii) Gas Welding

- Oxy-acetylene
- Air-acetylene
- Oxy-hydrogen

iii) Resistance Welding

- Butt
- Spot
- Seam
- Projection
- Percussion

(iv) Thermit Welding

(v) Solid State Welding

Friction
Ultrasonic
Diffusion
Explosive

(vi) Newer Welding

Electron-beam
Laser

(vii) Related Process

Oxy-acetylene cutting
Arc cutting
Hard facing
Brazing
Soldering

Welding practice & equipment

STEPS :

- Prepare the edges to be joined and maintain the proper position
- Open the acetylene valve and ignite the gas at tip of the torch
- Hold the torch at about 45deg to the work piece plane
- Inner flame near the work piece and filler rod at about 30 – 40 deg
- Touch filler rod at the joint and control the movement according to the flow of the material

Two Basic Types of AW Electrodes

- Consumable – consumed during welding process
  - Source of filler metal in arc welding
- Nonconsumable – not consumed during welding process
  - Filler metal must be added separately

Consumable Electrodes

Forms of consumable electrodes

- Welding rods (a.k.a. sticks) are 9 to 18 inches and 3/8 inch or less in diameter and must be changed frequently
- Weld wire can be continuously fed from spools with long lengths of wire, avoiding frequent interruptions

In both rod and wire forms, electrode is consumed by arc and added to weld joint as filler metal.

Nonconsumable Electrodes

- Made of tungsten which resists melting
- Gradually depleted during welding (vaporization is principal mechanism)
- Any filler metal must be supplied by a separate wire fed into weld pool

Flux

A substance that prevents formation of oxides and other contaminants in welding, or dissolves them and facilitates removal

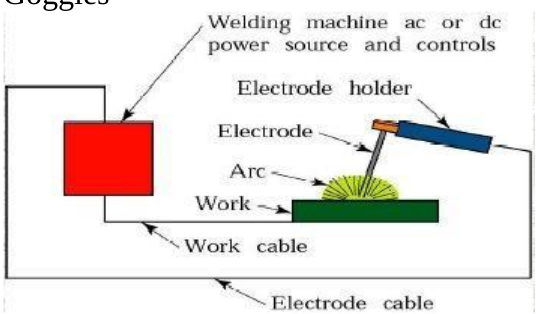
- Provides protective atmosphere for welding
- Stabilizes arc
- Reduces spattering

Arc welding

Uses an electric arc to coalesce metals
Arc welding is the most common method of welding metals
Electricity travels from electrode to base metal to ground

Arc welding Equipments

- A welding generator (D.C.) or Transformer (A.C.)
- Two cables- one for work and one for electrode
- Electrode holder
- Electrode
- Protective shield
- Gloves
- Wire brush
- Chipping hammer
- Goggles



Advantages

- Most efficient way to join metals
- Lowest-cost joining method
- Affords lighter weight through better utilization of materials
- Joins all commercial metals
- Provides design flexibility

Disadvantages

- Manually applied, therefore high labor cost.
- Need high energy causing danger
- Not convenient for disassembly.
- Defects are hard to detect at joints.

GAS WELDING

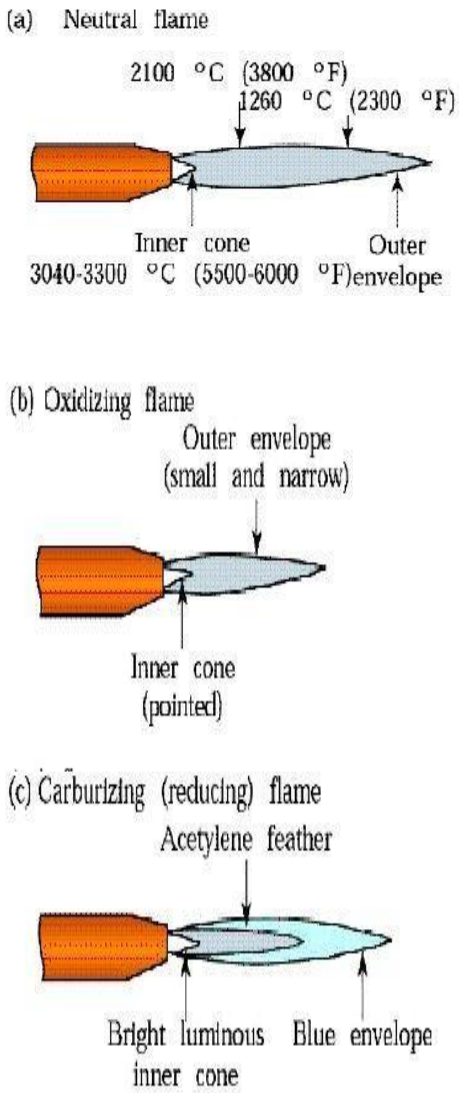
- Sound weld is obtained by selecting proper size of flame, filler material and method of moving torch
- The temperature generated during the process is 33000c.
- When the metal is fused, oxygen from the atmosphere and the torch combines with molten metal and forms oxides, results defective weld
- Fluxes are added to the welded metal to remove oxides
- Common fluxes used are made of sodium, potassium. Lithium and borax.
- Flux can be applied as paste, powder, liquid. solid coating or gas.

GAS WELDING EQUIPMENT

1.Gas Cylinders
Pressure
Oxygen – 125 kg/cm2
Acetylene – 16 kg/cm2
2. Regulators
Working pressure of oxygen 1 kg/cm2
Working pressure of acetylene 0.15 kg/cm2
Working pressure varies depends upon the thickness of the work pieces welded.
3. Pressure Gauges
4. Hoses
5. Welding torch
6. Check valve
7. Non return valve

Types of Flames

- Oxygen is turned on, flame immediately changes into a long white inner area (Feather) surrounded by a transparent blue envelope is called **Carburizing flame** (30000c)
- Addition of little more oxygen give a bright whitish cone surrounded by the transparent blue envelope is called **Neutral flame** (It has a balance of fuel gas and oxygen) (32000c)
- Used for welding steels, aluminium, copper and cast iron
- If more oxygen is added, the cone becomes darker and more pointed, while the envelope becomes shorter and more fierce is called **Oxidizing flame**
- Has the highest temperature about 34000c
- Used for welding brass and brazing operation



Three basic types of oxyacetylene flames used in oxyfuel-gas welding and cutting operations:

(a) neutral flame; (b) oxidizing flame; (c) carburizing, or reducing flame.

Fusion welding processes

- Definition : Fusion Welding is defined as melting together and coalescing materials by means of heat
- Energy is supplied by thermal or electrical means
- Fusion welds made without filler metals are known as autogenous welds

Filler Metals:

- Additional material to weld the weld zone
- Available as rod or wire
- They can be used bare or coated with flux
- The purpose of the flux is to retard the

Shielded metal arc welding process

- An electric arc is generated between a coated electrode and the parent metal
- The coated electrode carries the electric current to form the arc, produces a gas to control the atmosphere and provides filler metal for the weld bead
- Electric current may be AC or DC. If the current is DC, the polarity will affect the weld size and application

Process

- Intense heat at the arc melts the tip of the electrode
- Tiny drops of metal enter the arc stream and are deposited on the parent metal
- As molten metal is deposited, a slag forms over the bead which serves as an insulation against air contaminants during cooling
- After a weld „pass" is allowed the cool, the oxide layer is removed by a chipping hammer and then cleaned with a wirebrush before the next pass.

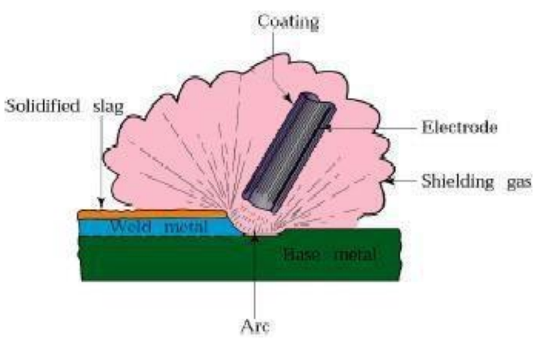


Fig : Schematic illustration of the shielded metal-arc welding process. About 50% of all large-scale industrial welding operations use this process.

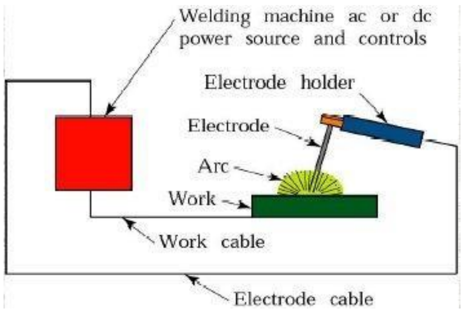


Fig : Schematic illustration of the shielded metal-arc welding process (also known as stick welding, because the electrode is in the shape of a stick).

Submerged arc welding

- Weld arc is shielded by a granular flux , consisting of silica, lime, manganese oxide, calcium fluoride and other compounds.
- Flux is fed into the weld zone by gravity flow through nozzle

- Thick layer of flux covers molten metal

- Flux acts as a thermal insulator ,promoting deep penetration of heat into the work piece
- Consumable electrode is a coil of bare round wire fed automatically through a tube
- Power is supplied by 3-phase or 2-phase power lines

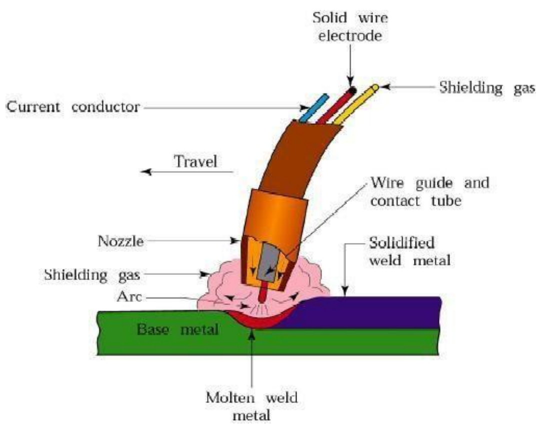


Fig : Schematic illustration of the submerged-arc welding process and equipment. The unfused flux is recovered and reused.

Gas metal arc welding

- GMAW is a metal inert gas welding (MIG)
- Weld area shielded by an effectively inert atmosphere of argon,helium,carbon dioxide,various other gas mixtures
- Metal can be transferred by 3 methods :
- Spray transfer
- Globular transfer
- Short circuiting

Process capabilities

- GMAV process is suitable for welding a variety of ferrous and non-ferrous metals
- Process is versatile ,rapid, economical, welding productivity is double that of SMAW

Flux cored arc welding

- Flux cored arc welding is similar to a gas metal arc welding
- Electrode is tubular in shape and is filled with flux
- Cored electrodes produce more stable arc improve weld contour and produce better mechanical properties
- Flux is more flexible than others

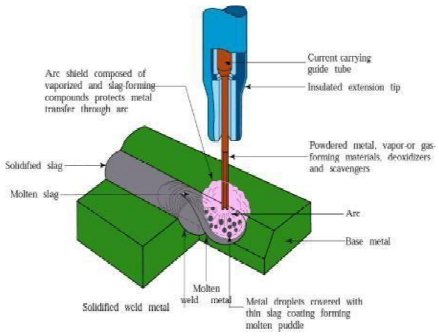


Fig : Schematic illustration of the flux-cored arc-welding process. This operation is similar to gas metal-arc welding.

Electro gas Welding

- EGW is welding the edges of sections vertically in one pass with the pieces placed edge to edge
- Similar to Electro gas welding
- Weld metal is deposited into weld cavity between the two pieces to be joined
- Difference is Arc is started between electrode tip and bottom part of the part to be welded
- Flux added first and then melted by the heat on the arc
- Molten slag reaches the tip of the electrode and the arc is extinguished
- Heat is then continuously produced by electrical resistance of the molten slag
- Single or multiple solid as well as flux-cored electrodes may be used

Process capabilities

- Weld thickness ranges from 12mm to 75mm
- Metals welded are steels, titanium, aluminum alloys
- Applications are construction of bridges, pressure vessels, thick walled and large diameter pipes, storage tanks and ships.

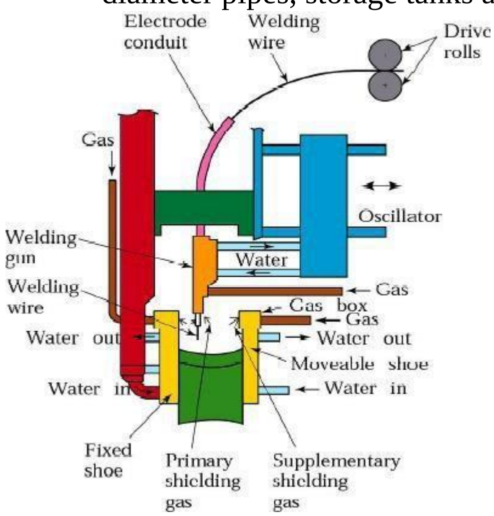


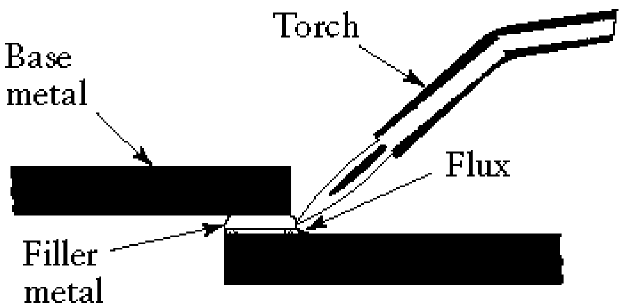
Fig : Schematic illustration of the electrogas welding process

Brazing

It is a low temperature joining process. It is performed at temperatures above 840º F and it generally affords strengths comparable to those of the metal which it joins. It is low temperature in that it is done below the melting point of the base metal. It is achieved by diffusion without fusion (melting) of the base

Brazing can be classified as

Torch brazing
Dip brazing
Furnace brazing
Induction brazing



Advantages

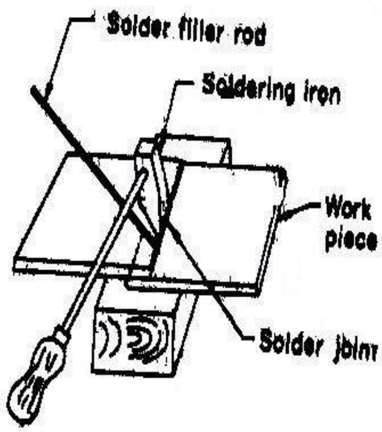
- Dissimilar metals which canot be welded can be joined by brazing
- Very thin metals can be joined
- Metals with different thickness can be joined easily
- In brazing thermal stresses are not produced in the work piece. Hence there is no distortion
- Using this process, carbides tips are brazed on the steel tool holders

Disadvantages

- Brazed joints have lesser strength compared to welding
- Joint preparation cost is more
- Can be used for thin sheet metal sections

Soldering

- It is a low temperature joining process. It is performed at temperatures below 840ºF for joining.
- Soldering is used for,
    - Sealing, as in automotive radiators or tin cans
    - Electrical Connections
    - Joining thermally sensitive components
    - Joining dissimilar metals



Inert Gas Welding

For materials such as Al or Ti which quickly form oxide layers, a method to place an inert atmosphere around the weld puddle had to be developed

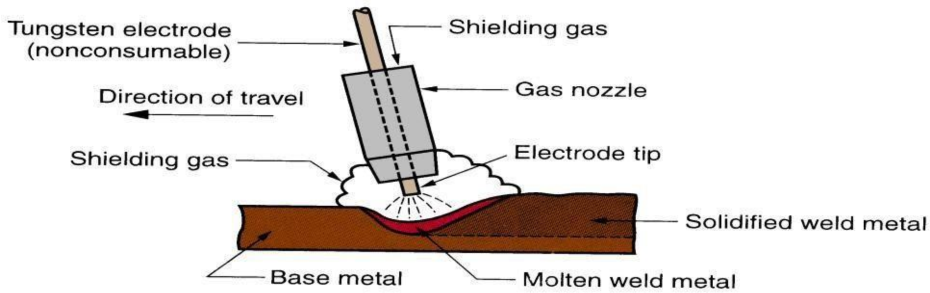
Metal Inert Gas (MIG)

- Uses a consumable electrode (filler wire made of the base metal)
- Inert gas is typically Argon

Gas Tungsten Arc Welding (GTAW)

Uses a non-consumable tungsten electrode and an inert gas for arc shielding

- Melting point of tungsten = 3410℃ (6170℉)
- A.k.a. Tungsten Inert Gas (TIG) welding
  - In Europe, called "WIG welding"
- Used with or without a filler metal
  - When filler metal used, it is added to weld pool from separate rod or wire
- Applications: aluminum and stainless steel most common



Advantages

- High quality welds for suitable applications
- No spatter because no filler metal through arc
- Little or no post-weld cleaning because no flux

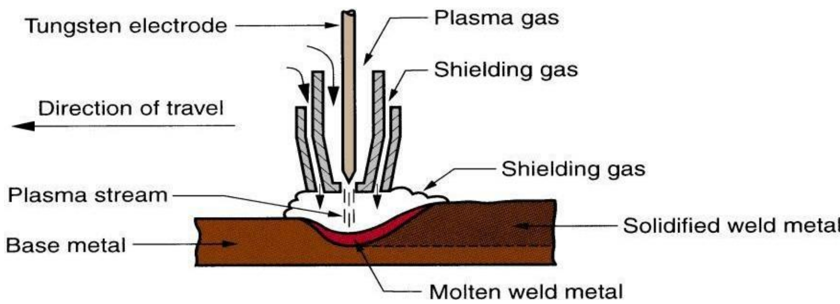
Disadvantages

- Generally slower and more costly than consumable electrode AW processes

Plasma Arc Welding (PAW)

Special form of GTAW in which a constricted plasma arc is directed at weld area

- Tungsten electrode is contained in a nozzle that focuses a high velocity stream of inert gas (argon) into arc region to form a high velocity, intensely hot plasma arc stream
- Temperatures in PAW reach 28,000℃ (50,000 ℉), due to constriction of arc, producing a plasma jet of small diameter and very high energy density



Resistance Welding (RW)

A group of fusion welding processes that use a combination of heat and pressure to accomplish coalescence

- Heat generated by electrical resistance to current flow at junction to be welded
- Principal RW process is resistance spot welding (RSW)

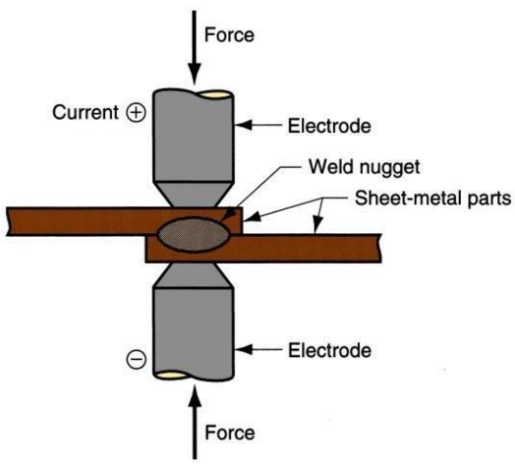


Fig: Resistance welding, showing the components in spot welding, the main process in the RW group.

Components in Resistance Spot Welding

- Parts to be welded (usually sheet metal)
- Two opposing electrodes
- Means of applying pressure to squeeze parts between electrodes
- Power supply from which a controlled current can be applied for a specified time duration

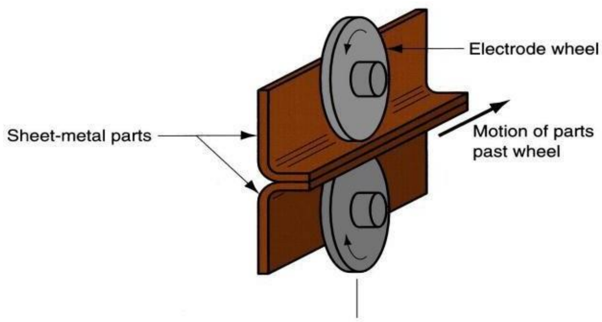
Advantages

- No filler metal required

- High production rates possible
- Lends itself to mechanization and automation
- Lower operator skill level than for arc welding
- Good repeatability and reliability

Disadvantages
- High initial equipment cost
- Limited to lap joints for most RW processes

Resistance Seam Welding



Electron Beam Welding (EBW)

Fusion welding process in which heat for welding is provided by a highly-focused, high-intensity stream of electrons striking work surface

- Electron beam gun operates at:
    - High voltage (e.g., 10 to 150 kV typical) to accelerate electrons
    - Beam currents are low (measured in milliamps)
- Power in EBW not exceptional, but power density is

Advantages
- High-quality welds, deep and narrow profiles
- Limited heat affected zone, low thermal distortion
- High welding speeds
- No flux or shielding gases needed

Disadvantages
- High equipment cost
- Precise joint preparation & alignment required
- Vacuum chamber required
- Safety concern: EBW generates x-rays

Laser Beam Welding (LBW)

Fusion welding process in which coalescence is achieved by energy of a highly concentrated, coherent light beam focused on joint

- Laser = "light amplification by stimulated emission of radiation"
- LBW normally performed with shielding gases to prevent oxidation

- Filler metal not usually added
- High power density in small area, so LBW often used for small parts

Comparison: LBW vs. EBW

- No vacuum chamber required for LBW
- No x-rays emitted in LBW
- Laser beams can be focused and directed by optical lenses and mirrors
- LBW not capable of the deep welds and high depth-to-width ratios of EBW
    - Maximum LBW depth = ~ 19 mm (3/4 in), whereas EBW depths = 50 mm (2 in)

Thermit Welding (TW)

FW process in which heat for coalescence is produced by superheated molten metal from the chemical reaction of thermite

- Thermite = mixture of Al and Fe_3O_4 fine powders that produce an exothermic reaction when ignited
- Also used for incendiary bombs
- Filler metal obtained from liquid metal
- Process used for joining, but has more in common with casting than welding

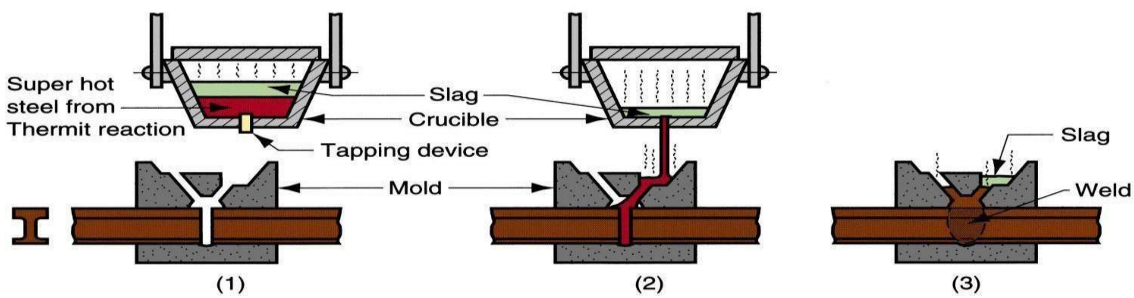


Fig: Thermit welding: (1) Thermit ignited; (2) crucible tapped, superheated metal flows into mold; (3) metal solidifies to produce weld joint.

Applications

- Joining of railroad rails
- Repair of cracks in large steel castings and forgings
- Weld surface is often smooth enough that no finishing is required

Diffusion Welding (DFW)

SSW process uses heat and pressure, usually in a controlled atmosphere, with sufficient time for diffusion and coalescence to occur

- Temperatures $\leq$ 0.5 Tm
- Plastic deformation at surfaces is minimal
- Primary coalescence mechanism is solid state diffusion
- Limitation: time required for diffusion can range from seconds to hours

Applications

- Joining of high-strength and refractory metals in aerospace and nuclear industries
- Can be used to join either similar and dissimilar metals
- For joining dissimilar metals, a filler layer of different metal is often sandwiched between base metals to promote diffusion

Friction Welding (FRW)

SSW process in which coalescence is achieved by frictional heat combined with pressure

- When properly carried out, no melting occurs at faying surfaces
- No filler metal, flux, or shielding gases normally used
- Process yields a narrow HAZ
- Can be used to join dissimilar metals
- Widely used commercial process, amenable to automation and mass production

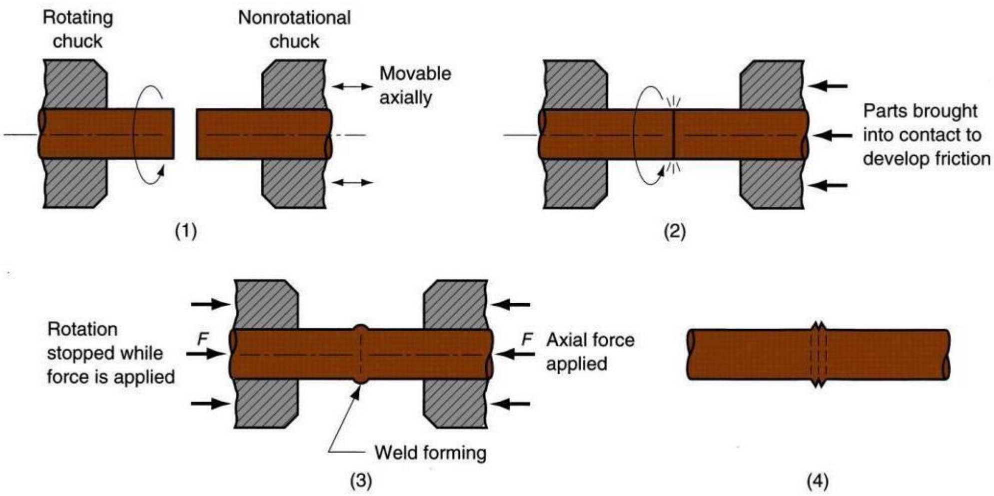


Fig: Friction welding (FRW): (1) rotating part, no contact; (2) parts brought into contact to generate friction heat; (3) rotation stopped and axial pressure applied; and (4) weld created.

Applications

- Shafts and tubular parts
- Industries: automotive, aircraft, farm equipment, petroleum and natural gas

Limitations

- At least one of the parts must be rotational
- Flash must usually be removed
- Upsetting reduces the part lengths (which must be taken into consideration in product design)

Weld Defects

- Undercuts/Overlaps
- Grain Growth

A wide ΔT will exist between base metal and HAZ. Preheating and cooling methods will affect the brittleness of the metal in this region

- Blowholes

Are cavities caused by gas entrapment during the solidification of the weld puddle. Prevented by proper weld technique (even temperature and speed)

- Inclusions

  Impurities or foreign substances which are forced into the weld puddle during the welding process. Has the same effect as a crack. Prevented by proper technique/cleanliness.

- Segregation

  Condition where some regions of the metal are enriched with an alloy ingredient and others aren‟t. Can be prevented by proper heat treatment and cooling.

- Porosity

  The formation of tiny pinholes generated by atmospheric contamination. Prevented by keeping a protective shield over the molten weld puddle.

UNIT - 2

PART – A (2 Marks)

1. Define welding process.

2. Define fusion welding .

3. What are different method of welding you know ?

4. Define arc crater.

5. Mention any two advantages of D .C and A. C welding.

6. What do you under stand by straight polarity?

7. When is the straight polarity used for arc welding?

8. What is the purpose of coating on an arc – welding electrode?

9. What are the two main different of consumable electrode and non –consumable electrode?

10. How does MIG welding differ from TIG welding?

11. What is the main different between upset butt welding and flash butt welding ?

12. What are the various types of flame?

13. Define plasma arc welding ?

Part-B (16 Marks)

1. Explain the method of laser beam welding and give their applications (16)

2. Explain the method of electron beam welding and given their applications (16)

3. Describe plasma Arc welding and given their applications. (16)

4. Describe and explain Ultrasonic welding and give their applications. (16)

5. Explain Thermit welding and given their applications. (16)

6. What is frication welding? give their advantage and limitations. (16)