WELDING

- **Solid state** (Autogenous)
  - Explosive
  - ultrasonic
  - Friction
  - Forge
  - Diffusion
- **Fusion — liquid state** (Homogenous joint)
  - Arc
    - Flux cored
    - Submerged Arc
    - Shielded gas
      - TIG
      - MIG
      - PAW
  - Resistance
  - Chemical Reaction
    - Gas
    - Thermit
- **Solid / liquid** (Heterogenous joint)
  - Brazing
  - Soldering

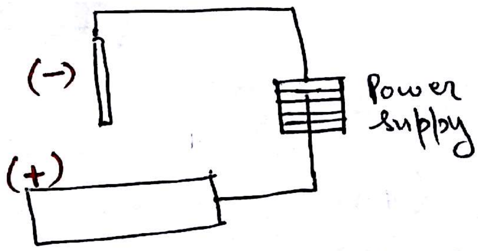
- <u>Arc welding</u>

- cathode (−) ⟶ $\frac{1}{3}$rd of total heat is generated on it

  Anode (+) ⟶ $\frac{2}{3}$rd of total heat is generated on it

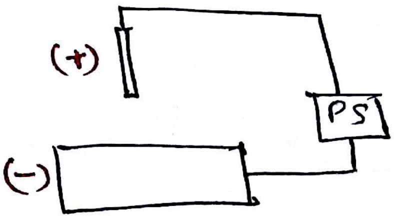
- <u>DC Arc welding</u>

1) Straight Polarity



- DCEN
- high thickness & high M.P. materials are welded
- Depth of penetration is more
- weld deposite rate is less

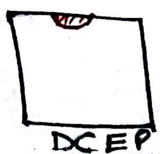
2) Reverse Polarity



- DCEP
- Less thickness & low M.P. materials welded.
- Depth of penetration is less
- weld deposite rate is more

- <u>Depth of Penetration</u>

DCEN AC

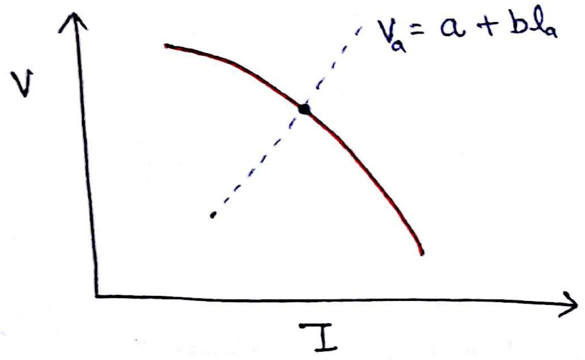


DCEP

- **Arc blow** : Due to deflection of electromagnetic field flux lines towards w/p, electric arc will also deviate towards w/p at begining and end of w/p. This causes weld spatter at both ends
  - Arc blow can be minimised by providing metal blocks at each end of w/p.
  - by flux coating of opposite charge
  - by reducing arc length & current intensity.

- Types of welding machine

1. constant Current type [droop]

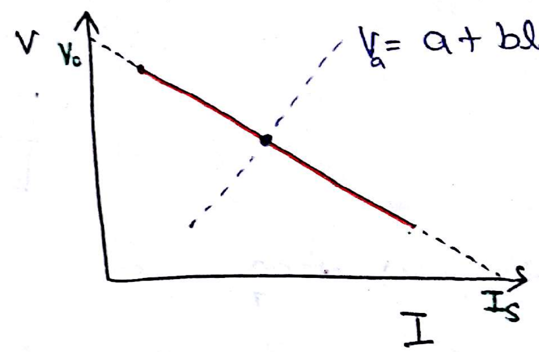


- manually operated m/c

put $v=0$ to get I_s

put $I=0$ to get V_0

2. Constant voltage type [linear]



- Automatic welding m/c
- $\frac{V}{V_0} + \frac{I}{I_s} = 1$
- $(V - V_1) = \left(\frac{V_2 - V_1}{I_2 - I_1}\right)(I - I_1)$

⇒ for max. Power ; $V = V_a = a + bl_a$

V_0 = open circuit voltage (V)

I_s = Short Circuit current (A)

l_a = arc length (mm) or according to Question

⇒ for max Power

$$\frac{dP}{dV} = 0 \quad \text{or} \quad \frac{dP}{dI} = 0 \quad \text{or} \quad \frac{dP}{dl_a} = 0$$

⇒ for linear Power Source

$P_{max} = VI$ here $V = \frac{V_0}{2}$

$I = \frac{I_s}{2}$

- Duty cycle = $\dfrac{\text{Arc on time}}{\text{Arc on time + idle time}}$

$$DI^2 = \text{const} = D_1 I_1^2 = D_2 I_2^2$$

⇒ **Shielded gas Arc welding**

1) TIG ⇒ Tungsten inert gas, Gas Tungsten ~~metal~~ Arc welding (GTAW)
   - DCEN (straight Polarity) used for all except Al & Mg
   - DCEP (reverse Polarity) known as cathodic cleaning
   - AC source is used for Mg & Al
   - non-consumable tungsten electrode.
   - t < 5 mm ⟶ no filler used
     t > 5 mm ⟶ filler needed [valid for all types of welding]
   - it is used to weld Al, Mg & its alloys in Aerospace, Automobile & chemical industries
   - inert gases are blown around electrod & weld pool
   - Zirconium, Thorium ⟶ alloyed with tungsten electrode to increase its MP.

2) MIG ⇒ Metal inert gas, Gas metal arc welding (GMAW)
   - Droplet transfer ⟶ at low current ⟶ only gravity force
   - Spray transfer ⟶ at high current ⟶ gravity + magnetic force [Pinch effect]
   - wire in form of consumable electrode is used
   - inert gas atmosphere is provided [He, Ar, CO_2]
   - used to weld Al, Mg, Cu & its alloys in aerospace & automobile industries
   - wire is bare or lightly coated.

3) Plasma Arc welding (PAW)
   - max tempr 11000°c
   - non-consumable tungsten electrode
   - ceramic nozzle
   - high depth of penetration & HAZ is high
   - used for welding titanium, nickel, cobalt & Stainless steel in aerospace, jet engine, turbine blades etc

Submerged Arc welding

- thickness 15 – 50 mm
- $I = 200 - 2000$ A
- deposition rate = 20 kg/hr
- $v = 5$ m/min
- Consumable electrode
- Solid granular flux is supplied
- Arc is under flux
- minimum heat loss & max. focus on w/p
- DCRP with high current is used

- used for welding of high thickness objects in ship building
- fabrication of pressure vessel and domestic LPG.

Heat Required for melting ⇒ $HR = mc\Delta T + mL$

$\Delta T = T_m - T_a$

T_m = melting tempr

T_a = atmospheric tempr

L = latent Heat

c = specific heat

Heat supplied ⇒ $HS = \eta_{HT} \cdot (VI)$

η_{HT} = Heat transfer efficiency

η_m = melting efficiency = $\frac{HR}{HS}$

Oxy-Acetylene Gas welding

$$C_2H_2 + O_2 \longrightarrow 2CO + H_2 + \Delta h_1$$

$$2CO + H_2 + \frac{3}{2}O_2 \longrightarrow 2CO_2 + H_2O + \Delta h_2$$

$$C_2H_2 + \frac{5}{2}O_2 \longrightarrow 2CO_2 + H_2O + \Delta h$$

1 ~~mole~~ Volume of C_2H_2 ⟶ 2.5 vol. of O_2

1 vol. of O_2 is taken from cylinder and 1.5 vol. O_2 taken from atmosphere.

- O_2 cylinder is black in colour

⇒ Neutral flame (Hissing Sound)
- inner cone ⟶ 3200°C
- MS, CI, low carbon steel & medium carbon steel
- $\frac{O_2}{C_2H_2} = 1$

⇒ Oxidising flame (Roaring Sound)
- Inner cone ⟶ 3300°C
- Cu, Zn, Brass
- $\frac{O_2}{C_2H_2} = 1.15$ to 1.5

⇒ Carburizing flame (no Sound)
- Inner cone ⟶ 2900°C
- Nickel alloys, High carbon steel
- $\frac{O_2}{C_2H_2} = 0.85$ to 0.95

Thermit welding
- $3Fe_3O_4 + 8Al \longrightarrow 9Fe + 4Al_2O_3 + \Delta h$

  $Fe_3O_4 : Al \equiv 3:1$ by mass
- used in repair works of railway rails
- Joining of high thickness plates
- Joining Broken casting

Atomic hydrogen welding
- used for joining of ⇒ tool steel
  - ⇒ die steels
  - ⇒ Repair works of cutting tools & die
- two non-consumable tungsten electrod is used.

$H_2 \longrightarrow H + H - \Delta h_1$

$H + H \longrightarrow H_2 + \Delta h_2$

- H_2 act as heating agent [2ndary fun^n is shielding]

Resistance welding [copper electrodes are used]

a) Spot welding

- thickness => 1 - 2 mm

  $I \Rightarrow 10,000 - 50,000$ A

  $t = 0.01 - 0.5$ sec.

  $$\left.\begin{aligned} HR &= mC\Delta T + mL \\ HS &= I^2Rt \end{aligned}\right] \rightarrow \eta_m = \frac{HR}{HS}$$

- Used for lap joining of sheet materials in automobile bodies and refrigerator bodies

b) Seam welding

- rollers or wheels as electrodes
- welding speed is high.
- used for leak proof joints => fabrication of fuel tanks
  => gasoline pipes
  => muffler in exhaust pipe

c) Projection welding

- Projections are made by Embosing technique
- used only for mass production
- used in - fabrication of wire mesh
  - joining of threaded screw & nut on sheet material.

d) Flash But welding

- $I = 80,000$ A to $90,000$ A
- one fixed & one movable copper electrode are used
- Heat is generated bcz of electric Resistance.
- used for ferrous materials like lead, tin, zinc.

e) Flash welding

- one fixed & one movable copper electrode are used
- Heat is generated bcz of electric Arc.
- used for non ferrous material like bars, rods, wires, tubes.

Electro slag welding

- $I \Rightarrow 1000$ A

  $t \Rightarrow 50 - 200$ mm

  DCRP

- initially Heat is generated due to electric arc.
  Later on Heat is generated due to resistance of slag.
- used in → joining of high thickness object in ship building
  → fabrication of Press frames
  → Rolling mill stands.

Solid state welding

1. Explosive welding

- target plate ⟶ fixed one
- flyer plated ⟶ movable
- low velocity explosive material is placed above flyer plate
- There will be no heat affected zone.
- Used for - high strength with Low strength material
  - cladding of objects to increase corrosive resistance

2) Ultrasonic welding

- Thickness < 1-2 mm foils
- f = 20 to 60 KHz
- Heat is generated due to rubbing action [40 to 50% of M.P. temp]
- Accuracy is good
- used in → fabrication of diodes & triodes in electronic industries
  → fabrication of Keys
  → joining similar & dissimilar material

3) Friction welding

- N ⇒ 4000 - 6000 rpm
  P ⇒ 40 - 400 MPa
- one is fixed w/p & other is rotated
- Heat is generated due to friction [upto recrystallisation temp]
- used for joining → Axel & Hub
  → pipes & valves
  → Drill bit & shank

4) Forge welding

- Exactly similar to blacksmith forging operation.
- w/p heated to recrystallisation temp & then hammered to get required joint.
- it is used for village level agricultural application only

5) Diffusion welding

- Both heat & Pressure simultenously applied at slow rate
- Grain diffusion will take place.
- Accuracy & strength is very high
- To minimise oxide formation → innert gases are provided
  → or vaccume is made.
- Used for → fabrication of composite laminates
  → joining of similar and Dissimilar materials like metal to ceramic.

Solid/liquid state welding

Brazing (capillary)

- 427°C < filler M.P. < WP MP
- filler ⇒ Cu + Zn (Brass)
- flux ⇒ Borax
- used for leakproof liquid circuits

Soldering (capillary)

- filler MP < 427°C
- filler ⇒ Lead + Tin (solder)
- flux ⇒ $ZnCl_2$ & NH_4Cl
- used in PCB component fabrication

Braze welding (gravity)

- when edge Preparation is Possible
- filler ⇒ Bronze (Cu + Tin)
- joining cutting tool tip to shank

Electron Beam welding (EBW)

- Electron beam is foccused using magnetic lens.
- no flux, no filler
- Vaccum neccessory
- welding dissimilar metals, super alloys, aircraft engine parts, farm equipments.
- more penetration compared to LBW.

LASER Beam welding (LBW)

- Laser beam is focused using optical lens.
- micro welding
- multilayered material with diff. thermal conductivity can be joined.
- no vaccum needed
- weld dissimilar metal & which are difficult to weld ex:- Cu, Ni, S.S., Ti

Weldability

Parameter	weldability
T_m ↑	↓
K ↑	↓
α ↑	↓
%C ↑	↓
oxides ↑	↓