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## Advance Welding

**By**

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**Semester – V: Departmental Elective – II: Specialization – Manufacturing and Automation**

| Subject Code: KME 055 | Advance welding | L T P : 3 0 0 | Credits: 3 |
|---|---|---|---|

| Course Outcome: Student will be able to | | Bloom Taxonomy |
|---|---|---|
| CO 1 | Understand the physics of arc welding process and various operating characteristics of welding power source. | K2 |
| CO 2 | Analyse various welding processes and their applications. | K3 |
| CO 3 | Apply the knowledge of welding for repair & maintenance, along with the weldability of different materials. | K3 |
| CO 4 | Apply the concept of quality control and testing of weldments in industrial environment. | K3 |
| CO 5 | Evaluate heat flow in welding and physical metallurgy of weldments. | K4 |

**UNIT-I:**

**Introduction:** Introduction to welding, application, classification and process selection criterion. Health & safety in welding.

**Welding Arc:** Physics of welding arc, arc initiation, voltage distribution, arc characteristics, arc efficiency, arc temperatures and arc blow.Mechanism and types of metal transfer.

**Welding Power Sources:** Types of welding power sources, operation characteristics and specifications.

**UNIT-II:**

**Welding Processes:** Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW) Gas Tungsten Arc Welding (GTAW) Plasma Arc, Submerged Arc Welding, Electro gas and Electroslag, Resistance welding, Friction welding, Brazing, Soldering & Braze welding. Laser beam welding, Electron beam welding, Ultrasonic welding, Explosive welding, Friction Stir Welding, Underwater welding.

**Advances in Welding Processes:** Narrow Gap, Tandem (Twin / Multi Wire) Welding, A-TIG, Hybrid Welding processes**,** Magnetically impelled arc butt (MIAB) welding**,** welding automation and robotic applications.

**UNIT-III:**

**Heat Flow Welding:** Weld thermal cycle, Temperature distribution, Peak temperature; Heat Affected Zone (HAZ), heating, cooling and solidification rates.

**Welding Metallurgy:** Fundamentals of physical metallurgy, Principle of solidification of weld metal, Reactions in weld pool - Gas metal reaction, Slag metal reaction, factors affecting changes in microstructure and mechanical properties of HAZ, Micro and macro structures in weld metal and HAZ

**UNIT-IV:**

**Repair & Maintenance Welding:** Hardfacing, Cladding, Surfacing, Metallizing processes and Reclamation welding.

**Weldability:** Effects of alloying elements on weldability, carbon equivalent, welding of plain carbon steel, Stainless steel, Cast Iron and Aluminium alloys, Welding of Dissimilar Materials

**UNIT-V:**

**Weld Design:** Types of welds & joints, Welding Symbols, Weld defects and Remedies, Residual Stresses & Distortion, Inspection and testing of welds: Introduction to Non Destructive Techniques; Destructive Techniques - Bulk and Microhardness test, Wear test and types, corrosion test, tensile test, bend test, SEM, EDS and XRD.

**Welding Codes, WPS & PQR:** Introduction to welding codes, ISO, ASME and BIS specifications, Welding Procedure Specification (WPS) & Procedure Qualification Record (PQR), Welding of pipe-lines and pressure vessels.

**Books and References:**

1. Welding and Welding Technology, by- Richard L. Little, McGraw Hill Education.
2. Welding Principals and Practices, by- Edwars R. Bohnart, McGraw Hill Education.
3. Welding Engineering and Technology, by- R. S. Parmar, KhannaPublishsers.
4. Welding Technology Fundamentals by William. A. Bowditch.
5. Welding Technology by N K Srinivasan.
6. Welding Engineering and Technology by R S Parmar.
7. Modern Welding Technology by Howard B Cary and Scott Helzer.
8. Welding Handbooks (Vol. I & II)
9. Advanced Welding Processes, Woodhead publishing, J. Norrish
10. ASME Sec. IX, Boiler and Pressure Vessel Code

1
UNIT

# Welding Arc and Power Sources

## CONTENTS

## PART- 1

*Introduction : Introduction to Welding, Application, Classification and Process Selection Criterion.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 1.1. What is welding ? Explain the importance of welding.**

**Answer**

**A. Welding :**

1. The term welding is used to cover a wide range of bonding techniques.
2. It is defined as a localized coalescence of metals, wherein coalescence is obtained by heating to suitable temperature with or without the application of pressure and with or without use of filler metal. The filler metal has a melting point approximately the same as base metal.
3. A good welded joint is as strong as the parent metal. The product is known as weldment.

**B. Importance of Welding :**

1. The welding process is readily adaptable to stream line structure and the welded joints are very tight.
2. Welded joints are strong, especially under static loading. However, they have poor fatigue resistance due to stress concentration, residual stresses and various weld defects, such as cracks, incomplete fusion, slag inclusion. But all these drawbacks can be overcome to a large extent.
3. Now a days many processes of welding have been developed and probably there is no industry which is not using welding process in the fabrication of its products in some form or the other.
4. Welding is most rapid and easiest way of fabrication and assembly of metal parts.
5. Welding is extensively used in the following fields : automobiles industry, aircraft machine frames, structural work, tanks, machine repair work, ship building, and refineries, fabrication of metal structures.

**Que 1.2. What are the advantages and limitations of welding ?**

**Answer**

**A. Advantages of Welding :**

1. Welding results in a good saving of material and reduced labour content of production.
2. Low manufacturing costs.
3. It gives the designer great latitude in planning and designing.
4. Welding is also useful as a method for repairing broken or defective metal parts.
5. Without welding techniques, the light weight methods of fabrication, so vital to the automotive and aircraft industries, would be unthinkable.
6. Welding joint is as stronger as base metal and its efficiency is upto 100 %.
7. Alteration and amendment is possible in existing structure by welding joint.

**B. Limitations of Welding :**

1. Special jigs and fixtures are required for welding.
2. Edge preparation is required before welding which is time and labour consuming process.
3. Skilled person is needed for welding purpose.
4. Ultraviolet rays and infrared rays generated during the welding process are harmful for operator's skin as well as for eyes.
5. Welding heat produces metallurgical changes in workpiece.
6. During welding, thermal stresses developed in the workpiece, heat treatment processes are required to relieve the thermal stresses.

**Que 1.3. What are the applications of welding ? Give in detail.**

**Answer**

Applications of welding are as follows :

**i. Automobile and Transport Industries :**

1. Wherein cars, trucks, jeeps and many other transportation machines and equipments are fabricated.

**ii. Building Construction Industries :**

1. Welding is greatly used in building industries for joining frames of doors and windows, reinforcement in concrete works, railings and staircases.
2. When building is a steel frame construction comprising of steel roofing frames covered with asbestos sheets or galvanized iron sheet, welding has still greater role to play in joining the structural components for joining building, frames and trusses.

**iii. Railroad Industries :**

1. Railroad industries is another important field where welding is involved in the production of locomotive under frames, bogies, trolleys, railway bridges, electric frame network, signal, equipment, lighting towers, platform shades and bodies etc.

**iv. Pressure Vessels and Tanks Industries :**

1. Pressure vessels and tanks are widely used in various industries for carrying or storing the fuel and other liquids.
2. These are made by welding together the bent steel plates.
3. Oil, gas and water storage tanks are also steel fabricated.

**v. Aircraft Industries :**

1. In aircraft industries welding is extensively used for joining the aircraft components of alloy steel, stainless steel and aluminium alloys.
2. Welding is used for the production of allied equipment that assists aircraft in operations and maintenance like material handling system, transport means for men and luggage etc.

**vi. Storage Tank Industries :**

1. Storage tanks are used to store the large quantity of liquid or gas.
2. They are as large as cannot build in a single unit therefore these are manufactured in parts for simplicity after that they can build in a single unit by welding.

**vii. Pipeline Industries :**

1. The welding process is efficiently used in pipeline industries to provide the seamless joint of the pipes.
2. Welding of pipe reduces the corrosion of joint as compared to riveting.
3. The welding provides more strength and high reliability to the pipes as compared to the pipes manufactured by other processes.

**viii. Petrochemical Industries :**

1. Chemical and petroleum industries make good use of welding for the fabrication of plant and machinery, stainless steel vessels and storage tanks besides many other structures.

**ix. Earth Moving Equipment Industries :**

1. Earth moving equipment manufacturing industries largely depends on the welding for the fabrication of earth moving machines like bulldozers, loaders, trenches and drilling ridge for all oil exploration and water tubewells and other related machines.

**x. Material Handling Equipment Industries :**

1. In this field welding is used for fabrication of overhead cranes, jib cranes and tower cranes etc., along with their auxiliary equipments like trolley, lifting aids etc.

**Que 1.4. What is the way in which welding processes can be classified ? Explain.**

**Answer**

**A. According to Source of Energy Employed for Heating :** These may be divided into two groups as follows :

**i. Pressure Welding :**

1. In these processes, the parts to be joined are heated to a plastic state and forced e.g., forge welding, thermit pressure welding etc., to form the joint.

**ii. Fusion Welding :**

1. In these processes, the material at the joint is heated to the molten state and allowed to solidify to make the joint, without the application of pressure.
2. Some joints may be made without the addition of a filler metal, but in general, a filler metal must be added to the weld to fill the space between the parts being welded.
3. The filler metal deposited should be of the same composition as the base metal. Examples are gas welding, electric arc welding etc.

**B. According to the Composition of Filler Metal :** These may be divided into three groups as follows :

**i. Autogenous Welding :**

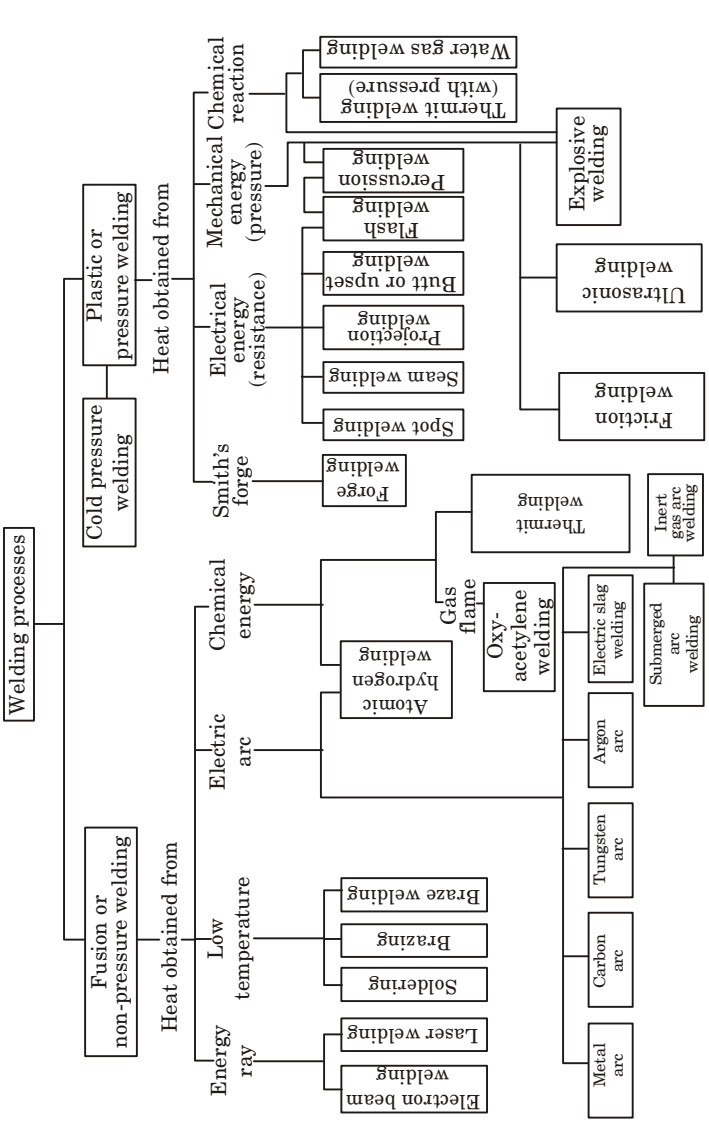
1. In these processes, no filler metal is added to the joint interface, for example, cold and hot pressure welding and electric resistance welding.

**ii. Homogeneous Welding :**

1. In these processes, filler metal is added and is of the same type as the parent metal, for example welding of plain low carbon steel with a low carbon welding rod and welding of 70-30 brass with a 70-30 brass welding rod etc.

**iii. Heterogeneous Welding :**

1. In these processes, a filler metal is used but is of a different type from the parent metal, for example brazing and soldering processes.




**Que 1.5.** **What factors should be considered while selecting a welding process ?**

**Answer**

Factors considered while selecting a welding process are as follows :

1. Type of metal and its metallurgical characteristics, joint location and welding position, its end use, cost of production, the quantity required, product size and its location, performance desired, welders skill, training and experience, joint accessibility, joint design, accuracy of assembly desired, welding equipment available, work sequence, and installation cost.
2. The process chosen should be suitable in terms of technical requirements and cost. These two factors may not be compatible with each other and thus may force a compromise.
3. The welding process and filler metal should be so selected that the weld deposit is compatible with the base metal and will have mechanical properties similar to or better than the base metal.

## PART-2

*Health and Safety in Welding.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 1.6. Describe in detail health and safety measures in welding.**

**Answer**

1. Every welder should be aware of health hazards like fires, explosion, electrocution, burns, welder flush, oxygen depletion, toxic fumes/gases/particles/vapours, radiation, trips and falls, and take adequate steps and measures to safeguard themselves against these hazards.
2. Exposure to welding smoke could cause irritation to eyes, chest, respiratory tract, inflammation of lungs.
3. Gases and particles in welding fume may be toxic or non toxic. While particles of size greater than 5 μm are filtered by nose, and less than 0.1 μm are breathed out, particles between size 0.1 and 5 μm are retained in lung.
4. Maximum acceptable concentration (MAC) in general is 6 $mg/m^3$.
5. Welding fume extraction equipment helps to reduce concentration.
6. Use material safety data sheets to identify hazardous material used in welding e.g., use cadmium free silver solders, asbestos free electrodes.

7. Ultraviolet radiation given off by welding reacts with oxygen and nitrogen in the air to form ozone and nitrogen oxides. Even 0.2 mg/m$^3$ of concentration is harmful and causes irritation of nose and throat and serious lung diseases.
8. Electrical hazards also exist in welding even though welding source operates at low voltage.
9. To keep insulation of electrode holder and cable high, these should be kept dry and in good condition. Machines should conform to safety standards.
10. All machines with moving part must be guarded for safety of workers. Keep welding area clean of equipments, cables,, hoses etc. to prevent trips and falls.
11. Intense light and radiation can damage retina/cornea of eye. Use auto darkening helmet, welding curtain and sound protection curtain for safety of welding operators and others.
12. All welding processes require protective measures. Use extraction hood over the workplace to avoid exposure of fumes and gases to workers. Use proper ventilation and welding helmet with overpressure.

## PART-3

*Welding Arc : Physics of Welding Arc, Arc Initiation, Voltage Distribution.*

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 1.7. Describe physics of welding in detail.**

**Answer**

1. The physics of welding deals with complex physical phenomena associated with welding including heat, electricity, magnetism, light etc.
2. Majority of welding processes require the application of heat which is obtained through :
   i. Flame,
   ii. Arc,
   iii. Contact resistance,
   iv. Electron beam,
   v. Laser, and
   vi. Exothermic reactions.

3. AC/DC electric power supply is used to generate heat for many welding processes.

4. Magnetic fields set up due to the flow of current through the electrode and the arc generate pinch effect and influence the welding arcs. Arc blow, plasma streaming and metal transfer are some of the welding arc features strongly influenced by the presence of magnetic fields.

**Que 1.8. What is arc initiation ? How it can be achieved ?**

**Answer**

1. Arc is initiated by providing a conducting path between the electrode and the job or by ionizing the gap between the two.

2. This can be achieved in the following manners :

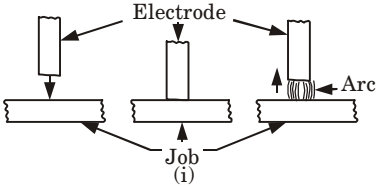
   i. By momentarily touching the electrode with the job and taking it away as shown in Fig. 1.8.1(i).

   ii. By scratching the electrode with the job. Scratching is initiated a little distance away from the point where the welding is to be started and during scratching the electrode is brought to the proper place of starting the welding as shown in Fig. 1.8.1(ii).

   iii. In this case steel wool is kept pressed between the electrode and the job. When the welding current is switched on, the steel wool provides a conducting path for the arc to establish as shown in Fig. 1.8.1(iii). This method can be used in atomic submerged arc welding sets and automatic MIG welding machines.

   iv. In automatic metal arc welding sets electric arc can also be initiated with the help of a carbon rod. Suitable arc gap is kept between the electrode and the workpiece, current is switched on, then the electrode and job simultaneously are momentarily touched with a carbon rod as shown in Fig. 1.8.1(iv).

   v. In order to eliminate the chances of electrode contamination, tungsten loss and tungsten transfer to the base metal the above methods of initiating the arcs are avoided in welding processes using tungsten or alloy tungsten electrodes. In such processes a high frequency unit is inserted in the circuit, which superimposes high frequency current, which jumps across the small gap between the electrode and job, thereby establishing the arc.



(i)

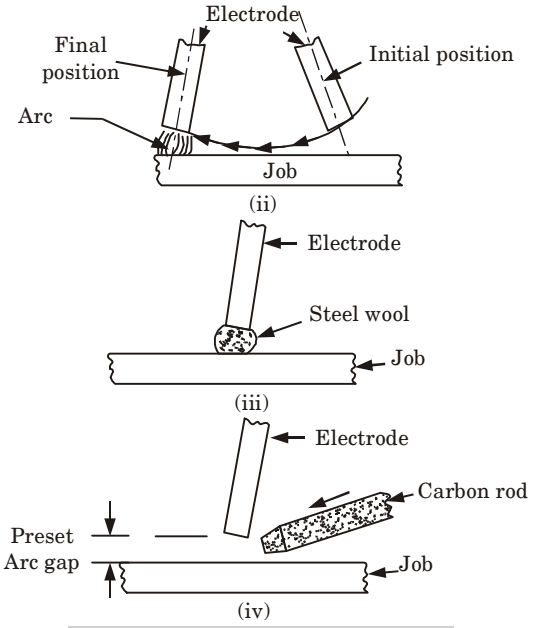



**Fig. 1.8.1.** Methods of arc initiation.

**Que 1.9.** **Discuss the phenomena of voltage distribution along the arc.**

**Answer**

1. In the anode and cathode drop zones, a nonlinear voltage distribution is prevalent along the arc length and high electric field strengths are found in cathode and anode drop zones.
2. Voltage drop is very low across the cathode and anode drop zone and voltage drop is very high across the arc column.
3. If $V$ is the sum of cathode drop ($V_c$), column drop ($V_p$) and anode drop ($V_a$) then,

$$V = V_c + V_p + V_a$$

4. Approximate potential drop in the cathode and anode drop regions is of the order of 10 volts and 12 to 1 volt respectively.

## PART-4

*Arc Characteristics, Arc Efficiency, Arc Temperature and Arc Blow.*

## Questions-Answers

## Long Answer Type and Medium Answer Type Questions

**Que 1.10. Describe characteristic of arc with the help of diagram.**

**Answer**

1. A welding arc is high current, low voltage, electric discharge operating generally in the range of 10 to 2000 A and 10 – 50 volts are act as a load resistor in a welding circuit.

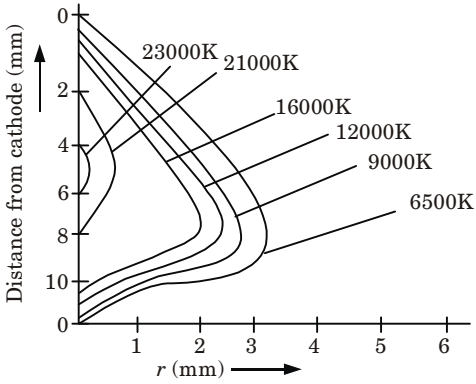



**Fig. 1.10.1.**

2. In broad sense, welding arc consists of a mechanism for emitting electron from cathode (–) which after passing temperature distribution through ionized hot gas merge into arc column anode.
3. Basically welding arc is divided into five parts which are as follows :
   i. Cathode spot,
   ii. Cathode drop zone,
   iii. Arc column,
   iv. Anode drop zone, and
   v. Anode spot.
4. Voltage drop is very low across the cathode and anode drop zone and voltage drop is very high across the arc column.

**Que 1.11. Define arc efficiency. Derive the formula for arc efficiency.**

**Answer**

**A. Arc Efficiency :**

1. Arc efficiency is defined as the ratio of the heat generated at anode and total heat generated in the arc.

**B. Derivation for Arc Efficiency :**

1. Arc efficiency equation for consumable arc welding processes must include heat used for melting of both work piece and electrode.

Since, $V = V_c + V_p + V_a$

Where, $V_c$ = Cathode voltage drop.

$V_p$ = Voltage drop in plasma column.

$V_a$ = Anode voltage drop.

$V_c I = \phi(I) + a_c$

$\phi$ = Work function at temperature $T$ K.

$\phi_0$ = Work function at 0 K.

And, $K$ = Boltzmann constant.
$= 8.62 \times 10^{-5}$ eV/K

And, $\phi = \phi_0 + \frac{3}{2} KT$

2. Total heat energy developed at the anode ($q_a$) is given by the sum of the energy received through the electrons,

$$q_a = \left(\phi + \frac{3}{2}KT\right) I + V_a I = \left(\phi + \frac{3}{2}KT + V_a\right) I$$

But, $q_p = V_p I$ is heat developed in arc column.

3. Rate of heat input to the anode $h_a$ can be expressed as,

$$h_a = q_a + m_{qp} = \left(\phi + \frac{3}{2}KT + V_a\right) I + m_{qp}$$

4. Total heat develop = $VI$

$$h_a = VI - q_e - (1-m)q_p$$
$$= VI - [q_e + (1-m)q_p]$$
$$= VI - [q_e + (1-m)V_p I]$$

Where, $q_e$ = Heat going to rod electrode.

5. Arc efficiency, $\eta = \frac{\text{Heat developed at the anode}}{\text{Total heat developed}}$

$$= \frac{h_a}{VI} = \frac{VI - [q_e + (1-m)V_p I]}{V \times I}$$

$$= 1 - \frac{[q_e + (1-m)V_p I]}{V \times I}$$

**Que 1.12.** **Find the arc efficiency for GTAW process. If the welding is 140 A and the voltage 15 V assume a cathode drop of 8 V and anode drop is 2 V with 35 % arc column. Energy being transferred to anode. Take arc temperature as 16000 K. Work function for tungsten = 4.5 eV and Boltzmann constant = $8.6 \times 10^{-5}$ eV/K.**

**Answer**

**Given :** $V_c = 8V, m = 0.35, I = 140$ A, $K = 8.6 \times 10^{-5}$ eV/K, $\phi_0 = 4.5$ eV
$V = 15$ V, $V_c = 8$ V, $V_a = 2$ V

**To Find :** Arc efficiency.

1. We know,

$$V_p = V - V_c - V_a$$
$$= 15 - 8 - 2$$
$$= 5 \text{ V}$$

2. Also, $V_c I = \phi I + q_e$

$$8 \times 140 = \left(\phi_0 + \frac{3}{2} KT\right) I + q_e \qquad \left(\because \phi = \phi_0 + \frac{3}{2} KT\right)$$

$$1120 = \left(4.5 + \frac{3}{2} \times 8.62 \times 10^{-5} \times 16000\right) \times 140 + q_e$$

$$1120 = 919.63 + q_e$$

$$q_e = 200 \text{ eV}$$

3. $$\text{Arc efficiency} = 1 - \frac{[q_e + (1 - m) V_p I]}{V \times I}$$

$$= 1 - \frac{[200 + (1 - 0.35) \times 5 \times 140]}{15 \times 140}$$

$$= 0.688 \text{ or } 68.8\ \%$$

**Que 1.13.** **Write a short note on isotherms of arcs and arc blow.**

**Answer**

**A. Isotherms of Arcs :**

1. Isotherms in the upper portion of Fig. 1.13.1 show the temperature distribution for a weld made at 1.3 mm/sec with an energy input of 3940 J/mm for an initial plate temperature of 27 °C.
2. The isotherms in the lower portion of Fig. 1.12.1 show the temperature distribution for a weld made at 2.5 mm/sec with an energy input of 1970 J/mm.
3. The arc current, voltage and preheat temperature is same in both cases. It can be observed from Fig. 1.13.1 :

i. The width of the heat affected zone reduces as the energy input decreases.

ii. As the speed increases, the ellipses crowd closer, increasing the arc heat spreads the ellipses out.

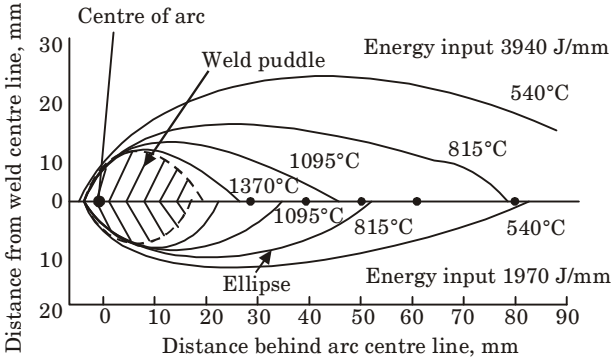



**Fig. 1.13.1.**

**B. Arc Blow :**

1. The unwanted deflection or the wandering of a welding arc from this intended path is termed as arc blow.
2. Arc blow is the result of magnetic disturbances which unbalance the symmetry of the self-induced magnetic field around the electrode, arc and workpiece.
3. Under arc blow, an arc may distort, deflect or rotate.
4. Arc blow becomes severe when welding is carried out in confined spaces and corners on heavy metal plates, using a DC power source.
5. AC arcs are less susceptible to arc blow than DC arcs, because the alternating current reverses direction which in turn reverses the magnetic field.
6. The magnetic field builds up, collapses and rebuilds as current reverses from positive to negative. This phenomenon does not permit the magnetic field strength to build to a value so as to cause arc blow.
7 On the other hand in DC welding, the magnetic field set up in the workpiece (adjacent to the arc) continuously builds up and the arc blow occurs.

**Que 1.14. What are the factors affecting arc blow ? Also give its effects.**

**Answer**

**A. Factors Affecting Arc Blow :**

1. Magnetic field produced in the workpiece adjacent to the welding arc, due to the current flow through the arc.

2. Presence of busbars carrying large DC, in the neighbourhood of the place where welding is being carried out.
3. With multiple welding heads, arc at one electrode may be affected by the magnetic field of the arc at the other electrode.
4. The magnetic field produced in the workpiece around the earth connection may tend to drive the arc away from the point where this connection is made.

**B. Effects of Arc Blow :**

1. Poor weld bead appearance.
2. Irregular and erratic weld deposition.
3. Undercutting and lack of fusion.
4. Spatter.
5. Uneven and weak welded joint.
6. Slag entrapment and porosity.

## PART-5

*Mechanism and Types of Metal Transfer.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

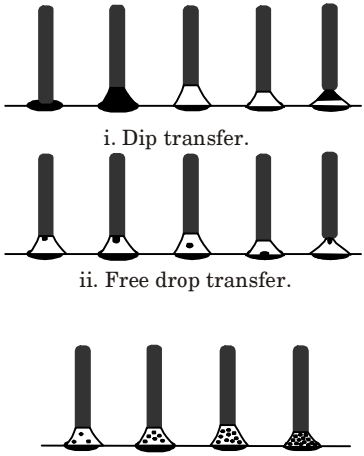
**Que 1.15. Explain in detail the mechanism and types of metal transfer in various arc welding processes.**

**AKTU 2018-19, Marks 10**

**Answer**

1. When electric arc is produced between the workpiece and consumable electrode, electrode start melting in the form of spherical shape, hangs towards the job and finally a drop down on the workpiece therefore metal transfer from electrode to workpiece is define metal transfer process.
2. Metal is transferred in arc welding in three ways :
   i. By dip transfer,
   ii. By free drop (large drop) transfer, and
   iii. By spray (small drop) transfer.
3. In dip transfer a globule of molten metal is formed at the end of the electrode during arcing in the first stage.

4. Subsequently it enlarges, elongates, touches the molten pool and separates from the electrode.
5. The process does not free the globules immediately from the electrode after its formation and as such a temporary short circuit occurs.
6. The process repeats several times to complete welding.
7. In free drop transfer, a drop of molten metal which is slightly smaller in diameter than the air gap flies off from the electrode end after temporarily (but partial) short circuiting the electrode with the molten pool of metal on the job.
8. In spray or small drop transfer, the transfer takes place in the form of tiny droplets (much smaller in diameter as compared to arc length) which make free flight from the electrode to the molten pool.
9. The transfer rate is steady and the final job will have better mechanical advantages.
10. The three transfer methods are shown in Fig. 1.15.1.



i. Dip transfer.

ii. Free drop transfer.

iii. Spray transfer.

**Fig. 1.15.1.** Metal transfer in arc welding.

## PART-6

*Welding Power Sources : Types of Welding Power Source, Operation Characteristics and Specification.*

## CONCEPT OUTLINE

**Transformer :** A transformer is a static electromagnetic device designed for the transformation of the (primary) alternating current system into another (secondary) one of the same frequency with other characteristics, in particulars, other voltage and current.

**Rectifier :** Rectifier is defined as an electronic device used for converting arc voltage into unidirectional voltage.

**Generator :** An electrical generator is a machine which converts mechanical energy (or power) into electrical energy (or power).

## Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 1.16. What are the various types of welding power sources ? Explain the working principle of a transformer.**

**Answer**

**A. Types of Welding Power Sources :** Various types of power sources are as follows :

1. AC transformer,
2. DC rectifier,
3. AC/DC transformer rectifier,
4. DC generator, and
5. Inverter.

**B. Working Principle of a Transformer :**

1. A transformer operates on the principle of mutual inductance, between two (and sometimes more) inductively coupled coils.
2. It consists of two windings in close proximity.
3. The two windings are coupled by magnetic induction. (There is no conductive connection between the windings).
4. One of the windings called primary is energized by a sinusoidal voltage. The second winding, called secondary feeds the load.
5. The alternating current in the primary winding set up an alternating flux in the core.

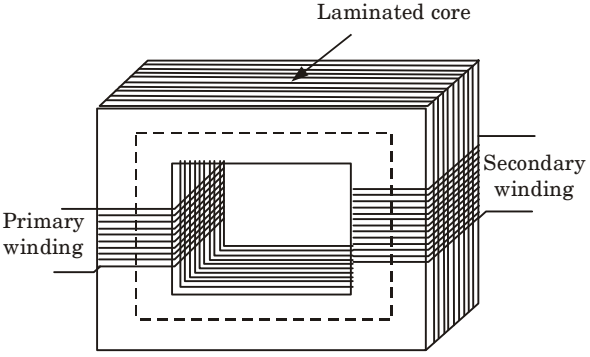



**Fig. 1.16.1.** Transformer.

6. The secondary winding is linked by most of this flux ($f$) and emf is induced in two windings.
7. The emf induced in the secondary winding drives a current through the load connected to the winding.
8. Energy is transferred from the primary circuit to the secondary circuit through the medium of the magnetic field.

**Que 1.17.** **The arc length voltage characteristic is given by expression $V = 24 + 4L$ ($L$ = Length of arc in mm). The volt ampere characteristics of power source can be approximated by a straight line with open circuit voltage 80 V and short circuit current 600 A determine optimum arc length and maximum power.**

**AKTU 2018-19, Marks 10**

**Answer**

**Given :** $V = 24 + 4L$, $V_{OC} = 80\text{V}$, $I_{SC} = 600\text{A}$.

**To Find :** i. Optimum arc length.

ii. Maximum power

1. We know

$$\frac{I}{I_{sc}} + \frac{V}{V_{oc}} = 1$$

$$\frac{I}{600} + \frac{V}{80} = 1$$

$$V = \left(80 - \frac{80}{600} I\right) \qquad \text{...(1.17.1)}$$

2. The arc characteristic is given as,

$$V = (24 + 4L) \quad ...(1.17.2)$$

3. At stable operation, arc characteristics equal to supply characteristics.
4. Equating eq. (1.17.1) and eq. (1.17.2), we get

$$80 - \frac{80}{600} I = 24 + 4L$$

$$I = (56 - 4L) \frac{600}{80} \quad ...(1.17.3)$$

5. Hence, the power $P$ is obtained from eq. (1.17.2) and eq. (1.17.3) as

$$P = VI = (24 + 4L)(56 - 4L) \frac{600}{80}$$

6. For maximum power,

$$\frac{dP}{dL} = 0$$

$$4(56 - 4L) - 4(24 + 4L) = 0$$

$$32 - 8L = 0$$

$$L = 4 \text{ mm}$$

7. So, the optimum arc length $L_{opt} = 4$ mm when the maximum power of the arc is

$$P_{max} = (24 + 4 \times 4)(56 - 4 \times 4) \times \frac{600}{80}$$

$$= 40 \times 40 \times \frac{600}{80} = 12 \text{ kVA}$$

**Que 1.18. What are the basic characteristics of power source for various arc welding processes ?**

**Answer**

Basic characteristics of power source for various arc welding processes are as follows :

**i. No Load Saturation Characteristics ($E_0/I_f$) :**

1. It is also known as magnetic or open circuit characteristic (OCC). It shows the relationship between the no load generated emf in armature, $E_0$ and field or exciting current $I_f$ at a given fixed speed.
2. The shape of the curve is practically same for all types of generators whether they are separately excited or self-excited.
3. It is just the magnetization curve for the material of the electromagnets.

**ii. Internal or Total Characteristics ($E/I_a$) :** It gives the relationship between the emf. $E$ actually induced in the armature after allowing for the demagnetizing effect of armature reaction and the armature current $I_a$.

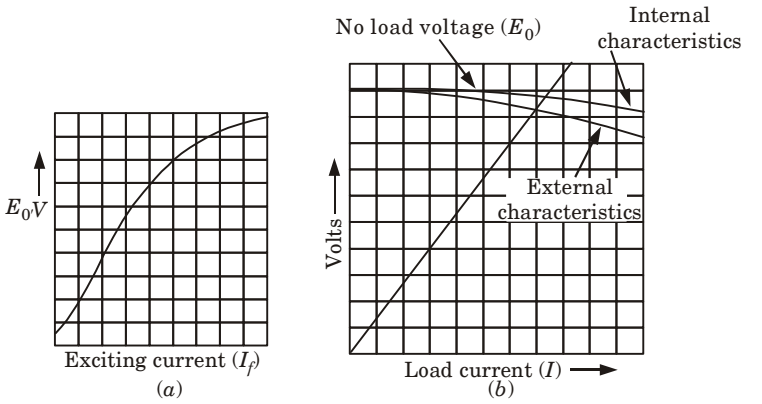



**Fig. 1.18.1.** (*a*) Open circuit characteristic of a separately excited generator. (*b*) Load characteristics of a separately excited generator.

### iii. External Characteristics (*V-I*) :

1. Three *V-I* (Voltage-current) characteristics used in arc welding DC machines to help control fluctuating currents are :
   - i. Drooping arc voltage or constant current,
   - ii. Constant arc voltage, and
   - iii. Rising arc voltage.
2. In drooping characteristics as the arc length increases, arc voltage rises and the current decreases and vice versa, as shown in Fig. 1.18.2. Machine with drooping characteristics is used for standard shielded arc manual welding.
3. Constant voltage characteristics are preferred for semi automatic (MIG) or automatic welding processes, because they maintain a preset voltage regardless of the amount of current being drawn from the machine.
4. In rising voltage characteristics, as the current increases, voltage also increases. Fully automatic welding processes use rising voltage characteristics machines.

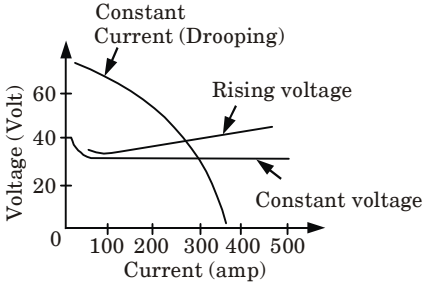



**Fig. 1.18.2.** Characteristics of DC welding machines.

**Que 1.19. Write short note on use of transformer, rectifier and generators in welding.** **AKTU 2018-19, Marks 10**

**Answer**

**A. Use of Transformer :**

1. Welding transformers are used in AC machines to change alternating current from the power line into a low-voltage, high amperage current in the secondary winding.
2. A combination of primary or secondary taps on the welding transformer is commonly used to provide a macro adjustment of the welding current, as well as adjustment of secondary voltage.
3. Transformer ratings for AC machines are expressed in kilovolt-amperes for a specified duty cycle.
4. This duty cycle rating is a thermal rating, and indicates the amount of energy that the transformer can deliver for a stated percentage of a specific time period, usually one minute, without exceeding its temperature rating.
5. Since heating is a function of the welding current, this parameter gives an indication of the thickness of the materials that can be welded.

**B. Use of Rectifier :**

1. The rectifier may consist of metal plates coated with a selenium compound or silicon diodes, each unit having the special property of allowing the current to flow in one direction only.
2. Rectifier units are designed to provide a choice of low voltage for MIG and submerged welding or a high open circuit with drooping voltage characteristics for TIG and flux shielded metal arc welding.

**C. Use of Generators :**

1. A DC welding generator produces direct current in either straight or reverse polarity. The polarity selected for welding depends upon the kind of electrode used and the material to be welded.
2. A DC generator is powered either by an electric motor or a diesel engine. Diesel operated generator sets are suitable for out-door applications or other areas where power is not available.

## VERY IMPORTANT QUESTIONS

***Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.***

**Q. 1. What are the applications of welding ? Give in detail.**
**Ans.** Refer Q. 1.3.

**Q. 2. What is the way in which welding processes can be classified ? Explain.**
**Ans.** Refer Q. 1.4.

**Q. 3. Describe in detail health and safety measures in welding.**
**Ans.** Refer Q. 1.6.

**Q. 4. What is arc initiation ? How it can be achieved ?**
**Ans.** Refer Q. 1.8.

**Q. 5. Write a short note on isotherms of arcs and arc blow.**
**Ans.** Refer Q. 1.13.

**Q. 6. Explain in detail the mechanism and types of metal transfer in various arc welding processes.**
**Ans.** Refer Q. 1.15.

**Q. 7. Write short note on use of transformer, rectifier and generators in welding.**
**Ans.** Refer Q. 1.19.

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2
UNIT

# Welding Processes

## CONTENTS

## PART- 1

*Welding Processes : Shielded Metal Arc Welding,(SMAW), Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW).*

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 2.1. What is a manual metal arc welding or shielded metal arc welding ?**

**Answer**

1. Arc welding is a welding process wherein coalescence is produced by heating with an electric arc.
2. Most of the electric arc welding is done by without pressure and with or without use of filler metal depending upon the parent plate thickness.
3. Electric arc is formed when an electric current passes between two electrodes separated by a short distance from each other.
4. In arc welding one electrode is the welding rod or wire while other is the metal to be welded (workpiece).
5. Arc connected to the supply, one to the positive terminal and other to the negative terminal.
6. Arc is started by momentarily touching the electrode on the plate and then withdrawing it to about 3 to 4 mm from the plate.

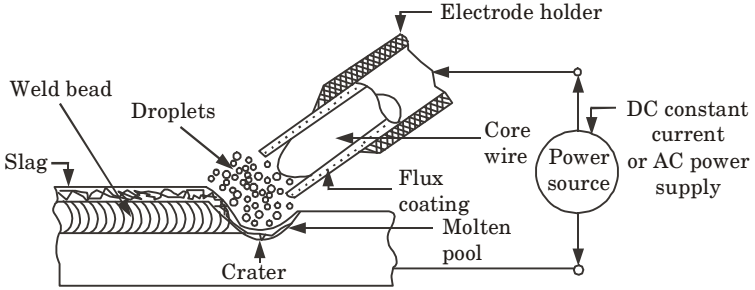


**Fig. 2.1.1.** Flux shielded manual metal arc welding.

7. When the electrode touches the plates, a current flows and as it is withdrawn from the plate the current continues to flow in the form of a spark across the very small gap first formed, this cause the air gap to

become ionised or made conducting and as a result the current is able to flow across the gap.

8. Approximately 2/3rd of the heat is generated on positive pole and 1/3rd on the negative pole.

**Que 2.2. Give the advantages, disadvantages and applications of arc welding.**

**Answer**

**A. Advantages of Arc Welding :**

1. Flux shielded manual arc (FSMA) welding is very simple as compared to all arc welding processes.
2. Cost of equipment is very low.
3. Portable equipment is available.
4. Various types of metal and their alloys can be welded.
5. Welding can be carried out in any position *i.e.*, horizontal, vertical, overhead, flat or inclined.
6. High deposition and penetration can be achieved.

**B. Disadvantages of Arc Welding :**

1. FSMA welding is a slow process as compared to MIG welding.
2. Different materials cannot be welded together.
3. Due to flux coated electrode, chance of slag entrapment and other defects are more as compared to MIG and TIG welding.
4. Metal transfer is not so clear as compared to MIG welding.

**C. Applications of Arc Welding :**

1. Ship building.
2. Pipes and penstocks joining.
3. Construction work.
4. Boiler, chemical and fertilizer industries etc.

**Que 2.3. Explain the MIG welding or GMAW process and also give advantages, disadvantages and applications of it.**

**Answer**

**A. MIG Welding :**

1. It is an arc welding process wherein coalescence is produced by heating the job with an electric arc established between a continuously fed metal electrode and the job.
2. No flux is used but the arc and molten metal are shielded by an inert gas, which may be argon, helium, etc.

**B. Principle of Operation of MIG Welding :**

1. Before igniting the arc, gas and water flow is checked.
2. Proper current and wire feed speed is set and the electrical connections are ensured.
3. The arc is struck by any one of the two methods :

i. In the first method, current and shielding gas flow is switched on and the electrode is scratched against the job as usual practice for striking the arc.

ii. In the second method, electrode is made to touch the job, is retracted and then moved forward to carry out welding, but before striking the arc, shielding gas, water and current is switched on.

4. About 15 mm length of the electrode is projected from the torch before striking the arc.

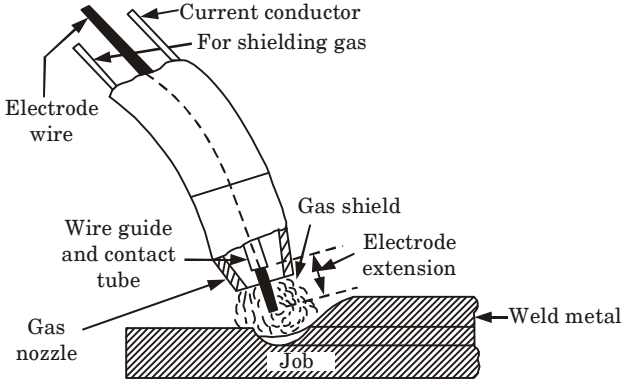


**Fig. 2.3.1.** MIG welding operation.

5. During welding, torch remains about 10-12 mm away from the job and arc length is kept between 1.5 to 4 mm.

**C. Advantages of MIG Welding :**

1. Because of continuously fed electrode, MIG welding process is much faster as compared to TIG welding.
2. It can produce joints with deep penetration.
3. Thick and thin, both types of workpieces can be welded effectively.
4. Large metal deposition rates are achieved by MIG welding process.
5. The process can be easily mechanised.
6. Higher arc travel speeds associated with MIG welding that reduce distortion considerably.

**D. Disadvantages of MIG Welding :**

1. The process is slightly more complex as compared to TIG welding.

2. Welding equipment is more complex, more costly and less portable.
3. Since air drafts may disperse the shielding gas, MIG welding may not work well in outdoor welding applications.
4. Weld metal cooling rates are higher than with the processes that deposit slag over the weld metal.

**E. Applications of MIG Welding :**

1. For welding tool steel and dies.
2. For the manufacturing of refrigerator parts.
3. In aircraft, automobile, pressure vessel and ship building industries.
4. For welding of carbon, silicon, and low carbon alloy steels, stainless steel, aluminium, nickel etc.

**Que 2.4. Explain the TIG welding or gas tungsten arc welding (GTAW) with their applications. And also give its advantages and disadvantages.**

**OR**

**With suitable sketch explain the process of TIG welding. What are its disadvantages ?**

**AKTU 2016-17, Marks 10**

**OR**

**Using neat sketch, explain TIG welding process. State its applications. What are the variants of TIG welding ?**

**AKTU 2017-18, Marks 10**

**Answer**

**A. TIG Welding :**

1. It is an arc welding process wherein coalescence is produced by heating the job with an electric arc struck between a tungsten electrode and the job.
2. A shielding gas (argon, helium, nitrogen, etc.) is used to avoid atmospheric contamination of the molten weld pool.

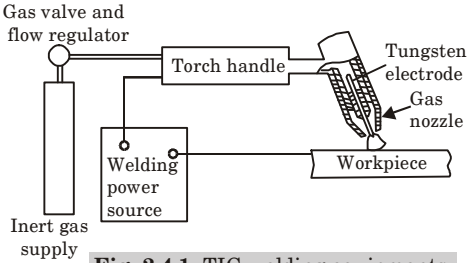


**Fig. 2.4.1.** TIG welding equipments.

**B. Principle of Operation of TIG Welding :**

1. Welding current, water and inert gas supply are turned on.
2. The arc is struck either by touching the electrode with a scrap metal tungsten piece or using high frequency unit.
3. In this arc is initially struck on a scrap metal piece and then broken by increasing the arc length.
4. This procedure repeated twice or thrice that warms up the tungsten electrode.
5. The arc is then struck between the electrodes and precleaned job to be welded.
6. This method avoids breaking electrode tip, job contamination and tungsten loss.
7. TIG welding is also known as Gas Tungsten Arc Welding (GTAW).
8. Both the AC and DC power source can be used for GTAW.
9. Electrodes employed varies in diameter from 0.5 to 6.5 mm carrying current from 5 A to 6.5 A.
10. GTAW is an all position welding and gives the highest quality weld amongst commonly used arc welding processes.

**C. Applications of TIG Welding :**

1. Precision welding in atomic energy, aircraft, chemical and instrument industries.
2. Welding aluminium, magnesium, copper, nickel and their alloys etc.
3. Rocket motor chamber fabrications in launch vehicles.
4. Welding of expansion bellows, transistor cases and can-sealing joints.

**D. Advantages of TIG Welding :**

1. No flux is used hence there is no chance of flux entrapment, when welding refrigerator and air conditioner components.
2. Because of clear visibility of the arc and the job, the operator can exercise a better control on the welding process.
3. This is very much suitable for high quality welding of thin materials.
4. It is a very good process for welding non ferrous metals and stainless steel.

**E. Disadvantages of TIG Welding :**

1. Equipment costs are higher than that for flux shielded metal arc welding.
2. Under same applications, MIG welding is faster as compared to TIG welding.

**F. Variants of TIG Welding :**

1. Activated tungsten inert gas (A-TIG) welding and Flux bound tungsten inert gas (FB-TIG) welding are two such variants that utilize suitable activating flux to improve upon various characteristics of conventional TIG welding.
2. These processes are also called flux assisted TIG welding as they mandatorily require a layer of activating flux on the components to be joined.

**Que 2.5. Differentiate between TIG and MIG welding process.**

**Answer**

| S. No. | Tungsten Inert Gas Welding (TIG) | Metal Inert Gas Welding (MIG) |
|---|---|---|
| 1. | In TIG welding a non-consumable electrode is used. | In MIG welding consumable electrode is used. |
| 2. | TIG welding electrode, serves the purpose of producing the arc only, filler rod needed if any. | MIG welding wire serves both the purpose of producing the arc as well as of filler metal. |
| 3. | TIG welding process is not as faster as MIG welding process as separate filler rod is added. | MIG welding is faster process as compared to TIG because no filler rod is added separately. |
| 4. | TIG welding requires a skill operator. | Not so much skill operator is needed. |
| 5. | TIG welding torch may be water cooled. | MIG welding torch is not water cooled. |
| 6. | Penetration is not so much deeper as compared to MIG. | Deeper penetration can be achieved very easily. |
| 7. | TIG welding is not recommended for greater than 6 mm thickness of sheet. | No such condition applicable in MIG welding. |
| 8. | If filler rod is added, operators both hands are engaged. So work must be held in position with clamps or fixture. | In MIG welding, wire electrode and gases come from same run and thus can be made easily mechanised. |

**Que 2.6. Differentiate between MIG and flux core arc welding (FCAW).**

**Answer**

| S. No. | MIG | FCAW |
|---|---|---|
| 1. | MIG process is external shielding. | FCAW process is internal shielding. |
| 2. | In MIG welding, we use inert gas for shielding. | In FCAW we do not use inert gas. |
| 3. | It is used for welding of carbon, aluminium, nickel etc. | It is only used to welding ferrous metals primarily steels. |
| 4. | Thick and thin both types of workpieces can be welded effectively. | Only medium thickness workpieces can be welded. |

## PART-2

*Plasma Arc Welding, Submerged Arc Welding, Electrogas and Electroslag Welding.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 2.7. Explain plasma arc welding along with their types.**

**Answer**

**A. Plasma Arc Welding :**

1. Plasma arc welding is an arc welding process wherein coalescence is produced by the heat obtained from a constricted arc set up between a tungsten electrode and the water cooled nozzle.
2. The process employs two inert gases, one forms the arc plasma and the second shields the arc plasma.
3. Filler metal may or may not be added and pressure normally is not employed.

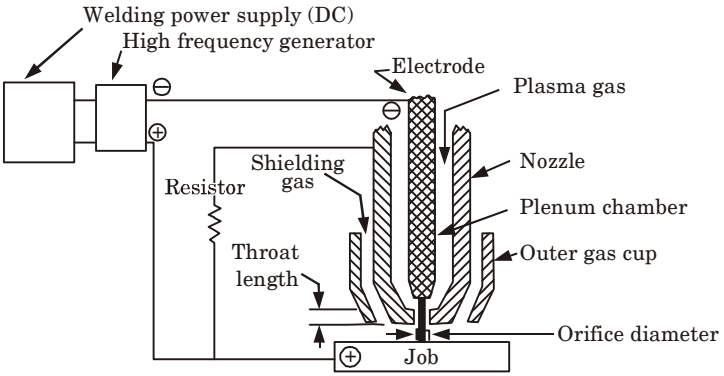


**Fig. 2.7.1.** Plasma arc welding.

**B. Principle of Plasma Arc Welding :**

1. Plasma arc welding is a constricted arc process.
2. The arc is constricted with the help of a water cooled small diameter nozzle which squeezes the arc, increases its pressure, temperature and heat intensively and thus improves arc stability, arc shape and heat transfer characteristics.

**C. Types of Plasma Arc Welding :**

**i. Non-Transferred Arc :**

1. The arc is formed between electrode (–) and the water cooled constricting nozzle (+).
2. Plasma arc comes out of the nozzle as a flame. The arc is independent of the workpiece and the workpiece does not form a part of the electrical circuit. Just as an arc flame, it can be moved from one place to another.
3. The non-transferred arc plasma possesses comparatively less energy density as compared to transferred arc plasma and it is employed for welding and in application involving ceramics or metal plating.

**ii. Transferred Arc :**

1. The arc is formed between the electrode (–) and the workpiece (+).
2. A transferred arc possesses high energy density and plasma jet velocity. For this reason it is employed to cut and melt metals.
3. For initiating a transferred arc, a current limiting resistor is put in the circuit which permits a flow of about 50 A between the nozzle and the electrode and a pilot arc is established between the electrode and the nozzle.
4. As the pilot arc touches the job, main current starts flowing between electrode and job, thus igniting the transferred arc.

5. The pilot arc initiating unit gets disconnected and pilot arc extinguishes as soon as the arc between the electrode and the job is started. The temperature of a constricted plasma arc may be of the order of 8000 - 25000 °C.

**Que 2.8.** **Explain the process of needle arc micro plasma welding.**

**AKTU 2016-17, Marks 10**

**Answer**

1. In micro plasma welding (MPAW) arc is formed between the electrode and the work piece in an inert atmosphere to fuse metal in a joint area and produce a molten weld pool.
2. The uniqueness of MPAW from other welding processes is the electrode is positioned within the body of the torch and the plasma forming gas is separated from the shielding gas envelope. While in the other processes the electrode is exposed to the atmosphere during the process.
3. It has a mechanism called the pilot arc that is struck between the electrode and nozzle to initiate the main welding arc. The pilot arc can be shut off after the main are starts or can be kept on all the time.
4. The current range of micro plasma arc varies from 0.1 A - 15 A. Even at welding current at 0.1 A the length can be varied possibly up to 10 mm without affecting stability of the arc.
5. The needle like stiff arc minimises wander and distortion.
6. Micro plasma arc welding torches are available both in manual and full automated mode.
7. Manual MPAW generally can work in all position where in fully mechanized MPAW is done in the flat and horizontal positions.
8. Generally in micro plasma arc welding DC current source is used. Micro plasma arc welding current generally can vary from a range 0.01 amp to 15 amp.
9. Pulsing facility is provided by power source. The pulsed arc has the ability to produce highest and precise weld quality.

**Que 2.9.** **What are the advantages, disadvantages and applications of plasma arc welding ?**

**Answer**

**A. Advantages of Plasma Arc Welding :**

1. Stability of arc and uniform penetration.
2. Simplified fixtures and rewelding of the root of the joint saved.
3. It is possible to produce fully penetrated key hole welds on pieces upto and about 6 mm thick with square butt joint.

4. Excellent weld quality.
5. Plasma arc welding can produce radiographic quality welds at high speeds. Weld steel pieces upto about one half inch thick, square butt joint in single run with no filler metal addition.

**B. Disadvantages of Plasma Arc Welding :**

1. Infrared and ultraviolet radiations necessitate special protection devices.
2. Welders need ear plugs because of unpleasant, disturbing and damaging noise.
3. More chances of electrical hazards are associated with this process.
4. The process is limited to metal thickness upto 25 mm.
5. Inert gas consumption is high.

**C. Applications of Plasma Arc Welding :**

1. Single run autogenous and multi-run circumferential pipe welding.
2. In tube mill applications.
3. Welding cryogenic, aerospace, high temperature corrosion resistant alloys and steel rocket motor cases.
4. Nuclear submarine pipe system.
5. Welding of carbon steel, stainless steel, nickel, copper, brass, monel metal, aluminium, titanium, etc.

**Que 2.10. Explain the submerged arc welding and also give advantages, disadvantages and applications.**

**Answer**

**A. Submerged Arc Welding :**

1. It is an arc welding process wherein coalescence is produced by heating with an electric arc or arcs set up between a bare metal electrode or electrodes and the job.
2. The arc, end of the electrode and molten pool remain completely hidden and arc invisible being submerged under a blanket of granular material (flux).

**B. Principle of Submerged Arc Welding :**

1. In submerged arc welding process, instead of a flux covered electrode, granular flux and a bare (or copper coated) electrode is used.
2. Arc between the electrode and job is the heat source and remains buried under the flux.
3. The flux serves as a shield and protects the molten weld pool from atmospheric contamination.
4. The process may be semi automatic or automatic.

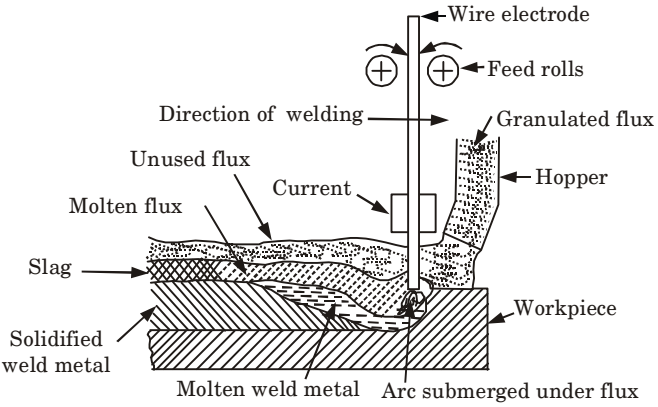


**Fig. 2.10.1.** Submerged arc welding operation.

**C. Advantages of Submerged Arc Welding :**

1. Molten flux provides very suitable conditions for high current to flow. Great intensities of heat can be generated and kept concentrated to weld thicker sections with deep penetration.
2. Because of high heat concentration, considerably higher welding speeds can be used.
3. High metal deposition rates can be achieved. Single pass welds can be made in thick plates with normal equipment.
4. Welding is carried out without sparks, smoke, flash or spatter.

**D. Disadvantages of Submerged Arc Welding :**

1. The flux needs preplacing of the same on the joint which is not always possible.
2. The process is limited to welding in flat position and on metal more than 4.8 mm thick. In small thicknesses burn through is likely to occur.
3. The process requires edge preparation and accurate fit up on the joint. Otherwise the flux may spill through the gap and arc may burn the workpiece edges.
4. Flux is subjected to contamination that may cause weld porosity.

**E. Applications of Submerged Arc Welding :**

1. Fabrication of pipes, penstocks, pressure vessels, boilers, structural shapes, rotary kilns, rail road, and earth moving equipment, cranes and under structure of railway coaches and locomotives.
2. Automotive, Aviation, ship-building and nuclear power industry.
3. Rebuilding of worn out parts and depositing wear resisting alloys, hardfacing of tractor rollers and idlers, and crane pulleys.

4. For welding metals like mild steel, medium and high tensile low alloy steels.

**Que 2.11. Explain electrogas welding process and also give advantages, disadvantages and applications.**

**Answer**

**A. Electrogas Welding :**

1. Electrogas welding is a method of gas metal arc welding or flux cored arc welding wherein an external (shielding) gas is supplied and molding shoes confine the molten weld metal for vertical position welding.
2. Electrogas welding was developed from electroslag welding.

**B. Principle of Operation :** Electrogas welding may be carried out using :

**i. Solid Electrode Process :**

1. The welding gun is installed over the joint between the two plates to be welded.
2. The weld area is purged with the shielding gas that is $CO_2$ or an argon-$CO_2$ mixture.
3. The electrode is fed through the welding gun and an electric arc is struck between the starting plate at the bottom of the joint and the electrode.
4. The arc heat melts the electrode and groove faces. The molten pool thus formed remains confined between two water cooled dams (molding shoes). As the molten metal solidifies, the molding shoes move upward with the welding head.
5. Depending upon thickness one or two electrode wires may be used.

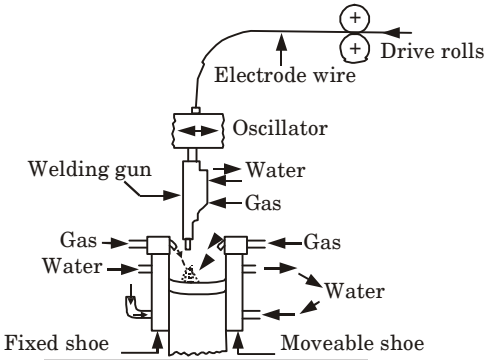


**Fig. 2.11.1.** Electorgas welding.

6. In this process, no flux is present on the top of molten metal pool.
7. Plates 12.5 mm to 75 mm thick are most commonly welded using solid electrode electrogas welding.

**ii. Flux Cored Electrode Process :**

1. The tubular portion of the electrode is made of low carbon steel, and the core contains flux and alloying elements are required to adjust weld metal composition.
2. In this process, therefore, a thin layer of molten slag forms and remains on the top of the molten weld metal.
3. Gas shielding is used when the electrode type needs it. Most electrogas welding is done with a square groove joint.

**C. Advantages of Electrogas Welding :**

1. Weld is much more visible to the welder.
2. Restarting the weld is much easier.
3. As welded impact properties are better. Thus, electrogas process is preferred if no heat treatment follows welding.
4. Welding is usually done in one pass.

**D. Disadvantages of Electrogas Welding :**

1. For job thicknesses above 75 mm, electroslag welding is usually more practical than electrogas welding.
2. As compared to electrogas welding, electroslag welding usually produces welds that are cleaner and more nearly crack free.
3. In electrogas process, porosity generally increases as job thickness increases, because gas shielding becomes less effective.

**E. Applications of Electrogas Welding :**

1. For joining thick plates in vertical position.
2. Ships, bridges, large tanks, pressure vessels, offshore drilling rigs and some parts for high rise buildings are profitably fabricated by the electrogas welding process.

**Que 2.12. Explain in brief about electroslag welding ? Also mention advantages and disadvantages of electroslag welding.**

**Answer**

**A. Electroslag Welding :**

1. Electroslag welding is a type of arc welding wherein the coalescence is produced by molten slag which melts the filler metal and the surface of the work to be welded, electroslag welding is quite similar to vertical submerged arc welding.
2. In electroslag welding process a granular flux is placed in the gap between the plate being welded and as the current is turned on, welding takes place in a watercooled copper shoes that bridge the gap of the joint as the flux melts, a slag blanket from 25.4 to 38.1 mm thickness is formed, high resistance of the slag causes most of the heating for the

remainder of the weld thus electroslag welding is a progressive process of melting and solidification from the bottom to upward.

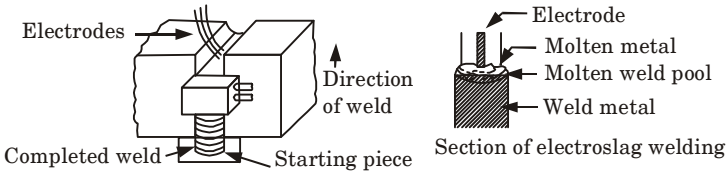


**Fig. 2.12.1.** Electroslag welding.

3. The maximum thickness that can be weld by this process is upto 100 mm.
4. Molten metal and slag are retained in the joint by means of copper shoes that automatically move upward as the weld progresses by means of a temperature sensitive mechanism.

**B. Advantages of Electroslag Welding :**

1. Joint preparation is quite simple as compared to other welding processes.
2. Very high thickness plate can be very easily welded in a single pass more economically.
3. It gives extremely high deposition rate.
4. Distortion and thermal stresses are in very low percentage.
5. Flux consumption is very low.

**C. Disadvantages of Electroslag Welding :**

1. Process is only limited to vertical position.
2. Electroslag welding tends to produce rather large grain size.
3. Complex shape joint cannot be welded by this process.
4. More chances of hot cracking and notch sensitivity in the heat affected zone.

## PART-3

*Resistance Welding, Friction Welding.*

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 2.13. Explain the resistance welding and its types. Also write advantages and disadvantages of it.**

**Answer**

**A. Resistance Welding :**

1. Resistance welding is a group of welding processes wherein coalescence is produced by the heat obtained from resistance of the work to the flow of electric current in a circuit of which the work is a part and by the applications of pressure. No filler metal is needed.
2. Resistance welding is also one of the types of pressure welding process during which the pressure is applied.
3. Basic working principle of resistance welding depends upon

$$H = I^2RT$$

Where, $H$ = Heat generated,
$I$ = Current required during welding,
$R$ = Resistance, and
$T$ = Time in second during which current flow.

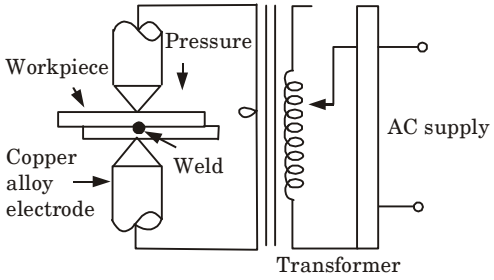


**Fig. 2.13.1.** Resistance welding block diagram.

**B. Types of Resistance Welding :**

1. Spot welding,
2. Seam welding,
3. Projection welding,
4. Percussion welding, and
5. Flash butt welding.

**C. Advantages of Resistance Welding :**

1. No filler rod or electrode is required.
2. High rate of production.
3. Semi-skilled operator can perform welding very easily.
4. No part distortion.
5. No need of edge preparation.
6. Metallurgy of workpiece is not so much change.

**D. Disadvantages of Resistance Welding :**

2. All types of metal cannot be welded.
2. Complex shapes and bigger jobs cannot be joined.
3. Welding joint is not so strong.
4. Initial cost of equipment is high.

**E. Applications of Resistance Welding :**

1. This is used for joining sheets, tubes, aircraft and automobile parts, fuel tank, wire fabrics, grills and containers.

**Que 2.14. Write a short note on the following types of resistance welding :**

**i. Spot welding,**
**ii. Seam welding, and**
**iii. Projection welding.**

**Answer**

**i. Spot Welding :**

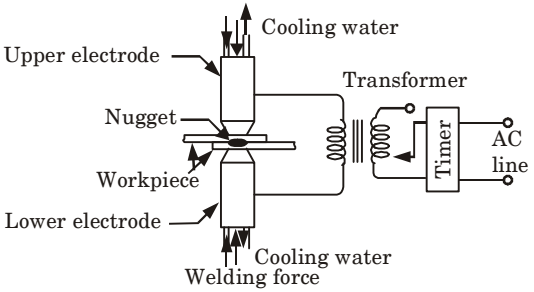


**Fig. 2.14.1.** Spot welding.

1. In resistance spot welding, the overlapping metal parts are held between two bar type metal electrodes which apply pressure, while an electric current is passed through them.
2. When the current is switched on and applied for as predetermined number of cycles, the lapped pieces of metal are heated in a restricted area.
3. The generated heat melts the surface layer of metal in the central, more highly heated, area of contact with the electrodes, and the adjacent layers of metal are softened to a plastic state.
4. Then the current is switched off and the electrodes are pressed and the pressure is released only after weld nugget has solidified.

**ii. Seam Welding :**

1. To obtain a series of spot welds along a line by this method, an interrupted work movement will be necessary.

2. The same result can be achieved much more conveniently and rapidly in seam welding where the electrodes are in the form of rotating disc electrodes, with the work being welded moving continuously by the electrodes.
3. Rollers may vary in diameter from 40 to 350 mm.
4. Welding currents range from 2000 to 5000 A, while the force applied to the rollers may be as high as 5 to 6 kN and welding speed is from 0.5 to 3.5 m/min.
5. In most cases of seam welding, a stream of water is directed over the disc electrodes except the joint interface.

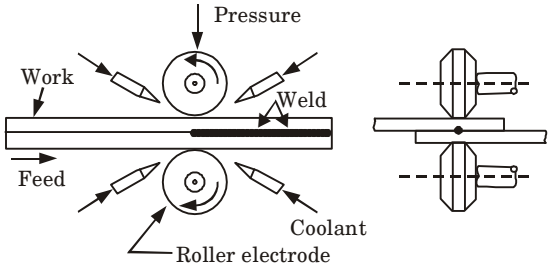


**Fig. 2.14.2.** Seam welding.

**iii. Projection Welding :**

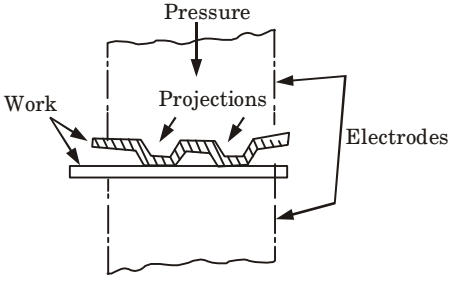


**Fig. 2.14.3.** Projection welding.

1. In this welding the current is concentrated at the spots to be welded, when small projections are embossed on one of the sheets.
2. When the current is applied, the projections soften and are pushed back in place by the electrode pressure as the weld nuggets form.
3. Also, because larger diameter electrodes can be used with a greater heat capacity, the need for water cooling is often eliminated.
4. The projections tend to localize the heat, permitting thicker materials to be welded resulting in a stronger weld structure.
5. This is used in automobile industry for joining nuts, bolts and studs to steel plates in car bodies.

**Que 2.15. Explain the principle and operation of friction welding process. Also give its advantages and disadvantages.**

**Answer**

**A. Principle and Operation of Friction Welding :**

1. Friction welding is defined as, a solid state welding process wherein coalescence is produced by heat obtained from mechanically induced sliding motion between the rubbing surfaces. The parts are held together under pressure.
2. One part is rotated at relatively high speed and under pressure against the second part which is held stationary.

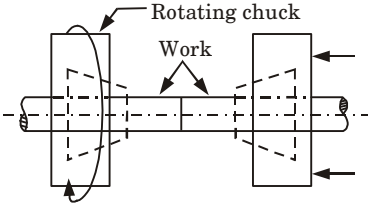


**Fig. 2.15.1.** Friction welding.

3. The frictional work at the contacting surfaces is transformed into heat.
4. The contacting surfaces are thus heated to a high temperature below the melting temperature.
5. At this point, the relative motion between the two is stopped.
6. The weld is then completed due to the pressure which still continues or additional pressure may be necessary to produce a solid state weld.
7. This method is most suitable for circular parts, *i.e.*, butt welding of round bars or tubes.

**B. Advantages of Friction Welding :**

1. Low initial capital cost and power requirement.
2. Annealing of weld zone is not necessary.
3. Very little loss of material through exclusions.
4. The process welds the whole surface of contact.
5. No flux, gas filler metal or slag present to cause imperfection in weld, no smoke too.
6. Heat affected zone is very narrow.

**C. Disadvantages of Friction Welding :**

1. Process is limited to only butt welding; complicated or complex shape cannot be welded.
2. Process is limited only for joining of small pieces in the form of bar stock.
3. Occasionally heavy flash is formed.
4. Process is not suitable for short run production.

## PART-4

*Brazing, Soldering and Braze Welding.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 2.16. What is brazing ? What are the methods that are used for it ?**

**Answer**

**A. Brazing :**

1. Brazing is used for joining the two similar or dissimilar metal pieces together by heating the surface and by using a non-ferrous filler metal having its melting point above 427 °C but below the melting point of metal to be brazed.
2. The molten filler metal is distributed between the joint surfaces by the capillary action which on cooling results in a sound joint.

**B. Methods of Brazing :** Methods of brazing are as follows :

**i. Vacuum Brazing :**

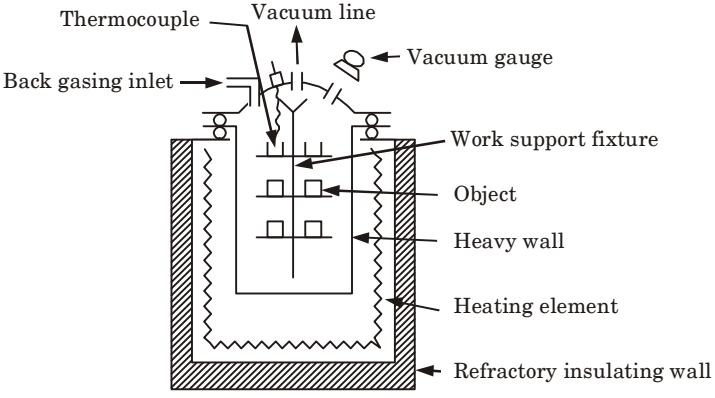


**Fig. 2.16.1.** Vacuum brazing.

1. Vacuum brazing is one of the types of furnace brazing.
2. For brazing purpose, vacuum is created in the furnace as it is suitable for surface oxides containing Cr, Mn, Ti, V, Al and Si alloys.

3. Inside temperature of vacuum brazing furnace is approximately 1100 °C.

**ii. Torch Brazing :**

1. It is the most commonly used method, heat is provided in this process by usual gas welding torch by burning acetylene and oxygen gases.
2. Oxy-hydrogen torches are also used for brazing aluminium and other non-ferrous metals.
3. A neutral or slightly reducing flame is applied on the thoroughly cleaned joint surfaces, heating thicker section first.
4. A flux is then applied on the joint area to avoid oxidation during heating and also to clean the surfaces.
5. Filler metal is then hand fed to the joint area as soon as the later attains the brazing temperature.
6. Torch brazing involves least investment on equipment heating of the metals and can be done in a controlled manner by adjusting the flow of gases in the torch.
7. However, it is a slow method for flame heating of inaccessible joints.

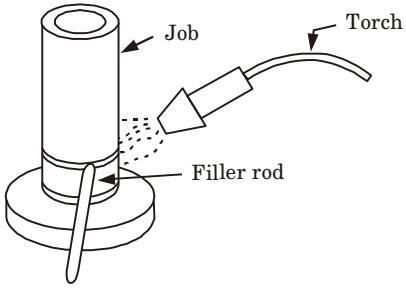


**Fig. 2.16.2.** Torch brazing.

**Que 2.17. Mention advantages, disadvantages and applications of brazing.**

**Answer**

**A. Advantages of Brazing :**

1. The main advantage of brazing process is joining of dissimilar metals and thin sections.
2. Cast and wrought material can be joined easily.
3. Metallurgical properties of the base material are not seriously distributed.
4. Assemblies can be brazed in a stress free condition.
5. Little or no finishing is required by the brazed joints.

**B. Disadvantages of Brazing :**

1. It requires tightly mating parts and proper cleaning.
2. Joints are not successful at elevated temperature.
3. Colour of the filler metal may not match that of the base metal.
4. High degree of skill is required.

**C. Applications of Brazing :**

1. Parts of bicycle such as frames and rims.
2. Pipe joints subjected to vibrations.
3. Exhaust pipe in motor engine.
4. Nipples and unions of mild steel and copper tubing.

**Que 2.18. What is soldering ? Explain various methods of soldering. Mention advantages and applications of it.**

**Answer**

**A. Soldering :**

1. Soldering is defined as a metal joining process wherein coalescence is produced by heating the surface to be joint to a suitable temperature and melting the filler metal which is a fusible alloy called solder whose melting point is below 427 °C.
2. Soldering operation is performed by bringing molten solder in contact with the preheated surfaces and heating the joint area to a good wetting temperature about 55 to 80 °C above the melting point of soldering alloy.
3. Solder is then left to cool and freeze as quickly as possible to avoid development of internal cracks in the joint.
4. Due to molecular attraction surface molecules of solder enter within the parent metal molecules and form a strong bond.

**B. Methods of Soldering :**

**i. Torch Soldering Method :**

1. A torch is used to supply heat which is the fast and versatile process of heating.
2. Soldering torches are available in different design, for example, gasoline blow torch, oxy-acetylene soldering torch etc.
3. These types of torches ensure a clean flame to heat the surfaces to be soldered, heat of flame is easily adjustable.
4. This process of soldering finds extensive use in refrigeration and air conditioning plants, building up of irregular surfaces to get a finished surface threaded connections in plumbing are being replaced by soldering.

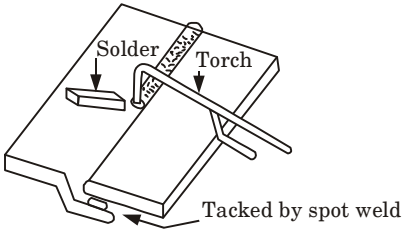


**Fig. 2.18.1.** Torch soldering method.

**ii. Dip Bath Method :**

1. In this type of soldering method, solder is melted in a pot and protected against atmospheric contamination by using a hood or cover on the pot or by providing a chemical coverage by powdered charcoal.
2. The workpiece is first dipped in the flux bath and later in the solder bath.
3. The object soldered with this method are required to be cleaned before they are coated with flux and soldered as the moisture present on the workpiece may produce instant high temperature steam leading to the explosion of bath.

**iii. Wave Soldering Method :**

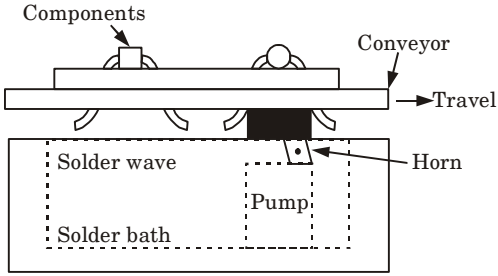


**Fig. 2.18.2.** Wave soldering method.

1. This is an automatic process of soldering used for the manufacturing of printed circuit boards wherein the components are passed over a wave of molten solder.
2. All components of the circuit are bonded in one quick operation as the molten solder is pumped vertically upward through a narrow slot forming a steady wave.
3. This way the dynamic movement of the solder across the work surface improves melting, minimize heat distortion resulting in an oxide free bright surface of solder.

**C. Advantages of Soldering :**

1. Low investment of cost.
2. Simplicity and cheapness of the equipment.
3. Properties of parent metal are not affected due to low operating temperature.

4. Good and effective sealing in fabrication as compared to other process like riveting, spot welding and bolts.

**D. Applications of Soldering :**

1. Connections in wireless set, TV sets, and wiring joints in electrical connections, battery etc.
2. Drain water gutters and pipes.
3. Radiator brass tube for motor car.
4. Copper tubing carrying liquid fuel, gas or air used on engine.

**Que 2.19. What is braze welding? Give advantages, disadvantages and applications of braze welding.**

**Answer**

**A. Braze Welding :**

1. Braze welding is a method of welding whereby a groove, fillet, plug or slot weld is made using a non ferrous filler metal having a melting point below that of the base metals but above 427 °C.
2. The filler metal is not distributed in the joint by capillary attraction.
3. Bronze welding does not mean the welding of bronze, but rather it is welding using a bronze filler rod.

**B. Advantages of Braze Welding :**

1. Braze welding associate lower fuel consumption and higher welding speeds.
2. Dissimilar metals may be joined by braze welding.
3. The weld deposit is relatively soft and ductile, providing machinability and low residual stresses.
4. Joints with good strength and generous fillets can be produced,
5. Brittle metals (e.g., gray cast iron) can be joined without much preheat.

**C. Disadvantages of Braze Welding :**

1. Braze welded joints are not satisfactory for service at over about 260 °C nor for dynamic loads of about 1000 kg/cm$^2$ or more.
2. Joints are subjected to galvanic corrosion and to differential chemical attack.
3. The brazing filler metal colour may not match with that of the base metal.

**D. Applications of Braze Welding :**

1. Braze welding may be employed for such fabrications as metal furniture, bicycles, automobiles, refrigerators and household appliances.

**Que 2.20. Give the comparison among welding, brazing and soldering.**

**Answer**

| S. No. | Welding | Soldering | Brazing |
|---|---|---|---|
| 1. | In welding process fusion is obtained by heat or pressure or both. | In soldering, joint is obtained by means of filler material whose melting point is less than 427 °C and less than the melting point of base metal. | In brazing the joint is obtained by means of filler material whose melting point is above 427 °C and less than the melting temperature of base metal. |
| 2. | The strength of the joint is highest comparing to soldering and brazing. | The soldered joints are weakest among the welding and brazing. | The brazed joints are stronger than soldered joint but weaker than welded joints. |
| 3. | The joint strength may be equal to or even greater than the strength of the base metals. | The joint strength depends upon the adhesive qualities of filler material and can never reach the strength of base metal. | The joint strength depends upon the adhesive qualities of filler material and can never reach the strength of base metal. |
| 4. | The filler material may or may not be used. | The filler material is essentially used because joint is made by filler material only. | The filler material is essentially used because joint is made by filler material only. |
| 5. | The composition of filler metal is normally same as that of base metal. | Essentially filler metals are alloys of lead and tin. | The filler metals are alloys of copper. |
| 6. | Welded joints can withstand at high temperature. | Soldered joints are not suitable for high temperature service because of lower melting point of the filler metal. | Brazed joints are also not suitable for high temperature service because of lower melting point of filler metal. |
| 7. | The process cannot join dissimilar metals which are insoluble in each other. | The process can join dissimilar metals which are insoluble in each other. | The process can join dissimilar metals which are insoluble in each other. |

## PART-5

*Laser Beam Welding, Electron Beam Welding, Ultrasonic Welding.*

### Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 2.21. Explain laser beam welding with the help of diagram. What is the principle of a laser generation ?**

**Answer**

**A. Laser Beam Welding :**

1. Laser beam welding is performed by focusing the coherent monochromatic light beam emitted by the laser source onto the metal parts which are to be welded by surface heating and thermal conduction through the metal.
2. There are two types of lasers used in solid state lasers, for example ruby laser and gas laser.
3. The laser crystal (Ruby) is in the form of a cylinder, the ends being flat and parallel to a high degree of accuracy and silvered to give mirror reflecting surfaces.

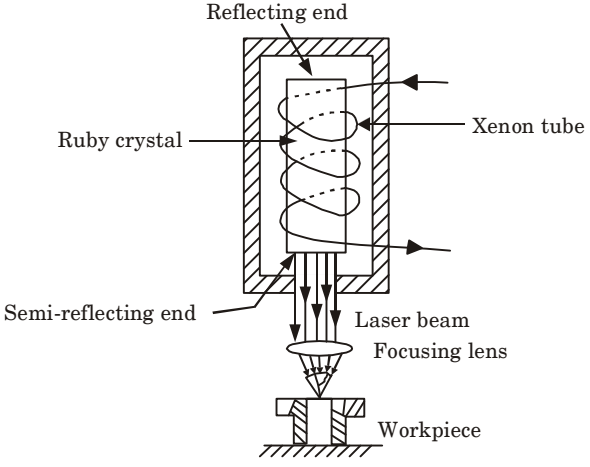


**Fig. 2.21.1.** Laser beam welding.

4. There is a small aperture on the axis of the crystal, through the mirror at the output end.
5. When the crystal is pumped with high intensity white light from a xenon or krypton lamp, the Cr ions in the crystal get excited.
6. The excited ions possess more energy and some of it is given as a red fluorescent light.
7. This light is reflected backward and forward in the crystal between the two ends, striking more Cr ions on the path.
8. These ions affected by the collisions are caused to emit their quota of red light exciting more and more Cr ions, until the number of collisions is high enough to cause a burst of red light through the small aperture in the mirror at the output end of the crystal.
9. The beam produced is extremely narrow and can be focused to a pin point area by an optical lens.

**B. Principle of Generation of Laser Beam :**

1. In this, capacitor bank stores electrical energy.
2. It is charged by a high voltage power supply.
3. When subjected to electrical discharge from the capacitors, xenon transforms a high proportion of the electrical energy into white light flashes.
4. As the ruby is exposed to the intense light flashes, the chromium atoms of the crystal are excited and pumped to a high energy level.
5. These chromium atoms immediately drop to an intermediate energy level with the evolution of heat, and eventually drop back to their original state with the evolution of a discrete quantity of radiation in the form of red fluorescent light.

**Que 2.22. Explain how different process parameter influence laser beam welding.** **AKTU 2016-17, Marks 10**

**Answer**

Different process parameter influence laser beam welding are as follows :

**i. Laser Power :**

1. A plasma will be generated only when the laser power density on the workpiece exceeds the threshold value (associated with the material), which marks the stable deep penetration.
2. If the laser power is lower than this threshold, the workpiece occurs only surface melting.
3. Welding penetration is directly related to the beam power density, is a function of the incident light beam power and beam focal spot.

**ii. Beam Focal Spot :**

1. The beam spot size is one of the most important variables in the laser welding, because it determines the power density.
2. The beam focus diffraction limited spot size can be calculated according to the theory of light diffraction, but due to the presence of the focus lens aberration, the actual spot than the calculated value is too large.

**iii. Welding Speed :**

1. Welding speed has a greater impact on penetration, increase the speed to make penetration shallow, but the too low speed will lead to excessive melting of the material.
2. So, for a certain laser power and a certain thickness of a particular material have a suitable welding speed range.

**iv. Shielding Gas :**

1. The laser welding process is often used an inert gas to protect the molten pool.
2. Helium has difficult ionization, allows the laser has beam energy direct access to the workpiece surface.
3. This is the most effective protection of the gas, but the price is more expensive.
4. Argon gas is cheaper, denser, so the protection is better.
5. Nitrogen as a protective gas is the cheapest, but does not apply to certain types of stainless steel metallurgical aspects.

**v. Lens Focal Length :**

1. Focus mode, 63 ~ 254 mm is generally used in the focal length of the lens.
2. Focal spot size is proportional to the focal length, the shorter the focal length the smaller will be the spot.
3. The short focal length can improve the power density.

**vi. Focus Position :**

1. In order to maintain a sufficient power density, the focal position is essential.
2. Changes in relative positions of the focus and the workpiece surface directly affect the weld width and depth.
3. In most laser welding applications, the position of the focus is usually set below the surface of the workpiece about the desired penetration depth of 1/4.

**vii. Laser Beam Position :**

1. The laser beam position control the final quality of the weld, especially in the case of butt joints.

2. For example, when a hardened steel gear is welded to the drum of the low-carbon steel, proper control of the laser beam position will be conducive to generate mainly low-carbon component composition of the weld, this weld having a good crack resistance.

**Que 2.23. What are the advantages, disadvantages and applications of laser beam welding ?**

**Answer**

**A. Advantages of Laser Beam Welding :**

1. Low total thermal input.
2. It can be transmitted over long distance with a minimum loss of power.
3. There is no vaporization of metal.
4. Heat affected zone is very narrow.
5. Beam can be focused with greater accuracy on the object as it is light.

**B. Disadvantages of Laser Beam Welding :**

1. Rapid cooling rate may cause cracking in certain metals.
2. High initial cost investment.
3. Optical surface can be damaged.
4. Maintenance cost is very high.
5. Skilled operator is required for performing the welding.

**C. Applications of Laser Beam Welding :**

1. Cutting and welding of material.
2. Welding of nuclear plant components.
3. For connecting leads on small electronic components and in integrated circuitry in the electronic industry.
4. Transmission component for a car.
5. For welding of high melting point metals.

**Que 2.24. Explain the procedure of electron beam welding process. What are the difficulties encountered during EBW ? Support with neat sketch.** **AKTU 2017-18, Marks 10**

**Answer**

**A. Procedure of Electron Beam Welding :**

1. Electron beam welding can be defined as, a welding process wherein coalescence is produced by the heat obtained from a concentrated beam composed primarily of high velocity electrons impinging upon the joint to be welded.

2. The kinetic energy of the electrons is changed into heat on impact with work, giving intense local heating.
3. The electron beam is produced in a high vacuum environment by an electron gun usually consisting of a tungsten cathode, a grid or forming electrode and an anode.
4. A stream of electrons is given off from a tungsten filament heated to about 2200 °C.
5. The electrons are gathered, accelerated to high velocity and shaped into a beam by the potential difference between cathode and anode.
6. The beam is collimated and focused by passing through the field of an electromagnetic focusing coil or magnetic lens.
7. Beams are focused to about 0.25 to 1 mm diameter and have a power density of about 10 kW/mm$^2$, which is sufficient to melt and vaporise any metal.
8. The operation is carried out in a vacuum, which enables the beam source to be at a distance of upto about 1 m from the work.
9. Deep penetration with a very narrow heat affected zone is achieved by this process.
10. Aluminium can be fused upto a depth of about 40 mm, and stainless steel upto 30 mm, with a width of fusion area of about one-tenth of the penetration.

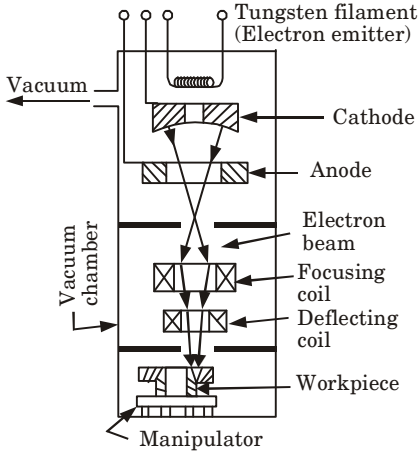


**Fig. 2.24.1.** Electron beam welding.

**B. Difficulties Encountered During EBW :**

1. In EBW or vacuum welding system, atmospheric scattering and energy absorption of the beam are negligible.

2. Moreover vacuum prevents the reduction of electron velocity however, the size of the vacuum chamber required naturally imposes serious limitation on the size of the workpiece that can obstruct the passage of beam and absorb some of its power.
3. Moreover if the welding is carried out in a vacuum chamber, considerable time is lost as the work chamber must be pumped down for each new workpiece.
4. These difficulties lead to the development of some electron beam machine that permit the workpiece to remain outside the vacuum chamber while it is being welded.

**Que 2.25.** **What are the advantages, disadvantages and applications of EBW ?**

**Answer**

**A. Advantages of EBW :**

1. Welds produced are of high quality and can be made at high speeds.
2. The fusion zone and the heat affected zone are extremely narrow.
3. Small thin parts can be welded to heavy sections.
4. Precise control is possible.

**B. Disadvantages of EBW :**

1. Initial cost of equipment is high and portable equipment is rare.
2. Work is to be manipulated through vacuum seals.
3. Workpiece size is limited by the work chamber dimensions.

**C. Applications of Electron Beam Welding :**

1. For welding of refractory and reactive metals.
2. Low distortion components can be welded which are used in automobile, aerospace shuttle, aeroplanes etc.
3. Gear cluster for transmission system and driven shaft.
4. Intricate valve arrangements made from corrosion-resistant alloys and pressure capsules.

**Que 2.26.** **Make comparison between laser beam welding and electron beam welding.** **AKTU 2018-19, Marks 10**

**Answer**

| S. No. | Parameters | Electron Beam Welding | Laser Beam Welding |
|---|---|---|---|
| 1. | Penetration | Deep penetration | Lack penetration |
| 2. | Power efficiency | 80–90 % | 7–10 % |
| 3. | Running cost | Cooling water electricity | Consumption of shield gas high electricity requires high purity water in cooling system to cool beam source |
| 4. | Generation of *X*-rays | Generated | Not generated |
| 5. | Size of workpiece | Narrower | Narrow |
| 6. | Cost | High | Low |
| 7. | Surrounding environment | Performed in a high vacuum environment | Performed in air or shielding gas |

**Que 2.27. Explain ultrasonic welding, with the help of neat sketch. Also give its application, advantages and disadvantages.**

**OR**

**Explain with neat labelled sketch the working of ultrasonic welding.**

**AKTU 2016-17, Marks 7.5**

**Answer**

**A. Ultrasonic Welding :**

1. Ultrasonic welding is a type of radiant welding process therefore it is considered as a advance welding technique.
2. Through ultrasonic welding many metals could be combined that could not be welded by any other joining processes.
3. In ultrasonic welding, metallic tip vibrating with ultrasonic frequency is produced to weld a thin plate to a thicker one supported on an anvil, range generally used of frequency from 20000 Hz to 60000 Hz.
4. Ultrasonic welding combines pressure and high frequency vibration motion to form a solid state bond.

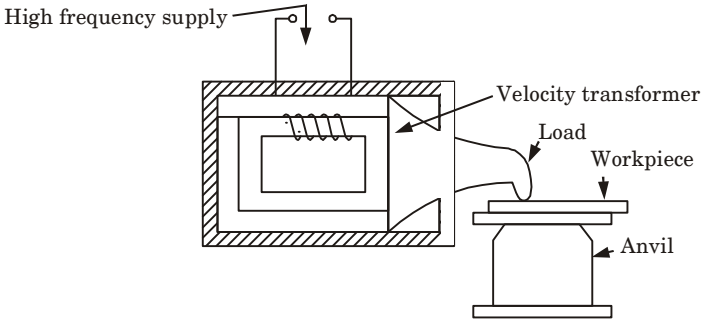


**Fig. 2.27.1.** Typical setup for ultrasonic welding arrangement.

**B. Working Principle of Ultrasonic Welding :**

1. This welding is produced due to vibration generated during the welding process.
2. Workpiece that is to be welded should be properly clamped between the welding tip and anvil in the process.
3. Both tip and anvil are faced with high speed steel.
4. In ultrasonic welding, a frequency convertor is used which converts 50 Hz line power into a very high power.
5. This system consists of transducer which converts electrical power into ultrasonic vibration energy and this vibration energy is transferred into joint through welding tip which is attached with transducer tip, oscillates in the plane of the joint interface.
6. Frequency and the pressure exerted on the material depend on the type and size of the rail and type of welding machine.
7. During ultrasonic welding, vibrations combine with static clamping force and produce dynamic shear stresses in the workpiece which results in plastic deformation.
8. At the joint interface, any coating or any other oxide coating are shattered and dispersed so that intimate contact and bonding on the workpiece surface take place.

**C. Advantages of Ultrasonic Welding :**

1. Stronger joint is produced.
2. Welding of aluminium to glass is possible.
3. There is no need for slag removal because it removes automatically due to vibration.
4. Minimum surface deformation results.
5. Dissimilar metal having different melting point can be joined easily.

**D. Disadvantages of Ultrasonic Welding :**

1. It is restricted to aluminium.
2. This process is applicable upto 3.2 mm thickness.
3. Due to fatigue loading, the life of equipment is short.
4. Material being welded tends to weld with the tip and anvil.
5. Ultrasonic welding is not economically competitive to other processes.

**E. Applications of Ultrasonic Welding :**

1. Joining of electrical and electronic components.
2. Hermetic sealing of volatile substances.
3. Welding of aluminium wire and sheet.
4. Fabricating of nuclear fuel elements.
5. Strainer screens have been welded without clogging of the holes.

## PART-6

*Explosive Welding, Friction Stir Welding, Underwater Welding.*

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 2.28. What do you understand by explosive welding ? Write its advantages, disadvantages and applications in detail.**

**AKTU 2018-19, Marks 10**

**Answer**

**A. Explosive Welding :**

1. Explosive welding is a solid state welding process wherein coalescence is produced by making one part strike over another part at a very high but subsonic velocity.
2. This can be done by the use of explosive usually ammonium nitrate base.
3. Basically explosive welding involves a high velocity oblique impact between a plate propelled by an explosive charge and a stationary plate when two plates are to be explosively welded.

**B. Advantages of Explosive Welding :**

1. Simplicity of the process.
2. Extremely large surface can be bonded.

3. Welds can be produced on heat treated metals without affecting their microstructures.
4. The foils can be bonded to heavier plates.
5. Wide range of thickness can be explosively clad together.
6. Good explosive bonds have strength equal to or greater than that of the weaker of the two metals joined.
7. Lack of porosity, phase changes and structural changes impart better mechanical properties to the joints.

**C. Disadvantages of Explosive Welding :**

1. In industrial areas the use of explosive will be severely restricted by the noise and ground vibration caused by explosion.
2. The regulation relating to the storage of explosives may well prove to be the main obstacle to the use of explosive welding.
3. Metals to be welded by this process must possess some ductility and some impact resistance.
4. Metal thickness greater than 62 mm of each alloy cannot be joined easily and require high explosive loads.

**D. Applications of Explosive Welding :**

1. This is used in welding, joining and cladding of metals.
2. A number of dissimilar metals combinations as aluminium to steel, tungsten to steel and aluminium to stainless steel have been joined successfully with the help of explosive welding.
3. Pipes and tubes upto 1.5 m length have been clad with this process.
4. Heat exchangers tube sheets and pressure vessels.

**Que 2.29. Describe with neat sketches, the working principle of explosive welding.**

**Answer**

1. The flyer plate is to be joined with the parent plate.
2. There is a buffer above the flyer plate which may be of rubber, cardboard or similar material to protect the top surface of the flyer plate from damage by detonation of the explosive charge.
3. Flyer plate should be an inclination from 1° to 10° range.
4. Thick plate is called as flyer plate.
5. Above the buffer, there is a layer of explosive which is detonated from the lower edge.
6. The parent plate rests on an anvil to limit distortion of the final product.
7. As the explosive is ignited, the detonation wave front progresses across the surface of the flyer plate in a straight-forward and uncomplicated manner.

8. The explosive impulse provides both extremely high normal pressure and a slight, relatively shear or sliding pressure between the flyer plate and the parent plate.
9. At the point of impact, a high instantaneous pressure is generated which is large compared with the shear strength of the materials.
10. This creates a surface free from oxides and other films which are brought together and stick fast.
11. The velocity is in the range of 150 to 500 m/s and pressure is in the range of 700 to 7000 N/m$^2$.

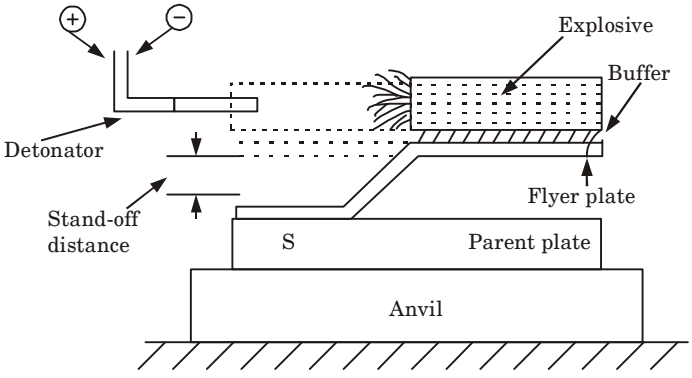


**Fig. 2.29.1.** Explosive welding.

**Que 2.30. Explain principle and working of friction stir welding with advantages and limitations**

**Answer**

**A. Friction Stir Welding (FSW) :**

1. FSW is a solid state joining process and is used for applications where the original metal characteristics must remain unchanged as far as possible.
2. This process is primarily used on aluminium and most often a large piece which cannot be easily heat treated post weld to recover temper characteristics.

**B. Principle of Operation of Friction Stir Welding :**

1. In FSW, a cylindrical, shouldered tool with a profiled probe (nib or pin) is rotated and slowly plunged into the joint line between two pieces of sheet or plate material, which are butted together.
2. The parts have to be clamped rigidly onto a backing bar in a manner that prevents a butting joint face from being forced apart.

3. Length of nib or pin is slightly less than the weld depth required and tool shoulder should be in intimate contact with the work surface, nib is then moved against the work or vice versa.

**C. Working of Friction Stir Welding :**

1. Frictional heat is generated between the wear resistant welding tool shoulder and pin and the material of the workpiece.

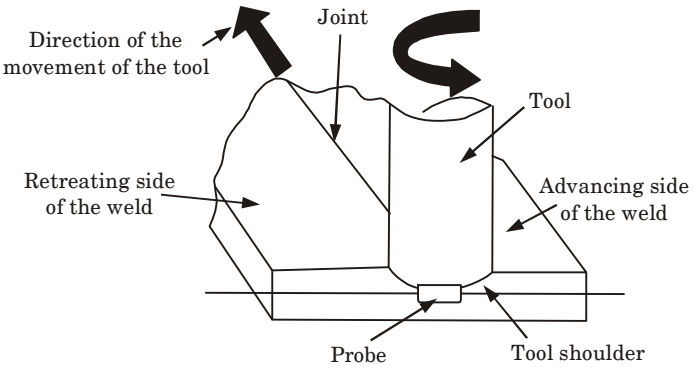


**Fig. 2.30.1.** Friction stir welding.

2. This heat long with the heat generated by the mechanical mixing process and adiabatic heat within the point allowing the traversing of the tool along the weldline in a plasticised tubular shaft of metal as the pin is moved profile, forces plasticised material to the back of the pin while applying a substantial forging force to consolidate the weld metal.

6. The welding of the material is facilitated by severe plastic deformation in the solid state, involving dynamic recrystallization of the base material.

**D. Advantages of Friction Stir Welding :**

1. Good mechanical properties.
2. Improved safety due to the absence of toxic fumes or the spatter of molten metal.
3. No need of consumables electrode.
4. Aluminium and no filler or shielding gas is required for aluminium.
5. Easily automated on simple milling machines lower setup costs and less training.

**E. Limitations of the Process :**

1. Exit hole left when tool is withdrawn.
2. Large down forces required with heavy duty clamping necessary to hold the plates together.

3. Less flexible than manual arc process, difficulties with thickness variation and non welding technique. Although these may be offset if fewer welding passes are required.

**Que 2.31. Write short note on underwater welding.**

**Answer**

**A. Underwater Welding :**

1. Underwater welding is an important tool for underwater fabrication works.
2. In 1946, special waterproof electrodes were developed in Holland by Vander Willingen.
3. In recent years the number of offshore structures including oil drilling rigs, pipelines, platforms are being installed significantly.
4. Some of these structures will experience failures of its elements during normal usage and during unpredicted occurrences like storms collisions.
5. Any repair method will require the use of underwater welding.
6. Problem with underwater welding is that deep water work is never easy, because diving operations are dependent on tide and weather and the difficulties arising from the various positions in which welding has to be done, also add to the problem encountered.
7. An essential requirement for underwater welding is the complete insulation of the welding circuit. Even the electrode coatings are protected by a layer of wax, varnish or cellulose.

**Que 2.32. Explain type of underwater welding and their working mechanisms.** **AKTU 2018-19, Marks 10**

**Answer**

Types of underwater welding are as follows :

**i. Wet Welding :**

1. In this welding process, the work to be welded is connected to one side of an electric circuit, and a metal electrode to the other side.
2. These two parts of the circuit are brought together, and then separated slightly.
3. The electric current jumps the gap and causes a sustained spark, which melts the bare metal, forming a weld pool.
4. At the same time, the tip of electrode melts, and metal droplets are projected into the weld pool.
5. During this operation, the flux covering the electrode melts to provide a shielding gas, which is used to stabilize the column and shield the transfer metal.

6. The arc burns in a cavity formed inside the flux covering which is designed to burn slower than the metal barrel of the electrode.

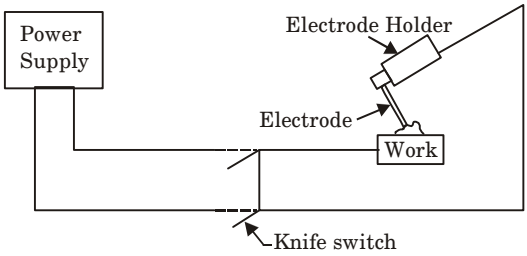


**Fig. 2.32.1.** Wet welding.

**ii. Dry Welding :**

1. This is carried out in a chamber, sealed around the structure to be welded.
2. The chamber is filled with a gas commonly helium (He) containing 0.5 bar of oxygen at the prevailing pressure.
3. The habitat is sealed onto the pipeline and filled with a breathable mixture of helium and oxygen, at or slightly above the ambient pressure at which the welding take place.
4. This method produces high quality weld joints that meet *X*-ray and code requirements.
5. The gas tungsten arc welding process is employed for this process.
6. The area under the floor of the habitat is open to water.
7. Thus welding is done in the dry but at the hydrostatic pressure of the sea water surrounding the habitat.

## PART-7

*Advances in Welding Processes : Narrow Gap Welding, Tandem (Twin/Multi Wire) Welding, A-TIG.*

### CONCEPT OUTLINE

**A-TIG Welding :** This process involves a method of increasing the penetration capability of the arc in Tin welding. This is achieved through the application of a thin coating of activating flux material onto the joint surface prior to welding.

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 2.33. What do you understand by narrow gap welding ? Also write down its advantages and disadvantages.**

**Answer**

**A. Narrow Gap Welding :**

1. Narrow gap welding is used to weld thick sections more economically.
2. This welding procedure uses joint preparations with small included angles typically in the range 2° – 20° which require less weld metal and less welding time to fill.
3. It have been applied when welding using submerged arc welding, gas shielded metal arc welding and tungsten inert gas welding.
4. It requires specialized equipment because of the limited accessibility to the root of the preparation.

**B. Advantages of Narrow Gap Welding :**

1. The process offers better economy.
2. There is low angular distortion.
3. Less time consuming process.

**C. Disadvantages of Narrow Gap Welding :**

1. The weld is more prone to defects.
2. It is difficult to remove any defects.

**Que 2.34. Explain in brief about tandem or twin wire welding.**

**Answer**

1. Tandem welding involves high performance MIG/MAG welding using two wire electrodes.
2. It is only used in fully automated (robot) applications and is ideal for increasing welding speed as well as deposition rate.
3. During tandem welding, two wire electrodes are melted at the same time. These are routed through two electrically isolated contact tips, *i.e.*, the potentials are separate.
4. As a result, the arcs can be controlled independently and despite differing products can be precisely coordinated.
5. It can be performed in both directions resulting in high degree of flexibility.
6. Tandem welding can be used to weld both thin and thick sections.
7. Tandem welding is used in construction machinery, uncommercial transport vehicles, automotive industries, etc.

## PART-8

*Hybrid Welding Processes, Magnetically Impelled Arc Butt (MIAB) Welding.*

## CONCEPT OUTLINE

**Hybrid Welding Process :** To improve the welding process capabilities, two or more than two welding processes are combined to take advantage of the worthiness of the constituent processes.

**Some Hybrid Welding Process :**

1. TIG welding,
2. Plasma arc welding, and
3. Laser welding.

### Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 2.35. Describe in detail about magnetically impelled arc butt (MIAB) welding.**

**Answer**

1. Magnetically impelled arc butt (MIAB) welding is a solid state welding process involving rotation of arc around the tube to aid the uniform heating of faying surfaces.
2. MIAB welding process is a single shot process and can readily be automated as no manual skill is involved, and is very fast with a welding time of 22 sec for a pipe thickness of 6 mm.
3. It produces a solid state bonding which is conducive to excellent mechanical properties. It also opens up to the possibility of dissimilar metal joints.
4. MIAB welding requires no part rotation unlike friction welding, and hence is much simpler and less expensive.
5. Other potential benefits of MIAB welding include less internal flash, shorter weld time, less metal loss, uniform heating and reduced machine maintenance.
6. MIAB welding process is characterized in six stages providing arc initiation, beginning of arc rotation, arc transitory rotation, arc stable rotation with each other arc instable rotation and tube upsetting.

7. MIAB welding process is widely used in power, defence, oil and gas sectors and is seen as an effective replacement to friction, flash, resistance and butt welding.

## PART-9

*Welding Automation and Robotic Applications.*

### Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 2.36. What do you understand by welding automation ?**

**Answer**

1. Welding automation is a specific type of manufacturing philosophy and thus, represents one of the types of manufacturing automation.
2. Since its goal has always been to replace actions of a manual welder with those of a machine, its definition can be drawn through an analysis of actions needed to effectively perform the welding operations.
3. Welding operations, when performed manually, are generally associated with three basic functions of the welder :

i. Physical function requires the welder's muscular energy or any kind of power to perform the operation.

ii. Programming function is associated with development of the welder's action instructions.

iii. Control function is associated with supervision of the established program of a welder's actions that are needed under abnormal conditions (variations in joint geometry, welding settings, position of the welding head, etc.).

4. When in addition to the physical function, one or both intelligent functions are transferred to a machine, the man-machine system and the group of operations served by this system may be called an automatic welding system and automatic welding operations.
5. The process, or the result of replacement of the operations associated with welder's intelligent efforts by that based on the intelligent actions of a machine, is called welding automation.

**Que 2.37. What are the applications of robot in welding ? Also give its advantages and disadvantages.**

**Answer**

**A. Applications of Robot in Welding :**

1. The typical arc welding application for a robot is one in which the quantities of production are medium or high.
2. A robot cell can be justified which consists of a welding robot and a part holder or part manipulator.
3. The part holder is used to fixture the components and position them for welding.
4. A part manipulator provides an additional capability in the form of 1 or 2 degrees of freedom to position and orient the components relative to the robot.
5. The robot is equipped with a welding rod or wire feed system, and the required power source to provide the electric current for the operation.
6. The workcell controller is used to coordinate the robot motion, the welding current, the wire feed, the part manipulator and any other activities in the cell.

**B. Advantages of Robot in Welding :**

1. Higher productivity.
2. Improved safety and quality of work life.
3. Greater quality of product.
4. Process rationalization.

**C. Disadvantages of Robot in Welding :**

1. There are significant technical and economic problems encountered in applying robot to arc welding.
2. Arc welding is often performed in confined areas that are difficult to access, such as the inside of tanks, pressure vessels, and ship hulls.
3. The presence of variations in the components that are to be welded.
4. Instead of being straight and regular, the edges are typically irregular.

**VERY IMPORTANT QUESTIONS**

***Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.***

**Q. 1. Explain the MIG welding or GMAW process and also give advantages, disadvantages and applications of it.**

**Ans.** Refer Q. 2.3.

**Q. 2. Explain the TIG welding or gas tungsten arc welding (GTAW) with their applications. And also give its advantages and disadvantages.**

**Ans.** Refer Q. 2.4.

**Q. 3. Differentiate between TIG and MIG welding process.**

**Ans.** Refer Q. 2.5.

**Q. 4. Explain the resistance welding and its types. Also explain advantages and disadvantages of it.**

**Ans.** Refer Q. 2.13.

**Q. 5. Write a short note on the following types of resistance welding :**

**i. Spot welding,**
**ii. Seam welding, and**
**iii. Projection welding.**

**Ans.** Refer Q. 2.14.

**Q. 6. What is soldering ? Explain various methods of soldering ? Mention advantages and applications of it.**

**Ans.** Refer Q. 2.18.

**Q. 7. Explain laser beam welding with the help of diagram. What is the principle of a laser generation ?**

**Ans.** Refer Q. 2.21.

**Q. 8. Explain ultrasonic welding, its application, advantages and disadvantages with the help of neat sketch.**

**Ans.** Refer Q. 2.27.

**Q. 9. Explain type of underwater welding and their working mechanisms.**

**Ans.** Refer Q. 2.32.

3
UNIT

# Heat Flow Welding and Welding Metallurgy

## CONTENTS

## PART- 1

*Heat Flow Welding : Weld Thermal Cycle, Temperature Distribution, Peak Temperature.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 3.1. Explain in brief about weld thermal cycle. What are the factors affecting weld thermal cycle ?**

**Answer**

**A. Weld Thermal Cycle :**

1. Weld thermal cycle shows variation in temperature of a particular location (in and around the weld) during the welding as a function of welding time.
2. As the heat source (welding arc or flame) approaches close to the location of interest first temperature increases heating regime followed by gradual decrease in temperature cooling regime.
3. A typical weld thermal cycle as shown in Fig. 3.1.1 the rate of heating peak temperature, and time required for attaining the peak temperature, cooling rate.

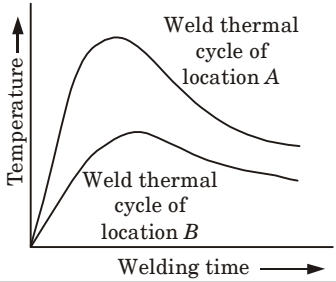


**Fig. 3.1.1.** Schematic of weld thermal cycle of two different locations away from the weld centre line.

4. Since distance of the point of interest away from the weld centre line directly affects all the above parameters heating and cooling rate, peak temperature of weld thermal cycle therefore each location $N$ point offers different and unique weld thermal cycle as shown in Fig. 3.1.2.

5. In general, an increase in distance of point of interest away from the weld centre line :
   i. Decreases the peak temperature.
   ii. Decreases the rate of heating and cooling.
   iii. Increases time to attain peak temperature.
   iv. Decreases rate of cooling with increase in time.

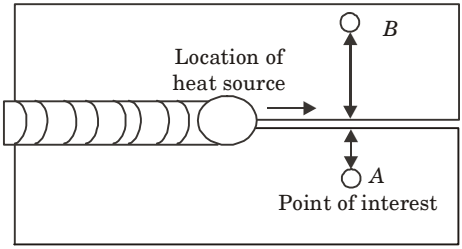


**Fig. 3.1.2.** Schematic of welding showing location of two points *A* and *B*.

**B. Factors Affecting Weld Thermal Cycle :**

1. Weld thermal cycle varies with distance from the weld centre line but it is also influenced by heat input rate, amount of heat supplied for welding, weldment geometry, thermal properties of base metal and initial plate temperature.
2. Rate of heat input is primarily governed by the energy density of heat input source which to a great extent depends upon the welding process being used for development of weld joints besides the welding parameters.
3. High energy density processes like plasma arc welding and laser beam welding offer higher rate of heating, peak temperature and cooling rates than low energy density processes such as gas welding, shielded metal arc welding.

**Que 3.2. Draw a neat graph and figure to illustrate the temperature distribution around a metallic arc butt weld.**

**Answer**

1. Fig. 3.2.1 shows the temperature distribution around a metallic arc butt weld. Electrode or arc is moving from right to left.

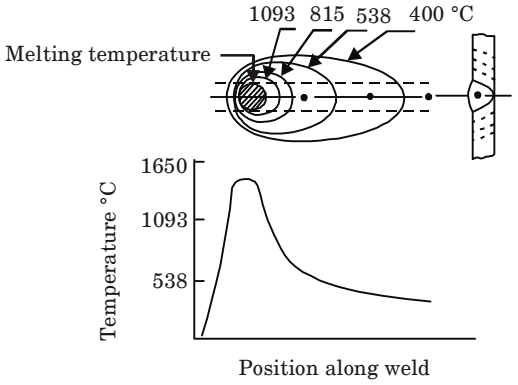


**Fig. 3.2.1.**

2. The leading edge of the temperature pattern is compressed, because the arc is moving towards cold metal and the trailing edge becomes extended due to the arc which leaves preheated metal in its wake.

**Que 3.3. Discuss in detail the calculation of peak temperature of weld metal.**

**Answer**

1. The temperature distribution in a plate for a moving line heat source is given as,

$$T - T_0 = \frac{Q}{2\pi k\alpha} \exp\left(-\frac{U_x \xi}{2k}\right) K_0\left(\frac{U_x r}{2k}\right) \quad ...(3.3.1)$$

Where $K_0$ ($\chi$) is the modified Bessel function of the second kind of order zero.

2. Eq. (3.3.1) is also sometimes known as the Rosenthal equation.
3. Samples of the temperature distribution as represented by a family of isotherms drawn around the instantaneous heat source position ($XY$ plane) are shown in Fig. 3.3.1 shows the effect of thermal conductivity by comparing the isotherms for a relatively low thermal conductivity material (say steel) and a relatively high thermal conductivity material (say aluminum) when other processing conditions are the same.
4. The point on any isotherm that is furthest from the $X$-axis (or line of motion of the heat source) is at its peak temperature at that instant.

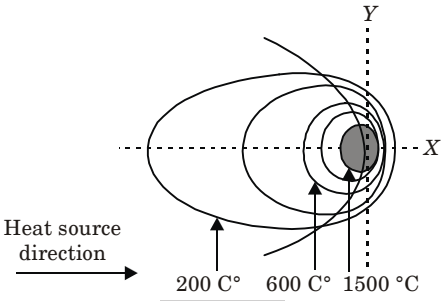


**Fig. 3.3.1.**

5. Using eq. (3.3.1) and considering temperatures in terms of distance from the fusion zone boundary, it can be shown that the peak temperature for a thin plate (line source) is given as,

$$\frac{1}{T_p - T_0} = \frac{\sqrt{2\pi\, e}}{Q} \frac{\rho C_p h \mu_x Y_{HAZ}}{1} + \frac{1}{T_m - T_0} \qquad ...(3.3.2)$$

6. For a thick plate (point source),

$$\frac{1}{T_p - T_0} = \frac{2\pi K \alpha e}{Q \mu_x} \left\{ 2 + \left( \frac{\mu_x Y_{HAZ}}{2\alpha} \right)^2 \right\} + \frac{1}{T_m - T_0} \qquad ...(3.3.3)$$

Where, $e$ = Natural exponent = 2.71828,

$Y$ = Distance from the fusion boundary at the workpiece surface, and

$T_p$ = Peak or maximum temperature at a distance $Y$ from the fusion boundary.

7. Eq. (3.3.2) and eq. (3.3.3) are applicable to single pass processes and have to be applied to each pass by itself.
8. They are useful for estimating the heat affected zone size and also for showing the effect of preheat on the HAZ size.
9. It is evident from the equations that all parameters being constant, preheating increases the size of the HAZ. Also, the size of the HAZ is proportional to the net energy input.
10. Thus, high intensity processes such as laser welding generally have a smaller HAZ.
11. A high intensity energy source results in a lower total heat input because the energy used in melting the metal is concentrated in a small region.

## PART-2

*Heat Affected Zone (HAZ).*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 3.4. What do you mean by heat affected zone (HAZ) in welding ? Why weld usually fails in HAZ ?**

**Answer**

**A. Heat Affected Zone :**

1. Heat affected zone is the portion near the weld metal zone which is composed of parent metal and did not melt but heat to a enough high temperature for a sufficient period. Due to this heating, mechanical properties and microstructure of this zone have been changed.
2. The HAZ in low carbon steel of normal structure welded in one run with coated electrodes or by submerged arc welding process comprises of three metallurgical different regions :

**i. Grain Growth Region :**

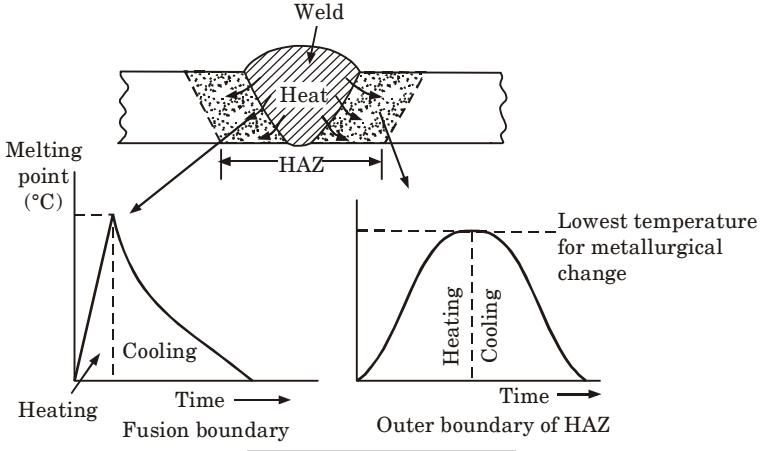


**Fig. 3.4.1.** HAZ boundary.

1. This region is immediately adjacent to the weld metal zone.
2. In this zone, base metal is heated to a temperature well above the upper critical temperature. This results in grain growth and coarsening of the structure.

**ii. Grain Refined Region :**

1. This region is adjacent to the grain growth region.

2. In this region, base metal is heated just above the upper critical temperature where grain refined is completed and finest grain structure exists.

**iii. Transition Zone :**

1. This region exists in a temperature range between the upper and lower critical transformation temperatures where partial allotropic recrystallization takes place.

**B. Weld usually fails in HAZ due to :**

1. The failure of weld is due to weld decay.
2. The weld decay is caused by following reasons :
   i. The time and the temperature of exposure.
   ii. The composition and prior treatment of the weld.

## PART-3

*Heating, Cooling and Solidification Rates.*

### Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 3.5. Describe in detail steps involved in cooling rate of welds.**

**Answer**

Steps involves in cooling rate of welds are as follows :

1. Calculate the relative plate thickness :

$$t_1 = t\sqrt{\frac{\rho C\,(T_c - T_0)}{H_{net}}} \qquad ...(3.5.1)$$

Where,

$t$ = Plate thickness, mm

$\rho$ = Density of material, g/mm$^3$

$C$ = Specific heat of solid metal, J/g °C

$\rho C$ = Volumetric specific heat, J/mm$^3$ °C

$T_c^*$ = 550 °C for most steels.

$$H_{net} = \frac{EI}{v} \cdot f$$

$E$ = Arc voltage, volt

$I$ = Arc current, amp

$v$ = Travel speed, mm/sec

$f$ = Heat transfer efficiency.

2. If $t_1$ comes out to be greater than 0.75, the welding plate will be regarded as a thick plate, then eq. (3.5.2) will be used to calculate cooling rate,

$$R = \frac{2\pi k (T_c - T_0)^2}{H_{net}} \quad ...(3.5.2)$$

Where, $R$ = Cooling rate at a point on the weld centre line, °C/sec. at just that moment when the point is cooling past $T_c$,

$k$ = Thermal conductivity of the metal, J/mm s °C, and

$T_0$ = Initial temperature of plate to be welded, °C.

3. If $t_1$ comes out to be lesser than 0.75, the welding plate will be regarded as a thin plate, than eq. (3.5.3) will be used to calculate cooling rate,

$$R = 2\pi\, k\rho C \left(\frac{t}{H_{net}}\right)^2 (T_c - T_0)^3 \quad ...(3.5.3)$$

4. It can be seen from eq. (3.5.2) and eq. (3.5.3) that if plate to be welded is preheated, *i.e.*, $T_0$ is raised, $(T_c - T_0)$ will decrease and hence $R$, *i.e.*, the cooling rate will be reduced.
5. Preheating is often done to reduce cooling rate when welding hardenable steels.

**Que 3.6. How the cooling rate affects the property of the welded joint ?**

**Answer**

1. The different types of cooling rate give the formation of different types of reaction products as shown in Fig. 3.6.1.

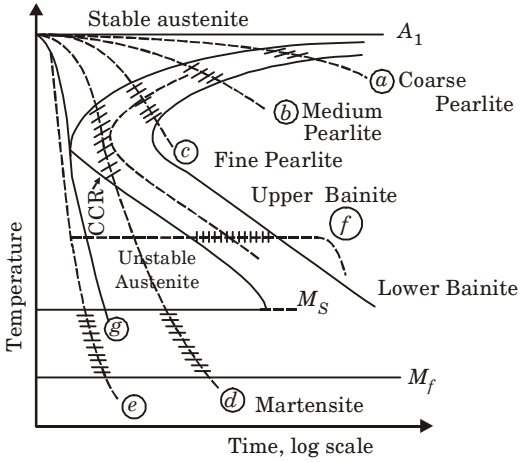


**Fig. 3.6.1. Cooling curves and TTT diagram.**

2. Cooling curve (*a*) shows very slow cooling rate (conventional annealing) and it forms a course pearlite with low hardness.

3. Cooling curve (*b*) involves a faster cooling rate than curve (*a*) (normalizing) and it forms the fine pearlite.
4. Cooling curve (*c*) involves a slow oil quench cooling; this results in a mixture of medium and fine pearlite.
5. Cooling curve (*d*) is typical of an intermediate cooling rate and results into the martensite and fine pearlite structure.
6. Cooling curve (*e*) is a drastic quench and results into the formation of martensite structure.
7. Cooling curve (*f*) obtains a bainite structure by cooling rapidly enough to miss the nose of curve and then holding in the temperature range at which bainite is formed until transformation is completed.
8. Cooling curve (*g*) is tangent to the nose of TTT curve.
9. The curve (*g*) is critical cooling rate (CCR) for the steel.
10. If cooling rate > CCR $\Rightarrow$ Martensite structure will form.
11. If cooling rate < CCR $\Rightarrow$ Some softer transformation products such as pearlite or bainite will form.

**Que 3.7.** **What do you mean by heating rate and cooling rate ? How it affects the properties of weld ?** **AKTU 2018-19, Marks 10**

**Answer**

**A. Heating Rate :**

1. The heating rate of a work piece depends on how hot the heat source is and how efficiently that heat is transferred to the work.
2. A higher temperature at the source means a steeper temperature gradient between it and the work, and so the heating rate will be faster.

**B. Cooling Rate :**

1. It is defined as the difference in the austenitizing temperature and quench temperature divided by the time to cool within some value of calculation of cooling rate on the centre line of the weld.

**C. Effect of Heating Rate :**

1. The welding heat input has a great influence on the weldments properties.
2. Mechanical properties and toughness of weldment depend on microstructure of weld metal.
3. The cross sectional area of a weld is generally proportional to the amount of heat input.
4. As more energy is supplied to the arc, more filler material and base metal will be melted per unit length, resulting in a larger weld bead.
5. The most important characteristic of heat input is that it governs the cooling rates in welds and thereby affects the microstructure of the weld metal.

6. A change in microstructure directly affects the mechanical properties of weld. Therefore, the control of heat input is very important in arc welding in terms of quality control.

**D. Effect of Cooling Rate :** Refer Q. 3.6, Page 3–8H, Unit-3.

**Que 3.8. Write short note on weld solidification rate.**

**Answer**

1. Weld solidification rate is basically the rate at which weld solidifies in welding.
2. Weld metal solidification rate influences metallurgical structure, properties and soundness of the weld.
3. The weld solidification time is given by,

$$S_t = \frac{LH_{net}}{2\pi k\rho C(T_m - T_0)^2}$$

Where, $S_t$ = Solidification time, the time lapse from beginning to end of solidification at a fixed point in the weld metal, sec.

$L$ = Heat of fusion, J/mm$^3$

$T_m$ = Liquids temperature of the metal being welded.

## PART-4

*Welding Metallurgy : Fundamentals of Physical Metallurgy, Principle of Solidification of Weld Metal.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 3.9. Discuss in brief about the welding metallurgy.**

**Answer**

1. The study of welding metallurgy is very important because the overall mechanical properties of a weldment are determined by the characteristic properties of the individual microstructure present in the weld deposit and the weld heat affected zone.
2. It has long been recognized that one of the major problems associated with fabrication by welding arises from the inability to obtain uniform mechanical properties throughout the weldment.

3. Welding metallurgy is concerned with :
   i. Melting of electrode and parent metal,
   ii. Solidification of weld metal,
   iii. Gas absorption and gas metal reactions,
   iv. Slag metal reactions,
   v. Surface phenomena, and
   vi. Solid state reactions.
4. Temperature change and change in microstructures introduce volume changes in the area surrounding the weld and hence cause straining, plastic flow, residual stresses or even cracking.
5. Parent metal is subjected to a complex thermal cycle with a temperature gradient extending from the melting range to ambient temperatures and followed by a cooling cycle induced by the surrounding cold metal.

**Que 3.10. Explain the weld metal solidification process.**

**Answer**

1. In all metallic systems, solidification is accompanied by the evolution of heat.
2. In a pure metal the rate of growth is determined solely by the rate of heat extraction from the solid-liquid interface. This situation, however, is of purely academic interest in welding, since this level of purity is never achieved.
3. The level of purity in welding operations is such that segregation always occurs on solidification.
4. As the alloy cools through the solidification range, solute is rejected at the solid-liquid interface.
5. Since very little mechanical mixing of the liquid occurs in the immediate vicinity of the advancing interface, the rejected solute must be redistributed in the liquid by diffusion.
6. The freezing process is so rapid that diffusional processes cannot effectively remove the excess solute near the interface. Hence, solute enrichment occurs at the moving interface until a dynamic equilibrium is reached.
7. The resulting dynamic equilibrium provides an excess of solute in the liquid near the interface with the solute content decreasing to the nominal liquid composition at some distance from the interface.
8. As a result, the effective liquidus temperature varies with distance from the interface as shown in Fig. 3.10.1.

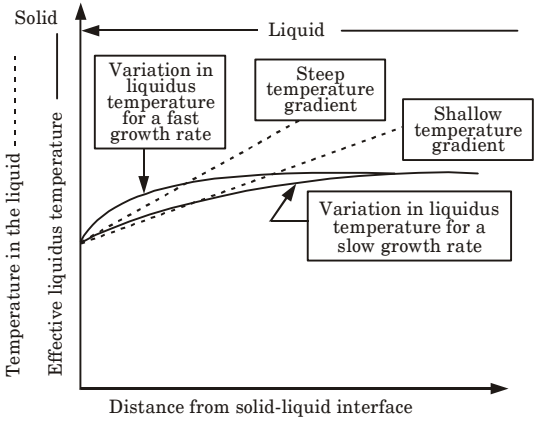


**Fig. 3.10.1.** Effect of growth rate and temperature gradient on constitutional supercooling.

## PART-5

*Reactions in Weld Pool, Gas Metal Reaction, Slag Metal Reaction.*

### CONCEPT OUTLINE

**Reactions in Weld Pool :** The weld pool is cooler and has a smaller surface to volume area than the transferring drop. Because of lower temperature there is a tendency for gas to evolve. The following reactions are possible :

$$2H + O \longrightarrow H_2O$$

$$C + O \longrightarrow CO$$

$$2H \longrightarrow H_2$$

$$2N \longrightarrow N_2$$

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 3.11. Discuss in brief about endothermic gas metal reaction.**

**Answer**

1. In physical (endothermic) solution, no compound is formed.

2. It does not inhibit fusion, but can result in porosity.
3. Porosity may be caused :
   i. Due to super saturation of the molten weld metal with a gas such as hydrogen, nitrogen or oxygen.
   ii. By reaction between two gases.
4. Heat affected zone may also get embrittled in some cases.
5. The mechanism of endothermic reaction is :
   i. Gas is absorbed up to the maximum solubility and is distributed throughout the weld pool by metal circulation.
   ii. Fig. 3.11.1 shows the solubility of hydrogen in various materials at different temperatures.

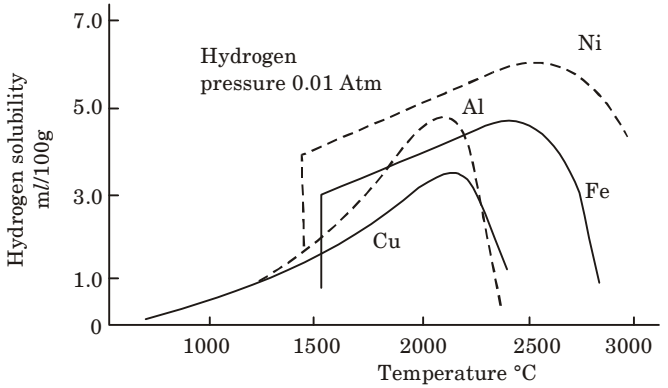


**Fig. 3.11.1.** Hydrogen solubility temperature curves.

   iii. Reaction takes place between gas and metal and between two gases, e.g.,

$$4Cu + O_2 \longrightarrow 2Cu_2O + \Delta G_1$$
$$2H + O_2 \longrightarrow 2H_2O + \Delta G_2$$

   Where, $\Delta G_1$ and $\Delta G_2$ are the free energy changes for two reactions.
   iv. Evolution of gas dissolved in weld pool :
      1. The gas which has been dissolved in the high temperature portion of the weld pool and is then transferred to cooler regions will form a supersaturated solution and will normally be evolved.
      2. For gas evolution to take place there should be a minimum degree of supersaturation and the presence of suitable nuclei.
      3. The gas bubbles if they become entrapped in the fast freezing metal, it will give rise to porosity.

**Que 3.12. Explain the mechanics of slag metal reactions.**

**Answer**

1. The nature of slag metal reactions is largely determined by the composition of the flux or electrode coating.
2. The form of electrode tip in shielded metal arc welding is illustrated in Fig. 3.12.1. The coating forms a cone within which a liquid drop forms. Interaction between slag and metal takes place initially at the junction between cone and liquid.
3. If alloying elements are added through the coating, they dissolve at this point and are mixed well enough for the drop, when it detaches, to be almost homogeneous.
4. This indicates rapid circulation in the drop, due to electromagnetic effects or drag from the gas evolved by the coating. At the same time, the liquid metal is heated to a high temperature.
5. In practice the drop profile is by no means as regular as shown in Fig. 3.12.1. It is in a state of constant movement, as is the arc root. This does not, however, affect the basic geometry of the arrangement.
6. In submerged arc welding the arc operates in a cavity of liquid slag and the liquid metal drops frequently transfer through the slag cavity or occasionally around the cavity wall.

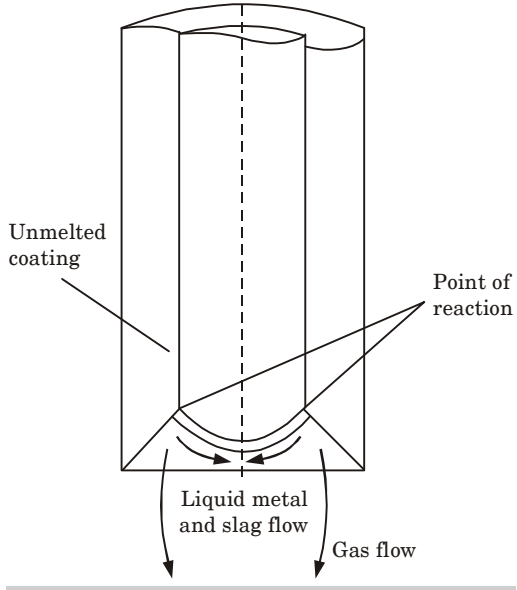


**Fig. 3.12.1.** Slag metal reaction in SMA welding.

7. Once again, because of the high temperature and the large surface-to-volume ratio of the drop, it is likely that significant slag metal reactions take place.
8. The deep penetration characteristic of submerged arc welding may also be relevant to slag metal reactions.

## PART-6

*Factors Affecting Changes in Microstructure and Mechanical Properties of HAZ, Micro and Macro Structures in Weld Metal and HAZ.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 3.13. Write down the various factors affecting changes in microstructure and mechanical properties of HAZ.**

**Answer**

Various factors affecting changes in microstructure and mechanical properties of HAZ are as follows :

1. Welding process used.
2. Filler rod composition and the composition of flux in case of coated electrodes.
3. The conditions under which the weld is made, *i.e.*, the amount of oxygen and nitrogen present.
4. The chemical composition of base metal.

**Que 3.14. Write short note on micro and macro structures in weld metal and HAZ.**

**Answer**

1. Fig. 3.14.1 shows the structure of a weld section.
2. It may be noted that columnar (long elongated) crystals are formed near fusion faces due to directional cooling of weld towards the centre.
3. Since the inner part of weld cools more uniformly it results in an enlarged but regular crystal structure.
4. Surface of weld being in contact with air cools very fast and small and slightly chilled crystal structure can be noted there.
5. The parent metal in heat affected zone experiences grain growth.
6. In case of thick plate, several passes of weld would be required and the structure of previous weld would be refined by the heat in the subsequent welding.

7. For single pass welding, post weld heat treatment is desirable to refine the weld metal structure.

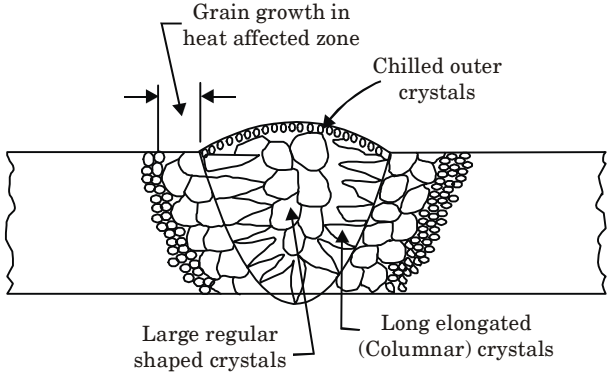


**Fig. 3.14.1.** Micro and macro structure of weld metal.

## VERY IMPORTANT QUESTIONS

***Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.***

**Q. 1. Explain in brief about weld thermal cycle. What are the factors affecting weld thermal cycle ?**

**Ans.** Refer Q. 3.1.

**Q. 2. What do you mean by heat affected zone (HAZ) in welding ? Why weld usually fails in HAZ ?**

**Ans.** Refer Q. 3.4.

**Q. 3. What do you mean by heating rate and cooling rate ? How it affects the properties of weld ?**

**Ans.** Refer Q. 3.7.

**Q. 4. Explain the weld metal solidification process.**

**Ans.** Refer Q. 3.10.

**Q. 5. Explain the mechanics of slag metal reactions.**

**Ans.** Refer Q. 3.12.

**Q. 6. Write short note on micro and macro structures in weld metal and HAZ.**

**Ans.** Refer Q. 3.14.

☺☺☺

4
UNIT

# Repair and Maintenance Welding

## CONTENTS

## PART-1

*Repair and Maintenance Welding : Hardfacing, Cladding, Surfacing.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 4.1. What is hardfacing ? What are the objectives and principle of operation of hardfacing ? Mention advantages and applications of hardfacing.**

**Answer**

**A. Hardfacing :**

1. In hardfacing, metal is deposited over another surface to increase the hardness of the surface, and to make the surface of material resistant to abrasion, convolution, impact, erosion, etc.
2. One of the most important applications of hardfacing is abrasion resistance.
3. In general purpose three layers of hardfacing alloys are deposited as effectiveness of the hardfacing reduces excessive dilution.

**B. Objectives of Hardfacing :**

1. To extend the service life of critical parts and assemblies in machines and mechanisms by depositing on them such metals or alloys that will impart to them resistance to wear or abrasion, corrosion, heat, impact, erosion, cavitation, hammering, and indentation.
2. To rebuild a worn or scratching out incorrectly cast part.
3. To repair a component.

**C. Principle of Operation of Hardfacing :**

1. Determine the exact composition of the base metal because it influences the success and quality of the surfacing method.
2. Determine the type and degree of wear of the base metal.
3. Determine the welding position of the job.
4. Estimate the area that needs to be hardfaced.
5. Select an appropriate hardfacing alloy.
6. Select an appropriate hardfacing method.
7. Prepare the surface to be hardfaced.
8. Apply the hardfacing alloy on the base metal.
9. Impart proper surface finish to the hardfaced base metal component.

**D. Advantages :**

1. This increases the service life of the product.
2. This imparts the corrosion resistance.
3. The cost of this process is less as compared to other processes.
4. Less skilled worker is required.

**E. Applications of Hardfacing :**

1. This is extensively used in construction equipments including bulldozer blades, scraper blades, textile industries equipments and engine valve facing.

**Que 4.2. What do you mean by cladding ? Explain principle of operation of cladding.**

**Answer**

**A. Cladding :**

1. Cladding is the covering of one material with another. In metallurgy, cladding is the bonding together of dissimilar metals.
2. It is distinct from welding or glueing as a method to fasten the metals together.
3. Regarding optical fibre in telecommunication, cladding is one or more layers of material of lower refractive index in intimate contact with a core material of higher refractive index.
4. Cladding is often achieved by extruding two metals through a die or pressing sheets together under high pressure.
5. Cladding has been providing high technological coating for a variety of end users to enhance functional performance whether it is to be medical, industrial or automotive.
6. Other industries use metal cladding to enhance their product performance. This is used :
   i. To form new parts,
   ii. To apply a harder surface onto a part, and
   iii. To resurface the worn or damaged parts.
7. This is used in production of vessels for chemical, paper mill, petroleum refining and nuclear power plant.

**B. Principle of Operation of Cladding :**

1. Cladding is usually performed by attaching plates of relatively thick metals together such as by welding and then rolling them down together.
2. The centre core and plating metal retain their proportions as the cross section is reduced.
3. In hot extrusion process, lubricants should be used between the billet, die and container, not only to reduce the work load but also to keep the flow laminar. As a result, the outer layer is also a case of cladding.

4. The temperature range of the billet during the hot extrusion of steels is 1200 -1500 °C. The die must be kept at a lower temperature around 200 °C to avoid excessive wear rate.
5. Glass fibres are normally used as lubricants since the viscosity of glass is sensitive to temperature. Thus, the viscosity is high at the die surface, providing a good protection to die wear and facilitating the formation of a glass skin on the product.
6. At the same time, the work load is reduced since the viscosity of glass is much lower at the billet-container interface.

**Que 4.3. Explain the term metal surfacing. What are the various methods of depositing metal ?**

**Answer**

**A. Metal Surfacing :**

1. Metal surfacing is a deposition process. In this process metal is deposited over another metal to improve the wear resistance properties of metal like resistance to abrasion, corrosion, friction or for achieving dimensional control as well as metallurgical requirement.
2. Common processes used for surfacing are fusion welding process such as arc welding, oxy-acetylene welding and thermal spraying.
3. This process is widely used for all equipment especially in chemical industries to increase the life of equipments against wear and chemical action.
4. Since the bond between the base metal and the deposited metal is purely mechanical, it is essential that the surface of the base metal should be prepared properly so that a good mechanical interlocking between the sprayed metal and base metal can be obtained.
5. The first step in surfacing is to clean the base metal surface by removing all foreign substances such as oxides, oil, water, etc.
6. Oxide and other coatings may be removed by using mechanical methods such as machining, grinding, sanding, etc.
7. Grease and oil can be chemically removed from the base metal surface.
8. The next step is to roughen the base metal by forming keys or openings on it so that the sprayed metal penetrates in them thereby resulting in a bonding or keying action.

**B. Various Methods of Depositing Metal :**

1. Cladding,
2. Hardfacing,
3. Build up, and
4. Buttering.

**Que 4.4. Explain in detail the advantage of hardfacing with oxy-acetylene torch.** **AKTU 2017-18, Marks 10**

**Answer**

1. Oxy-acetylene welding process can be used for surfacing purpose with the assistant of portable and low cost equipment.
2. In this surfacing process heating and cooling rates for parent metal are very slow which leads to very little dilution resulting in smooth, precise and extremely high quality surfacing deposits.
3. Groove, narrow gap and recesses can be easily filled and very thin layers may be smoothly applied.
4. Preheating and slow cooling nature of oxy-acetylene surfacing method tends to minimized cracking even with highly wear resistance but brittle over types of welding flame and size of tip.
5. During surfacing no flux is needed, a typical application of the process is the deposition of a low melting point high carbon filler metal.
6. This process also can be done by powdered material; in this case welding torch is fitted with hopper (a powder feeding device).
7. Oxy-acetylene surfacing process can be done in a semi-automatic manner where a large number of identical parts, which can be arranged in systematic manner are present.
8. The process can be easily employed in the field and very thin layers of hardfacing alloy can be applied.

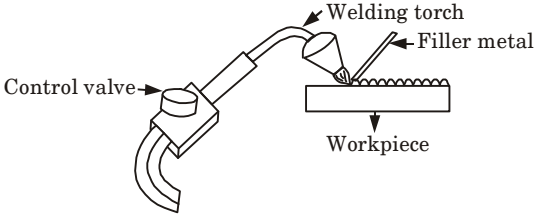


**Fig. 4.4.1.** Hardfacing by oxy-acetylene welding.

## PART-2

*Metallizing Processes and Reclamation Welding.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 4.5. State the principle and working of metallizing process. Also write down its advantages, disadvantages and applications.**

**Answer**

**A. Principle of Metallizing Process :**

1. The material to be sprayed is taken in powder or wire form and fed into the oxy-acetylene flame. There it melts by the heat of the neutral flame, gets atomized and blown by a stream of compressed air onto the base metal surface where it spreads around and interlocks with projections imbedded in pits, and freezes quickly upon contact with the base metal surface.
2. Separate particles overlap and intertwine with one another to form a coherent structure.
3. The sprayed material is generally applied in layers less than 0.25 mm thick.

**B. Working of Metallizing Process :**

1. This consists of a wire type spray gun which resembles an oxy-fuel gas torch with a hole for the wire through the centre of its tip.

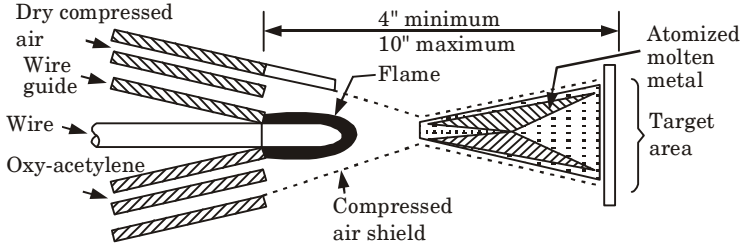


**Fig. 4.5.1.** Flame spraying (wire metallizing).

2. The gun also has an arrangement to drive a pair of knurled rolls to feed the wire into the flame, for this wire reel and straighteners are used.
3. An air cap encloses the tip of the gun and directs a blast of compressed air to pick up the molten metal, and project it, thoroughly atomized, onto the base metal.
4. A dry compressed air forms an air envelope around the outside of the flame and the liquid metal atomizes the molten wire metal that has been melted by oxy-acetylene flame and cools the substrate thus maintaining its temperature below 205 °C.
5. Compressed air also accelerates the molten metal particles on its path to the base metal and thus deposits them there.

**C. Advantages of Metallizing :**

1. This is approximately 70 % less costly than flame spraying.
2. No combustion gases are required thus eliminating all problems and dangers associated with these gases.
3. This can be interrupted and resumed at any time by simply engaging and disengaging the wire feed mechanism.
4. This requires less surface preparation than flame spraying.

**D. Disadvantages of Metallizing :**

1. The arc spraying velocity is lower than that of flame spraying.
2. Coatings do not resist high temperatures.
3. Adequate resistance to wear can be achieved, but the performance cannot be compared to a surface built-up by welding.
4. The process creates fumes, dust and odours around the work.

**E. Applications of Metallizing :**

1. This is used in production of portable water tanks, bridges, locks and dam gates, oil platforms, power transmission poles etc.

**Que 4.6.** **Write short note on reclamation welding.**

**Answer**

1. Reclamation welding is the simplest form of reclamation where the metallic components are joined together, if cracked/broken, with the use of suitable electrode using arc welding.
2. During this process, there is possibility of very high localised temperatures, which could result in distortion of the components, thus the process requires great care while being performed.

## PART-3

*Weldability : Effects of Alloying Elements on Weldability, Carbon Equivalent.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 4.7.** **Define weldability of materials and mention the factors on which weldability depends.**

**Answer**

**A. Weldability of Materials :**

1. Weldability is the capacity of a material to be welded under the fabrication conditions imposed into a specific suitably designed structure and to perform satisfactorily in the intended service.

**B. Factors Affecting the Weldability :**

**i. Metallurgical Compatibility :**

1. This implies that the base metals and weld metal can be combined within the degree of dilution encountered in a specific process without the production of any harmful constituents or phases.

**ii. Mechanical Properties :**

1. The mechanical properties must meet properties requirements and normal engineering standards.

**iii. Serviceability :**

1. Serviceability is concerned about the ability of the welded structure to work under low and high temperatures and impact loads etc.

**Que 4.8. Explain the effect of various alloying elements on weldability.** **AKTU 2018-19, Marks 10**

**Answer**

1. Alloying elements increase or decrease hardenability of the HAZ. C, Mn, Mo, Cr, V, Ni and Si have greatest effect on the hardenability of steel.
2. Alloying elements provide grain refinement. Al, V, Ti, Zr and N are the grain refiners for carbon and low alloy steels.
3. Alloying elements control ductile to brittle transformation temperature.
4. Alloying elements form substitutional alloys and strengthen the metal by solid solution hardening.
5. Alloying elements form interstitial alloys to increase mechanical properties by lattice distortion.
6. Alloying elements form carbides, age hardening precipitates and reduce segregation.
7. Alloying elements also provide grain refinement.
8. Alloying elements provide deoxidation of molten metal without loss of primary alloying elements. Ti, Zr, Al, Si have affinity for oxygen than iron and thus act as deoxidizers in carbon and low alloy steels.

**Que 4.9. Explain the effect of alloying elements (S, P, and Mn) in parent metal on the weld and explain how the weldability of steel can be increased.**

**Answer**

**A. Effect of Alloying Elements (S, P and Mn) in Parent Metal on the Weld :**

i. **Effect of Sulphur (S) :** Sulphur imparts free machining properties.

ii. **Effect of Phosphorus (P) :** Phosphorus improves irradiation stability and creep properties.

iii. **Effect of Manganese (Mn) :** Mn contributes to strength and hardness. Mn also lowers both ductility and weldability, if present in high percentage with high carbon content in steel.

**B. Weldability of Steel can be Increased by :**

1. For low carbon steel, flux shielded metal arc welding is used. Both mild steel and low hydrogen electrodes are employed for this purpose.
2. For medium carbon steel, flux shielded metal arc welding is used and low hydrogen electrodes may be employed to reduce weld cracking.
3. Preheating (between temperatures 150 °C to 260 °C) is done to eliminate and reduce the hard and brittle areas after welding, the workpiece should be allowed to cool to room temperature slowly by being buried in sand. Post heating of the job (between temperatures 595 °C to 675 °C) is done for 1 hour per 25 mm of section thickness.
4. For high carbon steel, oxy-acetylene welding can be used.

**Que 4.10. Write a short note on carbon equivalent.**

**Answer**

1. Carbon equivalent is an empirical value in weight percent, relating the combined effects of different alloying elements used in the making of carbon steels to an equivalent amount of carbon.
2. In terms of welding, carbon equivalent governs the hardenability of the parent metal.
3. It is a rating of weldability related to carbon, manganese, chromium, molybednum, vanadium, nickel and copper content.
4. It could be expressed as,

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15}$$

5. The ability to form hard metallurgical constituents such as martensites or any other hard phases is dependent on the carbon equivalent and the cooling rate of the steel involved in cooling from the transformation temperature.

6. The higher the carbon equivalent value, the faster the cooling rate, the higher the tendency for hard, brittle phases to form during cooling.

## PART-4

*Welding of Plain Carbon Steel, Stainless Steel, Cast Iron and Aluminium Alloys.*

### Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 4.11. Explain the welding of low carbon steels.**

**Answer**

1. Low carbon steel is most widely used for welding in industries because of its strength, its workability under fabricating methods and its relatively low price.
2. Low carbon steels may be welded by any of the commonly used welding processes, the choice depending upon section thickness and quality requirements.
3. Plate thicknesses above 25 mm need preheat, controlled interpass temperature and postwelding stress relief to avoid cracking and to maintain toughness, strength and ductility.
4. Welding processes employed for welding low carbon steels are as follows :
   i. Oxy-acetylene welding,
   ii. Flux shielded metal arc welding,
   iii. Submerged arc welding,
   iv. Gas metal arc welding,
   v. Gas tungsten arc welding,
   vi. Plasma arc welding,
   vii. Thermit welding,
   viii. Resistance welding,
   ix. Electroslag welding, and
   x. Brazing.
5. Flux shielded metal arc welding is commonly used for welding low carbon steels. Both mild steel and low hydrogen electrodes are employed for the purpose.
6. Oxy-acetylene welding is also frequently used to weld low carbon steels.

7. The selection of filler rod depends upon the base metal composition. A neutral flame is used for welding. Backhand technique is preferred and no flux is needed.

**Que 4.12. Write down various process used for welding stainless steel. Explain any one.**

**Answer**

**A. Various Process Used for Welding Stainless Steel :**

1. Oxy-acetylene welding,
2. Arc welding,
3. Resistance welding, and
4. Brazing.

**B. Oxy-Acetylene Welding :**

1. For gas welding of stainless steel :
   i. A flange-type joint is best for thin sheets.
   ii. Sheets up to 3 mm thick may be butted together.
   iii. For plates thicker than 3 mm, their edges are beveled to provide a vee to obtain fusion entirely to the bottom of the weld.
2. Before welding, the plate surfaces are cleaned with fine sand paper, stainless steel wool, wire brush etc.
3. During welding, torch is kept at an angle of 45° to the work and the tip of the inner cone of flame is kept within 1.5 mm of the molten puddle to avoid oxidation.
4. The flame is played on the work until the edges melt and mingle with the metal from the filler rod.
5. Welding speed is kept uniform.
6. The forehand technique is preferred on thinner sheets and the backhand technique is employed when welding thicker sheets.
7. At no time, the filler rod is withdrawn from the flame, as otherwise there is certain to be some oxidation of the metallic droplets.
8. The success of welding depends upon keeping the heat to a minimum and completing the weld in one pass.

**Que 4.13. Explain the welding procedure of cast iron.**

**OR**

**Briefly discuss the welding of cast iron. What kinds of defects are expected in such welding and what are their remedies.**

**AKTU 2017-18, Marks 10**

**Answer**

**A. Welding of Cast Iron :**

1. There are different types of cast iron. Here we discuss the welding procedure of gray cast iron, it contains,

| | |
|---|---|
| C = 2.5 – 3.8 % | Si = 1.1 – 2.8 % |
| Mn = 0.4 – 1 % | P = 0.15 % |
| S = 0.1 % | Fe = Remaining |

2. The welding of gray cast iron can be done by the following processes :

**i. Metal Arc Welding :**

1. A *V*-joint with included angle of 60° to 90° may be formed by chipping or machining.
2. The joint is carefully cleaned of all dust, dirt, oil, grease and paint.
3. Electrodes of cast iron, mild steel, austenitic stainless steel may be employed for welding gray cast iron.
4. The arc is struck by touching the electrode with the job. As the molten pool forms, the welding is carried out in the normal way.
5. In order to minimize the stresses set up in the workpiece, the weld may be laid in the short run and then each be allowed to cool.

**ii. Brazing :**

1. Brazing of gray cast iron is done to repair casting defects where strength and colour match are not of primary importance.
2. Brazing of cast iron requires special pre-cleaning methods to remove graphite from the surface of iron because the presence of graphite on the cast iron surface would prevent wetting and adhesion of the brazing alloy.
3. It carried out at temperature as low as feasible, in order to avoid reduction in the strength of iron.
4. Brazing is generally done with an oxy-acetylene torch and a neutral or slightly carburizing flame.
5. Preheating between 205 °C to 427 °C before torch or induction brazing may produce better results.

**B. Defects and Remedies in Welding of Cast Iron :**

**i. Undercut :**

1. Undercut is a kind of weld defect which forms a groove in the parent metal along the sides of the weld bead.
2. Groove reduces the thickness of the plate and also reduces the strength of the weld.

**a. Remedies of Undercut :**

1. Use proper arc current.

2. Use proper electrode.
3. Weaving should be proper and as per requirement.

**ii. Hot Tear :**

1. In this welding defect the deposited metal being hot, starts developing crack from the nearby edge so that after it has been solidified the crack increases.

**a. Remedies of Hot Tear :**

1. Select proper electrode material.
2. Welding current should be optimum as per the requirement.
3. Electrode thickness should be optimum and according to the base metal to be welded.

**Que 4.14. What are the welding characteristics of aluminium and its alloys ? Mention various methods for welding aluminium and its alloys.**

**Answer**

**A. Welding Characteristics of Aluminium and its Alloys :**

1. The first and the foremost consideration is the effect of the thin film of oxide which is chemically or mechanically removed before welding.
2. Aluminium being a very good conductor of heat, dissipates heat at a very fast rate from the joint being welded. This must be compensated by using bigger nozzle size.
3. Aluminium has got high coefficient of linear expansion.
4. Aluminium is weak when hot and thus extra care is required when welding thinner section which may buckle.
5. Aluminium does not show any colour change on heating and without experience it may be difficult to judge when the metal begins to melts.

**B. Various Methods for Welding Aluminium and its Alloys :**

1. Oxy-gas welding,
2. MIG or TIG welding,
3. Resistance welding,
4. Metallic arc welding,
5. Solid state welding, and
6. Atomic-hydrogen welding.

**Que 4.15. Explain in detail aluminium welding by double operator method.** **AKTU 2017-18, Marks 10**

**Answer**

1. Aluminium welding by double operator method as shown in Fig. 4.15.1.
2. The oxide of aluminium (alumina $Al_2O_3$) which is always present as a surface film and which is formed when aluminium is heated, has a very high melting point, much higher than that of aluminum.
3. If it is not removed it would become distributed throughout the weld, resulting in weakness and brittleness.
4. The work should be cleaned of grease and brushed with a wire brush-sheets below 20 gauge can be turned up at right angles and the weld made without a filler rod.
5. Aluminium, when near its melting point is extremely weak, and much trouble can be avoided by seeing that no collapsing can occur during the welding operation.
6. The flame is adjusted to have a very slight excess of acetylene and then adjusted by neutral and rod of pure aluminium or 5 % silicon-aluminium alloy should be little thicker then the section to be welded.
7. The double-operator method is used on sheets above 6 mm thickness, the angle of the blow pipes being 50 – 60° and the rods 70 – 80°.
8. This method gives a great increase in welding speed.

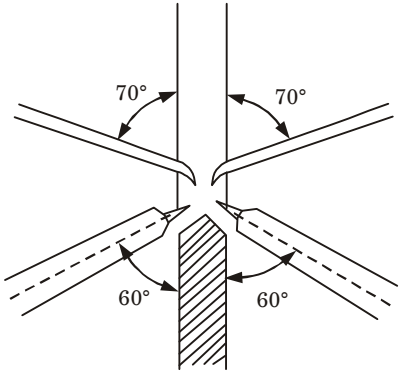


**Fig. 4.15.1.** Aluminium welding by double-operator method.

**Que 4.16. Write short note on metallic arc welding of aluminium.**

**Answer**

1. In the metallic arc welding of aluminium there remains a tendency to unsoundness in the welds.
2. The arc between the electrode and the job is struck by scratching action.

3. Electrode has to be scratched very hard against the job to strike the arc because of the insulation afforded by the flux coating on the electrode and the oxide film on the metal.
4. A short arc is maintained, the electrode is held at right angle to the work, the electrode coating almost touches the molten pool and no weaving is done.

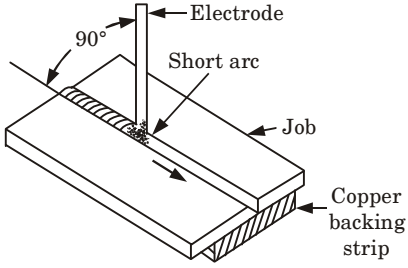


**Fig. 4.16.1.** Metallic arc welding of aluminum.

5. The arc is so directed that both edges of the joint to be welded are properly and uniformly heated.
6. The rate of welding should be uniform. As the metal warms up, the speed of welding must be increased.

## PART-5

*Welding of Dissimilar Materials.*

### CONCEPT OUTLINE

**Dissimilar Metal Welding :** This is a process which involves the joining of two metals that possess different chemical or mechanical properties.

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 4.17. Discuss the various techniques for welding the dissimilar materials.**

**Answer**

Various techniques for welding the dissimilar materials are as follows :

**i. Resistance Welding :**

1. It is often easier to make satisfactory joints between dissimilar metals by resistance welding than by arc welding, since the problem of fluxing or provision of an inert atmosphere does not arise and the techniques available often minimize the danger of the formation of brittle intermetallic compounds within the joint.
2. Copper and aluminium, for example, form a series of brittle phases when melted together, but flash-butt welding of the two metals is widely practised since these phases are forced out of the joint when the upset force is applied.
3. Spot and projection welding both are used to weld dissimilar metals.

**ii. Solid-State Welding :**

1. Solid-state welding processes include :
   i. Pressure welding with or without controlled atmospheres.
   ii. Ultrasonic welding.
   iii. Friction welding.
   iv. Diffusion bonding.
2. It is necessary that the surfaces should be clean and be in intimate contact.

**iii. Brazing :**

1. Brazing is of much importance in joining dissimilar metals because in good practice, alloying between the dissimilar metals cannot occur, and no unsuitable phases can be formed.
2. Materials susceptible to intergranular penetration should normally be annealed before brazing.
3. The zinc bearing silver solders and copper-zinc alloys may be used for joining copper, copper alloys, steels of all types, heat-resisting alloys and nickel alloys.

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**VERY IMPORTANT QUESTIONS**

***Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.***

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**Q. 1. Mention objectives and principle of operation of hardfacing. What are the advantages and applications of hardfacing ?**

**Ans.** Refer Q. 4.1.

**Q. 2. Explain cladding. Mention principle of operation of cladding.**

**Ans.** Refer Q. 4.2.

**Q. 3. State the principle and working of metallizing process. Also write down its advantages, disadvantages and applications.**

**Ans.** Refer Q. 4.4.

**Q. 4. Explain the welding of low carbon steels.**

**Ans.** Refer Q. 4.10

**Q. 5. Explain the welding procedure of cast iron.**

**Ans.** Refer Q. 4.12.

**Q. 6. Discuss the various techniques for welding the dissimilar materials.**

**Ans.** Refer Q. 4.15.

5
UNIT

# Weld Design and Welding Codes

## CONTENTS

## PART-1

*Weld Design : Types of Welds and Joints, Welding Symbols.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 5.1. Describe the various types of welded joints used in weld design.**

**Answer**

Various types of welded joints used in weld design are as follows :

**i. Butt Joint :**

1. Square butt joints (with or without gap) are recommended for smaller plate thicknesses (upto 4.8 mm) and much lesser loading as compared to single *V*, *U*, *J* or bevel joints.
2. Double joints are preferred over single joints for bigger plate thicknesses.
3. Out of various joints, *V* joint finds much more extensive use and applications.
4. Bevel joints are preferred for plates with thicknesses ranging from 10 mm to 35 mm and subjected to medium loading.
5. *U* joints are preferred over *V* joints when it is required to make high quality joints in certain pressure vessel having plate thickness ranging from 10 mm to 20 mm.
6. *J* joints are recommended for normal loading in some pressure vessels.
7. Among the double joints, double *V* joint is employed under most severe loading conditions.

**ii. Lap Joint :**

1. Single fillet and double fillet joints are used on all thicknesses.
2. Double fillet joint is better as compared to single fillet joint when joint is subjected to severe loading.
3. Single fillet joints are not recommended on plates under bending, fatigue or impact loading conditions.
4. Plug weld is employed to impart added strength to the structure. This plug weld joint is used where bottom or second plate cannot be accessed easily.

**iii. *T* Joint :**

1. Single fillet *T* joint is preferred for smaller plate thicknesses when subjected to low or no bending load conditions.
2. Double *T* joint is recommended for most severe loading conditions.
3. In *T* joint cost of edge preparation increases and electrode consumption decreases.

**iv. Corner Joint :**

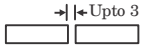
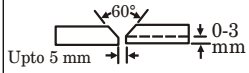
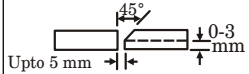
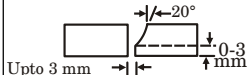
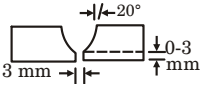
1. For smaller thickness plates and not subjected to severe loading, close and half open corner joints.
2. Full open corner joint can be used on plates of all thicknesses under severe load conditions.
3. The load bearing capacity increases when the joint is welded from both sides.

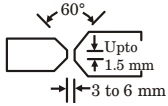
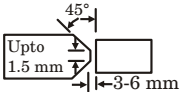
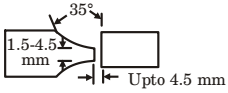
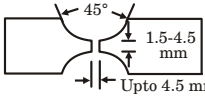
**v. Edge Joint :**

1. Two pieces of metals are lapped, with their edges in line and the pieces are joined by welding the two edges together.
2. Fillet welds (*i.e.*, corner joint, *T* joint, lap joint etc.) are the cheapest type of welds to make, as no edge preparation is required and setting up is simple.

**Que 5.2. Enlist some types of edge preparation for butt welds.**

**Answer**

| S. No. | Types of butt joint | Joint design | Plate thickness (mm) |
|---|---|---|---|
| 1. | Square |   | 3–6 |
| 2. | Single *V* |   | 7–18 |
| 3. | Single bevel |   | 10–25 |
| 4. | Single *J* |   | 12–35 |
| 5. | Single *U* |   | 10–25 |

| | | | |
|---|---|---|---|
| 6. | Double *V* |  | 10–50 |
| 7. | Double bevel |  | 10–35 |
| 8. | Double *J* |  | 15–50 |
| 9. | Double *U* |  | 12 and above |

**Que 5.3. Explain the welding symbol with an example.**

**AKTU 2016-17, Marks 10**

**Answer**

**A. Welding Symbols :**

1. Welding symbols provide the means of placing on drawings, the information concerning the type, size, position, etc., of the welds in welded joints.
2. The basic symbols used to represent various types of welds are given below in Fig. 5.3.1.

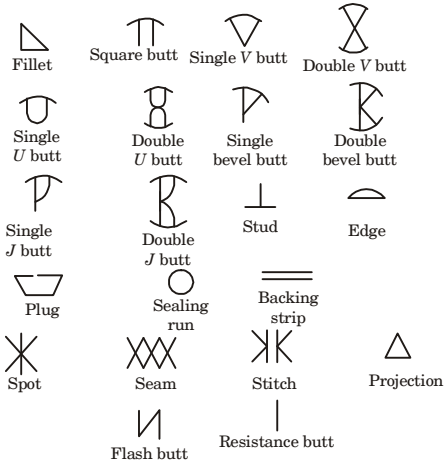



**Fig. 5.3.1.** Welding symbols.

**B. Different Welding Symbols :**

**i. Fillet Welds :**

1. Fillet weld symbol is used to make lap joints, corner joints, and T-joints.
2. The fillet weld is roughly triangular in cross-section.

**ii. Groove or Butt Welds :**

1. The variety of butt weld symbol depends primarily on the geometry of the parts to be joined and the preparation of their edges.
2. Some butt weld symbols are V-butt, square butt, U-butt, Bevel butt, J-butt etc.

**iii. Plug Welds :**

1. Plug welds symbols are used in joining the overlapping members, one of which has holes in it.
2. If the hole is not to be completely filled with weld metal, the depth to which it is to be filled is given within the weld symbol.
3. Plug welds are commonly used with other welds in the rails.

**iv. Stud Welds :**

1. Stud weld symbol is used in electric arc process that rapidly joins a fastener to a base metal or substrate.
2. It is a fast, reliable and accurate method of welding a metal fastener to another metal object.

**v. Slot Welds :**

1. Slot weld symbol contains similar information as plug weld symbol except that plug welds do not have a length component.
2. Size of a plug weld is its diameter while the size of a slot is its width.

**vi. Seam Welds :**

1. Seam weld symbol indicates a weld that takes place between the faying surfaces of a lap joint that may be composed of two or more lapped pieces.
2. It is used in resistance welding.

**vii. Edge Welds :**

1. This symbol is used where the edges of two sheets or plates are adjacent and are in approximately parallel planes at the point of welding.

**viii. Projection Welds :**

1. This symbol is used in the process of projection welding.
2. Projection welds must be dimensioned by strength.

**ix. Backing Strip Welds :**

1. The symbol is used to signify the welding of tanks.
2. It is deployed for root runs with single $V$ as well as double $V$ configurations.

**x. Spot Welds :**

1. The symbol is used specifically in resistance spot welding.
2. The process uses two shaped copper alloy electrodes to concentrate welding current into a small spot and to damp the sheets together.

**Que 5.4. Write short note on position of weld.**

**Answer**

1. The location of weld is indicated by an arrow and a reference line.

   For Example :

i. When the weld symbols is below the reference line the weld is made on the same side of the joint as the arrow head, *i.e.*, the arrow side Fig. 5.4.1(i).

ii. When the weld symbol is above the reference line, the weld is made on the other side of the joint opposite the arrow head Fig. 5.4.1(ii).

iii. When the weld symbol is on both sides of the reference line, the welding is to be carried out on both sides of the joint Fig. 5.4.1(iii).

iv. When resistance welds are to be indicated, the arrow shall point towards the centre line along which the welds are to be made Fig. 5.4.1(iv) and Fig. 5.4.1(v)

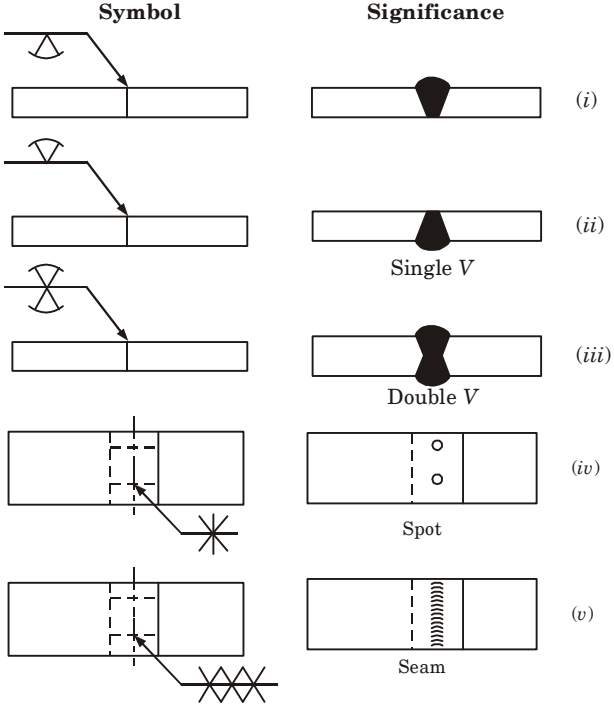



**Fig. 5.4.1.** Weld location.

**Que 5.5. Explain how a good joint design can be selected ?**

**Answer**

For selection of good joint design weldment should have following considerations :

1. Adequately designed to meet the intended service for the required life.
2. Fabricated with specified materials and in accordance with the design concepts.
3. Handled and maintained properly.
4. The design of a weldment should be consistent with sound engineering practices.
5. Components of adequate size should be specified to ensure that stresses from anticipated service loads are not excessive.
6. The intended service should be carefully analyzed to determine whether cyclic loading might result in fatigue failure in highly stressed members.
7. Environment conditions leading to brittle fracture, creep, and corrosion of welds should be considered in the design.

## PART-2

*Weld Defects and Remedies, Residual Stresses and Distortion.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 5.6. Define cracking of weld. Explain hot cracking and cold cracking. List the rules that must be followed to avoid cracking.**

**AKTU 2018-19, Marks 10**

**Answer**

**A. Cracking of Weld :**

1. Cracking is a weld defect that may appear on the weld surface or under the weld bead.
2. The cracking in the material is due to insufficient strength or ductility at the relevant stage to tolerate the welding stresses which exceed the fracture stresses.
3. Cracking may occur in weld metal, heat affected zone (HAZ) or in both.

**B. Hot Cracking :**

1. Cracking occurs at a high temperature just below the freezing point is known as hot cracking.

2. Hot cracking is influenced by the sulphur and carbon content of mild steel weld metals because sulphur tends to form a compound iron sulphide (FeS) which can form a low melting point eutectic of Fe/FeS and segregate to form a network at the grain boundaries of the steel and it remains liquid after the metal has frozen.
3. There is no cohesion between the grains and the weld metal which may tear apart under contractional stresses.
4. Hot crack may be continuous or discontinuous. It often extends from the weld root and may not extend to the face of the weld.

**C. Cold Cracking :**

1. Cold cracking is generally observed at room temperature.
2. Cold cracking occurs in both weld metal and adjacent base metal.
3. Causes of cold cracking are as follows :
   i. Metal brittleness combined with a tensile stress exceeding the fracture stress.
   ii. Joint restraint and high thermal severity.
   iii. Presence of hydrogen in the weld metal.

**D. Rules which must be followed to avoid cracking in welded joints :**

1. By keeping the weld metal and base metal ductile after welding because ductile constituents are able to deform plastically before the cracking.
2. By improving the strength or ductility of material so that it can tolerate the welding stresses at relevant stages of welding.
3. Maintaining the proper welding speed and proper arc length.
4. Maintaining the proper current density.
5. Removal or restriction of the impurities such as S and high C or Ni content because they form low freezing point liquid films.
6. Preventing the martensite formation in welding of steel during cooling.
6. By using correct welding technique or use of filler metal having same rate of contraction as that of the parent metal.
7. By preventing the martensite formation in the weld region, cracking can be avoided.

**Que 5.7. Describe the various defects in welding and its causes and remedies.**

**OR**

**Explain any five welding defects along with the causes and remedies.**

**AKTU 2017-18, Marks 10**

**Answer**

Various defects in welding and its causes and remedies are as follows :

**i. Incomplete Penetration :**

1. Incomplete penetration occurs when the depth of the welded joint is insufficient.
2. Penetration is defined as the distance from base plate's top surface to the maximum extent of the weld nugget.

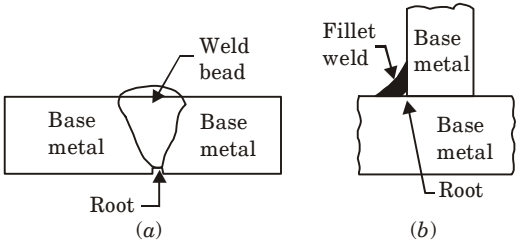



**Fig. 5.7.1.** (*a*) Incomplete penetration at the root of a butt weld. (*b*) Incomplete penetration at the root of a fillet weld.

**a. Causes of Incomplete Penetration :**

1. Improper joints.
2. Too large root face.
3. Less arc current and faster arc travel speed.
4. Too large electrode diameter and longer arc length.

**b. Remedies of Incomplete Penetration :**

1. Increasing the heat input.
2. Reducing the travel speed during the welding.
3. Changing the joint design.
4. Ensuring that the surfaces to be joined fit properly.

**ii. Inclusion :**

1. Inclusions may be in the form of slag or any other foreign material, which does not get a chance to float on the surface of the solidifying weld metal and thus gets entrapped inside the same.
2. Inclusions lower the strength of the joint and make it weaker.

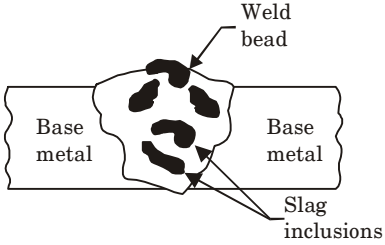



**Fig. 5.7.2.** Slag inclusions.

**a. Causes of Inclusion :**

1. Too high or too low arc current.
2. Long arc and too large electrode diameter.
3. Insufficient chipping and cleaning of previous passes in multipass welding.
4. Wrongly placed tack welds.
5. Too small included angle of the joint.

**b. Remedies of Inclusion :**

1. Cleaning the weld bead surface before the next layer is deposited, by means of a wire brush.
2. Providing sufficient shielding gas.
3. Redesigning the joint so as to permit sufficient space for proper manipulation of the puddle of molten weld metal.

**iii. Porosity and Blowholes :**

1. Porosity is a group of small voids and blowholes are comparatively bigger isolated holes or cavities.
2. They are mainly generated due to the entrapped gases.

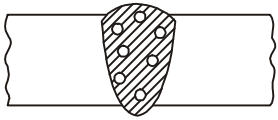


**Fig. 5.7.3.** Porosity.

**a. Causes of Porosity and Blowholes :**

1. Use of improper electrode and longer arc.
2. Faster arc travel speeds.
3. Too low and too high arc currents.
4. Unclean job surface *i.e.*, presence of scale, rust, oil and grease etc., on the surface of the job.
5. Due to the gas entrapment during solidification of weld.

**b. Remedies of Porosity and Blowholes :**

1. Proper selection of electrodes and filler metals.
2. Improved welding techniques such as preheating of the weld area or an increase in the rate of heat input.
3. Proper cleaning and the prevention of contaminants from entering the weld zone.
4. Reduced welding speeds, to allow time for gas to escape.

**iv. Spatter :**

1. Spatters are the small metal particles which are thrown out of the arc during welding and get deposited on the base metal around the weld bead along its length.

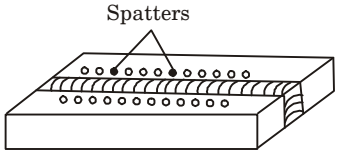



**Fig. 5.7.4.** Spatters.

**a. Causes of Spatter :**

1. Excessive arc current.
2. Use of longer arc.
3. Use of damp electrodes.
4. Electrodes being coated with improper flux ingredients.
5. Arc blow making the arc uncontrollable.

**b. Remedies of Spatter :**

1. Use proper arc current to weld.
2. Use proper arc length.
3. Use fresh electrodes.
4. Use of AC power to reduce arc blow.

**v. Undercut :**

1. Undercut is a kind of weld defect which forms a groove in the parent metal along the sides of the weld bead.
2. Groove reduces the thickness of the plate and also reduces the strength of the weld.

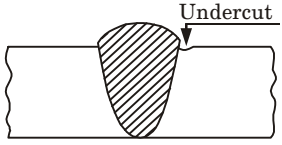



**Fig. 5.7.5.** Undercut.

**a. Causes of Undercut :**

1. Wrong manipulation and inclination of electrode and excessive weaving.
2. Too large electrode diameters.
3. Higher current.
4. Longer arc.
5. Faster arc travel speed.

**b. Remedies of Undercut :**

1. Use proper arc current.
2. Use proper electrode.

3. Weaving should be proper and as per requirement.
4. Use proper arc travel speed.

**vi. Hot Tear :**

1. In this welding defect the deposited metal being hot, starts developing crack from the nearby edge so that after it has been solidified the crack increases.
2. Hot tearing, also known as solidification cracking is due to tearing of the grain boundaries of weld metal before complete solidification has taken place and metal is still in plastic state.

**a. Causes of Hot Tear :**

1. Improper selection of electrode material.
2. Welding current is not proper.
3. Improper electrode thickness.

**b. Remedies of Hot Tear :**

1. Select proper electrode material.
2. Welding current should be optimum as per the requirement.
3. Electrode thickness should be optimum and according to the base metal to be welded.

**Que 5.8. What is residual stress ? Also write the causes and types of residual stress in welding.**

**Answer**

**A. Residual Stress :** It is the stress which remain within a welded/ structure/casting structure when no presence of external load therefore they are self balance within structure itself.

**B. Causes of Residual Stress in Welding :** Residual stresses in the welding arise due to :

1. The differential heating of the plates by the weld heat source.
2. The non-uniform plastic deformation.
3. The cooling rate that accompanies welding processes.

**C. Types of Residual Stresses :**

**i. Mechanical Residual Stresses :**

1. It is due to the local heating and rapid cooling of the weld metal during the welding and after the welding respectively.
2. Because of local heating metal expands and due to cooling it contracts. This process of local expansion and contraction set up stresses in the workpiece.

**ii. Metallurgical Residual Stresses :**

1. This type of residual stress is developed during the phase transformation which takes place while cooling from above the austenitizing temperature.

**iii. Reaction Stresses :**

1. Reaction stress is developed in a welding when the weldment is already attached to other portions of the structure.
2. Due to already being attached to other portion, thermal expansion and contraction occurs to the weldment by the part of structure to which it is being welded, this results into reaction stresses.

**Que 5.9. What are the methods used for measuring the stresses in weld structure ? Explain any one of them.**

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**Answer**

**A. Stress Measuring Method :**

1. Various methods are used for the measurement of stress some of them are as follows :
   i. Strain gauge method,
   ii. Brittle coat method, and
   iii. Photostress techniques.
2. Stresses in welded joints are measured by strain relaxation techniques in which the job is either machined, sectioned or a hole is drilled.
3. The locked-in residual stresses get thereby released and affect the brittle coat, photostress coat or strain gauge which in turn measures this effect and the relaxed residual stresses are calculated.

**B. Brittle Coat Method :**

1. This method makes use of a brittle coating also known as brittle lacquer or stress coat which is basically a limed wood rosin K and dibutyl phthalate with carbon disulphide as a solvent. The brittle coating is commercially available.
2. An appropriate coating for the existing temperature and humidity conditions is selected.
3. The job and the calibration strips are thoroughly cleaned and given an aluminium pre-coating to provide a bright background for facilitating the observation of the cracks.
4. Job and the calibration strips are sprayed with brittle coating and permitted to dry for 15 to 24 hours. The coat or lacquer becomes brittle on hardening.

5. At the place in the job where residual stress pattern and magnitude is to be determined, a hole of about 3 mm diameter is drilled.
6. The calibration strip is subjected to biaxial tensile stresses and the point to initial cracking is marked and the strain in the strain scale is read.
7. Residual stresses are calculated by comparing the results of the stress coat on the job with those of a calibration strip.
8. Brittle coat method gives quantitative results accurate to within ± 10 % and can be used to detect static and dynamic strains in tension or compression. In this method,
   1. Usual gauge length is very small.
   2. Approximate smallest measurable strain is $5 \times 10^{-4}$ mm/mm.
   3. Approximate range of strains % is 0.05 to 0.15.

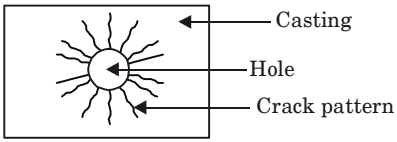



**Fig. 5.9.1.** A crack pattern in brittle coat.

**Que 5.10. Describe the residual life assessment in brief.**

**Answer**

1. Residual life assessment is the time period during which the equipment shall retain the fitness for service characteristics.
2. Each welded structures have an expected service life. The actual service life may be more or less than estimated or expected service life.
3. To monitor the extent of in-service deteriorations, extensive and expensive inspection programs are usually undertaken, in addition to routine inspections.
4. These inspections are more rigorous than the routine ones and are necessary with a view to determine whether a material condition was service induced or existed since the structure was built.
5. If a welded structure concerned is critical and its failure may cause hazard to life and health of the people living around.
6. A detailed examination of cracks (based on experience) and other damage observed in pipelines, pressure vessels and storage tanks are to be inspected and on the basis of experience of the inspection done, following points in regard to inspection techniques need to be considered.

i. Advanced techniques should be used to detect sub-surface flaws, dimension, location, depth and number of cracks.

ii. Improved or advanced techniques should be able to :

1. Inspect the entire vessel inside and outside.
2. Inspect during operation.
3. Monitor and measure flaw on line.
4. Have sizing accuracy adequate to identify the margins to critical flaw size.

**Que 5.11. What do you mean by distortion ? Discuss different types of welding distortion ?**

**Answer**

**A. Distortion :**

1. Distortion is the change in shape and difference between the positions of the two plates before welding and after welding.
2. There is a good amount of temperature difference at various points along the joint and thus at any instant certain areas of base metal expand and others including weld bead contract. This phenomena leads to distortion.

**B. Types of Distortion :**

**i. Longitudinal Shrinkage :**

1. When a weld is deposited lengthwise on a light, narrow and perfectly flat strip of metal that is neither clamped nor held in any way, the strip will tend to bow upward in the direction of bead. This is due to the longitudinal contraction of the weld metal as it cools.
2. Longitudinal contraction is maximum along the weld centre line and decreases towards the edges as shown in Fig. 5.11.1(*i*).
3. Longitudinal distortion depends upon the :
   i. Contraction forces.
   ii. Stiffness of the section being welded.
   iii. Distance between the centroids of weld and section.

**ii. Transverse Shrinkage :**

1. When two plates being butt-welded together are neither too heavy nor held together, and are thus free to move, they will be drawn closer together by the contraction of the weld metal. This is called transverse contraction.
2. Transverse contraction exists all along the weld length and it depends upon the permanent contraction of elements in the weld zone as shown in Fig. 5.11.1(*ii*).

3. The transverse contraction can be prevented by,
   i. Proper tack welding.
   ii. Placing a wedge between the plates.
   iii. Separating the plates (before welding) to provide allowance for contraction.
   iv. Increasing the arc travel speed.

**iii. Angular Shrinkage :**

1. When two beveled plates are welded, it is found that the plates are pulled out of line with each other as shown in Fig. 5.11.1(*iii*).
2. Since the opening at the top of the single *V* groove is greater than at the bottom, a greater portion of the weld metal is deposited there, and thus the drawing or pulling is greatest on that side of the joint.
3. Angular contraction is related to the shape and size of the cooling weld metal zone and the stiffness of the remaining unfused part.
4. Double groove joints tend to minimize angular distortion because the contraction effects of the two sides, *i.e.*, top and bottom of the plate, get cancelled with each other.

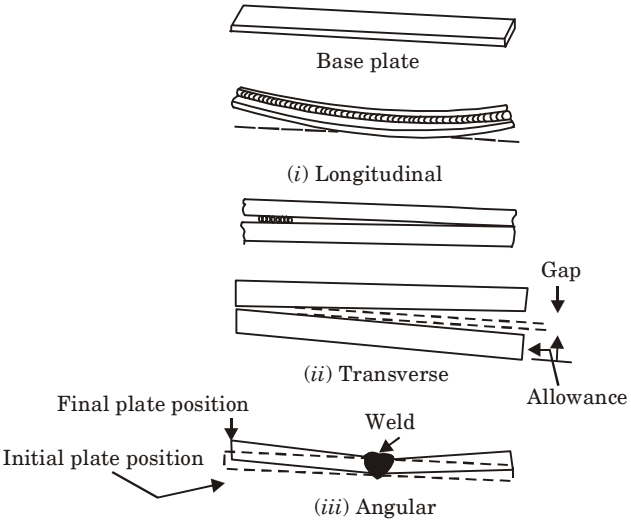



**Fig. 5.11.6.** Types of distortion.

## PART-3

*Inspection and Testing of Welds : Introduction to Non Destructive Techniques, Destructive Techniques.*

## CONCEPT OUTLINE

**Inspection :** Inspection refers just to examine visually of a welding structure. Inspection may be qualitative and involves only visual observation of correctness of functioning/dimensions.

**Types of Inspection :**

1. Inspection before welding,
2. Inspection in between the welding, and
3. Inspection after or completion of welding.

**Ultrasonic Inspection :** It can detect and locate internal defects such as cracks, porosity, inclusions, lack of fusion and incomplete penetration in ferrous and non-ferrous metallic objects as well as in plastics and ceramics. It can also measure the wall thickness of a closed vessel.

## Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 5.12. Explain in detail inspection before welding, inspection in between welding, inspection after welding.**

**AKTU 2017-18, Marks 10**

**Answer**

**A. Inspection before Welding :**

1. Check out the welding joint drawing such as dimensions, tolerances, process specification etc.
2. Choose the suitable welding process by easy method.
3. Set the welding parameters such as current, voltage, frequency, polarity etc.
4. Select the defect free material as per specification.

5. Selection of proper size, proper flux coated electrode as per specification (BIS specification).
6. Select the Jig and fixture of proper size as per welding joint complexity.
7. Proper arrangement of welding joint cooling and ventilation as well as smoke.

**B. Inspection in Between the Welding :** It is the second stage of inspection and it involves :

1. Welding groove (Edge preparation) should as per specification.
2. Tack welds should be of adequate size, length and pitch,
3. Method of welding such type that minimum distortion should be in welding joint.
4. Welding position, fit up gap should be as per welding procedure.
5. Slag on the welding joint should be properly removed from each pass in multipass arc welds.

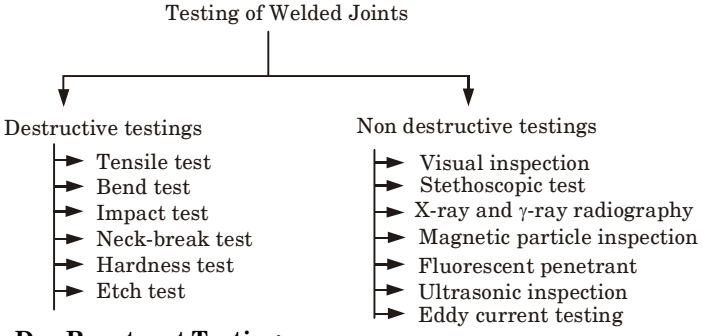
**C. Inspection after or Completion of Welding :**

1. Find out of determine properties and weld quality of a weld object.
2. Find out suitability of weldment with the help of :
   i. Destructive testing, and
   ii. Non destructive testing.

**Que 5.13. List the various destructive and non destructive methods of testing welded joints. Explain the working of dye penetrant testing methods.**

**Answer**

**A. Types of Testing :**




**B. Dye Penetrant Testing :**

1. It is a non destructive type testing to detect flaws that are open to the surface like cracks, seams, laps, lack of bond, porosity, cold shuts, etc.

2. In dye penetrant test, the strongly coloured red penetrant liquid has a property of seeping into surface flaws when applied on preventative or impermeable surface.
3. The working steps of dye penetrant tests are as follows :

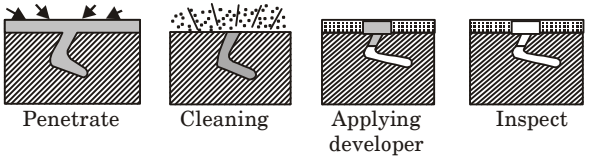



**Fig. 5.13.1.**

i. Firstly clean the surface of the component with a piece of cloth to make it free of dust and dirt.
ii. Use a soft wire brush to clean the surface of the component from scale, rust, paint, etc.
iii. To remove oil and grease from the surface spray the cleaner.
iv. Now spray the dye penetrant adequately to cover the area that has to be tested. Allow sometime (3 to 5 minutes) for dye to penetrate into the cracks.
v. The excess penetrant on the surface must be wiped off by using a ray stone.
vi. Again spray the surface with the cleaner to remove the remnants of the red dye.
vii. Spray a chemical (known as developer) evenly on the surface. This will give a thin even layer over the surface to be inspected. This layer absorbs the penetrant from the cracks and red spots or lines appear on the surface to give a visible indication of the flaws.
viii. The crack if any will be indicated with the red dye absorbed by the white absorbent.

4. For dye penetrant test :

| Defect | Test result |
|---|---|
| Crack | |
| Cold-shut | |
| Crack | |
| Porosity | |

**Que 5.14.** **Discuss the principle and working of ultrasonic inspections. Also describe its advantages, limitations and applications.** **AKTU 2018-19, Marks 10**

**Answer**

**A. Principle and Working of Ultrasonic Inspections :**

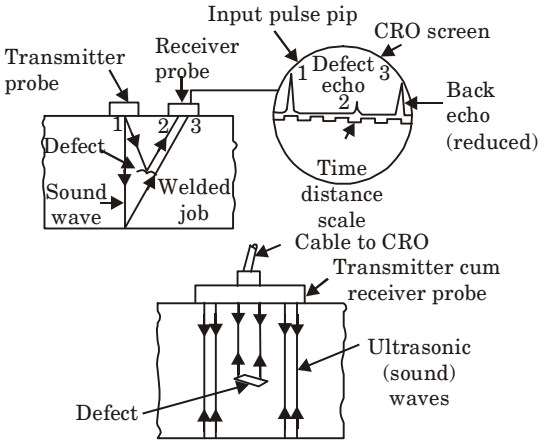



**Fig. 5.14.1.** Ultrasonic inspection.

1. Ultrasonic waves are usually generated by the piezoelectric effect and quartz crystal is used for this purpose.
2. When a high frequency AC current is impressed across the faces of the quartz crystal, the crystal will expand during the first half of the cycle and contracts in the next half cycle and produced a mechanical vibration in the quartz crystal.
3. The job surface that is to be inspected is made fairly smooth by machine (or by other processes) so that ultrasonic waves can be efficiently transmitted from the probe into the job and even small defects can be detected properly.
4. In ultrasonic inspection separate probes, one for transmitting the waves and other to receive them after passage through the welded jobs are used.
5. Before transmitting ultrasonic waves, an oil film is provided between the probe and job surface to ensure proper contact between them and better transmission of waves from the probe into the surface of the object to be tested.

6. For operation, ultrasonic wave is introduced into the metal and the time interval between transmission of the outgoing and reception of the incoming signals is measured with a cathode ray oscilloscope (CRO).
7. Time base of CRO is adjusted such that the full width of the trace represents the section being examined.
8. As the wave is sent from the transmitter probe, it strikes the upper surface of the job and makes a sharp (peak) or pip (echo) at the left hand side of the CRO screen.
9. If job is defect free then this wave will strike the bottom surface of the same, gets reflected and indicated by a pip towards the right hand end of the CRO screen.
10. If a defect is present in between the top and bottom surfaces, most of the beam striking this defect will get reflected from the defect, reach the receiver probe and indicate a pip (echo) on the CRO screen before the pip given by the waves striking the far end of the job and returning.
11. The distance of the defect from the surface where transmitter probe is applied can be determined with the help of a time distance scale in the form of a square wave constantly shown on CRO.

**B. Advantages of Ultrasonic Inspections :**

1. This method is fast, reliable NDT. It is more sensitive to locate flaws within the metallic objects than radiography.
2. About 0.1 % of the distance from the probe can be detected for the presence of defect.
3. It involves low cost and high speed of operation.
4. The sensitivity of ultrasonic flaw detection is extremely high, being at a maximum when using waves of highest frequency.

**C. Limitations of Ultrasonic Inspections :**

1. Testing surface of the job must be ground, smooth and clean.
2. Skilled and trained operator is required.
3. It cannot examine the complex shape or configuration.

**D. Applications of Ultrasonic Inspections :**

1. For inspecting large weldments, castings and forgings for internally defect free portion before carrying out expensive machining operations.
2. For inspecting the moving strips or plates to ensure their thickness.
3. For inspecting fatigue cracks in wheel pins and locomotive axles.
4. For inspecting rails for bolt-hole breaks.

**Que 5.15. Explain the destructive and non destructive testing. What are the advantages of each ?**

**Answer**

**A. Destructive Testing :**

1. In destructive testing load is applied on the welded joint.
2. Deformation takes place on removing the load, permanent deformation takes place inside the weld specimen, means specimen is no longer for use.

**i. Advantages :**

1. These tests give the actual data of tensile strength, impact strength, hardness, bend test, etc.
2. These types of tests can be used on all metals.

**B. Non Destructive Testing (NDT) :**

1. It is also another method of testing welded object to find out the properties or defects in the weldment.
2. In non destructive testing load is applied on welded specimen, no permanent deformation takes place on removing the load, means weld object can be further used.
3. With the help of NDT we can find out the several invisible subsurface defects, it makes weld component more reliable and safe.
4. Although NDT do not provide direct measurement of mechanical properties but they are extremely useful in revealing defects in components that could impair their performance when they are under load.

**i. Advantages :**

1. These types of tests require low initial cost.
2. These tests give the correct microscopic structure of object without destroying it.
3. These tests are fast and easy to handle.

**Que 5.16. Differentiate between destructive and non destructive testing of welds.**

**Answer**

| S. No. | Destructive Testing | Non Destructive Testing |
|---|---|---|
| 1. | In destructive testing, measurements are reliable and direct. | Measurements are in indirect form and reliability is to be verified in non destructive testing. |
| 2. | Measurements are usually quantitative. | Measurements are usually qualitative. |
| 3. | Preparation of the test specimen is costly. | Preparation of the test piece is not so costly and requires little preparation. |
| 4. | Direct correlation between test measurements and material properties. | Requires skill judgment and experience to interpret indications. |
| 5. | Conducting a test requires very much time. | Testing can be conducted very rapidly. |
| 6. | During service of any object this type of test cannot be performed. | During service this type of test can be performed. |
| 7. | 100 % testing is not possible as test piece deforms permanently. | 100 % testing is possible as test piece do not deform. |
| 8. | One test specimen checked for properties only for one time. | Repeated checks over a period of time are possible. |

## PART-4

*Bulk and Microhardness Test, Wear Test and Types, Corrosion Test, Tensile Test, Bend Test.*

## CONCEPT OUTLINE

**Bulk Hardness Test :** This test is used to determine hardness of castings and forgings.

**Microhardness Test :** This test is used to determine a material hardness when test samples are very small or thin.

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 5.17. What is hardness testing ? Explain any one method.**

**Answer**

**A. Hardness Testing :**

1. Hardness is the mechanical properties of material.
2. It is derived by destructive testing and sometimes it is obtained by a non destructive testing device.
3. During hardness testing surface of material deforms slightly.
4. There are several methods available as given below :
   i. Rockwell hardness test,
   ii. Brinell hardness test,
   iii. Vicker hardness test, and
   iv. Knoop test.

**B. Rockwell Hardness Test :**

1. The Rockwell hardness test is widely used because of its speed and freedom from personal errors.
2. This test requires much smaller penetrators (steel balls as well as cone-shaped diamond penetrators) and loads that used on Brinell hardness tester.
3. There are two scales on a Rockwell testing machine, *B*-scale and *C*-scale.
4. While performing the Rockwell hardness test the following procedure is used :
   i. The test piece is placed on the machine's test table.
   ii. The test piece is raised by turning the hand wheel, till it just touches the indenter and the needle on the machine dial reads zero. This indicates that a minor load of 10 kg has been applied on the test sample by the machine and ensures that the specimen is seated properly.
   iii. After that a major load of 100 kg (for *B*-scale) or 150 kg (for *C*-scale) is applied by pressing the crank provided for this purpose.
   iv. The depth of the indentation is recorded automatically by means of a dial scale. The reading is correlated with arbitrary hardness numbers.

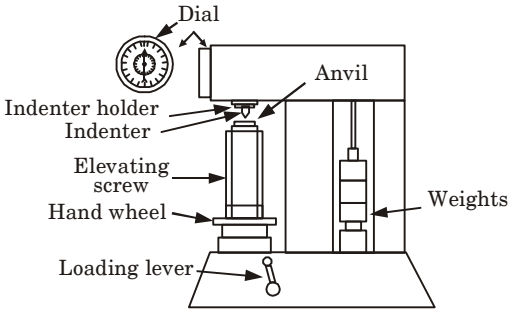



**Fig. 5.17.1.**

**Que 5.18. Write a short note on wear test. Also write down the various types of wear.**

**Answer**

**A. Wear Test :**

1. Wear test is carried out to predict the wear performance and to investigate the wear mechanism.
2. It is performed to evaluate the wear property of a material so as to determine whether the material is adequate for a specific wear application.
3. It could be done at various levels such as laboratory test, component simulation test and in-service test.
4. An apparatus used for wear testing is termed as wear tester, tribotester or tribometer.
5. A wear tester will always involve two components loaded against and relatively moving with each other. The movement can be driven by a motor or by an electromagnetic device.

**B. Types of Wear :**

1. Adhesive wear,
2. Abrasive wear,
3. Surface fatigue,
4. Erosive wear, and
5. Corrosion and oxidation wear.

**Que 5.19. Discuss in brief about salt spray test for testing corrosion.**

**Answer**

1. The salt spray test is a popular corrosion test method used to check corrosion resistance of materials and surface coatings.
2. Usually the materials to be tested are metallic and finished with a surface coating which is intended to provide a degree of corrosion protection to the underlying metal.
3. It is an accelerated corrosion test that produces a corrosive attack to coated samples in order to evaluate the suitability of the coating for use as a protective finish.
4. The appearance of corrosion products is evaluated after a pre-determined period of time.
5. Test duration depends on the corrosion resistance of the coating generally, the more corrosion resistant the coating is, the longer period of testing before the appearance of corrosion.
6. Salt spray testing is popular because it is relatively inexpensive, quick, well standardized and reasonably repeatable.
7. Salt spray testing is generally used for phosphated surfaces, zinc and zinc-alloy plating, chromium, nickel and organic coatings.

**Que 5.20. Describe in short about the tensile test.**

**Answer**

1. The machine generally used for this test is universal testing machine (UTM).
2. In this test tensile load $P$ is gradually applied on test specimen.
3. For each value of load there will be a value of elongation in gauge length $\delta L$.
4. Change in length beyond yield point may be done by a precision scale. The specimen finally fractures with sound.
5. Then stress-strain curve is plotted down, which helps in calculating the value of reduction in cross sectional area $A_r$ and percent elongation ($\% \delta L$) by

$$\% A_r = \frac{A_o - A_i}{A_o} \text{ and } \% \delta L = \frac{L_i - L_o}{L_o}$$

Where, $A_r$ = Reduction in cross sectional area,

$A_o$ = Original cross sectional area,

$A_i$ = Area after breaking,

$\delta L$ = Elongation in length,

$L_o$ = Original length,

$L_i$ = Length after breaking,

$l$ = Gauge length, and

$L$ = Full length of specimen.

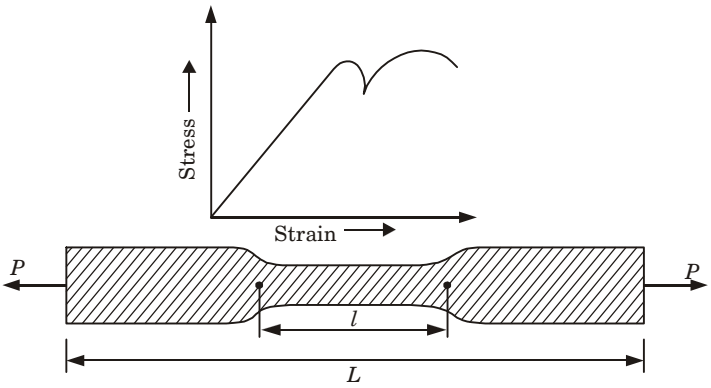



**Fig. 5.20.1.**

**Que 5.21. Explain bend test in brief.**

**Answer**

1. A bend test may be carried out on a tensile testing machine with the help of certain attachments.
2. A bend test is an easy and inexpensive test to apply. The method is fast and shows most weld faults quite accurately.
3. Bend tests may be used to find a number of weld properties such as :
   i. Ductility of the welded zone,
   ii. Weld penetration,
   iii. Fusion,
   iv. Crystalline structure, and
   v. Strength.
4. The bend test assists in determining the soundness of the weld metal, the weld junction and the heat affected zone.
5. The test shows the quality of the welded joint.
6. Any cracking of the metal will indicate false fusion or defective penetration.
7. Large crystals usually indicate wrong welding procedure or poor heat-treatment after welding. A good weld has small crystals.

8. Bend tests may be categorized as :
   i. Free bend test, and
   ii. Guided bend test.

## PART-5

*SEM, EDS and XRD.*

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 5.22. What do you understand by scanning electron microscope (SEM) ?**

**Answer**

1. A scanning electron microscope is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons.
2. The electrons interact with the atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample.
3. The electron beam is scanned in a raster scan pattern, and the position of the beam is combined with the intensity of the detected signal to produce an image.
4. In SEM, secondary electrons emitted by atoms excited by the electron beam are detected using a secondary electron detector.
5. The number of secondary electrons that can be detected and thus the signal intensity depends among other things on specimen topography.

**Que 5.23. Write a short note on EDS.**

**Answer**

1. Energy dispersive *X*-ray spectroscopy (EDS) is a chemical microanalysis technique used in conjunction with scanning electron microscopy (SEM).
2. It detects *X*-rays emitted from the sample during bombardment by an electron beam to characterize the elemental composition of the analyzed volume.
3. The EDS *X*-ray detector measures the relative abundance of emitted *X*-rays versus their energy. The detector is typically a lithium-drifted silicon solid state device.

4. When an incident *X*-ray strikes the detector, it creates a charge pulse that is proportional to the energy of the *X*-ray. The charge pulse is converted to a voltage pulse by a charge sensitive preamplifier.
5. The signal is then sent to a multichannel analyzer where the pulses are sorted by voltage.
6. The energy as determined from the voltage measurement, for each incident *X*-ray is sent to a computer for display and further data evaluation.

**Que 5.24. Explain in short about *X*-ray radiography with neat sketch.**

**Answer**

1. *X*-rays are produced in an *X*-ray tube (Fig. 5.24.1) where a cathode filament provides electrons which proceed towards the target anode, strike and are suddenly stopped, a part of their kinetic energy is converted to energy of radiation or *X*-rays.

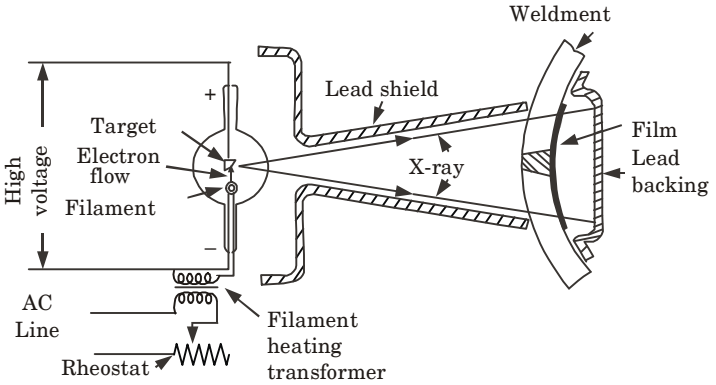



**Fig. 5.24.1.** X-ray radiography.

2. The portion of the weldment where defects are suspected is exposed to *X*-rays emitted from the *X*-ray tube (Fig. 5.24.1).
3. A cassette containing *X*-ray film is placed behind and in contact with the weldment, perpendicular to the rays.
4. During exposure, *X*-rays penetrate the welded object and thus affect *X*-ray film.
5. Since most defects (such as blow holes, porosity, cracks, etc.) possess lesser density than the sound parent metal, they transmit *X*-rays better than the sound metal does, therefore the film appears to be more dark where defects are in line of the *X*-ray beam.
6. The exposed and developed *X*-ray film showing light and dark areas is termed as radiograph.

## PART-6

*Welding Codes, WPS & PQR : Introduction to Welding Codes, ISO, ASME and BIS Specifications.*

### CONCEPT OUTLINE

**ISO :** International organization for standardization.
**ASME :** American society of mechanical engineers.
**BIS :** Indian standards.
**BPVC :** Boiler and pressure vessel code.

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 5.25. Write down the various welding codes as per ISO, ASME and BIS specifications.**

**Answer**

Various welding codes as per ISO, ASME and BIS specifications are as follows :

**i. ISO Codes :**

| S. No. | Standard Number | Description |
|---|---|---|
| 1. | ISO 2553 | Welded, brazed and soldered joints. |
| 2. | ISO 2560 | Welding consumables. Covered electrodes for manual metal arc welding of non-alloy and fine grain steels. |
| 3. | ISO 3580 | Covered electrodes for manual arc welding of creep-resisting steels. |
| 4. | ISO 3581 | Covered electrodes for manual arc welding of stainless and other similar high alloy steels. |
| 5. | ISO 3834 | Quality requirements for fusion welding of metallic materials. |
| 6. | ISO 4063 | Welding and allied processes, nomenclature of processes and reference numbers. |

**ii. ASME Codes :**

| S. No. | Code | Description |
|---|---|---|
| 1. | ASME BPVC Section I | Rules for construction of power boilers. |
| 2. | ASME BPVC Section II | Specifications for welding rods, electrodes, and filler metals. |
| 3. | ASME BPVC Section III | Rule for nuclear-fuel containers. |
| 4. | ASME BPVC Section IV | Rules for construction of heating Boilers |
| 5. | ASME BPVC Section V | Nondestructive examination. |

**iii. BIS Codes :**

| S. No. | CODE | Description |
|---|---|---|
| 1. | IS 812 : 1957 | Glossary of terms relating to welding and cutting. |
| 2. | IS 813 : 1986 | Scheme of symbols for welding. |
| 3. | IS 814 : 2004 | Covered electrodes for manual metal arc welding. |
| 4. | IS 817 : 1966 | Code of practice for training and testing of metal. |
| 5. | IS 817 : 1992 | Manual metal arc welding. |
| 6. | IS 817 : 1996 | Oxyfuel welding. |

## PART-7

*Welding Procedure Specifications(WPS) and Procedure Qualification Record (PQR).*

## CONCEPT OUTLINE

**PQR :** Procedure qualification record (PQR) is essentially the actual method that is used to create and test the welds to ensure they meet all applicable requirements. It lists the actual values recorded during the welding of test piece.

## Questions-Answers

## Long Answer Type and Medium Answer Type Questions

**Que 5.26. Write a short note on welding procedure specification (WPS).**

**Answer**

1. Welding procedure specification (WPS) is a written procedure prepared to provide direction for making production welds as per national codes and its purpose is to determine that the weldment proposed for construction is capable of providing the required properties for its intended application.
2. The welder has to be skilled workman and no compromise can be made in selection.
3. WPS includes both essential and non-essential variables with acceptable ranges.

**Que 5.27. Explain the qualification of welding procedure specification.**

**Answer**

1. The aspect of qualification of welding procedure specification (WPS), welding procedure qualification record (PQR), welders performance qualification and qualification of welding consumables is very essential to ensure requisite quality of welding.
2. No compromise can be made on this as consequences can be disastrous.
3. Welding procedure qualification record (PQR) is a record of welding data used to weld a test coupon and includes variables recorded during welding as also the results of various tests carried out.
4. Welders performance qualification ensures that the qualified welders using approved welding procedures are capable of developing the minimum requirement specified for acceptable weldment.
5. Welders are tested under the full supervision and control of manufacturer.
6. The welders qualification is limited by essential variables given for each welding process for each type of weld and position.
7. The performance qualification tests are intended to determine the ability of welders to make sound welds.
8. Qualification of welding consumables like welding electrodes and filler materials is done as per ASME codes.

## PART-8

*Welding of Pipelines and Pressure Vessels.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 5.28. Write a short note on pipeline welding.**

**Answer**

1. Mostly pipeline welding consist girth welding from external side only as the diameter of pipe is very small to permit welding from inside.
2. Joint for pipeline welding is shown in Fig. 5.28.1.

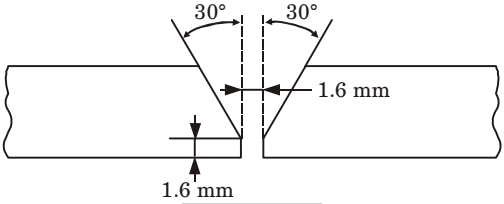



**Fig. 5.28.1.**

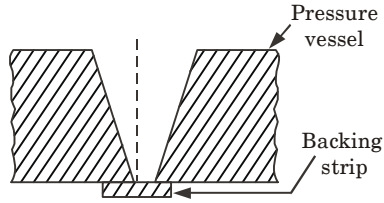
3. Standard joint for pipeline welding for some special cases angle of bevel is increased from 30° to 37.5° backing strip from the inside are not provided as they not only cause turbulence in the flow of material, even also cause not for internal cleaning of pipe.
4. Store pipe welding is only possible only by 5G position at 360° by deposition sound weld metal at the root of pipe (joint).

**Que 5.29. Write short note on welding of pressure vessels.**

**Answer**

1. Pressure vessels are fabricated using commonly used and well developed processes.
2. For the main seam welding, the processes used include electroslag welding, submerged arc welding, shielded metal arc welding, TIG welding, MIG welding, oxy-acetylene welding, resistance welding, flux cored arc welding and other special welding.
3. For pressure vessels involving thicknesses exceeding 50 mm electroslag welding is most economical. There are almost no defects.

4. The coarse grained structure produced requires refinement by normalising course grained structure.
5. Submerged arc welding is used for thick plates, joint design is special and given in Fig. 5.29.1.




Weld-edge preparation for multi layer submerged arc welding

**Fig. 5.29.1.**

6. SMAW is also not commonly used for pressure vessels, mainly because of non-availability of highly skilled welders.
7. Gas metal arc and flux-cored metal arc are not used for thick plates.
8. For thin shells made of austenitic stainless steels MIG welding with Argon shielding is used.

## VERY IMPORTANT QUESTIONS

***Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.***

**Q. 1. Describe the various types of welded joints used in weld design.**

**Ans.** Refer Q. 5.1.

**Q. 2. Explain the welding symbol with an example.**

**Ans.** Refer Q. 5.3.

**Q. 3. Describe the various defects in welding and its causes and remedies.**

**Ans.** Refer Q. 5.7.

**Q. 4. What do you mean by distortion ? Discuss different types of welding distortion ?**

**Ans.** Refer Q. 5.11.

**Q. 5. List the various destructive and non destructive methods of testing welded joints. Explain the working of dye penetrant testing methods.**

**Ans.** Refer Q. 5.13.

**Q. 6. Discuss in brief about salt spray test for testing corrosion.**

**Ans.** Refer Q. 5.19.

**Q. 7. What do you understand by scanning electron microscope (SEM) ?**

**Ans.** Refer Q. 5.22.

**Q. 8. Explain in short about X-ray radiography with neat sketch.**

**Ans.** Refer Q. 5.24.

**Q. 9. Write down the various welding codes as per ISO, ASME and BIS specifications.**

**Ans.** Refer Q. 5.25.

**Q. 10. Write a short note on welding procedure specification (WPS).**

**Ans.** Refer Q. 5.26.

**Q. 11. Write a short note on pipeline welding.**

**Ans.** Refer Q. 5.28.

1 UNIT

# Welding Arc and Power Sources (2 Marks Questions)

**1.1. Define welding. Make comparison with other joining process.** **AKTU 2018-19, Marks 02**

**Ans.** **Welding :**
Welding is defined as localised coalescence of metal, wherein coalescence is obtained by heating to suitable temperature, with or without application of pressure and with or without use of filler metal.

**Comparison :**

| S. No. | Welding | Soldering | Brazing |
|---|---|---|---|
| 1. | The strength of the joint is highest comparing to soldering and brazing. | The soldered joints are weakest among the welding and brazing. | The brazed joints are stronger than soldered joint but weaker than welded joints. |
| 2. | The composition of filler metal is normally same as that of base metal. | Essentially filler metals are alloys of lead and tin. | The filler metals are alloys of copper. |

**1.2. Give the two main advantages of welding.**

**Ans.** Two main advantage of welding are as follows :
1. Welding result in good saving of material and reduced labour content of production.
2. Welding joint is as stronger as base metal and its efficiency is upto 100 %.

**1.3. What are the limitations of welding ?**

**Ans.** Limitations of welding as follows :
1. Special jigs and fixtures are required for welding.
2. Welding heat produces metallurgical changes in workpiece.

**1.4. Write down three applications of welding.**

**Ans.** Applications of welding are as follows :

1. Automobile industries,
2. Railroad industries, and
3. Aircraft industries.

**1.5. What is physics of arc welding ?**

**AKTU 2018-19, Marks 02**

**Ans.** It deals with complex physical phenomena associated with welding including heat, electricity, magnetism, light etc.

**1.6. What are the different power sources used for various arc welding processes ?**

**Ans.** Different power sources used for various arc welding processes are as follows :

1. AC type,
2. DC type, and
3. AC/DC type.

**1.7. Write down three *V-I* characteristics used in arc welding.**

**Ans.** Three *V-I* characteristics used in arc welding are as follows :

1. Dropping arc voltage or constant current,
2. Constant arc voltage, and
3. Rising arc voltage.

**1.8. What is welding arc and arc initiation ?**

**Ans.** **Welding Arc :** It is defined as sustained electrical discharge through an ionized gas.

**Arc Initiation :** Arc is initiated by providing a conducting path between electrode and job or by ionizing the gap between the two.

**1.9. What is arc efficiency ?**

**Ans.** Arc efficiency is defined as the ratio of heat developed at the anode to the total heat developed.

**1.10. What is metal transfer ?**

**Ans.** When electric arc is produced between the workpiece and consumable electrode, electrode start melting in the form of spherical shape, hangs towards the job and finally drop down on the workpiece. It is known as metal transfer process.

**1.11. Write down the types of metal transfer ?**

**Ans.** Types of metal transfer are as follows :

1. Dip transfer,
2. Spray transfer,
3. Jet transfer, and
4. Globular transfer.

**1.12. Compare vacuum brazing with welding.**

**AKTU 2016-17, Marks 02**

**Ans.**

| S. No. | Vacuum Brazing | Welding |
|---|---|---|
| 1. | Post-heat treatment is not necessary for vacuum brazing. | Post-heat treatment is often required. |
| 2. | The filler material is essentially used because joint is made by filler material only. | The filler material may or may not be used. |
| 3. | Distortion is low. | Distortion is high. |

**1.13. What are the effects of gases in welding ?**

**AKTU 2016-17, Marks 02**

**Ans.** Effect of gases in welding are as follows :

1. Gases absorbed in the weld metal result in the formation of porosity.
2. Reduce the tensile strength of weld.
3. Lower the corrosion resistance of weld metal.
4. Decrease ductility and impact resistance.

**1.14. Write short note on arc blow in welding process.**

**AKTU 2018-19, Marks 02**

**Ans.**

1. The unwanted deflection or the wandering of a welding arc from this intended path is termed as arc blow.
2. Arc blow is the result of magnetic disturbances which unbalance the symmetry of the self-induced magnetic field around the electrode, arc and workpiece.

2 UNIT

# Welding Processes (2 Marks Questions)

**2.1. What is manual metal arc welding ?**

**Ans.** Manual metal arc welding is a welding process in which coalescence is produced by heating with an electrical arc.

**2.2. Define TIG welding.**

**Ans.** Tungsten inert gas (TIG) is an arc welding process wherein coalescence is produced by heating the job with an electric arc struck between tungsten and the job.

**2.3. Define MIG welding.**

**Ans.** Metal inert gas (MIG) is an arc welding process wherein coalescence is produced by heating the job with an electric arc established between continuously fed metal electrode and the job.

**2.4. Write down applications of MIG welding.**

**Ans.** Applications of MIG welding are as follows :

1. For welding tool steel and dies.
2. For the manufacture of refrigerator parts.

**2.5. Define plasma arc welding.**

**Ans.** It is an arc welding process in which coalescence is produced by heat obtained from a constricted arc set up between tungsten electrode and the water cooled nozzle.

**2.6. Give two advantages and two disadvantages of plasma arc welding.**

**Ans.** **Advantages of Plasma Arc Welding :**

1. Stability of arc and uniform penetration.
2. Simplified fixtures and rewelding of root of the joint saved.

**Disadvantages of Plasma Arc Welding :**

1. Infrared and ultraviolet radiations necessitate special protection devices.
2. Inert gas consumption is high.

**2.7. Define submerged arc welding.**

**Ans.** Submerged arc welding is an arc welding process wherein coalescence is produced by heating with an electric arc set up between bare metal electrode and the job.

**2.8. What is electroslag welding ?**

**Ans.** Electroslag welding is a type of arc welding wherein the coalescence is produced by molten slag which melts the filler metal and the surface of the work to be welded.

**2.9. Explain electrogas welding process.**

**Ans.** Electrogas welding is a method of gas metal arc welding wherein an external gas is supplied and molding shoes confine the molten weld metal for vertical position welding piece.

**2.10. Name the types of resistance welding.**

**AKTU 2017-18, Marks 02**

**Ans.** Types of resistance welding are as follows :

1. Spot welding,
2. Seam welding,
3. Projection welding,
4. Percussion welding, and
5. Flash butt welding.

**2.11. What is friction welding ?**

**Ans.** Friction welding is defined as a solid state welding process wherein coalescence is produced by heat obtained from mechanically induced sliding motion between the rubbing surfaces. The parts are held together under pressure.

**2.12. What is deformation resistance welding ?**

**AKTU 2016-17, Marks 02**

**Ans.** It is a process that employs resistance heating to raise the temperature of the materials being welded to the appropriate forging range, followed by shear deformation which increases the contacting surface area of the materials being welded.

**2.13. How radial friction welding is used to join collars to shafts and tubes ?**

**AKTU 2016-17, Marks 02**

**Ans.** Steps to join collars to shafts and tubes :

1. The two components are held in axial alignments.
2. One component is rotated and other is stationary which move forward to come into pressure contact with the rotating component.
3. Pressure and rotation are maintained until the resulting high temperature makes the components metal plastic for welding.

4. Allow the joint soften for weld.

**2.14. What are the advantages of constricting plasma in PAW ?**

**AKTU 2016-17, Marks 02**

**Ans.** The advantages of constricting plasma in PAW are as follows :

1. It improves the arc stability.
2. It also improves the arc shape.
3. It provides better heat transfer characteristics.

**2.15. List different type of brazing techniques available. Explain any one in detail.**

**AKTU 2018-19, Marks 02**

**Ans.** **Brazing Techniques :**

1. Furnace brazing,
2. Dip brazing,
3. Induction brazing, and
4. Torch brazing etc.

**Torch Brazing :**

1. It is the most commonly used method, heat is provided in this process by usual gas welding torch by burning acetylene and oxygen gases.
2. Oxy-hydrogen torches are also used for brazing aluminium and other non-ferrous metals.

**2.16. Give two examples of adhesives and mention its general characteristics.**

**AKTU 2016-17, Marks 02**

**Ans.**

**A. Examples of Adhesives :** Glue and cement.

**B. Characteristics :**

1. High strength to weight ratio.
2. Superior vibration and fatigue.

3 UNIT

# Heat Flow Welding and Welding Metallurgy (2 Marks Questions)

**3.1. Define heat affected zone (HAZ).**

**AKTU 2017-18, Marks 02**

**Ans.** The region of the parent metal which has undergone a metallurgical change as a result of thermal cycle is known as heat affected zone (HAZ).

**3.2. Write down the different regions of HAZ.**

**Ans.** Different regions of HAZ are as follows :

1. Grain growth region,
2. Grain refined region, and
3. Transition region.

**3.3. Give the formula of cooling rate in welding.**

**Ans.** Cooling rate when $t < 0.75$ mm,

$$R = 2\pi\, k\rho C \left(\frac{t}{H_{net}}\right)^2 (T_c - T_0)^3$$

Cooling rate when $t > 0.75$ mm

$$R = \frac{2\pi k\,(T_c - T_0)^2}{H_{net}}$$

Where, $t$ = Plate thickness, mm
$\rho$ = Density of material, g/mm$^3$
$C$ = Specific heat of solid metal, J/g°C
$k$ = Thermal conductivity of the metal, J/mm s°C
$t_0$ = Initial temperature of plate to be welded, °C

**3.4. What is weld metal solidifications ?**

**Ans.** The solidification of metals is usually considered to be a nucleation and growth process *i.e.*, the transformation of a liquid phase to a solid normally occurs by a process of nucleation and growth.

**3.5. What are the effects of thermal cycle in the weld metal ?**

**Ans.** Thermal cycle in the weld metal and heat affected zone has important effects on the properties of certain alloys, particularly hardenable alloy steels, and for such materials control of the thermal cycle may be a prerequisite to successful welding.

**3.6. Define residual stress in welding ?**

**Ans.** Residual stress is the stress which remains within a welded structure without the presence of external load. Therefore they are self balance within structure itself.

**3.7. What are the factors responsible for residual stresses in welding ?**

**Ans.** Factors responsible for residual stresses in welding are as follows :

1. Differential heating of the plates by the weld heat source.
2. Non-uniform plastic deformation.
3. Cooling rate that accompanies welding process.

**3.8. Define dilution.** **AKTU 2016-17, Marks 02**

**Ans.** When base metal and filler metal have the different composition, the weld bead may be expected to exhibit a composition lying somewhere between that of the filler metal and the base metal. This effect is known as dilution.

**3.9. Explain weld affected zone.** **AKTU 2018-19, Marks 02**

**Ans.** Weld affected zone is formed as the weld metal solidifies from the molten state. This is a mixture of parent metal and electrode (or filler metal), the ratio depending upon the welding process used, the type of joint, the plate thickness etc.

4 UNIT

# Repair and Maintenance Welding (2 Marks Questions)

**4.1. What do you mean by cladding and surfacing ?**

**AKTU 2018-19, Marks 02**

**Ans.** **Cladding :** Cladding is the covering of one material with another. In metallurgy, cladding is the bonding together of dissimilar metals.
**Surfacing :** Surfacing is the process of depositing filler metal by arc or gas welding on a metal surface to obtain desired properties or dimensions.

**4.2. Give the classifications of surfacing.**

**Ans.** Classifications of surfacing are as follows :
1. Hardfacing,
2. Cladding,
3. Built up, and
4. Buttering.

**4.3. What do you mean by hardfacing ?**

**AKTU 2017-18, Marks 02**

**Ans.** In hardfacing metal is deposited over another surface to increase the hardness of the surface and to make the surface of material resistant to abrasion, convolution impact, erosion etc.

**4.4. What is metallizing process ?**

**Ans.** Metallizing is a process of applying molten metal to a base metal surface in the form of fine spray that bonds to the base metal and forms a metal coating.

**4.5. Define reclamation welding.** **AKTU 2018-19, Marks 02**

**Ans.** Reclamation welding is the simplest form of reclamation where the metallic components are joined together, if cracked/broken, with the use of suitable electrode using arc welding.

**4.6. What is weldability ? How carbon content affects the weldability ?**

**Ans.** Weldability is the ability of material to be welded with ease *i.e.*, the easiness of welding of the materials. As the amount of carbon content increases in the metal the weldability reduces.

**4.7. Write down the factors affecting the weldability.**

**Ans.** The factors which affect the weldability are follows :

1. Metallurgical compatibility,
2. Mechanical properties, and
3. Serviceability.

**4.8. Define effect of sulphur on weld.**

**Ans.** Sulphur imparts free machining properties in the parent metal on weld.

**4.9. What are the effects of manganese in parent metal on weld ?**

**Ans.** Manganese contributes to strength and hardness. Manganese also lowers both ductility and weldability if present in high percentage with high carbon content in steel.

**4.10. Write down the welding methods of plain carbon steel.**

**Ans.** Welding methods of plain carbon steel are as follows :

1. Oxy acetylene welding,
2. Flux shielded metal arc welding,
3. Submerged arc welding,
4. Gas metal arc welding, and
5. Gas tungsten arc welding.

**4.11. Mention welding processes used for welding of cast iron ?**

**Ans.** Welding processes used for welding of cast iron are as follows :

1. Metal arc welding,
2. Oxy acetylene welding,
3. Brazing, and
4. Thermite welding.

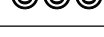
**4.12. Enlist the welding methods used for aluminium.**

**Ans.** Welding methods used for aluminium are as follows :

1. Oxy-gas welding,
2. TIG or MIG welding,
3. Resistance welding,
4. Brazing,
5. Atomic hydrogen welding, and
6. Solid state welding.

**4.13. What are the applications of hardfacing ?**

**Ans.** Hardfacing is used in construction equipments including bulldozer blades, scraper blades, textile industries equipments and engine valve facing.



5 UNIT

# Weld Design and Welding Codes (2 Marks Questions)

**5.1. What do you understand by welded joint ?**

**Ans.** Welded joint is a permanent joint which is obtained by joining two or more metals, with or without the application of pressure and with or without filler material and with the application of heat.

**5.2. What types of welded joints used in welding ?**

**AKTU 2018-19, Marks 02**

**Ans.** The main types of welded joints are as follows :

1. Butt joint,
2. Lap joint,
3. T-joint,
4. Corner joint, and
5. Edge joint.

**5.3. What do you mean by weld joint design ?**

**Ans.** Weld joint design is an important step in welding process as proper joint design helps to control various welding defects like distortion and other defects.

**5.4. Describe various welding symbols.**

**AKTU 2018-19, Marks 02**

**Ans.** Various welding symbols are as follows :

| S. No. | Type of Weld | Symbol |
|---|---|---|
| 1. | Fillet |  |
| 2. | Square Butt |  |
| 3. | Single V-Butt |  |
| 4. | Double V-Butt |  |
| 5. | Spot |  |

**5.5. What is the objective of weld inspection ?**

**Ans.** The objective of weld inspection is to ascertain the satisfaction of the welding carried out for making a sound joint between the two parts.

**5.6. Why the welded joint is in tension ?**

**Ans.** Weld filler metal is in liquid state and it undergoes both solidification shrinkage and contraction during cooling. Parent metal being cooler and larger in mass inhibits the contraction of the weld material, putting weld in tension.

**5.7. What is the weld testing ?**

**Ans.** Weld testing involves the physical performance of operations on the weldments to check the quantitative measure of certain properties of weldments such as their mechanical properties.

**5.8. What are types of weld testing methods ?**

**Ans.** There are two types of weld testing methods :

1. Destructive testing, and
2. Non destructive testing.

**5.9. What is weld distortion and its prevention ?**

**AKTU 2018-19, Marks 02**

**Ans.** **Weld Distortion :** An object is said to be distorted when it is put out of shape or it becomes unshapely.

**Prevention :**

1. Use double sided welds rather than single sided.
2. Use minimum gap sizes.
3. Use clamps, strong back, jigs or fixtures.
4. Make use of sub assemblies.

**5.10. What are the types of weld distortion ?**

**Ans.** Types of weld distortion are as follows :

1. Longitudinal shrinkage,
2. Transverse shrinkage, and
3. Angular shrinkage.

**5.11. What are the factors responsible for weld distortion ?**

**Ans.** Factors responsible for weld distortion are as follows :

1. Non uniform stresses because of expansion and contraction.
2. Thermal stresses produced in welds.

**5.12. List down the factors affecting the distortion.**

**Ans.** Factors affecting the distortion are as follows :

1. Parent material properties,

2. Amount of restraint,
3. Joint design,
4. Part fitup, and
5. Welding procedure.

**5.13. Enlist destructive methods to measure the stresses in weld structure.**

**Ans.** Destructive methods to measure the stresses in weld structure are as follows :

1. Strain gauge method,
2. Brittle coat method, and
3. Photostress technique.

**5.14. What are the main factors affecting the welding design ?**

**AKTU 2016-17, Marks 02**

**Ans.** Factor affecting the welding design are as follows :

1. Material going to be welded.
2. Nature of the process.
3. Dimensions of workpiece.
4. Length of weldment etc.

**5.15. Name any four weld defects.** **AKTU 2016-17, Marks 02**

**Ans.** Four weld defects are as follows :

1. Cracks, 2. Inclusions,
3. Crater, and 4. Distortion.

**5.16. What are the factors that cause slag inclusion ?**

**AKTU 2016-17, Marks 02**

**Ans.** Factors that cause slag inclusion are as follows :

1. Too high or too low arc current.
2. Too small included angle of the joint.

# B.Tech.
# (SEM. VIII) EVEN SEMESTER THEORY EXAMINATION, 2016-17
# ADVANCE WELDING TECHNOLOGY

**Time : 3 Hours** **Max. Marks : 100**

## Section-A

**1.** Attempt **all** parts of the following questions : **(2 × 10 = 20)**

**a. What is deformation resistance welding ?**

**b. Compare vacuum brazing with welding.**

**c. How radial friction welding is used to join collars to shafts and tubes ?**

**d. What are the advantages of constricting plasma in PAW ?**

**e. What are the effects of gases in welding ?**

**f. What are the main factors affecting the welding design ?**

**g. Define dilution.**

**h. Name any four weld defects.**

**i. What are the factors that cause slag inclusion ?**

**j. Give two examples of adhesives and mention its general characteristics.**

## Section-B

**2.** Attempt any **five** of the following questions : **(10 × 5 = 50)**

**a. What are the different joint designs in adhesive bonding ? Explain how a good joint design can be selected ?**

**b. Explain the welding symbol with an example.**

**c. Explain the process of needle arc micro plasma welding.**

**d. Describe the reasons that fatigue failure generally occur in HAZ of welds instead of through the weld bead itself.**

**e. Explain how different process parameter influence laser beam welding.**

**f. With suitable sketch explain the process of TIG welding. What are its disadvantages ?**

**g. Describe principle of operation of EBW (Electron beam welding). What are the possible problem or difficulties and how it can be dealt with ? Write down the advantage and limitation.**

## Section-C

Attempt any **two** of the following questions : **(15 × 2 = 30)**

**3. Explain how the weld quality of different welded joints can be determined ?**

**4. Explain the following :**

**i. Dye Penetrant Testing.**

**ii. Inspection of welds.**

**iii. Discontinuities in welds and their causes.**

**5. i. Explain with neat labelled sketch the working of ultrasonic welding.**

**ii. What are the different methods of diffusion welding ? How surface preparations affect the strength of the joint ?**

# SOLUTION OF PAPER (2016-17)

## Section-A

**1.** Attempt **all** parts of the following questions : **(2 × 10 = 20)**

**a. What is deformation resistance welding ?**

**Ans.** It is a process that employs resistance heating to raise the temperature of the materials being welded to the appropriate forging range, followed by shear deformation which increases the contacting surface area of the materials being welded.

**b. Compare vacuum brazing with welding.**

**Ans.**

| S. No. | Vacuum Brazing | Welding |
|---|---|---|
| 1. | Post-heat treatment is not necessary for vacuum brazing. | Post-heat treatment is often required. |
| 2. | The filler material is essentially used because joint is made by filler material only. | The filler material may or may not be used. |
| 3. | Distortion is low. | Distortion is high. |

**c. How radial friction welding is used to join collars to shafts and tubes ?**

**Ans.** Steps to join collars to shafts and tubes :

1. The two components are held in axial alignments.
2. One component is rotated and other is stationary which move forward to come into pressure contact with the rotating component.
3. Pressure and rotation are maintained until the resulting high temperature makes the components metal plastic for welding.
4. Allow the joint soften for weld.

**d. What are the advantages of constricting plasma in PAW ?**

**Ans.** The advantages of constricting plasma in PAW are as follows :

1. It improves the arc stability.
2. It also improves the arc shape.
3. It provides better heat transfer characteristics.

**e. What are the effects of gases in welding ?**

**Ans.** Effect of gases in welding are as follows :

1. Gases absorbed in the weld metal result in the formation of porosity.
2. Reduce the tensile strength of weld.

3. Lower the corrosion resistance of weld metal.
4. Decrease ductility and impact resistance.

**f. What are the main factors affecting the welding design ?**

**Ans.** Factor affecting the welding design are as follows :

1. Material going to be welded.
2. Nature of the process.
3. Dimensions of workpiece.
4. Length of weldment etc.

**g. Define dilution.**

**Ans.** When base metal and filler metal have the different composition, the weld bead may be expected to exhibit a composition lying somewhere between that of the filler metal and the base metal. This effect is known as dilution.

**h. Name any four weld defects.**

**Ans.** Four weld defects are as follows :

1. Cracks, 2. Inclusions,
3. Crater, and 4. Distortion.

**i. What are the factors that cause slag inclusion ?**

**Ans.** Factors that cause slag inclusion are as follows :

1. Too high or too low arc current.
2. Too small included angle of the joint.

**j. Give two examples of adhesives and mention its general characteristics.**

**Ans.**

**A. Examples of Adhesives :** Glue and cement.

**B. Characteristics :**

1. High strength to weight ratio.
2. Superior vibration and fatigue.

## Section-B

**2.** Attempt any **five** of the following questions : **(10 × 5 = 50)**

**a. What are the different joint designs in adhesive bonding ? Explain how a good joint design can be selected ?**

**Ans.**

**A. Different Joint Designs in Adhesive Bonding :**

Different joint designs in adhesive bonding are as follows :

**i. Butt Joint :**

1. Square butt joints (with or without gap) are recommended for smaller plate thicknesses (upto 4.8 mm) and much lesser loading as compared to single *V*, *U*, *J* or bevel joints.

2. Double joints are preferred over single joints for bigger plate thicknesses.
3. Out of various joints, *V* joint finds much more extensive use and applications.

**ii. Lap Joint :**

1. Single fillet and double fillet joints are used on all thicknesses.
2. Double fillet joint is better as compared to single fillet joint when joint is subjected to severe loading.
3. Single fillet joints are not recommended on plates under bending, fatigue or impact loading conditions.
4. Plug weld is employed to impart added strength to the structure. This plug weld joint is used where bottom or second plate cannot be accessed easily.

**iii. *T* Joint :**

1. Single fillet *T* joint is preferred for smaller plate thicknesses when subjected to low or no bending load conditions.
2. Double *T* joint is recommended for most severe loading conditions.
3. In *T* joint cost of edge preparation increases and electrode consumption decreases.

**iv. Corner Joint :**

1. For smaller thickness plates and not subjected to severe loading, close and half open corner joints.
2. Full open corner joint can be used on plates of all thicknesses under severe load conditions.
3. The load bearing capacity increases when the joint is welded from both sides.

**v. Edge Joint :**

1. Two pieces of metals are lapped, with their edges in line and the pieces are joined by welding the two edges together.
2. Fillet welds (*i.e.*, corner joint, *T* joint, lap joint etc.) are the cheapest type of welds to make, as no edge preparation is required and setting up is simple.

**B. Selection Criteria for a Good Weld Design :**

For selection of good joint design weldment should have following considerations :

1. Adequately designed to meet the intended service for the required life.
2. Fabricated with specified materials and in accordance with the design concepts.
3. Handled and maintained properly.
4. The design of a weldment should be consistent with sound engineering practices.
5. Components of adequate size should be specified to ensure that stresses from anticipated service loads are not excessive.
6. The intended service should be carefully analyzed to determine whether cyclic loading might result in fatigue failure in highly stressed members.

7. Environment conditions leading to brittle fracture, creep, and corrosion of welds should be considered in the design.

**b. Explain the welding symbol with an example.**

**Ans.**

**A. Welding Symbols :**

1. Welding symbols provide the means of placing on drawings, the information concerning the type, size, position, etc., of the welds in welded joints.
2. The basic symbols used to represent various types of welds are given below in Fig. 1.

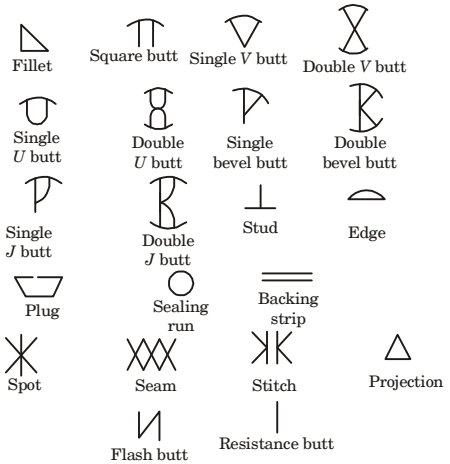



**Fig. 1.**

**B. Different Welding Symbols :**

**i. Fillet Welds :**

1. Fillet weld symbol is used to make lap joints, corner joints, and T-joints.
2. The fillet weld is roughly triangular in cross-section.

**ii. Groove or Butt Welds :**

1. The variety of butt weld symbol depends primarily on the geometry of the parts to be joined and the preparation of their edges.
2. Some butt weld symbols are V-butt, square butt, U-butt, Bevel butt, J-butt etc.

**iii. Plug Welds :**

1. Plug welds symbols are used in joining the overlapping members, one of which has holes in it.
2. If the hole is not to be completely filled with weld metal, the depth to which it is to be filled is given within the weld symbol.
3. Plug welds are commonly used with other welds in the rails.

**iv. Stud Welds :**

1. Stud weld symbol is used in electric arc process that rapidly joins a fastener to a base metal or substrate.
2. It is a fast, reliable and accurate method of welding a metal fastener to another metal object.

**v. Slot Welds :**

1. Slot weld symbol contains similar information as plug weld symbol except that plug welds do not have a length component.
2. Size of a plug weld is its diameter while the size of a slot is its width.

**vi. Seam Welds :**

1. Seam weld symbol indicates a weld that takes place between the faying surfaces of a lap joint that may be composed of two or more lapped pieces.
2. It is used in resistance welding.

**vii. Edge Welds :**

1. This symbol is used where the edges of two sheets or plates are adjacent and are in approximately parallel planes at the point of welding.

**viii. Projection Welds :**

1. This symbol is used in the process of projection welding.
2. Projection welds must be dimensioned by strength.

**ix. Backing Strip Welds :**

1. The symbol is used to signify the welding of tanks.
2. It is deployed for root runs with single *V* as well as double *V* configurations.

**x. Spot Welds :**

1. The symbol is used specifically in resistance spot welding.
2. The process uses two shaped copper alloy electrodes to concentrate welding current into a small spot and to damp the sheets together.

**c. Explain the process of needle arc micro plasma welding.**

**Ans.**

1. In micro plasma welding (MPAW) arc is formed between the electrode and the work piece in an inert atmosphere to fuse metal in a joint area and produce a molten weld pool.
2. The uniqueness of MPAW from other welding processes is the electrode is positioned within the body of the torch and the plasma forming gas is separated from the shielding gas envelope. While in the other processes the electrode is exposed to the atmosphere during the process.
3. It has a mechanism called the pilot arc that is struck between the electrode and nozzle to initiate the main welding arc. The pilot arc can be shut off after the main are starts or can be kept on all the time.
4. The current range of micro plasma arc varies from 0.1 A - 15 A. Even at welding current at 0.1 A the length can be varied possibly up to 10 mm without affecting stability of the arc.

5. The needle like stiff arc minimises wander and distortion.
6. Micro plasma arc welding torches are available both in manual and full automated mode.
7. Manual MPAW generally can work in all position where in fully mechanized MPAW is done in the flat and horizontal positions.
8. Generally in micro plasma arc welding DC current source is used. Micro plasma arc welding current generally can vary from a range 0.01 amp to 15 amp.
9. Pulsing facility is provided by power source. The pulsed arc has the ability to produce highest and precise weld quality.

**d. Describe the reasons that fatigue failure generally occur in HAZ of welds instead of through the weld bead itself.**

**Ans.**

1. Heat affected zone is the portion near the weld metal zone which is composed of parent metal and did not melt but heat to a enough high temperature for a sufficient period. Due to this heating, mechanical properties and microstructure of this zone have been changed.
2. These changes in structure can reduce the metal's strength.
3. It is very important to understand that the HAZ accounts for reduced strength to design safe applications. The weakest sections of a structure exist in the HAZ.
4. The heat affected zone leads to structural changes in the metal that weaken the part in this area. A metal's mechanical properties such as fatigue resistance, distortion, and surface cracking are affected.

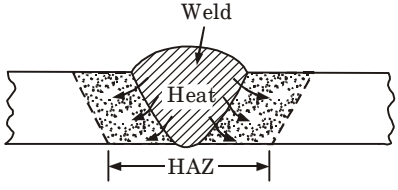



**Fig. 2.**

5. Weld usually fails in HAZ due to :

i. The failure of weld is due to weld decay.
ii. The weld decay is caused by following reasons :
a. The time and the temperature of exposure.
b. The composition and prior treatment of the weld.

**e. Explain how different process parameter influence laser beam welding.**

**Ans.** Different process parameter influence laser beam welding are as follows :

**i. Laser Power :**

1. A plasma will be generated only when the laser power density on the workpiece exceeds the threshold value (associated with the material), which marks the stable deep penetration.
2. If the laser power is lower than this threshold, the workpiece occurs only surface melting.
3. Welding penetration is directly related to the beam power density, is a function of the incident light beam power and beam focal spot.

**ii. Beam Focal Spot :**

1. The beam spot size is one of the most important variables in the laser welding, because it determines the power density.
2. The beam focus diffraction limited spot size can be calculated according to the theory of light diffraction, but due to the presence of the focus lens aberration, the actual spot than the calculated value is too large.

**iii. Welding Speed :**

1. Welding speed has a greater impact on penetration, increase the speed to make penetration shallow, but the too low speed will lead to excessive melting of the material.
2. So, for a certain laser power and a certain thickness of a particular material have a suitable welding speed range.

**iv. Shielding Gas :**

1. The laser welding process is often used an inert gas to protect the molten pool.
2. Helium has difficult ionization, allows the laser has beam energy direct access to the workpiece surface.
3. This is the most effective protection of the gas, but the price is more expensive.
4. Argon gas is cheaper, denser, so the protection is better.
5. Nitrogen as a protective gas is the cheapest, but does not apply to certain types of stainless steel metallurgical aspects.

**v. Lens Focal Length :**

1. Focus mode, 63 ~ 254 mm is generally used in the focal length of the lens.
2. Focal spot size is proportional to the focal length, the shorter the focal length the smaller will be the spot.
3. The short focal length can improve the power density.

**vi. Focus Position :**

1. In order to maintain a sufficient power density, the focal position is essential.
2. Changes in relative positions of the focus and the workpiece surface directly affect the weld width and depth.
3. In most laser welding applications, the position of the focus is usually set below the surface of the workpiece about the desired penetration depth of 1/4.

**vii. Laser Beam Position :**

1. The laser beam position control the final quality of the weld, especially in the case of butt joints.
2. For example, when a hardened steel gear is welded to the drum of the low-carbon steel, proper control of the laser beam position will be conducive to generate mainly low-carbon component composition of the weld, this weld having a good crack resistance.

**f. With suitable sketch explain the process of TIG welding. What are its disadvantages ?**

**Ans.**

**A. TIG Welding :**

1. It is an arc welding process wherein coalescence is produced by heating the job with an electric arc struck between a tungsten electrode and the job.
2. A shielding gas (argon, helium, nitrogen, etc.,) is used to avoid atmospheric contamination of the molten weld pool.

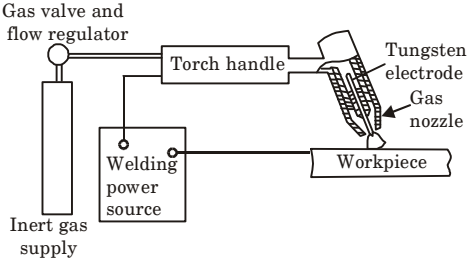



**Fig. 3.**

**B. Principle of Operation of TIG Welding :**

1. Welding current, water and inert gas supply are turned on.
2. The arc is struck either by touching the electrode with a scrap metal tungsten piece or using high frequency unit.
3. In this arc is initially struck on a scrap metal piece and then broken by increasing the arc length.
4. This procedure repeated twice or thrice that warms up the tungsten electrode.
5. The arc is then struck between the electrodes and precleaned job to be welded.
6. This method avoids breaking electrode tip, job contamination and tungsten loss.
7. TIG welding is also known as Gas Tungsten Arc Welding (GTAW).
8. Both the AC and DC power source can be used for GTAW.
9. Electrodes employed varies in diameter from 0.5 to 6.5 mm carrying current from 5 A to 6.5 A.
10. GTAW is an all position welding and gives the highest quality weld amongst commonly used arc welding processes.

**C. Disadvantages of TIG Welding :**

1. Equipment costs are higher than that for flux shielded metal arc welding.
2. Under same applications, MIG welding is faster as compared to TIG welding.

**g. Describe principle of operation of EBW (Electron beam welding). What are the possible problem or difficulties and how it can be dealt with ? Write down the advantage and limitation.**

**Ans.**

**A. Principle of Operation of Electron Beam Welding :**

1. Electron beam welding can be defined as, a welding process wherein coalescence is produced by the heat obtained from a concentrated beam composed primarily of high velocity electrons impinging upon the joint to be welded.
2. The kinetic energy of the electrons is changed into heat on impact with work, giving intense local heating.
3. The electron beam is produced in a high vacuum environment by an electron gun usually consisting of a tungsten cathode, a grid or forming electrode and an anode.
4. A stream of electrons is given off from a tungsten filament heated to about 2200 °C.
5. The electrons are gathered, accelerated to high velocity and shaped into a beam by the potential difference between cathode and anode.
6. The beam is collimated and focused by passing through the field of an electromagnetic focusing coil or magnetic lens.

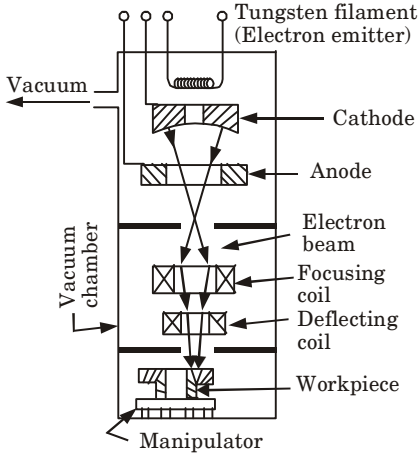



**Fig. 4.**

7. Beams are focused to about 0.25 to 1 mm diameter and have a power density of about 10 kW/mm$^2$, which is sufficient to melt and vaporise any metal.
8. The operation is carried out in a vacuum, which enables the beam source to be at a distance of upto about 1 m from the work.
9. Deep penetration with a very narrow heat affected zone is achieved by this process.
10. Aluminium can be fused upto a depth of about 40 mm, and stainless steel upto 30 mm, with a width of fusion area of about one-tenth of the penetration.

**B. Difficulties Encountered During EBW :**

1. In EBW or vacuum welding system, atmospheric scattering and energy absorption of the beam are negligible.
2. Moreover vacuum prevents the reduction of electron velocity however, the size of the vacuum chamber required naturally imposes serious limitation on the size of the workpiece that can obstruct the passage of beam and absorb some of its power.
3. Moreover if the welding is carried out in a vacuum chamber, considerable time is lost as the work chamber must be pumped down for each new workpiece.
4. These difficulties lead to the development of some electron beam machine that permit the workpiece to remain outside the vacuum chamber while it is being welded.

**C. Advantages of EBW :**

1. Welds produced are of high quality and can be made at high speeds.
2. The fusion zone and the heat affected zone are extremely narrow.
3. Small thin parts can be welded to heavy sections.
4. Precise control is possible.

**D. Limitation of EBW :**

1. Initial cost of equipment is high and portable equipment is rare.
2. Work is to be manipulated through vacuum seals.
3. Workpiece size is limited by the work chamber dimensions.

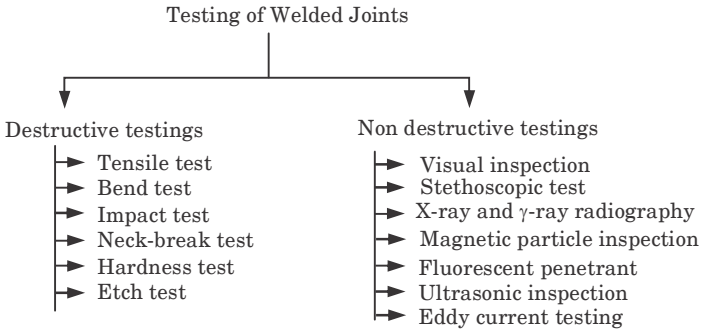
## Section-C

Attempt any **two** of the following questions : **(15 × 2 = 30)**

**3. Explain how the weld quality of different welded joints can be determined ?**

**Ans.**

**A. Determination of Weld Quality :** The weld quality of different welded joints can be determined by following testing :




**B. Bend Test :**

1. A bend test may be carried out on a tensile testing machine with the help of certain attachments.
2. A bend test is an easy and inexpensive test to apply. The method is fast and shows most weld faults quite accurately.
3. Bend tests may be used to find a number of weld properties such as :

i. Ductility of the welded zone,
ii. Weld penetration,
iii. Fusion,
iv. Crystalline structure, and
v. Strength.

4. The bend test assists in determining the soundness of the weld metal, the weld junction and the heat affected zone.
5. The test shows the quality of the welded joint.
6. Any cracking of the metal will indicate false fusion or defective penetration.
7. Large crystals usually indicate wrong welding procedure or poor heat-treatment after welding. A good weld has small crystals.
8. Bend tests may be categorized as :

i. Free bend test, and
ii. Guided bend test.

**4. Explain the following :**

**i. Dye Penetrant Testing.**

**Ans. Dye Penetrant Testing :**

1. It is a non destructive type testing to detect flaws that are open to the surface like cracks, seams, laps, lack of bond, porosity, cold shuts, etc.
2. The working steps of dye penetrant tests are as follows :

i. Firstly clean the surface of the component with a piece of cloth to make it free of dust and dirt.
ii. Use a soft wire brush to clean the surface of the component from scale, rust, paint, etc.

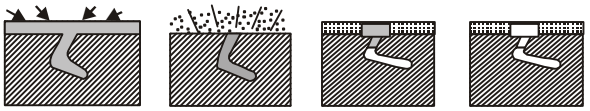



**Fig. 5.**

iii. To remove oil and grease from the surface spray the cleaner.
iv. Now spray the dye penetrant adequately to cover the area that has to be tested. Allow sometime (3 to 5 minutes) for dye to penetrate into the cracks.
v. The excess penetrant on the surface must be wiped off by using a ray stone.
vi. Again spray the surface with the cleaner to remove the remnants of the red dye.
vii. Spray a chemical (known as developer) evenly on the surface. This will give a thin even layer over the surface to be inspected. This layer absorbs the penetrant from the cracks and red spots or lines appear on the surface to give a visible indication of the flaws.
viii. The crack if any will be indicated with the red dye absorbed by the white absorbent.

**ii. Inspection of welds.**

**Ans.**

**A. Inspection of Welding :** Inspection refers just to examine visually of a welding structure. Inspection may be qualitative and involves only visual observation of correctness of functioning/dimensions.

**B. Types of Inspection of Welding :** Types of inspection are as follows :

**i. Inspection before Welding :**

1. Check out the welding joint drawing such as dimensions, tolerances, process specification etc.
2. Choose the suitable welding process by easy method.
3. Set the welding parameters such as current, voltage, frequency, polarity etc.
4. Proper arrangement of welding joint cooling and ventilation as well as smoke.

**ii. Inspection in Between the Welding :** It is the second stage of inspection and it involves :

1. Welding groove (Edge preparation) should as per specification.
2. Tack welds should be of adequate size, length and pitch,
3. Method of welding such type that minimum distortion should be in welding joint.
4. Welding position, fit up gap should be as per welding procedure.
5. Slag on the welding joint should be properly removed from each pass in multipass arc welds.

**iii. Inspection after or Completion of Welding :**

1. Find out of determine properties and weld quality of a weld object.
2. Find out suitability of weldment with the help of :

i. Destructive testing, and
ii. Non destructive testing.

**iii. Discontinuities in welds and their causes.**

**Ans.** Various discontinuities in welds and their causes are as follows :

**i. Incomplete Penetration :** Incomplete penetration occurs when the depth of the welded joint is insufficient.

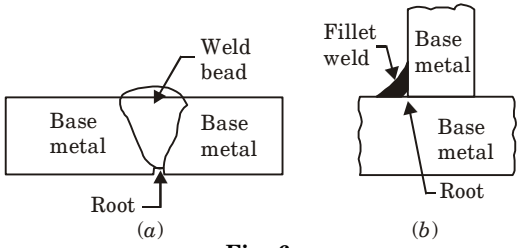



**Fig. 6.**

**a. Causes of Incomplete Penetration :**

1. Improper joints.
2. Too large root face.

**ii. Inclusion :** Inclusions may be in the form of slag or any other foreign material, which does not get a chance to float on the surface of the solidifying weld metal and thus gets entrapped inside the same.

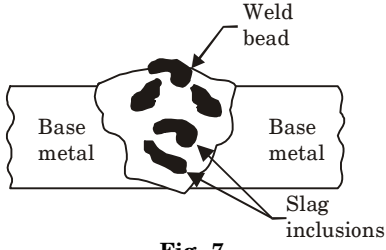



**Fig. 7.**

**a. Causes of Inclusion :**

1. Too high or too low arc current.
2. Long arc and too large electrode diameter.

**iii. Porosity and Blowholes :** Porosity is a group of small voids and blowholes are comparatively bigger isolated holes or cavities.

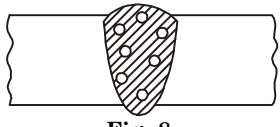


**Fig. 8.**

**a. Causes of Porosity and Blowholes :**

1. Use of improper electrode and longer arc.
2. Faster arc travel speeds.

**iv. Spatter :** Spatters are the small metal particles which are thrown out of the arc during welding and get deposited on the base metal around the weld bead along its length.

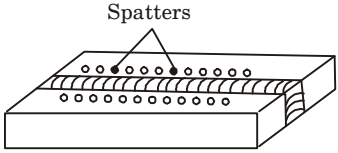



**Fig. 9.**

**a. Causes of Spatter :**

1. Excessive arc current.
2. Use of longer arc.

**v. Undercut :** Undercut is a kind of weld defect which forms a groove in the parent metal along the sides of the weld bead.

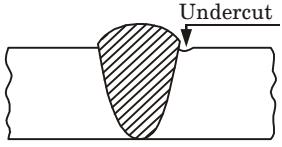



**Fig. 10.**

**a. Causes of Undercut :**

1. Wrong manipulation and inclination of electrode and excessive weaving.
2. Too large electrode diameters.

**vi. Hot Tear :** In this welding defect the deposited metal being hot, starts developing crack from the nearby edge so that after it has been solidified the crack increases.

**a. Causes of Hot Tear :**

1. Improper selection of electrode material.
2. Welding current is not proper.

**5. i. Explain with neat labelled sketch the working of ultrasonic welding.**

**Ans.**

1. Ultrasonic welding is a type of radiant welding process therefore it is considered as a advance welding technique.
2. Through ultrasonic welding many metals could be combined that could not be welded by any other joining processes.
3. In ultrasonic welding, metallic tip vibrating with ultrasonic frequency is produced to weld a thin plate to a thicker one supported on an anvil, range generally used of frequency from 20000 Hz to 60000 Hz.

4. Ultrasonic welding combines pressure and high frequency vibration motion to form a solid state bond.

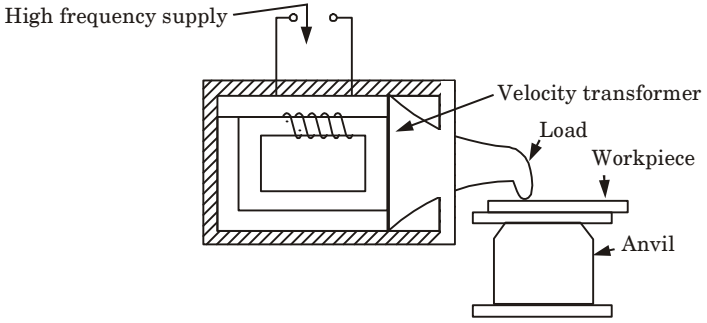



**Fig. 11.**

5. This welding is produced due to vibration generated during the welding process.
6. Workpiece that is to be welded should be properly clamped between the welding tip and anvil in the process.
7. Both tip and anvil are faced with high speed steel.
8. In ultrasonic welding, a frequency convertor is used which converts 50 Hz line power into a very high power.
9. This system consists of transducer which converts electrical power into ultrasonic vibration energy and this vibration energy is transferred into joint through welding tip which is attached with transducer tip, oscillates in the plane of the joint interface.
10. Frequency and the pressure exerted on the material depend on the type and size of the rail and type of welding machine.
11. During ultrasonic welding, vibrations combine with static clamping force and produce dynamic shear stresses in the workpiece which results in plastic deformation.
12. At the joint interface, any coating or any other oxide coating are shattered and dispersed so that intimate contact and bonding on the workpiece surface take place.

**ii. What are the different methods of diffusion welding ? How surface preparations affect the strength of the joint ?**

**Ans.** This question is out of syllabus from session 2020-21.

# B.Tech.
# (SEM. VIII) EVEN SEMESTER THEORY EXAMINATION, 2017-18
# ADVANCE WELDING TECHNOLOGY

**Time : 3 Hours** **Max. Marks : 100**

**Note : 1.** Attempt **all** sections. If require any missing data; then choose suitably.

## Section-A

**1.** Attempt **all** questions in brief : **(2 × 10 = 20)**

**a. Differentiate between gas welding and gas cutting.**

**b. State the uses of welding flux.**

**c. Name the types of resistance welding.**

**d. Which welding process requires creation of vacuum ?**

**e. Define heat affected zone (HAZ).**

**f. Name any two non-destructive techniques for residual stress determination in welds.**

**g. What are the applications of cladding process ?**

**h. What do you mean by hardfacing ?**

**i. State any two general sources of welding defects.**

**j. What are the causes for undercut in welding ?**

## Section-B

**2.** Attempt any **three** of the following : **(10 × 3 = 30)**

**a. Explain in detail the advantages, limitations, applications of welding process.**

**b. State the principle of arc welding and explain the working of MIG welding, with suitable diagrams.**

**c. Define residual stresses in welding. State and explain the major factors responsible for residual stress.**

**d. Explain in detail the advantages of hardfacing with Oxy-acetylene torch ?**

**e. Explain in detail inspection before welding, inspection in between welding, inspection after welding.**

## Section-C

**3.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Using block diagram, classify the welding processes and explain the same.**

**b. What are the similarities and differences between casting and welding process ?**

**4.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Using neat sketch, explain TIG welding process. State its applications. What are the variants of TIG welding ?**

**b. Explain the procedure of electron beam welding process. What are the difficulties encountered during EBW ? Support with neat sketch.**

**5.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Explain any two destructive techniques for residual stress determination.**

**b. What are the main types of weld distortion ? What are the causes for distortion ?**

**6.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Briefly discuss the welding of cast iron. What kinds of defects are expected in such welding and what are their remedies ?**

**b. Explain in detail aluminium welding by double-operator method.**

**7.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Explain any five welding defects along with the causes and remedies.**

**b. Using neat sketches, broadly categorize the welding joints. Also draw sketches for the different welding positions.**

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# SOLUTION OF PAPER (2017-18)

**Note :** **1.** Attempt **all** sections. If require any missing data; then choose suitably.

## Section-A

**1.** Attempt **all** questions in brief : **(2 × 10 = 20)**

**a. Differentiate between gas welding and gas cutting.**

**Ans.**

| S. No. | Gas Welding | Gas Cutting |
|---|---|---|
| 1. | Gas welding involves the joining of metal by using the heat created by gas flame. | Gas cutting uses acetylene and oxygen to red hot and then uses pure oxygen to burn away the pre heated metal. |
| 2. | Gas welding, uses welding torch to weld metal. | Gas cutting, uses a cutting torch to cut the metal. |
| 3. | In gas welding filler metal is used. | In gas cutting filler metal is not used. |

**b. State the uses of welding flux.**

**Ans.** Uses of welding flux are as follows :

1. Stabilize the arc and control arc resistivity.
2. Reduce spattering.
3. Permit use of different types of current and polarity.
4. Promote slag detachability.

**c. Name the types of resistance welding.**

**Ans.** Types of resistance welding are as follows :

1. Spot welding,
2. Seam welding,
3. Projection welding,
4. Percussion welding, and
5. Flash butt welding.

**d. Which welding process requires creation of vacuum ?**

**Ans.** Electron beam welding.

**e. Define heat affected zone (HAZ).**

**Ans.** The region of the parent metal which has undergone a metallurgical change as a result of thermal cycle is known as heat affected zone (HAZ).

**f. Name any two non-destructive techniques for residual stress determination in welds.**

**Ans.** Non-destructive techniques for residual stress determination in welds are as follows :

1. X-ray technique, and
2. Ultrasonic technique.

**g. What are the applications of cladding process ?**

**Ans.** Applications of cladding process are as follows :

1. It is used to enhance product performance.
2. It is used in production of vessels for chemical, paper mill and nuclear power plant.

**h. What do you mean by hardfacing ?**

**Ans.** In hardfacing metal is deposited over another surface to increase the hardness of the surface and to make the surface of material resistant to abrasion, convolution impact, erosion etc.

**i. State any two general sources of welding defects.**

**Ans.** Sources of welding defects are :

1. Residual stresses, and
2. Hydrogen embrittlement.

**j. What are the causes for undercut in welding ?**

**Ans.** Causes for undercut in welding are as follows :

1. Wrong manipulation and inclination of electrode and excessive weaving.
2. Too large electrode diameters.
3. Higher current.

## Section-B

**2.** Attempt any **three** of the following : **(10 × 3 = 30)**

**a. Explain in detail the advantages, limitations, applications of welding process.**

**Ans.**

**A. Advantages of Welding :**

1. Welding results in a good saving of material and reduced labour content of production.
2. Low manufacturing costs.
3. It gives the designer great latitude in planning and designing.
4. Welding is also useful as a method for repairing broken or defective metal parts.
5. Without welding techniques, the light weight methods of fabrication, so vital to the automotive and aircraft industries, would be unthinkable.

6. Welding joint is as stronger as base metal and its efficiency is upto 100 %.
7. Alteration and amendment is possible in existing structure by welding joint.

**B. Limitations of Welding :**

1. Special jigs and fixtures are required for welding.
2. Edge preparation is required before welding which is time and labour consuming process.
3. Skilled person is needed for welding purpose.
4. Ultraviolet rays and infrared rays generated during the welding process are harmful for operator's skin as well as for eyes.
5. Welding heat produces metallurgical changes in workpiece.
6. During welding, thermal stresses developed in the workpiece, heat treatment processes are required to relieve the thermal stresses.

**C. Application of Welding :**

Applications of welding are as follows :

**i. Automobile and Transport Industries :**

1. Wherein cars, trucks, jeeps and many other transportation machines and equipments are fabricated.

**ii. Building Construction Industries :**

1. Welding is greatly used in building industries for joining frames of doors and windows, reinforcement in concrete works, railings and staircases.
2. When building is a steel frame construction comprising of steel roofing frames covered with asbestos sheets or galvanized iron sheet, welding has still greater role to play in joining the structural components for joining building, frames and trusses.

**iii. Railroad Industries :**

1. Railroad industries is another important field where welding is involved in the production of locomotive under frames, bogies, trolleys, railway bridges, electric frame network, signal, equipment, lighting towers, platform shades and bodies etc.

**iv. Pressure Vessels and Tanks Industries :**

1. Pressure vessels and tanks are widely used in various industries for carrying or storing the fuel and other liquids.
2. These are made by welding together the bent steel plates.
3. Oil, gas and water storage tanks are also steel fabricated.

**v. Aircraft Industries :**

1. In aircraft industries welding is extensively used for joining the aircraft components of alloy steel, stainless steel and aluminium alloys.
2. Welding is used for the production of allied equipment that assists aircraft in operations and maintenance like material handling system, transport means for men and luggage etc.

**b. State the principle of arc welding and explain the working of MIG welding, with suitable diagrams.**

**Ans.**

**A. Principle of Arc Welding :**

1. In arc welding one electrode is the welding rod or wire while other is the metal to be welded (workpiece).
2. Arc connected to the supply, one to the positive terminal and other to the negative terminal.
3. Arc is started by momentarily touching the electrode on the plate and then withdrawing it to about 3 to 4 mm from the plate.
4. When the electrode touches the plates, a current flows and as it is withdrawn from the plate the current continues to flow in the form of a spark across the very small gap first formed, this cause the air gap to become ionised or made conducting and as a result the current is able to flow across the gap.
5. Approximately $2/3^{rd}$ of the heat is generated on positive pole and $1/3^{rd}$ on the negative pole.

**B. Principle of Operation of MIG Welding :**

1. Before igniting the arc, gas and water flow is checked.
2. Proper current and wire feed speed is set and the electrical connections are ensured.
3. The arc is struck by any one of the two methods :

i. In the first method, current and shielding gas flow is switched on and the electrode is scratched against the job as usual practice for striking the arc.

ii. In the second method, electrode is made to touch the job, is retracted and then moved forward to carry out welding, but before striking the arc, shielding gas, water and current is switched on.

4. About 15 mm length of the electrode is projected from the torch before striking the arc.

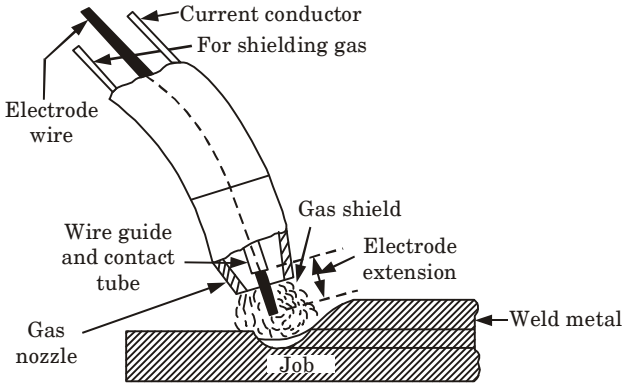



**Fig. 1.** MIG welding operation.

5. During welding, torch remains about 10-12 mm away from the job and arc length is kept between 1.5 to 4 mm.

**c. Define residual stresses in welding. State and explain the major factors responsible for residual stress.**

**Ans.**

**A. Residual Stresses in Welding :** It is the stress which remain within a welded/structure/casting structure when no presence of external load therefore they are self balance within structure itself.

**B. Factors Responsible for Residual Stress :**

1. Parent metal quality, filler rod or electrode quality.
2. Size and shape of weldment.
3. Comparative weight of parent metal and weld metal.
4. Joint nature and method of welding (backing strip, tracking etc.).
5. Heat input into weldment *i.e.*, value of current, dia of electrode and speed of welding in arc welding.
6. Nature of structure.
7. Expansion and contraction of structure after welding.
8. Cooling rate.
9. Stress present in parent metal.

**d. Explain in detail the advantages of hardfacing with Oxy-acetylene torch ?**

**Ans.**

1. Oxy-acetylene welding process can be used for surfacing purpose with the assistant of portable and low cost equipment.
2. In this surfacing process heating and cooling rates for parent metal are very slow which leads to very little dilution resulting in smooth, precise and extremely high quality surfacing deposits.
3. Groove, narrow gap and recesses can be easily filled and very thin layers may be smoothly applied.
4. Preheating and slow cooling nature of oxy-acetylene surfacing method tends to minimized cracking even with highly wear resistance but brittle over types of welding flame and size of tip.
5. During surfacing no flux is needed, a typical application of the process is the deposition of a low melting point high carbon filler metal.
6. This process also can be done by powdered material; in this case welding torch is fitted with hopper (a powder feeding device).

7. Oxy-acetylene surfacing process can be done in a semi-automatic manner where a large number of identical parts, which can be arranged in systematic manner are present.
8. The process can be easily employed in the field and very thin layers of hardfacing alloy can be applied.

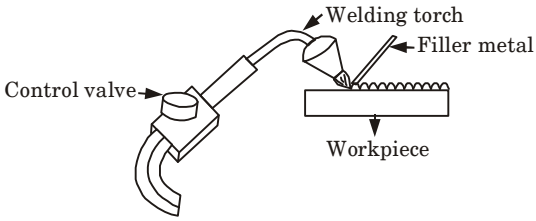



**Fig. 2.**

**e. Explain in detail inspection before welding, inspection in between welding, inspection after welding.**

**Ans.**

**A. Inspection before Welding :**

1. Check out the welding joint drawing such as dimensions, tolerances, process specification etc.
2. Choose the suitable welding process by easy method.
3. Set the welding parameters such as current, voltage, frequency, polarity etc.
4. Select the defect free material as per specification.
5. Selection of proper size, proper flux coated electrode as per specification (BIS specification).
6. Select the Jig and fixture of proper size as per welding joint complexity.
7. Proper arrangement of welding joint cooling and ventilation as well as smoke.

**B. Inspection in Between the Welding :** It is the second stage of inspection and it involves :

1. Welding groove (Edge preparation) should as per specification.
2. Tack welds should be of adequate size, length and pitch,
3. Method of welding such type that minimum distortion should be in welding joint.
4. Welding position, fit up gap should be as per welding procedure.
5. Slag on the welding joint should be properly removed from each pass in multipass arc welds.

**C. Inspection after or Completion of Welding :**

1. Find out of determine properties and weld quality of a weld object.
2. Find out suitability of weldment with the help of :

i. Destructive testing, and

ii. Non destructive testing.

## Section-C

**3.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Using block diagram, classify the welding processes and explain the same.**

**Ans.**

**A. According to Source of Energy Employed for Heating :** These may be divided into two groups as follows :

**i. Pressure Welding :**

1. In these processes, the parts to be joined are heated to a plastic state and forced e.g., forge welding, thermit pressure welding etc., to form the joint.

**ii. Fusion Welding :**

1. In these processes, the material at the joint is heated to the molten state and allowed to solidify to make the joint, without the application of pressure.
2. Some joints may be made without the addition of a filler metal, but in general, a filler metal must be added to the weld to fill the space between the parts being welded.
3. The filler metal deposited should be of the same composition as the base metal. Examples are gas welding, electric arc welding etc.

**B. According to the Composition of Filler Metal :** These may be divided into three groups as follows :

**i. Autogenous Welding :**

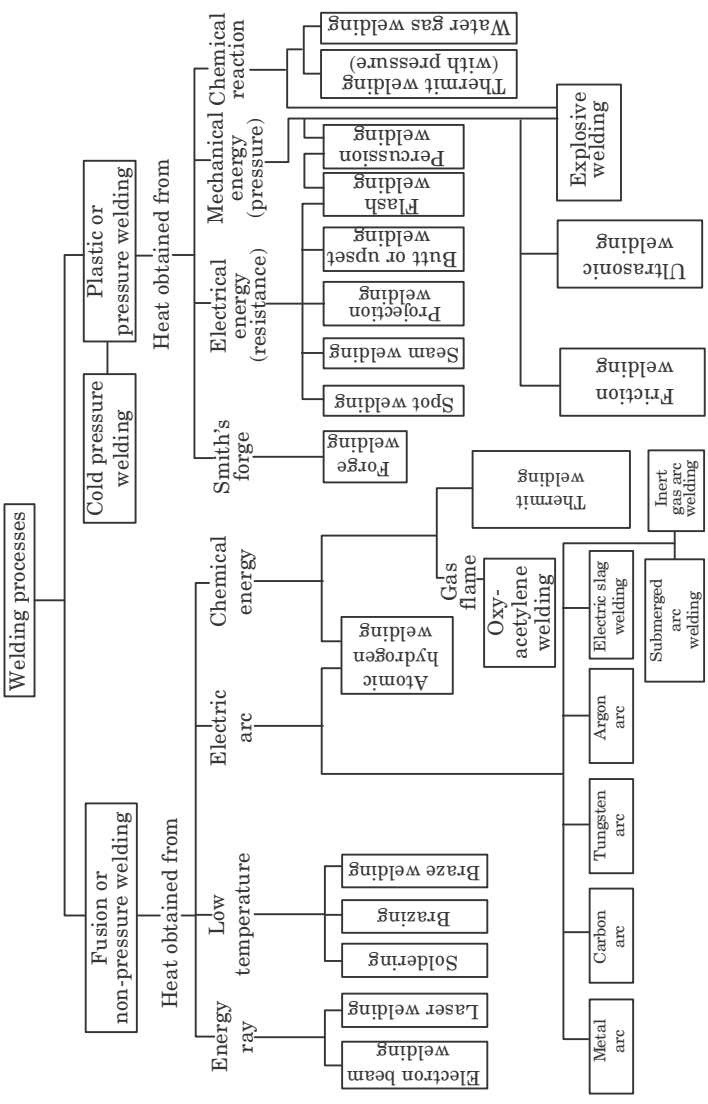
1. In these processes, no filler metal is added to the joint interface, for example, cold and hot pressure welding and electric resistance welding.

**ii. Homogeneous Welding :**

1. In these processes, filler metal is added and is of the same type as the parent metal, for example welding of plain low carbon steel with a low carbon welding rod and welding of 70-30 brass with a 70-30 brass welding rod etc.

**iii. Heterogeneous Welding :**

1. In these processes, a filler metal is used but is of a different type from the parent metal, for example brazing and soldering processes.




**b. What are the similarities and differences between casting and welding process ?**

**Ans.**

**A. Similarities :** Casting and welding are similar in that they are associated with transformation of liquid metal to solid metal for

fabrication, with all the considerations related to the directionality of solidification, segregation, gas entrapment, etc., being similar.

**B. Differences :**

| S. No. | Casting | Welding |
|---|---|---|
| 1. | In casting the mould wall does not interact with the solidifying liquid metal. | In welding mould walls interact with the liquid metal to participate in the solidification process to become an integral part of the weldment. |
| 2. | In casting the liquid metal is always added from an external source. | In welding, the liquid metal can be either be autogenously generated or introduced from an external filer metal source. |
| 3. | Casting will always involve liquid metal. | Welding may or may not involve liquid phase. |
| 4. | In the casting process, metal is melted and then poured as a liquid into a prepared mold. | Welding involves joining two pieces of solid metal by melting a small portion of each piece along the interface, and allowing the melt metal to flow together. |

**4.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Using neat sketch, explain TIG welding process. State its applications. What are the variants of TIG welding ?**

**Ans.**

**A. TIG Welding :**

1. It is an arc welding process wherein coalescence is produced by heating the job with an electric arc struck between a tungsten electrode and the job.
2. A shielding gas (argon, helium, nitrogen, etc.,) is used to avoid atmospheric contamination of the molten weld pool.

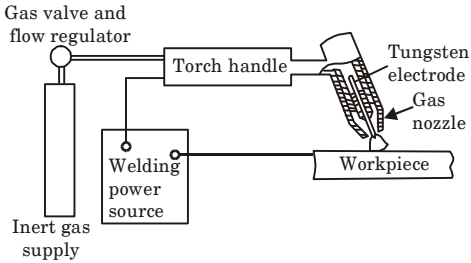



**Fig. 3.**

**B. Principle of Operation of TIG Welding :**

1. Welding current, water and inert gas supply are turned on.

2. The arc is struck either by touching the electrode with a scrap metal tungsten piece or using high frequency unit.
3. In this arc is initially struck on a scrap metal piece and then broken by increasing the arc length.
4. This procedure repeated twice or thrice that warms up the tungsten electrode.
5. The arc is then struck between the electrodes and precleaned job to be welded.
6. This method avoids breaking electrode tip, job contamination and tungsten loss.
7. TIG welding is also known as Gas Tungsten Arc Welding (GTAW).
8. Both the AC and DC power source can be used for GTAW.
9. Electrodes employed varies in diameter from 0.5 to 6.5 mm carrying current from 5 A to 6.5 A.
10. GTAW is an all position welding and gives the highest quality weld amongst commonly used arc welding processes.

**C. Applications of TIG Welding :**

1. Precision welding in atomic energy, aircraft, chemical and instrument industries.
2. Welding aluminium, magnesium, copper, nickel and their alloys etc.
3. Rocket motor chamber fabrications in launch vehicles.
4. Welding of expansion bellows, transistor cases and can-sealing joints.

**D. Variants of TIG Welding :**

1. Activated tungsten inert gas (A-TIG) welding and Flux bound tungsten inert gas (FB-TIG) welding are two such variants that utilize suitable activating flux to improve upon various characteristics of conventional TIG welding.
2. These processes are also called flux assisted TIG welding as they mandatorily require a layer of activating flux on the components to be joined.

**b. Explain the procedure of electron beam welding process. What are the difficulties encountered during EBW ? Support with neat sketch.**

**Ans.**

**A. Procedure of Electron Beam Welding :**

1. Electron beam welding can be defined as, a welding process wherein coalescence is produced by the heat obtained from a concentrated beam composed primarily of high velocity electrons impinging upon the joint to be welded.
2. The kinetic energy of the electrons is changed into heat on impact with work, giving intense local heating.
3. The electron beam is produced in a high vacuum environment by an electron gun usually consisting of a tungsten cathode, a grid or forming electrode and an anode.

4. A stream of electrons is given off from a tungsten filament heated to about 2200 °C.
5. The electrons are gathered, accelerated to high velocity and shaped into a beam by the potential difference between cathode and anode.
6. The beam is collimated and focused by passing through the field of an electromagnetic focusing coil or magnetic lens.
7. Beams are focused to about 0.25 to 1 mm diameter and have a power density of about 10 kW/mm$^2$, which is sufficient to melt and vaporise any metal.
8. The operation is carried out in a vacuum, which enables the beam source to be at a distance of upto about 1 m from the work.
9. Deep penetration with a very narrow heat affected zone is achieved by this process.
10. Aluminium can be fused upto a depth of about 40 mm, and stainless steel upto 30 mm, with a width of fusion area of about one-tenth of the penetration.

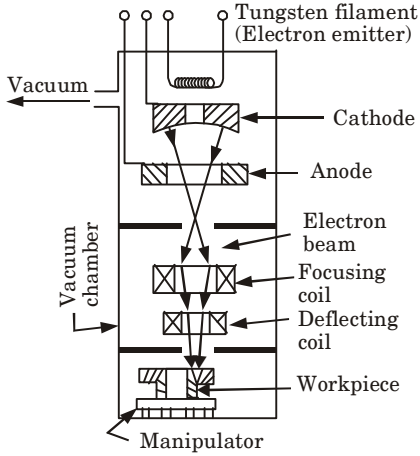



**Fig. 4.**

**B. Difficulties Encountered During EBW :**

1. In EBW or vacuum welding system, atmospheric scattering and energy absorption of the beam are negligible.
2. Moreover vacuum prevents the reduction of electron velocity however, the size of the vacuum chamber required naturally imposes serious limitation on the size of the workpiece that can obstruct the passage of beam and absorb some of its power.
3. Moreover if the welding is carried out in a vacuum chamber, considerable time is lost as the work chamber must be pumped down for each new workpiece.

4. These difficulties lead to the development of some electron beam machine that permit the workpiece to remain outside the vacuum chamber while it is being welded.

**5.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Explain any two destructive techniques for residual stress determination.**

**Ans.** Destructive techniques for residual stress determination are as follows :

**i. Ring Core (RC) Technique :**

1. Ring core (RC) technique, also known as the Trepan technique.
2. The technique involves cutting an annular groove into a component and the resulting surface strain relaxation within the central core is measured at predetermined depth increments using a strain gauge rosette (SGR) or optical methods.
3. The surface strain relaxation is then decomposed into residual stresses for each depth increment using numerically determined influence coefficients.
4. Typically, depths are limited to 5 mm for a standard 14 mm diameter core, but the use of different strain gauges and groove geometries will permit changes in total measurement depth
5. Analyse the depth and strain gauge data to calculate the residual stress

**ii. The Hole Drilling Technique :**

1. It is a technique for measuring residual stresses, in a material. Residual stress occurs in a material in the absence of external loads.
2. The hole drilling technique can measure macroscopic residual stresses near the material surface. The principle is based on drilling of a small hole into the material.
3. When the material containing residual stress is removed the remaining material reaches a new equilibrium state. The new equilibrium state has associated deformations around the drilled hole.
4. The deformations are related to the residual stress in the volume of material that was removed through drilling.
5. The deformations around the hole are measured during the experiment using strain gauges or optical methods. The original residual stress in the material is calculated from the measured deformations.

**b. What are the main types of weld distortion ? What are the causes for distortion ?**

**Ans.**

**A. Types of Distortion :**

**i. Longitudinal Shrinkage :**

1. When a weld is deposited lengthwise on a light, narrow and perfectly flat strip of metal that is neither clamped nor held in any way, the strip will tend to bow upward in the direction of bead. This is due to the longitudinal contraction of the weld metal as it cools.
2. Longitudinal contraction is maximum along the weld centre line and decreases towards the edges as shown in Fig. 5(*i*).
3. Longitudinal distortion depends upon the :

i. Contraction forces.

ii. Stiffness of the section being welded.

iii. Distance between the centroids of weld and section.

**ii. Transverse Shrinkage :**

1. When two plates being butt-welded together are neither too heavy nor held together, and are thus free to move, they will be drawn closer together by the contraction of the weld metal. This is called transverse contraction.
2. Transverse contraction exists all along the weld length and it depends upon the permanent contraction of elements in the weld zone as shown in Fig. 5(*ii*).
3. The transverse contraction can be prevented by,

i. Proper tack welding.

ii. Placing a wedge between the plates.

iii. Separating the plates (before welding) to provide allowance for contraction.

iv. Increasing the arc travel speed.

**iii. Angular Shrinkage :**

1. When two beveled plates are welded, it is found that the plates are pulled out of line with each other as shown in Fig. 5(*iii*).
2. Since the opening at the top of the single *V* groove is greater than at the bottom, a greater portion of the weld metal is deposited there, and thus the drawing or pulling is greatest on that side of the joint.
3. Angular contraction is related to the shape and size of the cooling weld metal zone and the stiffness of the remaining unfused part.
4. Double groove joints tend to minimize angular distortion because the contraction effects of the two sides, *i.e.*, top and bottom of the plate, get cancelled with each other.

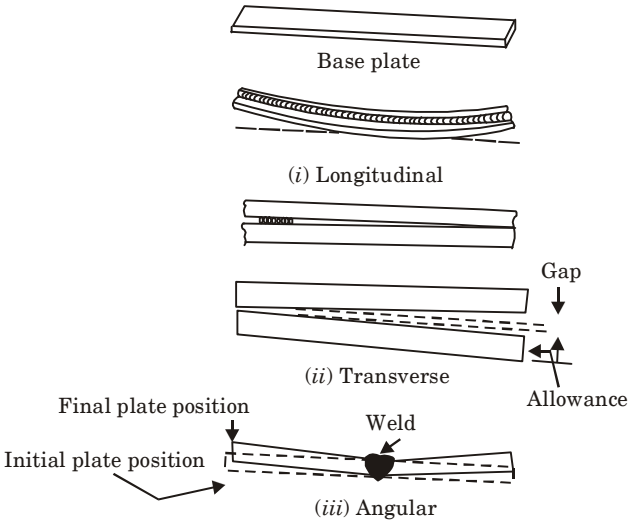



**Fig. 5.**

**B. Causes for Distortion :**

1. More number of passes with small diameter electrodes.
2. Slow arc travel speed.
3. High residual stresses in plates to be welded.
4. Using improper welding sequence.

**6.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Briefly discuss the welding of cast iron. What kinds of defects are expected in such welding and what are their remedies ?**

**Ans.**

**A. Welding of Cast Iron :**

1. There are different types of cast iron. Here we discuss the welding procedure of gray cast iron, it contains,

C = 2.5 – 3.8 % Si = 1.1 – 2.8 %
Mn = 0.4 – 1 % P = 0.15 %
S = 0.1 % Fe = Remaining

2. The welding of gray cast iron can be done by the following processes :

**i. Metal Arc Welding :**

1. A *V*-joint with included angle of 60° to 90° may be formed by chipping or machining.
2. The joint is carefully cleaned of all dust, dirt, oil, grease and paint.
3. Electrodes of cast iron, mild steel, austenitic stainless steel may be employed for welding gray cast iron.
4. The arc is struck by touching the electrode with the job. As the molten pool forms, the welding is carried out in the normal way.

5. In order to minimize the stresses set up in the workpiece, the weld may be laid in the short run and then each be allowed to cool.

**ii. Brazing :**

1. Brazing of gray cast iron is done to repair casting defects where strength and colour match are not of primary importance.
2. Brazing of cast iron requires special pre-cleaning methods to remove graphite from the surface of iron because the presence of graphite on the cast iron surface would prevent wetting and adhesion of the brazing alloy.
3. It carried out at temperature as low as feasible, in order to avoid reduction in the strength of iron.
4. Brazing is generally done with an oxy-acetylene torch and a neutral or slightly carburizing flame.
5. Preheating between 205 °C to 427 °C before torch or induction brazing may produce better results.

**B. Defects and Remedies in Welding of Cast Iron :**

**i. Undercut :**

1. Undercut is a kind of weld defect which forms a groove in the parent metal along the sides of the weld bead.
2. Groove reduces the thickness of the plate and also reduces the strength of the weld.

**a. Remedies of Undercut :**

1. Use proper arc current.
2. Use proper electrode.
3. Weaving should be proper and as per requirement.

**ii. Hot Tear :**

1. In this welding defect the deposited metal being hot, starts developing crack from the nearby edge so that after it has been solidified the crack increases.

**a. Remedies of Hot Tear :**

1. Select proper electrode material.
2. Welding current should be optimum as per the requirement.
3. Electrode thickness should be optimum and according to the base metal to be welded.

**b. Explain in detail aluminium welding by double-operator method.**

**Ans.**

1. Aluminium welding by double operator method as shown in Fig. 6.
2. The oxide of aluminium (alumina $Al_2O_3$) which is always present as a surface film and which is formed when aluminium is heated, has a very high melting point, much higher than that of aluminum.
3. If it is not removed it would become distributed throughout the weld, resulting in weakness and brittleness.
4. The work should be cleaned of grease and brushed with a wire brush-sheets below 20 gauge can be turned up at right angles and the weld made without a filler rod.

5. Aluminium, when near its melting point is extremely weak, and much trouble can be avoided by seeing that no collapsing can occur during the welding operation.
6. The flame is adjusted to have a very slight excess of acetylene and then adjusted by neutral and rod of pure aluminium or 5 % silicon-aluminium alloy should be little thicker then the section to be welded.
7. The double-operator method is used on sheets above 6 mm thickness, the angle of the blow pipes being 50 – 60° and the rods 70 – 80°.
8. This method gives a great increase in welding speed.

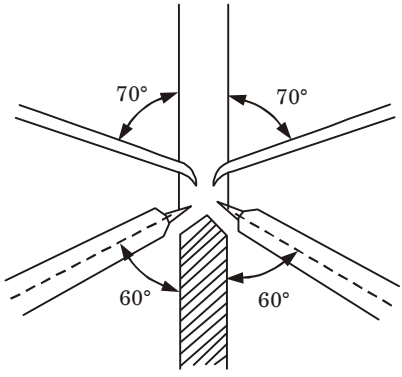



**Fig. 6.**

**7.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Explain any five welding defects along with the causes and remedies.**

**Ans.** Welding defects and its causes and remedies are as follows :

**i. Incomplete Penetration :**

1. Incomplete penetration occurs when the depth of the welded joint is insufficient.
2. Penetration is defined as the distance from base plate's top surface to the maximum extent of the weld nugget.

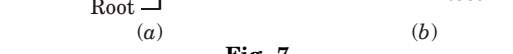



**Fig. 7.**

**a. Causes of Incomplete Penetration :**

1. Improper joints.
2. Too large root face.
3. Less arc current and faster arc travel speed.
4. Too large electrode diameter and longer arc length.

**b. Remedies of Incomplete Penetration :**

1. Increasing the heat input.
2. Reducing the travel speed during the welding.
3. Changing the joint design.
4. Ensuring that the surfaces to be joined fit properly.

**ii. Inclusion :**

1. Inclusions may be in the form of slag or any other foreign material, which does not get a chance to float on the surface of the solidifying weld metal and thus gets entrapped inside the same.
2. Inclusions lower the strength of the joint and make it weaker.

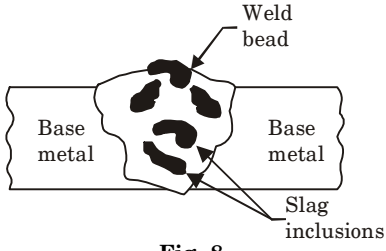



**Fig. 8.**

**a. Causes of Inclusion :**

1. Too high or too low arc current.
2. Long arc and too large electrode diameter.
3. Insufficient chipping and cleaning of previous passes in multipass welding.
4. Wrongly placed tack welds.
5. Too small included angle of the joint.

**b. Remedies of Inclusion :**

1. Cleaning the weld bead surface before the next layer is deposited, by means of a wire brush.
2. Providing sufficient shielding gas.
3. Redesigning the joint so as to permit sufficient space for proper manipulation of the puddle of molten weld metal.

**iii. Porosity and Blowholes :**

1. Porosity is a group of small voids and blowholes are comparatively bigger isolated holes or cavities.
2. They are mainly generated due to the entrapped gases.

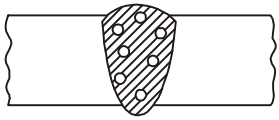


**Fig. 9.**

**a. Causes of Porosity and Blowholes :**

1. Use of improper electrode and longer arc.
2. Faster arc travel speeds.
3. Too low and too high arc currents.
4. Unclean job surface *i.e.*, presence of scale, rust, oil and grease etc., on the surface of the job.
5. Due to the gas entrapment during solidification of weld.

**b. Remedies of Porosity and Blowholes :**

1. Proper selection of electrodes and filler metals.
2. Improved welding techniques such as preheating of the weld area or an increase in the rate of heat input.
3. Proper cleaning and the prevention of contaminants from entering the weld zone.
4. Reduced welding speeds, to allow time for gas to escape.

**iv. Spatter :**

1. Spatters are the small metal particles which are thrown out of the arc during welding and get deposited on the base metal around the weld bead along its length.

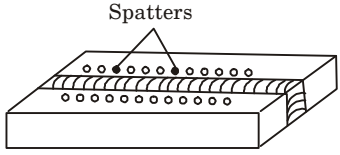



**Fig. 10.**

**a. Causes of Spatter :**

1. Excessive arc current.
2. Use of longer arc.
3. Use of damp electrodes.
4. Electrodes being coated with improper flux ingredients.
5. Arc blow making the arc uncontrollable.

**b. Remedies of Spatter :**

1. Use proper arc current to weld.
2. Use proper arc length.
3. Use fresh electrodes.
4. Use of AC power to reduce arc blow.

**v. Undercut :**

1. Undercut is a kind of weld defect which forms a groove in the parent metal along the sides of the weld bead.
2. Groove reduces the thickness of the plate and also reduces the strength of the weld.

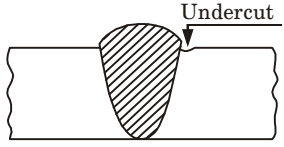



**Fig. 11.**

**a. Causes of Undercut :**

1. Wrong manipulation and inclination of electrode and excessive weaving.
2. Too large electrode diameters.
3. Higher current.
4. Longer arc.
5. Faster arc travel speed.

**b. Remedies of Undercut :**

1. Use proper arc current.
2. Use proper electrode.
3. Weaving should be proper and as per requirement.
4. Use proper arc travel speed.

**b. Using neat sketches, broadly categorize the welding joints. Also draw sketches for the different welding positions.**

**Ans.**

**A. Classification of Welding Joint :** Various types of welded joints used in weld design are as follows :

**i. Butt Joint :**

1. Square butt joints (with or without gap) are recommended for smaller plate thicknesses (upto 4.8 mm) and much lesser loading as compared to single *V*, *U*, *J* or bevel joints.
2. Double joints are preferred over single joints for bigger plate thicknesses.
3. Out of various joints, *V* joint finds much more extensive use and applications.

**ii. Lap Joint :**

1. Single fillet and double fillet joints are used on all thicknesses.
2. Double fillet joint is better as compared to single fillet joint when joint is subjected to severe loading.
3. Single fillet joints are not recommended on plates under bending, fatigue or impact loading conditions.
4. Plug weld is employed to impart added strength to the structure. This plug weld joint is used where bottom or second plate cannot be accessed easily.

**iii. *T* Joint :**

1. Single fillet *T* joint is preferred for smaller plate thicknesses when subjected to low or no bending load conditions.
2. Double *T* joint is recommended for most severe loading conditions.
3. In *T* joint cost of edge preparation increases and electrode consumption decreases.

**iv. Corner Joint :**

1. For smaller thickness plates and not subjected to severe loading, close and half open corner joints.
2. Full open corner joint can be used on plates of all thicknesses under severe load conditions.

3. The load bearing capacity increases when the joint is welded from both sides.

**v. Edge Joint :**

1. Two pieces of metals are lapped, with their edges in line and the pieces are joined by welding the two edges together.
2. Fillet welds (*i.e.*, corner joint, *T* joint, lap joint etc.) are the cheapest type of welds to make, as no edge preparation is required and setting up is simple.

**B. Different Welding Positions :**

The location of weld is indicated by an arrow and a reference line. For Example :

i. When the weld symbols is below the reference line the weld is made on the same side of the joint as the arrow head, *i.e.*, the arrow side Fig. 12(i).

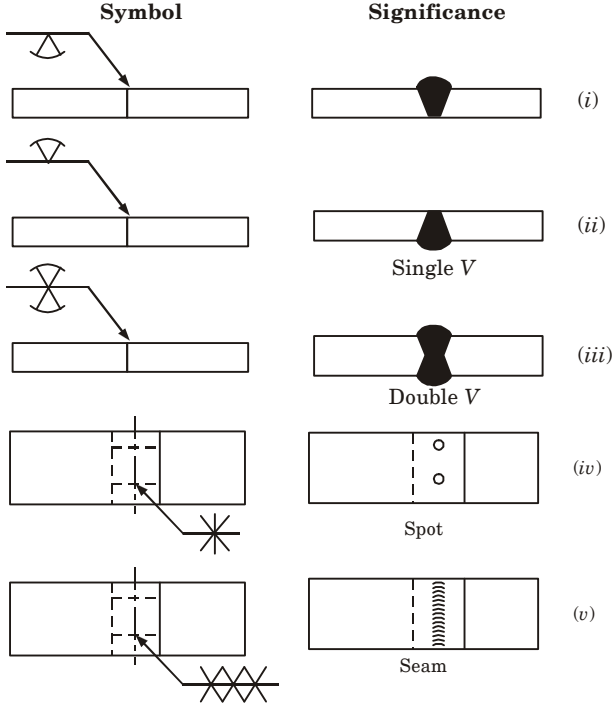



**Fig. 12.**

ii. When the weld symbol is above the reference line, the weld is made on the other side of the joint opposite the arrow head Fig. 12(ii).
iii. When the weld symbol is on both sides of the reference line, the welding is to be carried out on both sides of the joint Fig. 12(iii).
iv. When resistance welds are to be indicated, the arrow shall point towards the centre line along which the welds are to be made Fig. 12(iv) and Fig. 12(v).

# B.Tech.
# (SEM. VIII) EVEN SEMESTER THEORY EXAMINATION, 2018-19
# ADVANCE WELDING TECHNOLOGY

**Time : 3 Hours** **Max. Marks : 100**

**Note :** **1.** Attempt **all** section. If require any missing data; then choose suitable.

## Section-A

**1.** Attempt **all** questions in brief : **(2 × 10 = 20)**

**a. What types of welded joints used in welding ?**

**b. What do you mean by cladding and surfacing ?**

**c. Define welding. Make comparison with other joining process.**

**d. Describe various welding symbols.**

**e. Write short note on arc blow in welding process.**

**f. What is weld distortion and its prevention ?**

**g. Explain weld affected zone.**

**h. List different type of brazing techniques available. Explain any one in detail.**

**i. What is physics of arc welding ?**

**j. Define reclamation welding.**

## Section-B

**2.** Attempt any **three** of the following : **(10 × 3 = 30)**

**a. Make comparison between laser beam welding and electron beam welding.**

**b. Explain type of underwater welding and their working mechanisms.**

**c. List various types of weld defects and explain any two with neat diagram.**

**d. Explain the effects of various alloying elements on weldability.**

**e. Write short note on use of transformer, rectifier and generators in welding.**

## Section-C

**3.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. What do you mean by heating and cooling rate ? How it affects the properties of weld ?**

**b. What are the methods used for measuring the stresses in weld structure ? Explain any one of them.**

**4.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. What do you mean by metallizing and hardfacing ? Explain process giving its advantages and applications.**

**b. Write short note on :**

**i. Welding of cast iron.**

**ii. Welding of low carbon steel.**

**iii. Welding of aluminum.**

**5.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Discuss the principle and working of ultrasonic inspections. Also describes its advantages, limitations and applications.**

**b. Define cracking of weld. Explain hot cracking and cold cracking. List the rules that must be followed to avoid cracking.**

**6.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. What do you understand by explosive welding ? Write its advantages, disadvantages and applications in detail.**

**b. Explain the principle and working of FCAW welding. Differentiate MIG and FCAW. What variables affect weld quality of FCAW welding ?**

**7.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. The arc length voltage characteristic is given by expression $V = 24 + 4L$ ($L$ = Length of arc in mm). The volt ampere characteristics of power source can be approximated by a**

**straight line with open circuit voltage 80 V and short circuit current 600 A. Determine optimum arc length and maximum power.**

**b. Explain in detail the mechanism and types of metal transfer in various arc welding processes.**

# SOLUTION OF PAPER (2018-19)

**Note :** **1.** Attempt **all** section. If require any missing data; then choose suitable.

## Section-A

**1.** Attempt **all** questions in brief : **(2 × 10 = 20)**

**a. What types of welded joints used in welding ?**

**Ans.** The main types of welded joints are as follows :

1. Butt joint,
2. Lap joint,
3. T-joint,
4. Corner joint, and
5. Edge joint.

**b. What do you mean by cladding and surfacing ?**

**Ans.** **Cladding :** Cladding is the covering of one material with another. In metallurgy, cladding is the bonding together of dissimilar metals.
**Surfacing :** Surfacing is the process of depositing filler metal by arc or gas welding on a metal surface to obtain desired properties or dimensions.

**c. Define welding. Make comparison with other joining process.**

**Ans.** **Welding :**
Welding is defined as localised coalescence of metal, wherein coalescence is obtained by heating to suitable temperature, with or without application of pressure and with or without use of filler metal.
**Comparison :**

| S. No. | Welding | Soldering | Brazing |
|---|---|---|---|
| 1. | The strength of the joint is highest comparing to soldering and brazing. | The soldered joints are weakest among the welding and brazing. | The brazed joints are stronger than soldered joint but weaker than welded joints. |
| 2. | The composition of filler metal is normally same as that of base metal. | Essentially filler metals are alloys of lead and tin. | The filler metals are alloys of copper. |

**d. Describe various welding symbols.**

**Ans.** Various welding symbols are as follows :

| S. No. | Type of Weld | Symbol |
|---|---|---|
| 1. | Fillet |  |
| 2. | Square Butt |  |
| 3. | Single V-Butt |  |
| 4. | Double V-Butt |  |
| 5. | Spot |  |

**e. Write short note on arc blow in welding process.**

**Ans.**

1. The unwanted deflection or the wandering of a welding arc from this intended path is termed as arc blow.
2. Arc blow is the result of magnetic disturbances which unbalance the symmetry of the self-induced magnetic field around the electrode, arc and workpiece.

**f. What is weld distortion and its prevention ?**

**Ans.** **Weld Distortion :** An object is said to be distorted when it is put out of shape or it becomes unshapely.

**Prevention :**

1. Use double sided welds rather than single sided.
2. Use minimum gap sizes.
3. Use clamps, strong back, jigs or fixtures.
4. Make use of sub assemblies.

**g. Explain weld affected zone.**

**Ans.** Weld affected zone is formed as the weld metal solidifies from the molten state. This is a mixture of parent metal and electrode (or filler metal), the ratio depending upon the welding process used, the type of joint, the plate thickness etc.

**h. List different type of brazing techniques available. Explain any one in detail.**

**Ans.** **Brazing Techniques :**

1. Furnace brazing,
2. Dip brazing,
3. Induction brazing, and
4. Torch brazing etc.

**Torch Brazing :**

1. It is the most commonly used method, heat is provided in this process by usual gas welding torch by burning acetylene and oxygen gases.

2. Oxy-hydrogen torches are also used for brazing aluminium and other non-ferrous metals.

**i. What is physics of arc welding ?**

**Ans.** It deals with complex physical phenomena associated with welding including heat, electricity, magnetism, light etc.

**j. Define reclamation welding.**

**Ans.** Reclamation welding is the simplest form of reclamation where the metallic components are joined together, if cracked/broken, with the use of suitable electrode using arc welding.

## Section-B

**2.** Attempt any **three** of the following : **(10 × 3 = 30)**

**a. Make comparison between laser beam welding and electron beam welding.**

**Ans.**

| S. No. | Parameters | Electron Beam Welding | Laser Beam Welding |
|---|---|---|---|
| 1. | Penetration | Deep penetration | Lack penetration |
| 2. | Power efficiency | 80–90 % | 7–10 % |
| 3. | Running cost | Cooling water electricity | Consumption of shield gas high electricity requires high purity water in cooling system to cool beam source |
| 4. | Generation of *X*-rays | Generated | Not generated |
| 5. | Size of workpiece | Narrower | Narrow |
| 6. | Cost | High | Low |
| 7. | Surrounding environment | Performed in a high vacuum environment | Performed in air or shielding gas |

**b. Explain type of underwater welding and their working mechanisms.**

**Ans.** Types of underwater welding are as follows :

**i. Wet Welding :**

1. In this welding process, the work to be welded is connected to one side of an electric circuit, and a metal electrode to the other side.

2. These two parts of the circuit are brought together, and then separated slightly.
3. The electric current jumps the gap and causes a sustained spark, which melts the bare metal, forming a weld pool.
4. At the same time, the tip of electrode melts, and metal droplets are projected into the weld pool.
5. During this operation, the flux covering the electrode melts to provide a shielding gas, which is used to stabilize the column and shield the transfer metal.
6. The arc burns in a cavity formed inside the flux covering which is designed to burn slower than the metal barrel of the electrode.

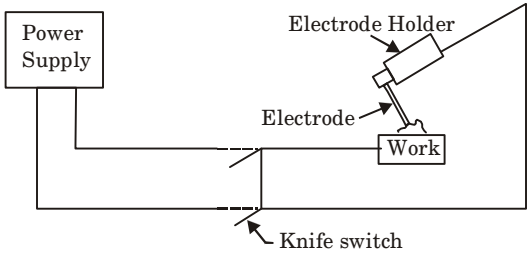



**Fig. 1.**

**ii. Dry Welding :**

1. This is carried out in a chamber, sealed around the structure to be welded.
2. The chamber is filled with a gas commonly helium (He) containing 0.5 bar of oxygen at the prevailing pressure.
3. The habitat is sealed onto the pipeline and filled with a breathable mixture of helium and oxygen, at or slightly above the ambient pressure at which the welding take place.
4. This method produces high quality weld joints that meet *X*-ray and code requirements.
5. The gas tungsten arc welding process is employed for this process.
6. The area under the floor of the habitat is open to water.
7. Thus welding is done in the dry but at the hydrostatic pressure of the sea water surrounding the habitat.

**c. List various types of weld defects and explain any two with neat diagram.**

**Ans.**

**A. Types of Weld Defects :** Types of weld defects are as follows :

1. Incomplete penetration,
2. Inclusion,
3. Porosity and blowholes,
4. Spatter,
5. Undercut, and
6. Hot tear.

**B. Incomplete Penetration :**

1. Incomplete penetration occurs when the depth of the welded joint is insufficient.
2. Penetration is defined as the distance from base plate's top surface to the maximum extent of the weld nugget.

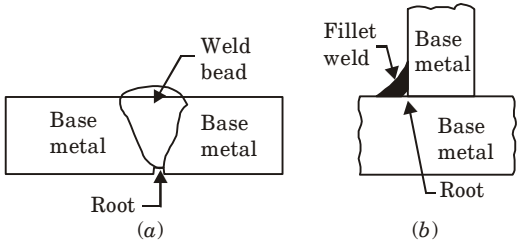



**Fig. 2.**

**i. Causes of Incomplete Penetration :**

1. Improper joints.
2. Too large root face.
3. Less arc current and faster arc travel speed.
4. Too large electrode diameter and longer arc length.

**ii. Remedies of Incomplete Penetration :**

1. Increasing the heat input.
2. Reducing the travel speed during the welding.
3. Changing the joint design.
4. Ensuring that the surfaces to be joined fit properly.

**C. Inclusion :**

1. Inclusions may be in the form of slag or any other foreign material, which does not get a chance to float on the surface of the solidifying weld metal and thus gets entrapped inside the same.
2. Inclusions lower the strength of the joint and make it weaker.

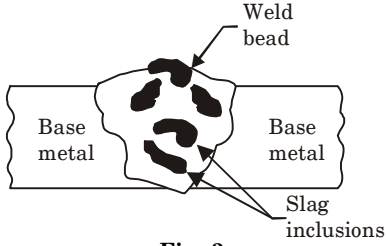



**Fig. 3.**

**i. Causes of Inclusion :**

1. Too high or too low arc current.
2. Long arc and too large electrode diameter.
3. Insufficient chipping and cleaning of previous passes in multipass welding.
4. Wrongly placed tack welds.

5. Too small included angle of the joint.

**ii. Remedies of Inclusion :**

1. Cleaning the weld bead surface before the next layer is deposited, by means of a wire brush.
2. Providing sufficient shielding gas.
3. Redesigning the joint so as to permit sufficient space for proper manipulation of the puddle of molten weld metal.

**d. Explain the effects of various alloying elements on weldability.**

**Ans.**

1. Alloying elements increase or decrease hardenability of the HAZ. C, Mn, Mo, Cr, V, Ni and Si have greatest effect on the hardenability of steel.
2. Alloying elements provide grain refinement. Al, V, Ti, Zr and N are the grain refiners for carbon and low alloy steels.
3. Alloying elements control ductile to brittle transformation temperature.
4. Alloying elements form substitutional alloys and strengthen the metal by solid solution hardening.
5. Alloying elements form interstitial alloys to increase mechanical properties by lattice distortion.
6. Alloying elements form carbides, age hardening precipitates and reduce segregation.
7. Alloying elements also provide grain refinement.
8. Alloying elements provide deoxidation of molten metal without loss of primary alloying elements. Ti, Zr, Al, Si have affinity for oxygen than iron and thus act as deoxidizers in carbon and low alloy steels.

**e. Write short note on use of transformer, rectifier and generators in welding.**

**Ans.**

**A. Use of Transformer :**

1. Welding transformers are used in AC machines to change alternating current from the power line into a low-voltage, high amperage current in the secondary winding.
2. A combination of primary or secondary taps on the welding transformer is commonly used to provide a macro adjustment of the welding current, as well as adjustment of secondary voltage.
3. Transformer ratings for AC machines are expressed in kilovolt-amperes for a specified duty cycle.
4. This duty cycle rating is a thermal rating, and indicates the amount of energy that the transformer can deliver for a stated percentage of a specific time period, usually one minute, without exceeding its temperature rating.

5. Since heating is a function of the welding current, this parameter gives an indication of the thickness of the materials that can be welded.

**B. Use of Rectifier :**

1. The rectifier may consist of metal plates coated with a selenium compound or silicon diodes, each unit having the special property of allowing the current to flow in one direction only.
2. Rectifier units are designed to provide a choice of low voltage for MIG and submerged welding or a high open circuit with drooping voltage characteristics for TIG and flux shielded metal arc welding.

**C. Use of Generators :**

1. A DC welding generator produces direct current in either straight or reverse polarity. The polarity selected for welding depends upon the kind of electrode used and the material to be welded.
2. A DC generator is powered either by an electric motor or a diesel engine. Diesel operated generator sets are suitable for out-door applications or other areas where power is not available.

## Section-C

**3.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. What do you mean by heating and cooling rate ? How it affects the properties of weld ?**

**Ans.**

**A. Heating Rate :**

1. The heating rate of a work piece depends on how hot the heat source is and how efficiently that heat is transferred to the work.
2. A higher temperature at the source means a steeper temperature gradient between it and the work, and so the heating rate will be faster.

**B. Cooling Rate :**

1. It is defined as the difference in the austenitizing temperature and quench temperature divided by the time to cool within some value of calculation of cooling rate on the centre line of the weld.

**C. Effect of Heating Rate :**

1. The welding heat input has a great influence on the weldments properties.
2. Mechanical properties and toughness of weldment depend on microstructure of weld metal.
3. The cross sectional area of a weld is generally proportional to the amount of heat input.
4. A change in microstructure directly affects the mechanical properties of weld. Therefore, the control of heat input is very important in arc welding in terms of quality control.

**D. Effect of Cooling Rate :**

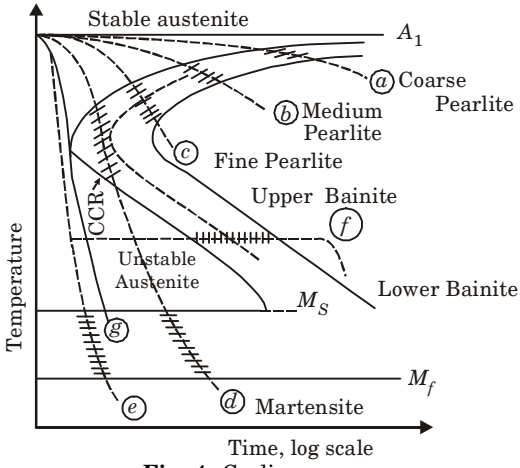



**Fig. 4.** Cooling curves.

1. Cooling curve (*a*) shows very slow cooling rate (conventional annealing) and it forms a course pearlite with low hardness.
2. Cooling curve (*b*) involves a faster cooling rate than curve (*a*) (normalizing) and it forms the fine pearlite.
3. Cooling curve (*c*) involves a slow oil quench cooling; this results in a mixture of medium and fine pearlite.
4. Cooling curve (*d*) is typical of an intermediate cooling rate and results into the martensite and fine pearlite structure.
5. Cooling curve (*e*) is a drastic quench and results into the formation of martensite structure.
6. Cooling curve (*f*) obtains a bainite structure by cooling rapidly enough to miss the nose of curve and then holding in the temperature range at which bainite is formed until transformation is completed.
7. Cooling curve (*g*) is tangent to the nose of TTT curve.
8. The curve (*g*) is critical cooling rate (CCR) for the steel.
9. If cooling rate > CCR $\Rightarrow$ Martensite structure will form.
10. If cooling rate < CCR $\Rightarrow$ Some softer transformation products such as pearlite or bainite will form.

**b. What are the methods used for measuring the stresses in weld structure ? Explain any one of them.**

**Ans.**

**A. Stress Measuring Method :** Various methods are used for the measurement of stress some of them are as follows :

i. Strain gauge method,
ii. Brittle coat method, and
iii. Photostress techniques.

**B. Brittle Coat Method :**

1. This method makes use of a brittle coating also known as brittle lacquer or stress coat which is basically a limed wood rosin K and dibutyl phthalate with carbon disulphide as a solvent. The brittle coating is commercially available.
2. An appropriate coating for the existing temperature and humidity conditions is selected.
3. The job and the calibration strips are thoroughly cleaned and given an aluminium pre-coating to provide a bright background for facilitating the observation of the cracks.
4. Job and the calibration strips are sprayed with brittle coating and permitted to dry for 15 to 24 hours. The coat or lacquer becomes brittle on hardening.
5. At the place in the job where residual stress pattern and magnitude is to be determined, a hole of about 3 mm diameter is drilled.
6. The calibration strip is subjected to biaxial tensile stresses and the point to initial cracking is marked and the strain in the strain scale is read.
7. Residual stresses are calculated by comparing the results of the stress coat on the job with those of a calibration strip.
8. Brittle coat method gives quantitative results accurate to within ± 10 % and can be used to detect static and dynamic strains in tension or compression. In this method,

1. Usual gauge length is very small.
2. Approximate smallest measurable strain is $5 \times 10^{-4}$ mm/mm.
3. Approximate range of strains % is 0.05 to 0.15.

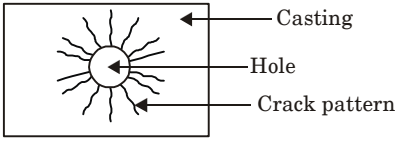



**Fig. 5.**

**4.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. What do you mean by metallizing and hardfacing ? Explain process giving its advantages and applications.**

**Ans.**

**A. Metallizing :**

1. The material to be sprayed is taken in powder or wire form and fed into the oxy-acetylene flame. There it melts by the heat of the neutral flame, gets atomized and blown by a stream of compressed air onto the base metal surface where it spreads around and interlocks with projections imbedded in pits, and freezes quickly upon contact with the base metal surface.
2. Separate particles overlap and intertwine with one another to form a coherent structure.

3. The sprayed material is generally applied in layers less than 0.25 mm thick.

**i. Advantages of Metallizing :**

1. This is approximately 70 % less costly than flame spraying.
2. No combustion gases are required thus eliminating all problems and dangers associated with these gases.
3. This can be interrupted and resumed at any time by simply engaging and disengaging the wire feed mechanism.
4. This requires less surface preparation than flame spraying.

**ii. Applications of Metallizing :**

1. This is used in production of portable water tanks, bridges, locks and dam gates, oil platforms, power transmission poles etc.

**B. Hardfacing :**

1. In hardfacing, metal is deposited over another surface to increase the hardness of the surface, and to make the surface of material resistant to abrasion, convolution, impact, erosion, etc.
2. One of the most important applications of hardfacing is abrasion resistance.
3. In general purpose three layers of hardfacing alloys are deposited as effectiveness of the hardfacing reduces excessive dilution.

**i. Advantages :**

1. This increases the service life of the product.
2. This imparts the corrosion resistance.
3. The cost of this process is less as compared to other processes.
4. Less skilled worker is required.

**ii. Applications of Hardfacing :**

1. This is extensively used in construction equipments including bulldozer blades, scraper blades, textile industries equipments and engine valve facing.

**b. Write short note on :**

**i. Welding of cast iron.**

**Ans.**

1. There are different types of cast iron. Here we discuss the welding procedure of gray cast iron, it contains,

C = 2.5 – 3.8 % Si = 1.1 – 2.8 %
Mn = 0.4 – 1 % P = 0.15 %
S = 0.1 % Fe = Remaining

2. The welding of gray cast iron can be done by the following processes :

**i. Metal Arc Welding :**

1. A *V*-joint with included angle of 60° to 90° may be formed by chipping or machining.
2. The joint is carefully cleaned of all dust, dirt, oil, grease and paint.
3. Electrodes of cast iron, mild steel, austenitic stainless steel may be employed for welding gray cast iron.

4. The arc is struck by touching the electrode with the job. As the molten pool forms, the welding is carried out in the normal way.
5. In order to minimize the stresses set up in the workpiece, the weld may be laid in the short run and then each be allowed to cool.

**ii. Brazing :**

1. Brazing of gray cast iron is done to repair casting defects where strength and colour match are not of primary importance.
2. Brazing of cast iron requires special pre-cleaning methods to remove graphite from the surface of iron because the presence of graphite on the cast iron surface would prevent wetting and adhesion of the brazing alloy.
3. It carried out at temperature as low as feasible, in order to avoid reduction in the strength of iron.
4. Brazing is generally done with an oxy-acetylene torch and a neutral or slightly carburizing flame.
5. Preheating between 205 °C to 427 °C before torch or induction brazing may produce better results.

**ii. Welding of low carbon steel.**

**Ans.**

1. Low carbon steel is most widely used for welding in industries because of its strength, its workability under fabricating methods and its relatively low price.
2. Low carbon steels may be welded by any of the commonly used welding processes, the choice depending upon section thickness and quality requirements.
3. Plate thicknesses above 25 mm need preheat, controlled interpass temperature and postwelding stress relief to avoid cracking and to maintain toughness, strength and ductility.
4. Welding processes employed for welding low carbon steels are as follows :
   i. Oxy-acetylene welding,
   ii. Flux shielded metal arc welding,
   iii. Submerged arc welding,
   iv. Gas metal arc welding,
   v. Gas tungsten arc welding,
   vi. Plasma arc welding,
   vii. Thermit welding,
   viii. Resistance welding,
   ix. Electroslag welding, and
   x. Brazing.
5. Flux shielded metal arc welding is commonly used for welding low carbon steels. Both mild steel and low hydrogen electrodes are employed for the purpose.
6. Oxy-acetylene welding is also frequently used to weld low carbon steels.

7. The selection of filler rod depends upon the base metal composition. A neutral flame is used for welding. Backhand technique is preferred and no flux is needed.

**iii. Welding of aluminum.**

**Ans.**

1. In the metallic arc welding of aluminium there remains a tendency to unsoundness in the welds.
2. The arc between the electrode and the job is struck by scratching action.
3. Electrode has to be scratched very hard against the job to strike the arc because of the insulation afforded by the flux coating on the electrode and the oxide film on the metal.
4. A short arc is maintained, the electrode is held at right angle to the work, the electrode coating almost touches the molten pool and no weaving is done.

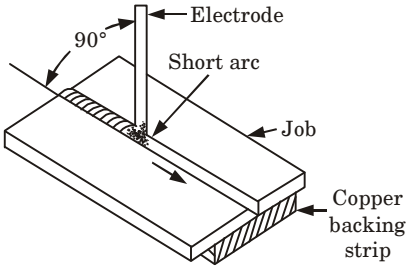



**Fig. 6.**

5. The arc is so directed that both edges of the joint to be welded are properly and uniformly heated.
6. The rate of welding should be uniform. As the metal warms up, the speed of welding must be increased.

**5.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. Discuss the principle and working of ultrasonic inspections. Also describes its advantages, limitations and applications.**

**Ans.**

**A. Principle and Working of Ultrasonic Inspections :**

1. Ultrasonic waves are usually generated by the piezoelectric effect and quartz crystal is used for this purpose.
2. When a high frequency AC current is impressed across the faces of the quartz crystal, the crystal will expand during the first half of the cycle and contracts in the next half cycle and produced a mechanical vibration in the quartz crystal.
3. The job surface that is to be inspected is made fairly smooth by machine (or by other processes) so that ultrasonic waves can be efficiently transmitted from the probe into the job and even small defects can be detected properly.

4. In ultrasonic inspection separate probes, one for transmitting the waves and other to receive them after passage through the welded jobs are used.

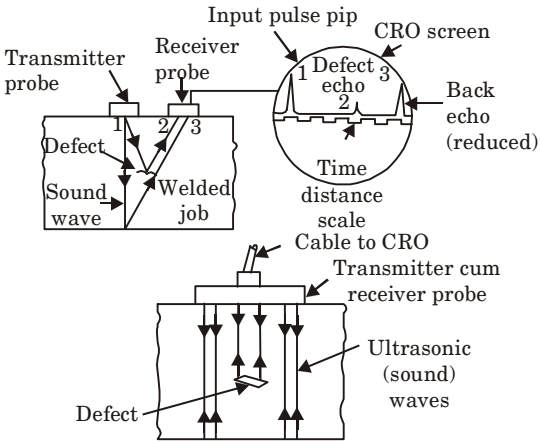



**Fig. 7.**

5. Before transmitting ultrasonic waves, an oil film is provided between the probe and job surface to ensure proper contact between them and better transmission of waves from the probe into the surface of the object to be tested.
6. For operation, ultrasonic wave is introduced into the metal and the time interval between transmission of the outgoing and reception of the incoming signals is measured with a cathode ray oscilloscope (CRO).
7. Time base of CRO is adjusted such that the full width of the trace represents the section being examined.
8. As the wave is sent from the transmitter probe, it strikes the upper surface of the job and makes a sharp (peak) or pip (echo) at the left hand side of the CRO screen.
9. If job is defect free then this wave will strike the bottom surface of the same, gets reflected and indicated by a pip towards the right hand end of the CRO screen.
10. If a defect is present in between the top and bottom surfaces, most of the beam striking this defect will get reflected from the defect, reach the receiver probe and indicate a pip (echo) on the CRO screen before the pip given by the waves striking the far end of the job and returning.
11. The distance of the defect from the surface where transmitter probe is applied can be determined with the help of a time distance scale in the form of a square wave constantly shown on CRO.

**B. Advantages of Ultrasonic Inspections :**

1. This method is fast, reliable NDT. It is more sensitive to locate flaws within the metallic objects than radiography.
2. About 0.1 % of the distance from the probe can be detected for the presence of defect.
3. It involves low cost and high speed of operation.
4. The sensitivity of ultrasonic flaw detection is extremely high, being at a maximum when using waves of highest frequency.

**C. Limitations of Ultrasonic Inspections :**

1. Testing surface of the job must be ground, smooth and clean.
2. Skilled and trained operator is required.
3. It cannot examine the complex shape or configuration.

**D. Applications of Ultrasonic Inspections :**

1. For inspecting large weldments, castings and forgings for internally defect free portion before carrying out expensive machining operations.
2. For inspecting the moving strips or plates to ensure their thickness.
3. For inspecting fatigue cracks in wheel pins and locomotive axles.
4. For inspecting rails for bolt-hole breaks.

**b. Define cracking of weld. Explain hot cracking and cold cracking. List the rules that must be followed to avoid cracking.**

**Ans.**

**A. Cracking of Weld :**

1. Cracking is a weld defect that may appear on the weld surface or under the weld bead.
2. The cracking in the material is due to insufficient strength or ductility at the relevant stage to tolerate the welding stresses which exceed the fracture stresses.
3. Cracking may occur in weld metal, heat affected zone (HAZ) or in both.

**B. Hot Cracking :**

1. Cracking occurs at a high temperature just below the freezing point is known as hot cracking.
2. Hot cracking is influenced by the sulphur and carbon content of mild steel weld metals because sulphur tends to form a compound iron sulphide (FeS) which can form a low melting point eutectic of Fe/FeS and segregate to form a network at the grain boundaries of the steel and it remains liquid after the metal has frozen.

3. There is no cohesion between the grains and the weld metal which may tear apart under contractional stresses.
4. Hot crack may be continuous or discontinuous. It often extends from the weld root and may not extend to the face of the weld.

**C. Cold Cracking :**

1. Cold cracking is generally observed at room temperature.
2. Cold cracking occurs in both weld metal and adjacent base metal.
3. Causes of cold cracking are as follows :

i. Metal brittleness combined with a tensile stress exceeding the fracture stress.
ii. Joint restraint and high thermal severity.
iii. Presence of hydrogen in the weld metal.

**D. Rules which must be followed to avoid cracking in welded joints :**

1. By keeping the weld metal and base metal ductile after welding because ductile constituents are able to deform plastically before the cracking.
2. By improving the strength or ductility of material so that it can tolerate the welding stresses at relevant stages of welding.
3. Maintaining the proper welding speed and proper arc length.
4. Maintaining the proper current density.
5. Removal or restriction of the impurities such as S and high C or Ni content because they form low freezing point liquid films.
6. Preventing the martensite formation in welding of steel during cooling.
7. By using correct welding technique or use of filler metal having same rate of contraction as that of the parent metal.
8. By preventing the martensite formation in the weld region, cracking can be avoided.

**6.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. What do you understand by explosive welding ? Write its advantages, disadvantages and applications in detail.**

**Ans.**

**A. Explosive Welding :**

1. Explosive welding is a solid state welding process wherein coalescence is produced by making one part strike over another part at a very high but subsonic velocity.
2. This can be done by the use of explosive usually ammonium nitrate base.
3. Basically explosive welding involves a high velocity oblique impact between a plate propelled by an explosive charge and a stationary

plate when two plates are to be explosively welded.

**B. Advantages of Explosive Welding :**

1. Simplicity of the process.
2. Extremely large surface can be bonded.
3. Welds can be produced on heat treated metals without affecting their microstructures.
4. The foils can be bonded to heavier plates.
5. Wide range of thickness can be explosively clad together.
6. Good explosive bonds have strength equal to or greater than that of the weaker of the two metals joined.
7. Lack of porosity, phase changes and structural changes impart better mechanical properties to the joints.

**C. Disadvantages of Explosive Welding :**

1. In industrial areas the use of explosive will be severely restricted by the noise and ground vibration caused by explosion.
2. The regulation relating to the storage of explosives may well prove to be the main obstacle to the use of explosive welding.
3. Metals to be welded by this process must possess some ductility and some impact resistance.
4. Metal thickness greater than 62 mm of each alloy cannot be joined easily and require high explosive loads.

**D. Applications of Explosive Welding :**

1. This is used in welding, joining and cladding of metals.
2. A number of dissimilar metals combinations as aluminium to steel, tungsten to steel and aluminium to stainless steel have been joined successfully with the help of explosive welding.
3. Pipes and tubes upto 1.5 m length have been clad with this process.
4. Heat exchangers tube sheets and pressure vessels.

**b. Explain the principle and working of FCAW welding. Differentiate MIG and FCAW. What variables affect weld quality of FCAW welding ?**

**Ans.** This question is out of syllabus from session 2020-21.

**7.** Attempt any **one** part of the following : **(10 × 1 = 10)**

**a. The arc length voltage characteristic is given by expression $V = 24 + 4L$ ($L$ = Length of arc in mm). The volt ampere characteristics of power source can be approximated by a straight line with open circuit voltage 80 V & short circuit current 600 A. Determine optimum arc length & maximum power.**

**Ans.**

**Given :** $V = 24 + 4L$, $V_{OC} = 80\text{V}$, $I_{SC} = 600\text{A}$.

**To Find :** i. Optimum arc length.

ii. Maximum power

1. We know

$$\frac{I}{I_{sc}} + \frac{V}{V_{OC}} = 1$$

$$\frac{I}{600} + \frac{V}{80} = 1$$

$$V = \left(80 - \frac{80}{600} I\right) \quad \ldots(1)$$

2. The arc characteristic is given as,

$$V = (24 + 4L) \quad \ldots(2)$$

3. At stable operation, arc characteristics equal to supply characteristics.
4. Equating eq. (1) and eq. (2), we get

$$80 - \frac{80}{600} I = 24 + 4L$$

$$I = (56 - 4L)\ \frac{600}{80} \quad \ldots(3)$$

5. Hence, the power $P$ is obtained from eq. (2) and eq. (3) as

$$P = VI = (24 + 4L)(56 - 4L)\ \frac{600}{80}$$

6. For maximum power,

$$\frac{dP}{dL} = 0$$

$$4(56 - 4L) - 4(24 + 4L) = 0$$

$$32 - 8L = 0$$

$$L = 4 \text{ mm}$$

7. So, the optimum arc length $L_{\text{opt}} = 4$ mm when the maximum power of the arc is

$$P_{\max} = (24 + 4 \times 4)(56 - 4 \times 4) \times \frac{600}{80}$$

$$= 40 \times 40 \times \frac{600}{80} = 12 \text{ kVA}$$

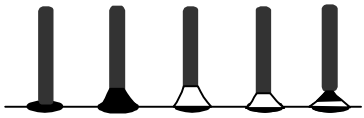
**b. Explain in detail the mechanism and types of metal transfer in various arc welding processes.**

**Ans.**

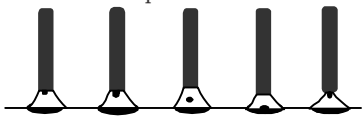
1. When electric arc is produced between the workpiece and consumable electrode, electrode start melting in the form of spherical shape, hangs towards the job and finally a drop down on the

workpiece therefore metal transfer from electrode to workpiece is define metal transfer process.

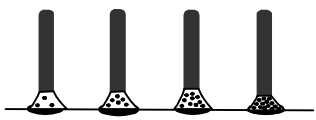
2. Metal is transferred in arc welding in three ways :
   i. By dip transfer,
   ii. By free drop (large drop) transfer, and
   iii. By spray (small drop) transfer.
3. In dip transfer a globule of molten metal is formed at the end of the electrode during arcing in the first stage.
4. Subsequently it enlarges, elongates, touches the molten pool and separates from the electrode.
5. The process does not free the globules immediately from the electrode after its formation and as such a temporary short circuit occurs.
6. The process repeats several times to complete welding.
7. In free drop transfer, a drop of molten metal which is slightly smaller in diameter than the air gap flies off from the electrode end after temporarily (but partial) short circuiting the electrode with the molten pool of metal on the job.
8. In spray or small drop transfer, the transfer takes place in the form of tiny droplets (much smaller in diameter as compared to arc length) which make free flight from the electrode to the molten pool.
9. The transfer rate is steady and the final job will have better mechanical advantages.
10. The three transfer methods are shown in Fig. 8.



i. Dip transfer.



ii. Free drop transfer.



iii. Spray transfer.

**Fig. 8.**

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