

CHAPTER 48

Learning Objectives

- Definition of Welding
- Welding Processes
- Four Positions of Arc Welding
- Electrodes for Metal Arc Welding
- Advantages of Coated Electrodes
- Arc Welding Machines
- V-I Characteristics of Arc Welding D.C. Machines
- D.C. Welding Machines with Motor Generator Set
- AC Rectified Welding Unit
- AC Welding Machines
- Carbon Arc Welding
- Submerged Arc Welding
- Gas Shield Arc Welding
- TIG Welding
- MIG Welding
- MAG Welding
- Resistance Welding
- Spot Welding
- Seam Welding
- Projection Welding
- Butt Welding
- Flash Butt Welding
- Upset Welding
- Stud Welding
- Electrogas Welding
- Electron Beam Welding

ELECTRIC WELDING



Electricity is used to generate heat necessary to melt the metal to form the necessary joints

48.1. Definition of Welding

It is the process of joining two pieces of metal or non-metal at faces rendered plastic or liquid by the application of heat or pressure or both. Filler material may be used to effect the union.

48.2. Welding Processes

All welding processes fall into two distinct categories :

1. Fusion Welding—It involves melting of the parent metal. Examples are:

- (i) Carbon arc welding, metal arc welding, electron beam welding, electrosag welding and electrogas welding which utilize electric energy and
- (ii) Gas welding and thermit welding which utilize chemical energy for the melting purpose.

2. Non-fusion Welding—It does not involve melting of the parent metal. Examples are:

- (i) Forge welding and gas non-fusion welding which use chemical energy.
- (ii) Explosive welding, friction welding and ultrasonic welding etc., which use mechanical energy.
- (iii) Resistance welding which uses electrical energy.

Proper selection of the welding process depends on the (a) kind of metals to be joined (b) cost involved (c) nature of products to be fabricated and (d) production techniques adopted. The principal welding processes have been tabulated in Fig. 48.1

48.3. Use of Electricity in Welding

Electricity is used in welding for generating heat at the point of welding in order to melt the material which will subsequently fuse and form the actual weld joint. There are many ways of producing this localised heat but the two most common methods are as follows :

1. resistance welding—here current is passed through the inherent resistance of the joint to be welded thereby generating the heat as per the equation $I^2 R t / J$ kilocalories.

2. arc welding—here electricity is conducted in the form of an arc which is established between the two metallic surfaces

48.4. Formation and Characteristics of Electric Arc

An electric arc is formed whenever electric current is passed between two metallic electrodes which are separated by a short distance from each other. The arc is started by momentarily touching the positive electrode (anode) to the negative metal (or plate) and then withdrawing it to about 3 to 6 mm from the plate. When electrode first touches the plate, a large short-circuit current flows and as it is later withdrawn from the plate, current continues to flow in the form of a spark across the air gap so formed. Due to this spark (or discharge), the air in the gap becomes ionized *i.e.* is split into negative electrons and positive ions. Consequently, air becomes conducting and current is able to flow across the gap in the form of an arc.

As shown in Fig. 48.2, the arc consists of *lighter* electrons which flow from cathode to anode and *heavier* positive ions which flow from anode to cathode. Intense heat is generated when high-velocity electrons strike the anode. Heat generated at the cathode is much less because of the low velocity of the impinging ions. It is found that nearly **two-third** of the heat is developed at the anode which burns into the form of a crater where temperature rises to a value of 3500-4000°C. The remaining one-third of the heat is developed near the cathode. The above statement is true in all d.c. systems of welding where positive side of the circuit is the hottest side. As a result, an electrode connected to the positive end of the d.c. supply circuit will burn 50% faster than if connected to the negative end. This fact can be used for obtaining desired penetration of the base metal during welding.

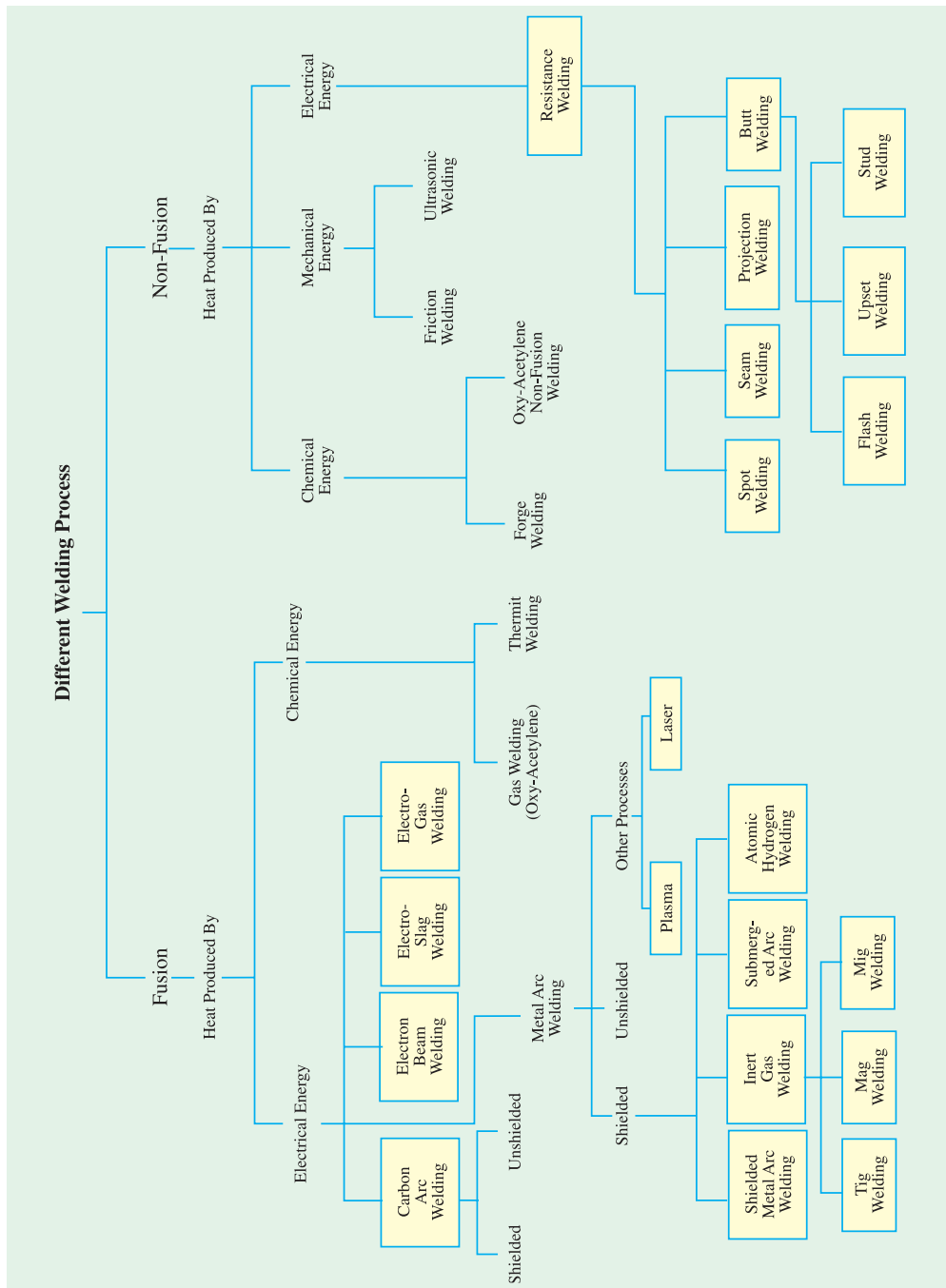


Fig. 48.1

If positive supply end is connected to the base metal (which is normally grounded), penetration will be greater due to more heat and, at the same time, the electrode will burn away slowly [Fig. 48.3 (a)] since it is connected to the negative end of the supply. If supply connections are reversed, the penetration of heat zone in the base metal will be comparatively shallow and, at the same time, electrode will burn fast [Fig. 48.3 (b)]. AC supply produces a penetration depth that is nearly halfway between that achieved by the d.c. positive ground and negative ground as shown in Fig. 48.3 (c).

It may be noted that with a.c. supply, heat is developed equally at the anode and cathode due to rapid reversal of their polarity. The arc utilized for arc welding is a low-voltage high-current discharge. The voltage required for striking the arc is higher than needed for maintaining it. Moreover, amperage increases as voltage decreases after the arc has been established. Fig 48.4 shows V/I characteristics of an electric arc for increasing air-gap lengths. The voltage required to strike a d.c. arc is about 50-55 V and that for a.c. arc is 80-90 V. The voltage drop across the arc is nearly 15-20 V. It is difficult to maintain the arc with a voltage less than 14 V or more than 40 V.

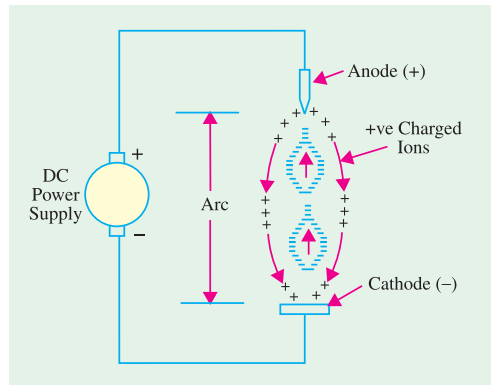


Fig. 48.2

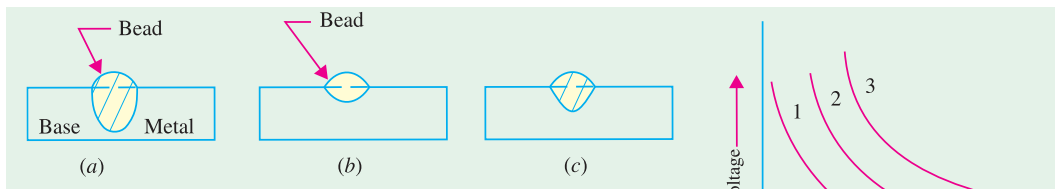


Fig. 48.3

48.5. Effect of Arc Length

In metal arc welding, a fairly short arc length is necessary for getting good welds. Short arc length permits the heat to be concentrated on the workpiece, is more stable because effect of magnetic blow is reduced and the vapours from the arc surround the electrode metal and the molten pool thereby preventing air from destroying the weld metal. When arc length is long

1. large amount of heat is lost into the surrounding area thus preventing good penetration and fusion;
2. arc flame is very unstable since effect of magnetic blow is increased. Hence, arc flame will have a tendency to blow out;
3. air is able to reach the molten globule of metal as it passes from the electrode to the weld and weld pool. It leads to the contamination of the weld due to absorption of oxygen and nitrogen;
4. weld deposits have low strength, poor ductility, high porosity, poor fusion and excessive spatter.

The length of arc required for welding will depend on the kind of electrode used, its coating, its diameter, position of welding and the amount of current used. Usually, shorter arc length are necessary for vertical, horizontal and overhead welding than for flat welding.

48.6. Arc Blow

An arc column can be considered as a flexible current-carrying conductor which can be easily deflected by the magnetic field set up in its neighbourhood by the positive and negative leads from the d.c. welding set. The

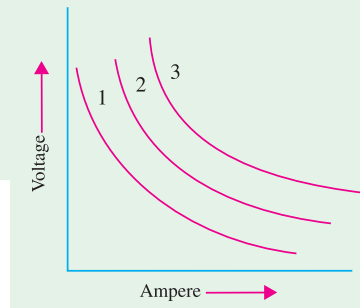


Fig. 48.4



An electric arc is produced when electricity is passed between two electrodes

two leads carry currents in the opposite directions and hence, set up a repulsive magnetic force which pulls the arc away from the weld point particularly when welding corners where field concentration is maximum. The deflection of the arc is called **arc blow**. This condition is encountered only with d.c. welding sets and is especially noticeable when welding with bare electrodes. It is experienced most when using currents above 200 A or below 40 A.

Due to arc blow, heat penetration in the required area is low which leads to incomplete fusion and bead porosity apart from excessive weld spatter.

Arc blow can be avoided by using a.c. rather than d.c. welding machines because reversing currents in the welding leads produce magnetic fields which cancel each other out thereby eliminating the arc blow. However, with d.c. welding machines, arc blow effects can be minimized by (i) welding away from the earth ground connection, (ii) changing the position of the earth connection on the work, (iii) wrapping the welding electrode cable a few turns around the work, (iv) reducing the welding current or electrode size, (v) reducing the rate of travel of the electrode and (vi) shortening the arc column length etc.

48.7. Polarity in DC Welding

Arc welding with the electrode connected to the positive end of the d.c. supply is called reverse polarity.* Obviously, the workpiece is connected to the negative end.

A better name for d.c. reverse polarity (DCRP) is **electrode-positive** as shown in Fig. 48.5 (a). As stated earlier in Art. 48.4, two-third of the arc heat is developed at the anode. Hence, in DCRP welding, electrode is the hottest whereas workpiece is comparatively cooler. Consequently, electrode burns much faster but weld bead is relatively shallow and wide. That is why thick and heavily-coated electrodes are used in DCRP welding because they require more heat for melting.

Arc welding with the electrode connected to the negative end of the d.c. supply is called **straight polarity**.** Obviously, the workpiece is connected to the positive end as shown in Fig. 48.5 (b). A better name for d.c. straight polarity (DCSP) is **electrode-negative**.

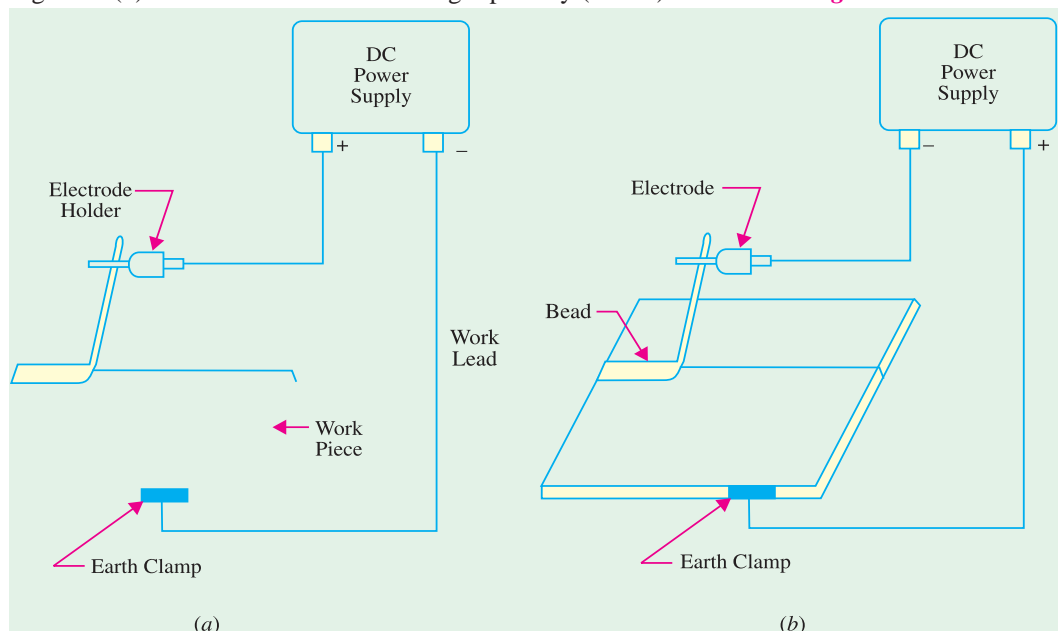


Fig. 48.5

* In British literature, it is called straight polarity.

** In British literature, it is called reverse polarity.

In DCSP welding, workpiece is the hottest, hence base metal penetration is narrow and deep. Moreover, bare and medium-coated electrodes can be used in this welding as they require less amount of heat for melting.

It is seen from the above discussion that polarity necessary for the welding operation is determined by the type of electrode used.

It is also worth noting that in a.c. welding, there is no choice of polarity because the circuit becomes alternately positive, first on one side and then on the other. In fact, it is a combination of D C S P and D C R P.

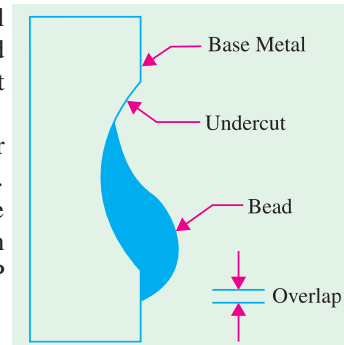


Fig. 48.6

48.8. Four Positions of Arc Welding

There are four basic positions in which manual arc welding is done.

1. Flat position. It is shown in Fig. 48.7 (a). Of all the positions, flat position is the easiest, most economical and the most used for all shielded arc welding. It provides the strongest weld joints. Weld beads are exceedingly smooth and free of slag spots. This position is most adaptable for welding of both ferrous and non-ferrous metals particularly for cast iron.

2. Horizontal Position. It is the second most popular position and is shown in Fig. 48.7 (b). It also requires a short arc length because it helps in preventing the molten puddle of the metal from sagging. However, major errors that occur while welding in horizontal position are under-cutting and over-lapping of the weld zone (Fig. 48.6).

3. Vertical Position. It is shown in Fig. 48.7 (c). In this case, the welder can deposit the bead either in the uphill or downhill direction. Downhill welding is preferred for thin metals because it is faster than the uphill welding. Uphill welding is suited for thick metals because it produces stronger welds.

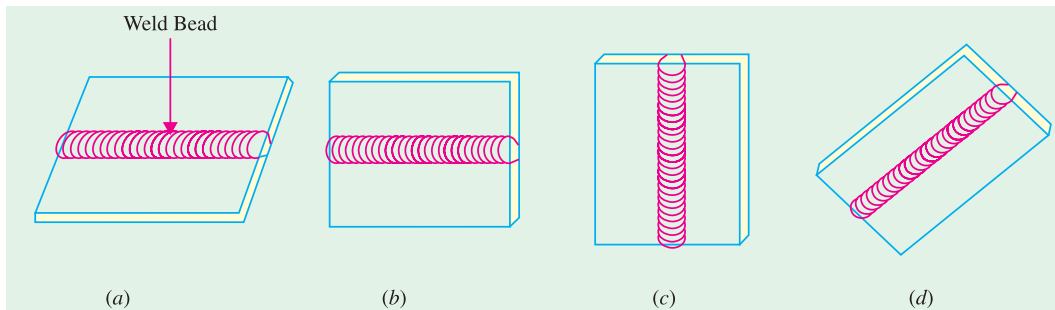


Fig. 48.7.

4. Overhead Position. It is shown in Fig. 48.7 (d). Here, the welder has to be very cautious otherwise he may get burnt by drops of falling metal. This position is thought to be the most hazardous but not the most difficult one.

48.9. Electrodes for Metal Arc Welding

An electrode is a filler metal in the form of a wire or rod which is either bare or coated uniformly with flux. As per IS : 814-1970, the contact end of the electrode is left bare and clean to a length of 20-30 mm. for inserting it into electrode holder (Fig. 48.8).

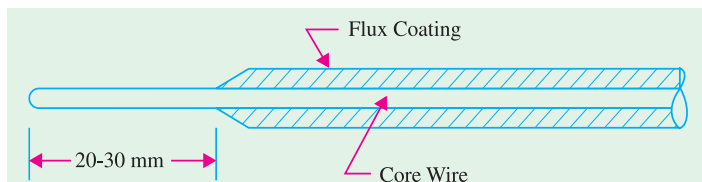


Fig. 48.8

Metal arc welding was originally done with bare electrodes which consisted of a piece of wire or rod of the same metal as the base metal. However, due to atmospheric contamination, they produced brittle and poor quality welds.

Hence, bare wire is no longer used except for automatic welding in which case arrangement is made to protect the weld area from the atmosphere by either powdered flux or an inert gas. Since 1929, coated electrodes are being extensively used for shielded arc welding. They consist of a metal core wire surrounded by a thick flux coating applied by

extrusion, winding or other processes. Depending on the thickness of the flux coating, coated electrodes may be classified into (i) lightly-dusted (or dipped) electrodes and (ii) semi-coated (or heavy-coated) electrodes. Materials commonly used for coating are (i) titanium oxide (ii) ferromanganese (iii) silica flour (iv) asbestos clay (v) calcium carbonate and (vi) cellulose with sodium silicate often used to hold ingredients together.

Electrode coating contributes a lot towards improving the quality of the weld. Part of the coating burns in the intense heat of the arc and provides a gaseous shield around the arc which prevents oxygen, nitrogen and other impurities in the atmosphere from combining with the molten metal to cause a poor quality brittle and weak weld. Another portion of the coating flux melts and mixes with the impurities in the molten pool causing them to float to the top of the weld where they cool in the form of slag (Fig. 48.9). This slag improves the bead quality by protecting it from the contaminating effects of the atmosphere and causing it to cool down more uniformly. It also helps in controlling the basic shape of the weld bead.

The type of electrode used depends on the type of metal to be welded, the welding position, the type of electric supply whether a.c. or d.c. and the polarity of the welding machine.

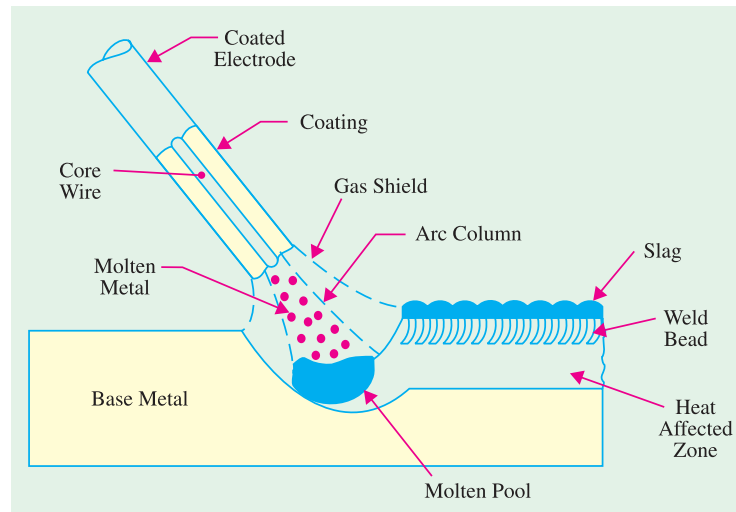


Fig. 48.9

48.10. Advantages of Coated Electrodes

The principal advantages of using electrode coating are as under :

1. It stabilizes the arc because it contains ionizing agents such as compounds of sodium and potassium.
2. It fluxes away impurities present on the surface being welded.
3. It forms slag over the weld which (i) protects it from atmospheric contamination (ii) makes it cool uniformly thereby reducing the changes of brittleness and (iii) provides a smoother surface by reducing 'ripples' caused by the welding operation.
4. It adds certain materials to the weld metal to compensate for the loss of any volatile alloying elements or constituents lost by oxidation.
5. It speeds up the welding operation by increasing the rate of melting.
6. It prevents the sputtering of metal during welding.

7. it makes it possible for the electrode to be used on a.c. supply. In a.c. welding, arc tends to cool and interrupt at zero-current positions. But the shielding gases produced by the flux keep the arc space ionized thus enabling the coated electrodes to be used on a.c. supply.

It is worth noting that efficiency of all coated (or covered) electrodes is impaired by dampness. Hence, they must always be stored in a dry space. If dampness is suspected, the electrodes should be dried in a warm cabinet for a few hours.

48.11. Types of Joints and Types of Applicable Welds

Bureau of Indian Standards (B.I.S.) has recommended the following types of joints and the welds applicable to each one of them (Fig. 48.10).

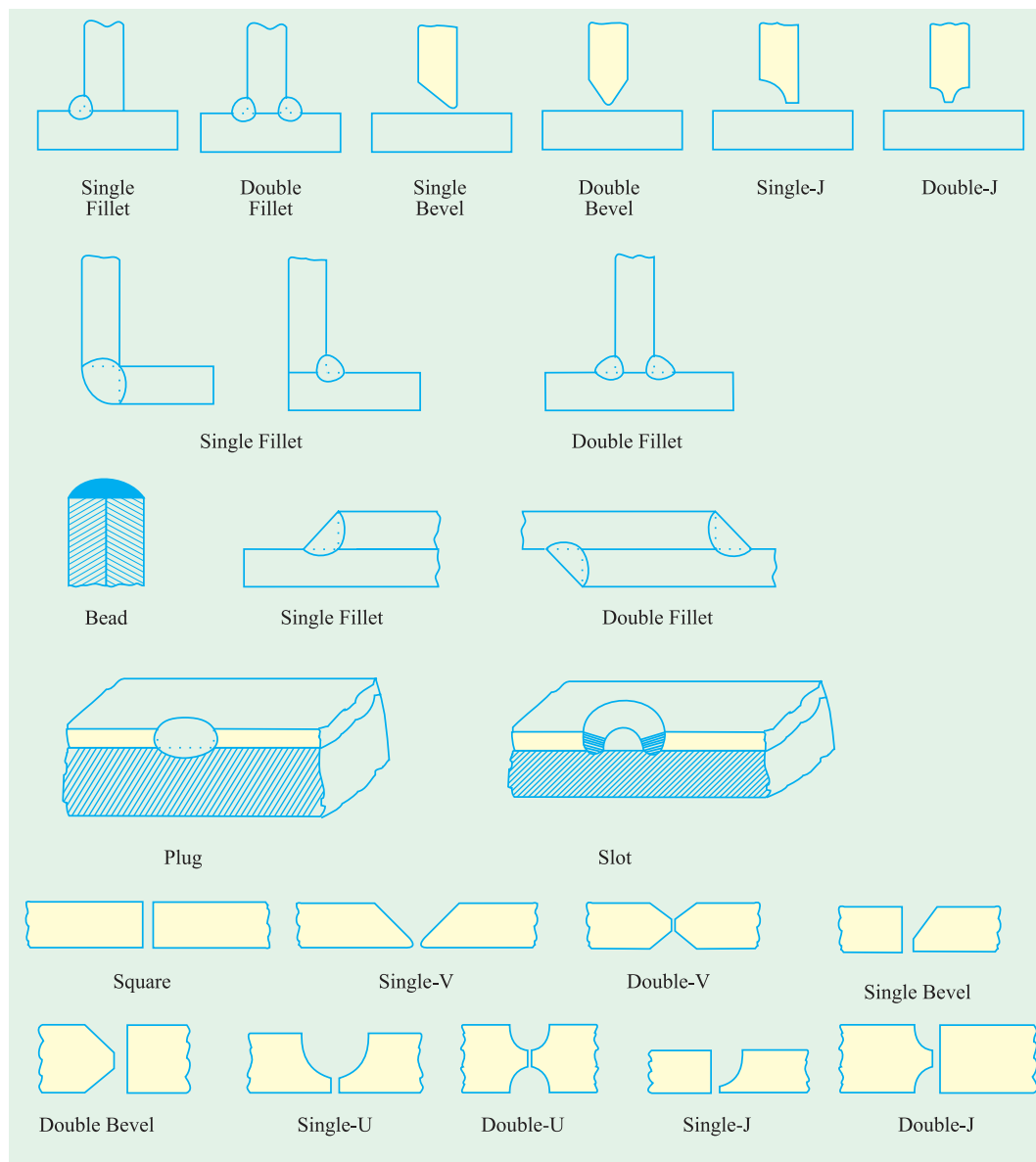


Fig. 48.10

- | | |
|-----------------|-----------------------------|
| 1. Tee joint | — with six types of welds. |
| 2. Corner joint | — with two types of welds. |
| 3. Edge joint | — with one type of weld. |
| 4. Lap joint | — with four types of welds. |
| 5. Butt joint | — with nine types of welds. |

48.12. Arc Welding Machines

Welding is never done directly from the supply mains. Instead, special welding machines are used which provided currents of various characteristics. Use of such machines is essential for the following reasons :

1. To convert a.c. supply into d.c. supply when d.c. welding is desired.
2. To reduce the high supply voltage to a safer and suitable voltage for welding purposes.
3. To provide high current necessary for arc welding without drawing a corresponding high current from the supply mains.
4. To provide suitable voltage/current relationships necessary for arc welding at minimum cost.

There are two general types of arc welding machines :

(a) d.c. welding machines

- (i) motor-generator set
- (ii) a.c. transformers with rectifiers

(b) a.c. welding machines

48.13. V-I Characteristics of Arc Welding DC Machines

It is found that during welding operation, large fluctuations in current and arc voltage result from the mechanism of metal transfer and other factors. The welding machine must compensate for such changes in arc voltage in order to maintain an even arc column. There are three major voltage/current characteristics used in modern d.c. welding machines which help in controlling these current fluctuations :

1. drooping arc voltage (DAV).
2. constant arc voltage (CAV).
3. rising arc voltage (RAV).

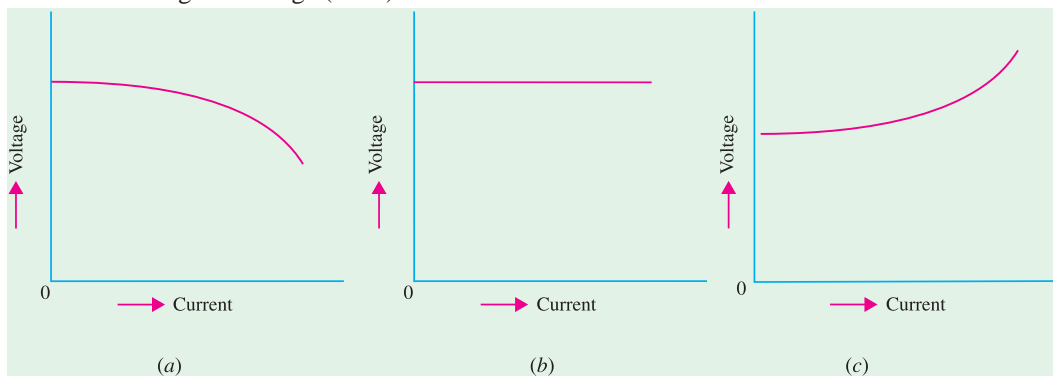


Fig. 48.11

The machines with DAV characteristics have high open-circuit voltage which drops to a minimum when arc column is started. The value of current rises rapidly as shown in Fig. 48.11 (a). This type of characteristic is preferred for manual shield metal arc welding.

The CAV characteristic shown in Fig. 48.11 (b) is suitable for semi-automatic or automatic welding processes because voltage remains constant irrespective of the amount of current drawn.

Because of its rising voltage characteristic, RAV has an advantage over CAV because it maintains a constant arc gap even if short circuit occurs due to metal transfer by the arc. Moreover, it is well-adapted to fully automatic process.

DC welding machines can be controlled by a simple rheostat in the exciter circuit or by a combination of exciter regulator and series of field taps. Some arc welding are equipped with remote-controlled current units enabling the operator to vary voltage-amperage requirement without leaving the machines.



DC and AC welding machines

48.14. DC Welding Machines with Motor Generator Set

Such a welding plant is a self-contained single-operator motor-generator set consisting of a reverse series winding d.c. generator driven by either a d.c. or an a.c. motor (usually 3-phase). The series winding produces a magnetic field which opposes that of the shunt winding. On open-circuit, only shunt field is operative and provides maximum voltage for striking the arc. After the arc has been established, current flows through the series winding and sets up a flux which opposes the flux produced by shunt winding. Due to decreases in the net flux, generator voltage is decreased (Art. 48.13).

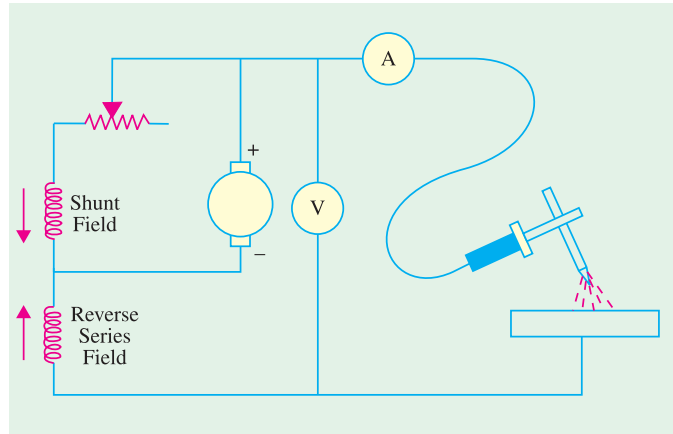


Fig. 48.12

With the help of shunt regulator, generator voltage and current values can be adjusted to the desired level. Matters are so arranged that despite changes in arc voltage due to variations in arc length, current remains practically constant. Fig. 48.12 shows the circuit of a d.c. motor-generator type of welding machine.

Advantages. Such a d.c. welder has the following advantages :

1. It permits portable operation.
2. It can be used with either straight or reverse polarity.
3. It can be employed on nearly all ferrous and non-ferrous materials.
4. It can use a large variety of stick electrodes.
5. It can be used for all positions of welding.

Disadvantages

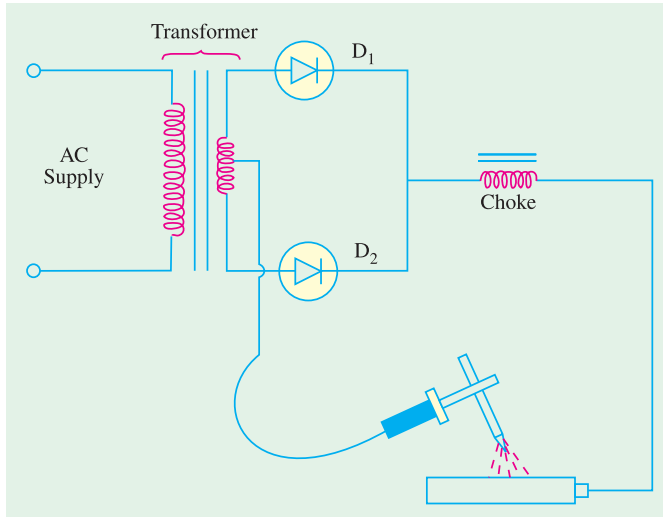
1. It has high initial cost.
2. Its maintenance cost is higher.
3. Machine is quite noisy in operation.
4. It suffers from arc blow.

48.15. AC Rectified Welding Unit

It consists of a transformer (single-or three-phase) and a rectifier unit as shown in Fig. 48.13. Such a unit has no moving parts, hence it has long life. The only moving part is the fan for cooling the transformer. But this fan is not the basic part of the electrical system. Fig. 48.13 shows a single-phase full-wave rectified circuit of the welder. Silicon diodes are used for converting a.c. into d.c. These diodes are hermetically sealed and are almost ageless because they maintain rectifying characteristics indefinitely.

Such a transformer-rectifier welder is most adaptable for shield arc welding because it provides both

d.c. and a.c. polarities. It is very efficient and quiet in operation. These welders are particularly suitable for the welding of (i) pipes in all positions (ii) non-ferrous metals (iii) low-alloy and corrosion-heat and creep-resisting steel (iv) mild steels in thin gauges.

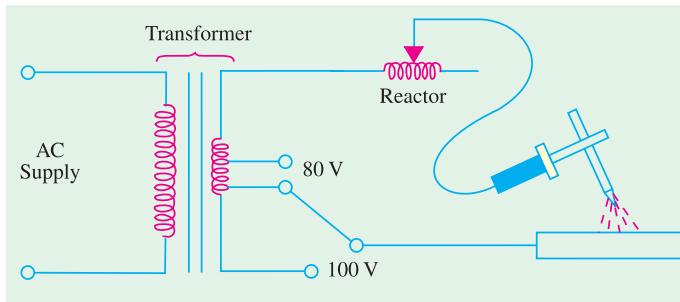
**Fig. 48.13****48.16. AC Welding Machines**

As shown in Fig. 48.14, it consists of a step-down transformer with a tapped secondary having an adjustable reactor in series with it for obtaining drooping V/I characteristics. The secondary is tapped to give different voltage/current settings.

Advantages. This a.c. welder which can be operated from either a single-phase or 3-phase supply has the following advantages :

- | | |
|----------------------|---|
| (i) Low initial cost | (ii) Low operation and maintenance cost |
| (iii) Low wear | (iv) No arc blow |

Disadvantages. (i) its polarity cannot be changed (ii) it is not suitable for welding of cast iron and non-ferrous metals.

**Fig. 48.14****48.17. Duty Cycle of a Welder**

The duty cycle of an arc welder is based on a working period of 10 minutes. For example, if a welder is operated for 2 minutes in a period of 10 minutes, then its percentage duty cycle is $(2/10) \times 100 = 20$ percent. Conversely, a 10 percent duty cycle would mean that the welder would

be operated for 10 percent of 10 minutes *i.e.* for one minute only in a period of 10 minutes.

Usually, values of maximum amperage and voltage are indicated along with the duty cycle. It is advisable to adhere to these values. Suppose a welding machine has maximum amperage of 300A and voltage of 50 V for a duty cycle of 60 percent. If this machine is operated at higher settings and for periods longer than 6 minutes, then its internal insulation will deteriorate and cause its early failure.

48.18. Carbon Arc Welding

(a) General

Carbon arc welding was the first electric welding process developed by a French inventor Auguste de Meritens in 1881. In this process, fusion of metal is accomplished by the heat of an electric arc. No pressure is used and generally, no shielding atmosphere is utilized. Filler rod is used only when necessary. Although not used extensively these days, it has, nevertheless, certain useful fields of application.

Carbon arc welding differs from the more common shield metal arc welding in that *it uses non-consumable carbon or graphic electrodes* instead of the consumable flux-coated electrodes.

(b) Welding Circuit

The basic circuit is shown in Fig. 48.15 and can be used with d.c. as well as a.c. supply. When direct current is used, the electrode is mostly negative (DCSP). The process is started by adjusting the amperage on the d.c. welder, turning welder ON and bringing the electrode into contact with the workpiece. After the arc column starts, electrode is withdrawn 25 – 40 mm away and the arc is maintained at this distance. The arc can be extinguished by simply removing the electrode from the workpiece completely. The only function of the carbon arc is to supply heat to the base metal. This heat is used to melt the base metal or filler rod for obtaining fusion weld. Depending on the type and size of electrodes, maximum current values range from 15 A to 600 A for single-electrode carbon arc welding.

(c) Electrodes

These are made of either carbon or graphite, are usually 300 mm long and 2.5 – 12 mm in diameter. Graphite electrodes are harder, more brittle and last longer than carbon electrodes. They can withstand higher current densities but their arc column is harder to control. Though considered non-consumable, they do disintegrate gradually due to vaporisation and oxidation.

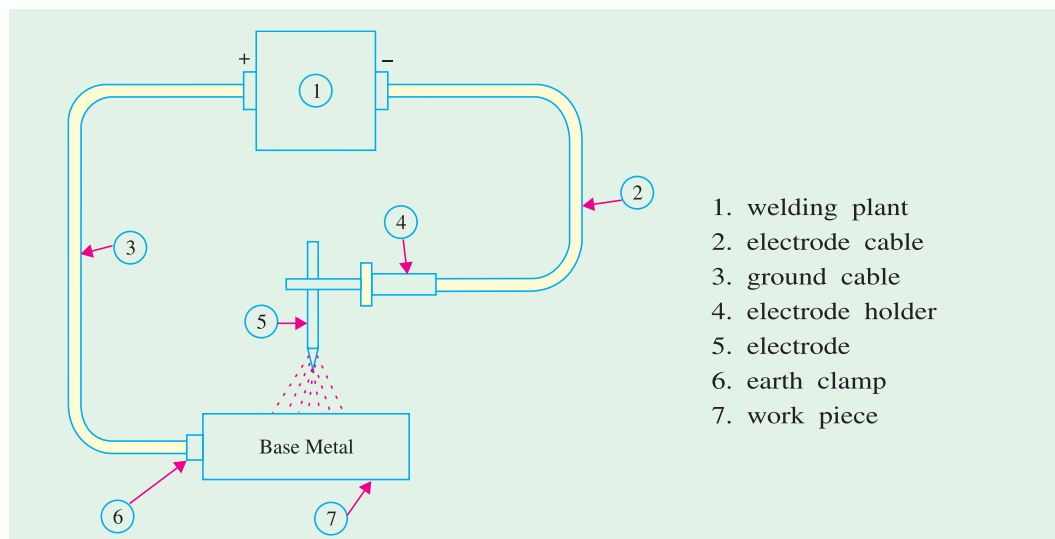


Fig. 48.15

(d) Applications

1. The joint designs that can be used with carbon arc welding are butt joints, bevel joints, flange joints, lap joints and fillet joints.
2. This process is easily adaptable for automation particularly where amount of weld deposit is large and materials to be fabricated are of simple geometrical shapes such as water tanks.
3. It is suitable for welding galvanised sheets using copper-silicon-manganese alloy filler metal.
4. It is useful for welding thin high-nickel alloys.
5. Monel metal can be easily welded with this process by using a suitable coated filler rod.
6. Stainless steel of thinner gauges is often welded by the carbon-arc process with excellent results.

(e) Advantages and Disadvantages

1. The main advantage of this process is that the temperature of the molten pool can be easily controlled by simply varying the arc length.
2. It is easily adaptable to automation.
3. It can be easily adapted to inert gas shielding of the weld and
4. It can be used as an excellent heat source for brazing, braze welding and soldering etc.

Its disadvantages are as under :

1. A separate filler rod has to be used if any filler material is required.
2. Since arc serves only as a heat source, it does not transfer any metal to help reinforce the weld joint.
3. The major disadvantage of the carbon-arc process is that blow holes occur due to magnetic arc blow especially when welding near edges of the workpiece.

48.19. Submerged Arc Welding

In this *fusion* process, welding is done under a blanket of granulated flux which shields the weld from all bad effects of atmospheric gases while a consumable electrode is continuously and mechanically fed into the arc. The arc, the end of the bare metal electrode and the molten weld pool are all submerged under a thick mound of finely-divided granulated powder that contains deoxidisers, cleansers and other fluxing agents. The fluxing powder is fed from a hopper that is carried on the welding head itself (Fig. 48.16). This hopper spread the powder in a continuous mound ahead of the

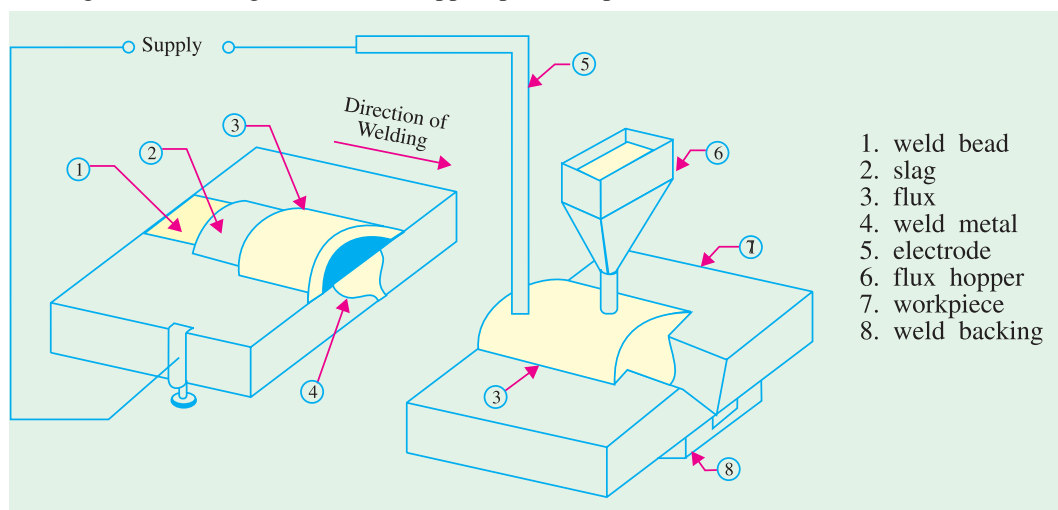


Fig. 48.16

electrode in the direction of welding. Since arc column is completely submerged under the powder, there is no splatter or smoke and, at the same time, weld is completely protected from atmospheric contamination. Because of this protection, weld beads are extremely smooth. The flux adjacent to the arc column melts and floats to the top of the molten pool where it solidifies to form slag. This slag is easy to remove. Often it cracks off by itself as it cools. The unused flux is removed and is reused again and again.

The electrode is either a bare wire or has a slight mist of copper coated over it to prevent oxidation. In automatic or semi-automatic submerged arc welding, wire electrode is fed mechanically through an electrically contacting collet. Though a.c. power supply may be used, yet d.c. supply is more popular because it assures a simplified and positive control of the welding process. This process requires high current densities about 5 to 6 times of those used in ordinary manual stick electrode welding. As a result, melting rate of the electrode as well as welding speed become much higher. Faster welding speed minimizes distortion and warpage.

The submerged arc process is suitable for

1. Welding low-alloy, high-tensile steels.
2. Welding mild, low-carbon steels.
3. Joining medium-carbon steel, heat-resistant steels and corrosion-resistant steels etc.
4. Welding nickel, Monel and other non-ferrous metals like copper.

This process has many industrial applications such as fabrication of pipes, boiler pressure vessels, railroad tank cars, structural shapes etc. which demand welding in a straight line. Welds made by this process have high strength and ductility. A major advantage of this process is that fairly thick sections can be welded in a single pass without edge preparation.

Submerged arc welding can be done manually where automatic process is not possible such as on curved lines and irregular joints. Such a welding gun is shown in Fig. 48.17. Both manual and automatic submerged arc processes are most suited for flat and slightly downhill welding positions.

48.20. Twin Submerged Arc Welding

As shown in Fig. 48.18, in this case, two electrodes are used simultaneously instead of one. Hence, weld deposit size is increased considerably. Moreover, due to increase in welding current (upto 1500 A), much deeper penetration of base metal is achieved.

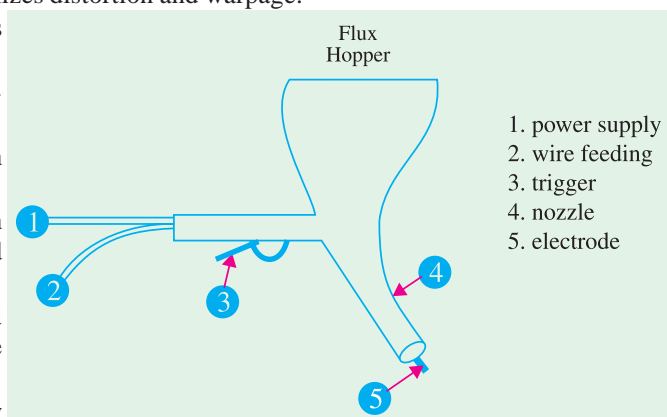


Fig. 48.17

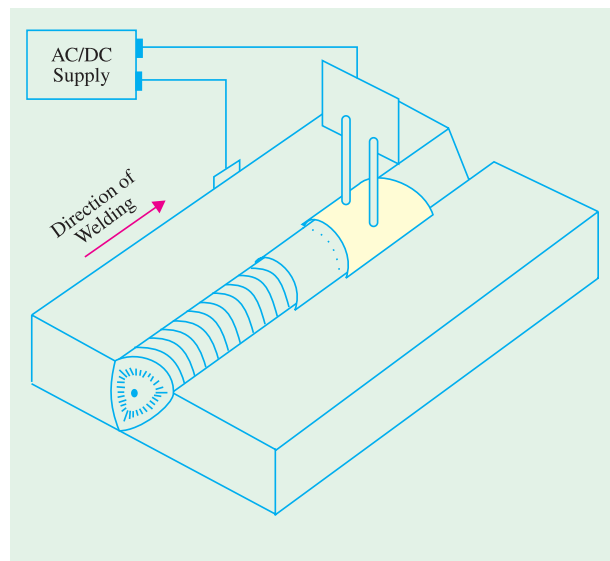


Fig. 48.18

48.21. Gas Shield Arc Welding

In this fusion process, welding is done with bare electrodes but weld zone is shielded from the atmosphere by a gas which is piped to the arc column. Shielding gases used are carbon dioxide, argon, helium, hydrogen and oxygen. No flux is required. Different processes using shielding gas are as follows.

(a) Tungsten inert-gas (TIG) Process

In this process, non-consumable tungsten electrode is used and filler wire is fed separately. The weld zone is shielded from the atmosphere by the inert gas (argon or helium) which is ducted directly to the weld zone where it surrounds the tungsten and the arc column.

(b) Metal inert-gas (MIG) Process

It is a refinement of the TIG process. It uses a bare consumable (*i.e.* fusible) wire electrode which acts as the source for the arc column as well as the supply for the filler material. The weld zone is shielded by argon gas which is ducted directly to the electrode point.

48.22. TIG Welding

(a) Basic Principle

It is an electric process which uses a bare non-consumable tungsten electrode for striking the arc only (Fig. 48.19). Filler material is added separately. It uses an inert gas to shield the weld puddle from atmospheric contamination. This gas is ducted directly to the weld zone from a gas cylinder.

(b) Welding Equipment

The usual TIG welding system consists of the following (Fig. 48.20).

1. A standard shield arc welding machine complete with cables etc.
2. A supply of inert gas complete with hose, regulators etc.
3. A source of water supply (in the case of water-cooled torches).
4. A TIG torch with a control switch to which all the above are connected.

(c) Electrodes

The electrodes are made of either pure tungsten or zirconiated or thoriated tungsten. Addition of zirconium or thorium (0.001 to 2%) improves electron emission tremendously.

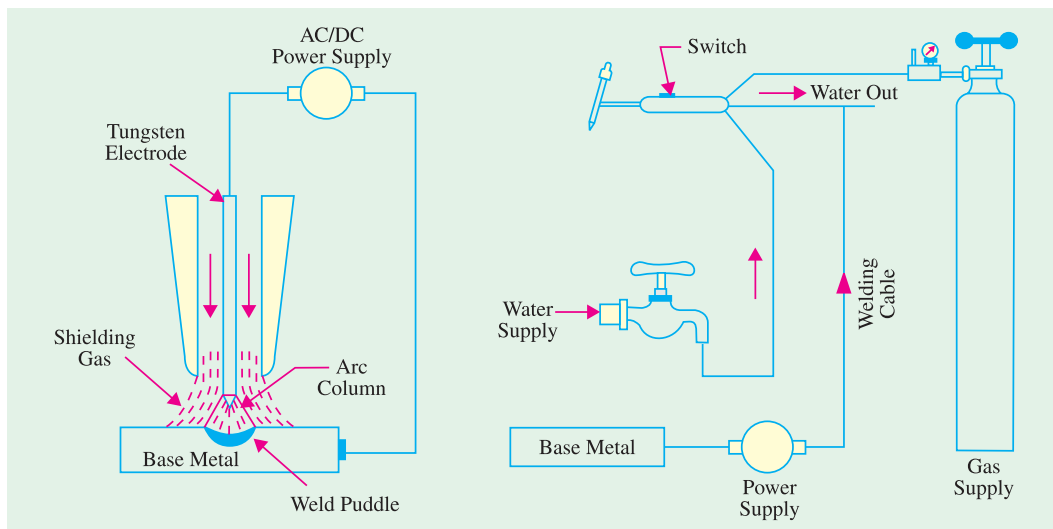


Fig. 48.19

Fig. 48.20

(d) Power Supply

The three basic power supplies used in TIG operation are :

1. DCSP power supply—here electrode is negative, runs cooler and, hence, can be thin.
2. DCRP power supply—here electrode is positive and hot. Hence, it has to be large.
3. A.C. high frequency (ACHF) power supply—it is a combination of standard a.c. supply of 50 Hz and high-voltage high-frequency d.c. supply. The function of this d.c. supply is to sustain the arc when a.c. supply is at zero current positions.

(e) Advantages of TIG Welding

1. It provides maximum protection to weld bead from atmospheric contamination.
2. TIG welds are stronger, more ductile and more corrosion-resistant than those of shield metal arc welding.
3. Since no flux is used, there is no flux entrapment in the bead.
4. Since no flux is required, a wider variety of joint designs can be used.
5. No post-weld cleansing is necessary.
6. There is no weld splatter or sparks that could damage the surface of the base metal.
7. It gives relatively fast welding speeds.
8. It is suitable for welding food or medical containers where entrapment of any decaying organic matter could be extremely harmful.
9. It is suitable for all welding positions—the flat, horizontal, vertical and overhead positions. The joints suitable for TIG welding process are (i) butt joint (ii) lap joint (iii) T-joint, (iv) corner joint and (v) edge joint.

(f) Applications

- | | | |
|--|---|---------|
| 1. aluminium and its alloys | — | AC/DCRP |
| 2. magnesium and its alloys | — | ACHF |
| 3. stainless steel | — | DCSP |
| 4. mild steel, low-alloy steel, medium | — | DCSP |
| -carbon steel and cast iron | — | DCSP |
| 5. copper and alloys | — | DCSP |
| 6. nickel and alloys | — | DCSP |

TIG welding is also used for dissimilar metals, hardfacing and surfacing of metals. Special industrial applications include manufacture of metal furniture and air-conditioning equipment.

Fig. 48.21 shows Phillips 400-D compact fan-cooled DC TIG welding set which has an open-circuit voltage of 80 V and a welding current of 400 A with 60% duty cycle and 310 A with 100% duty cycle.

48.23. MIG Welding**(a) Basic Principle**

It is also called inert-gas consumable- electrode process. The fusible wire electrode is driven by the drive wheels. Its function is two-fold: to produce arc column and to provide filler material. This process uses inert gas for shielding the weld zone from atmospheric contamination. Argon is used to weld non-ferrous metals though helium gives better control of porosity and arc stability. This



Fig. 48.21 (TIG welding set)

process can deposit large quantities of weld metal at a fast welding speed. The process is easily adaptable to semi-automatic or fully automatic operations.

(b) Welding Equipment

The basic MIG welding system (Fig. 48.23) consists of the following :

1. Welding power supply
2. Inert gas supply with a regulator and flow meter
3. Wire feed unit containing controls for wire feed, gas flow and the ON/OFF switch for MIG torch
4. MIG torch
5. Depending on amperage, a water cooling unit.

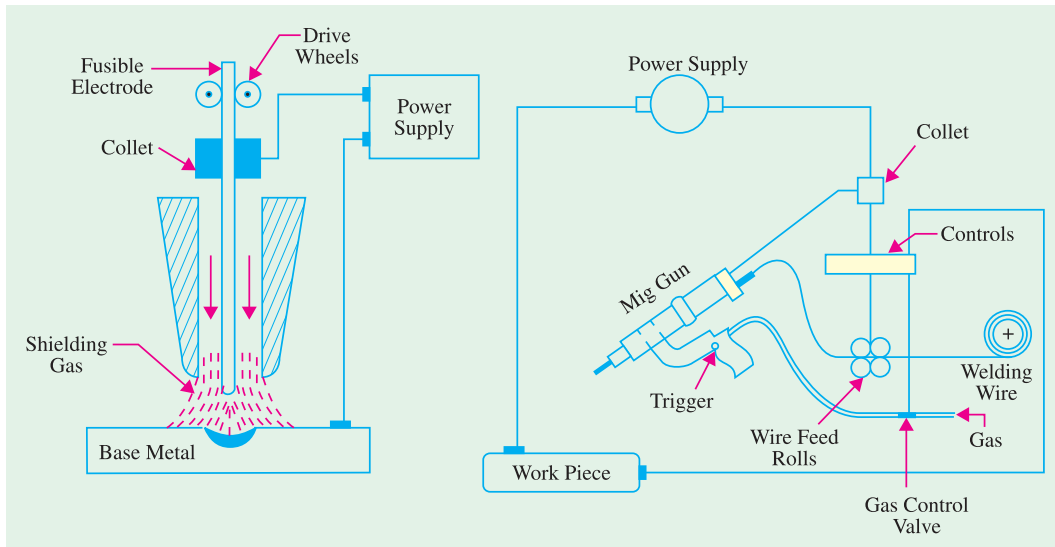


Fig. 48.22

Fig. 48.23

(c) Electrode

It is a bare wire fed to the MIG gun by a suitable wire-feed mechanism.

(d) Power Supply

The major power supply used for MIG welding is DCRP and the machines which provide this supply are motor-generator sets or a.c. transformers with rectifiers (Art. 48.14). They have either CAV or RAV characteristics (Art. 48.12). The CAV supply gives the operator great latitude in arc length and is helpful in preventing the wire electrode from stubbing. A DCRP current produces deeper penetration and a cleaner weld surface than other types of current.

The RAV machines are more suitable for automatic operation. They are capable of handling large diameter wires than CAV machines.

Fig. 48.24 shows semi-automatic forced-air cooled arc welding set MIG-400. It consists of

- (i) Indarc 400 MMR rectifier which is basically a 3-phase transformer rectifier with silicon



Fig. 48.24.

MIG-400 Welding Set. (Courtesy : Indian Oxygen Ltd. Calcutta)

diodes and a constant potential output. It provides maximum current of 400 A at 40 V for 75% duty cycle and 350 A at 42 V for 100% duty cycle.

- (ii) Indarc Wire Feeder which has a twin roll drive system, designed to feed 0.8 to 2.4 mm diameter welding wires to a hand-operated MIG welding torch.
- (iii) MIG Torches which are available in both air-cooled and water-cooled varieties. Fig. 48.25 (a) and (b) show light-weight swan-necked torches which are designed to operate upto 360 A and 400 A with CO₂ as shielding gas. Fig. 48.25 (c) shows a heavy-duty water-cooled torch designed to operate upto 550 A with CO₂/mixed shielding gases at 100% duty cycle.
- (iv) CO₂ Kit for hard wire applications and Argon Kit for soft wire applications.

(e) Advantages of MIG Welding

1. Gives high metal deposit rates varying from 2 to 8 kg/h.
2. Requires no flux.
3. Requires no post-welding cleaning.
4. Gives complete protection to weld bead from atmospheric contamination.
5. Is adaptable for manual and automatic operations.
6. Can be used for a wide range of metals both ferrous and non-ferrous.
7. Is easy to operate requiring comparatively much less operating skill.
8. Is especially suited for horizontal, vertical and overhead welding positions.

(f) Applications

With inert gas shielding, this process is suitable for fusion welding of (i) aluminium and its alloys (ii) nickel and its alloys (iii) copper alloys (iv) carbon steels (v) low-alloy steels (vi) high strength steels and (vii) titanium.

48.24. MAG Welding

As discussed earlier, in MIG welding process, the shielding gas used is monoatomic (argon or helium) and is inert *i.e.* chemically inactive and metal transfer takes place by axial pulverization. In MAG (metal-active-gas) process, shielding gas used is chemically active *i.e.* carbon dioxide or its mixture with other gases. Transfer of metal takes place in big drops.

48.25. Atomic Hydrogen Welding

(a) General

It is a non-pressure fusion welding process and the welder set is used only as heat supply for the base metal. If additional metal is required, a filler rod can be melted into the joint. It uses two tungsten electrodes between which an arc column (actually, an arc fan) is maintained by an a.c. supply.

(b) Basic Principle

As shown in Fig. 48.26, an arc column is struck between two tungsten electrodes with an a.c.

power supply. Soon after, normal molecular hydrogen (H₂) is forced through this arc column. Due to intense heat of the arc column, this diatomic hydrogen is dissociated into atomic hydrogen (H).

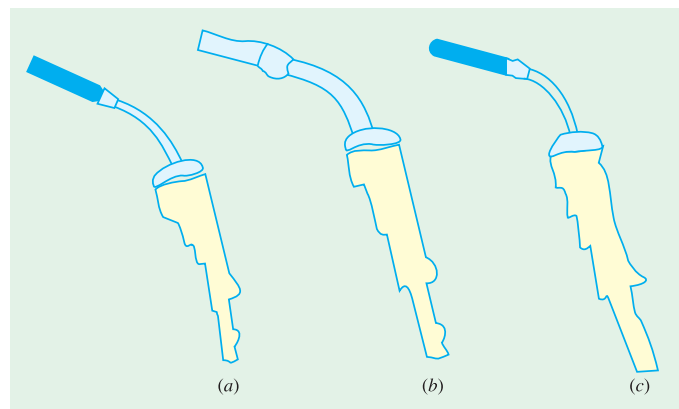


Fig. 48.25

However, atomic hydrogen being unstable, recombines to form stable molecular hydrogen. In so doing, it releases intense heat at about 3750°C which is used to fuse the metals.

(c) Welding Equipment

The welding equipment essentially consists of the following :

1. Standard welding machine consisting of a step-down transformer with tapped secondary (not shown in Fig. 48.27) energised from normal a.c. supply. Amperage requirement ranges from 15 A to 150 A
2. Hydrogen gas supply with an appropriate regulator
3. Atomic hydrogen welding torch having an ON-OFF switch and a trigger for moving the two tungsten electrodes close together for striking and maintaining the arc column.

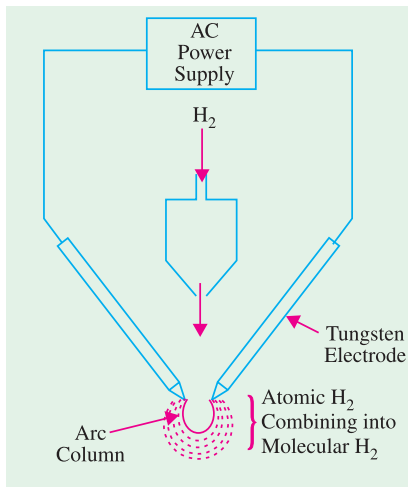


Fig. 48.26

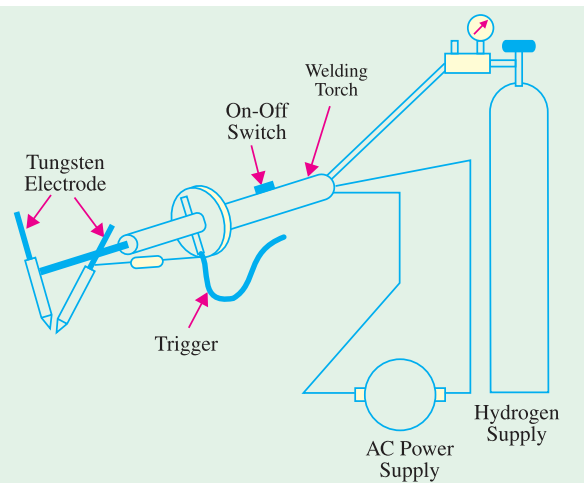


Fig. 48.27

(d) Method of Welding

The torch is held in the right hand with first finger resting lightly on the trigger. The arc is struck either by allowing the two tungsten electrodes to touch and separate or by drawing the separated electrodes over a carbon block. At the same time, a stream of hydrogen is allowed to flow through the arc. As soon as the arc strikes, an intensely hot flame extends fanwise between the electrodes. When this fan touches the workpiece, it melts it down quickly. If filler material is required, it can be added from the rod held in the left hand as in gas welding.

(e) Advantages

1. Arc and weld zone are shrouded by burning hydrogen which, being an active reducing agent, protects them from atmospheric contamination.
2. Can be used for materials too thin for gas welding.
3. Can weld quite thick sections.
4. Gives strong, ductile and sound welds.
5. Can be used for welding of mild steel, alloy steels and stainless steels and aluminium alloys.
6. Can also be used for welding of most non-ferrous metals such as nickel, monel, brass, bronze, tungsten and molybdenum etc.

48.26. Resistance Welding

It is fundamentally a heat and squeeze process. The term '*resistance welding*' denotes a group

of processes in which welding heat is produced by the resistance offered to the passage of electric current through the two metal pieces being welded. These processes differ from the fusion processes in the sense that no extra metal is added to the joint by means of a filler wire or electrode. According to Joule's law, heat produced electrically is given by $H = I^2 R t / J$. Obviously, amount of heat produced depends on.

(i) square of the current (ii) the time of current and (iii) the resistance offered.

As seen, in simple resistance welding, high-amperage current is necessary for adequate weld. Usually, R is the contact resistance between the two metals being welded together. The current is passed for a suitable length of time controlled by a timer. The various types of resistance welding processes may be divided into the following four main groups :

(i) spot welding (ii) seam welding (iii) projection welding and (iv) butt welding which could be further subdivided into flash welding, upset welding and stud welding etc.

Advantages

Some of the advantages of resistance welding are as under :

1. Heat is localized where required
2. Welding action is rapid
3. No filler material is needed
4. Requires comparatively lesser skill
5. Is suitable for large quantity production
6. Both similar and dissimilar metals can be welded
7. Parent metal is not harmed
8. Difficult shapes and sections can be welded.

Only disadvantages are with regard to high initial as well as maintenance cost.

It is a form of resistance welding in which the two surfaces are joined by spots of fused metal caused by fused metal between suitable electrodes under pressure.

48.27. Spot Welding

The process depends on two factors :

1. Resistance heating of small portions of the two workpieces to plastic state and

2. Application of forging pressure for welding the two workpieces.

Heat produced is $H = I^2 R t / J$. The resistance R is made up of (i) resistance of the electrodes and metals themselves (ii) contact resistance between electrodes and workpieces and (iii) contact resistance between the two workpieces. Generally, contact resistance between the two workpieces is the greatest.

As shown in 48.28 (b), mechanical pressure is applied by the tips of the two electrodes. In fact, these electrodes not only provide the forging pressure but also carry the welding current and concentrate the welding heat on the weld spot directly below them.

Fig. 48.28 (a) shows diagrammatically the basic parts of a modern spot welding. It consists of a step-down transformer which can supply huge currents (upto 5,000 A) for short duration of time.



Spot welding machine

The lower arm is fixed whereas the upper one is movable. The electrodes are made of low-resistance, hard-copper alloy and are either air cooled or butt-cooled by water circulating through the rifled drillings in the electrode. Pointed electrodes [Fig. 48.29 (a)] are used for ferrous materials

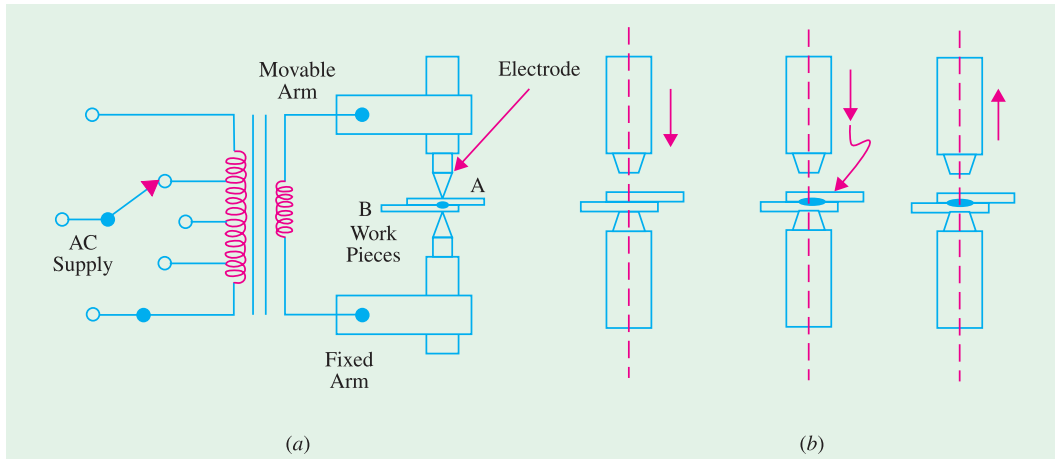


Fig. 48.28

whereas domed electrodes [Fig. 48.25 (b)] are used for non-ferrous materials. Flat domes are used when spot-welding deformation is not desired. The weld size is determined by the diameter of the electrode.

The welding machine is cycled in order to produce the required heat timed to coincide with the pressure exerted by the electrodes as shown in Fig. 48.28 (a). As the movable electrode comes down and presses the two workpieces A and B together, current is passed through the assembly. The metals under the pressure zone get heated upto about 950°C and fuse together. As they fuse, their resistance is reduced to zero, hence there is a surge of current. This surge is made to switch off the welding current automatically. In motor-driven machines, speeds of 300 strokes/minute are common.

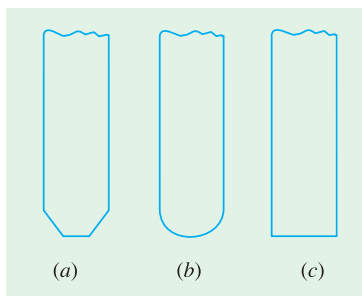


Fig. 48.29

and most widely-used because of its low cost, speed and dependability. It can be easily performed by even a semi-skilled operator. This process has a fast welding rate and quick set-up time apart from having low unit cost per weld.

Spot welding is used for galvanized, tinned and lead-coated sheets and mild steel sheet work. This technique is also applied to non-ferrous materials such as brass, aluminium, nickel and bronze etc.

48.28. Seam Welding

The seam welder differs from ordinary spot welder only

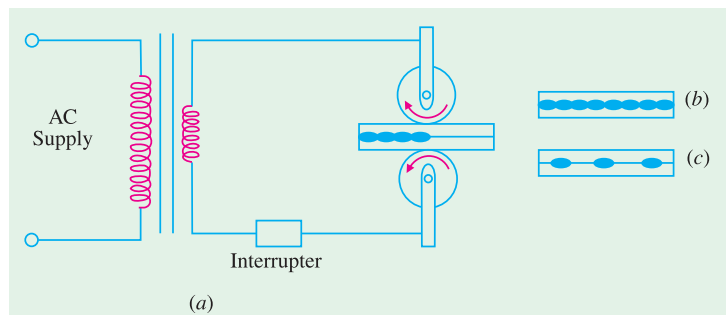


Fig. 48.30

in respect of its electrodes which are of disc or roller shape as shown in Fig. 48.30 (a). These copper wheels are power driven and rotate whilst gripping the work. The current is so applied through the wheels that the weld spots either overlap as in Fig. 48.30 (b) or are made at regular intervals as in Fig. 48.30 (c). The continuous or overlapped seam weld is also called *stitch weld* whereas the other is called roll weld.

Seam welding is confined to welding of thin materials ranging in thickness from 2 mm to 5 mm. It is also restricted to metals having low hardenability rating such as hot-rolled grades of low-alloy steels. Stitch welding is commonly used for long water-tight and gas-tight joints. Roll welding is used for simple joints which are not water-tight or gas-tight. Seam welds are usually tested by pillow test.

48.29. Projection Welding

It can be regarded as a mass-production form of spot welding. Technically, it is a cross between spot welding and butt welding. It uses the same equipment as spot welding. However, in this process, large-diameter flat electrodes (also called platens) are used. This welding process derives its name

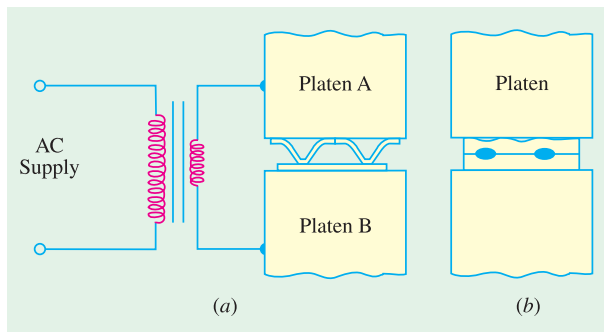


Fig. 48.31

from the fact that, prior to welding, projections are raised on the surfaces to be welded [Fig. 48.31 (a)]. As seen, the upper and lower platens are connected across the secondary of a step-down transformer and are large enough to cover all the projections to be welded at one stroke of the machine. When platen A touches the workpiece, welding current flows *through each projection*.

The welding process is started by first lowering the upper platen A on to

the work-piece and then applying mechanical pressure to ensure correctly-forged welds. Soon after, welding current is switched on as in spot welding. As projection areas heat up, they collapse and union takes place at all projections simultaneously [Fig. 48.31 (b)].

It is seen that projections serve many purposes :

1. They increase the welding resistance of the material locally.
2. They accurately locate the positions of the welds.
3. They speed up the welding process by making it possible to perform several small welds simultaneously.
4. They reduce the amount of current and pressure needed to form a good bond between two surfaces.
5. They prolong the life of the electrode considerably because the metal itself controls the heat produced.

Projection welding is used extensively by auto manufactures for joining nuts, bolts and studs to steel plates in car bodies. This process is especially suitable for metals like brass, aluminium and copper etc. mainly due to their high thermal conductivity.

A variation of projection welding is the metal fibre welding which uses a metal fibre rather than a projection point (Fig. 48.32). This metal fibre is generally a felt material. Instead of projections, tiny elements of this felt material are placed between the two metals which are then projection-welded in the usual way.

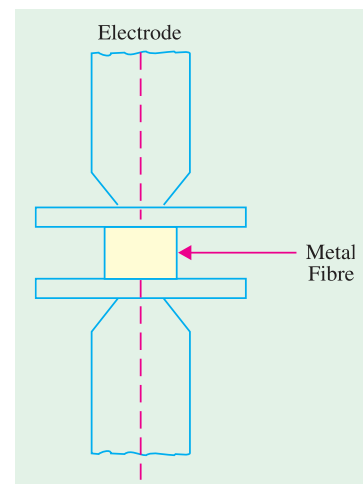


Fig. 48.32

48.30. Butt Welding

In this case, the two workpieces are brought into contact end-to-end and the butted ends are heated by passing a heavy current through the joint. As in other forms of resistance welding, the weld heat is produced mainly by the electrical resistance of the joint faces. In this case, however, the electrodes are in the form of powerful vice clamps which hold the work-pieces and also convey the forging pressure to the joint [Fig. 48.33].

This process is useful where parts have to be joined end-to-end or edge-to-edge. *i.e.* for welding pipes, wires and rods. It is also employed for making continuous lengths of chain.

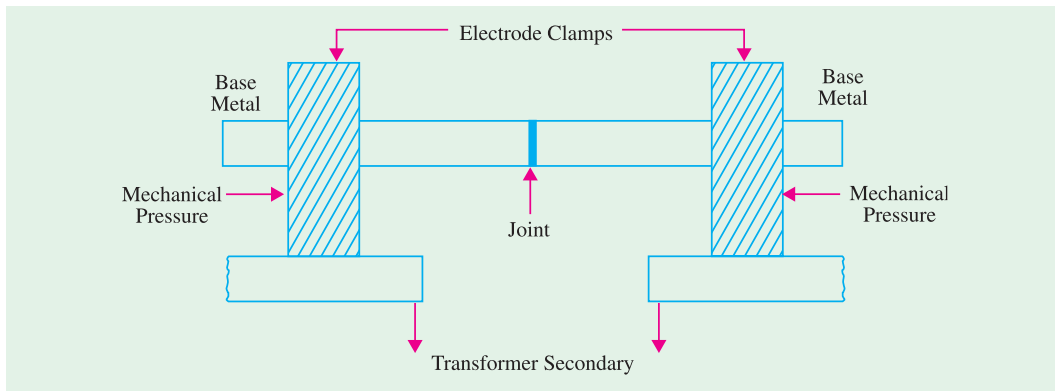


Fig. 48.33

48.31. Flash Butt Welding

It is also called by the simple name of *flash welding*. It is similar to butt welding but with the difference that here current is applied when ends of the two metal pieces are quite close to each other *but do not touch intimately*. Hence, an arc or flash is set up between them which supplies the necessary welding heat. As seen, in the process heat is applied *before* the two parts are pressed together.

As shown in Fig. 48.34 (a), the workpieces to be welded are clamped into specially designed electrodes one of which is fixed whereas the other is movable. After the flash has melted their faces, current is cut off and the movable platen applies the forging pressure to form a fusion weld. As shown in Fig. 48.34 (b), there is increase in the size of the weld zone because of the pressure which forces the soft ends together.

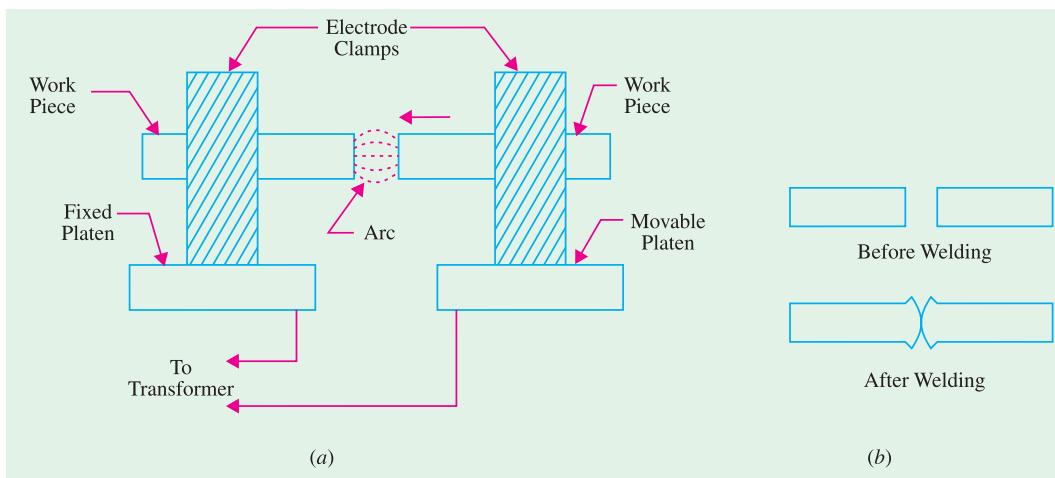


Fig. 48.34

Advantages

1. Even rough or irregular ends can be flash-welded. There is no need to level them by machining and grinding because all irregularities are burnt away during flashing period.
2. It is much quicker than butt welding.
3. It uses considerably less current than butt welding.
4. One of its major advantages is that dissimilar metals with different welding temperatures can be flash-welded.

Applications

1. To assemble rods, bars, tubings, sheets and most ferrous metals.
2. In the production of wheel rims for automobiles and bicycles.
3. For welding tubular parts such as automobile break cross-shafts.
4. For welding tube coils for refrigeration plants etc.

48.32. Upset Welding

In this process, *no flash is allowed to occur* between the two pieces of the metals to be welded. When the two base metals are brought together to a single interface, heavy current is passed between them which heats them up. After their temperature reaches a value of about 950°C , the two pieces of base metal are pressed together more firmly. This pressing together is called **upsetting**. This upsetting takes place *while current is flowing and continues even after current is switched off*. This upsetting action mixes the two metals homogeneously while pushing out many atmospheric impurities.

48.33. Stud Welding**(a) Basic Principle**

It is similar to flash welding because it incorporates a method of drawing an arc between the stud (a rod) and the surface of the base metal. Then, the two molten surfaces are brought together under pressure to form a weld. Stud welding eliminates the need for drilling holes in the main structure.

(b) Welding Equipment

The stud welding equipment consists of a stud welding gun, a d.c. power supply capable of giving currents upto 400 A, a device to control current and studs and ferrules which are used not only as arc shields but also as containing walls for the molten metal.

(c) Applications

It is a low-cost method of fastening extensions (studs) to a metal surface. Most of the ferrous and non-ferrous metals can be stud-welded successfully. Ferrous metals include stainless steel, carbon steel and low-alloy steel. Non-ferrous metals include aluminium, lead-free brass, bronze and chrome-plated metals.

Stud welding finds application in the installations of conduit pipe hangers, planking and corrugated roofings.

This process is also used extensively in shipbuilding, railroad and automotive industries.

48.34. Plasma Arc Welding**(a) Basic Principle**

It consists of a high-current electronic arc which is forced through a small hole in a water-cooled metallic nozzle [Fig. 48.35 (a)]. The plasma gas itself is used to protect the nozzle from the extreme heat of the arc. The plasma arc is shielded by inert gases like argon and helium which are pumped through an extra passageway within the nozzle of the plasma torch. As seen, plasma arc consists of electronic arc, plasma gas and gases used to shield the jet column. The idea of using the nozzle is to

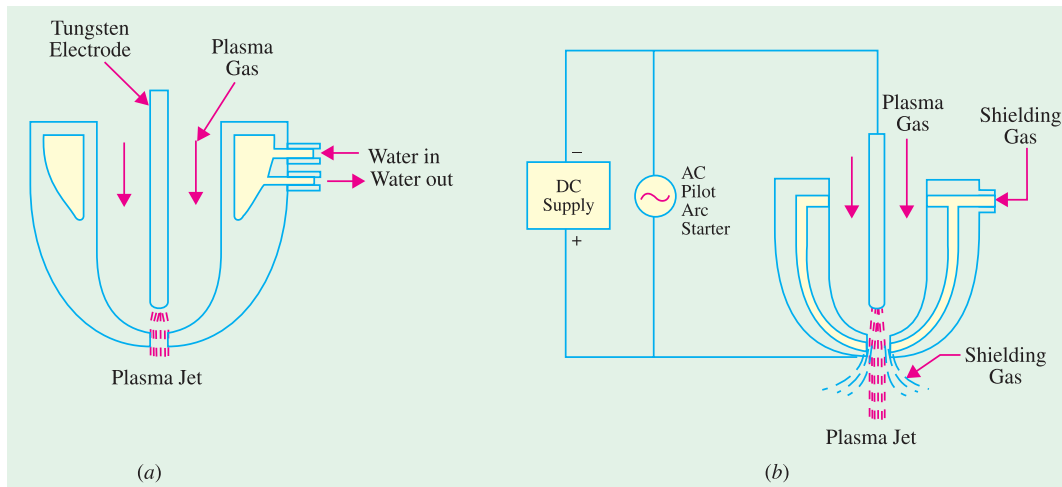


Fig. 48.35

constrict the arc thereby increasing its pressure. Collision of high-energy electrons with gas molecules produces the plasma which is swept through the nozzle and forms the current path between the electrode and the workpiece. Plasma jet torches have temperature capability of about $35,000^{\circ}\text{C}$.

(b) Electrodes

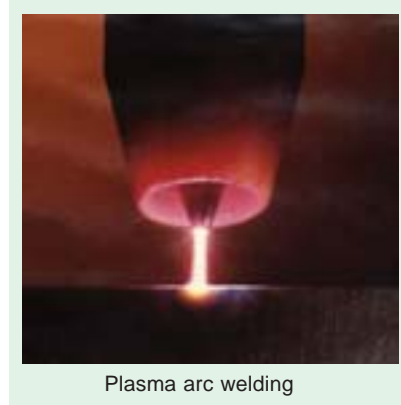
For stainless steel welding and most other metals, straight polarity tungsten electrodes are used. But for aluminium welding, reverse polarity water-cooled copper electrodes are used.

(c) Power Supply

Plasma arc welding requires d.c. power supply which could be provided either by a motor-generator set or transformer-rectifier combination. The latter is preferred because it produces better arc stability. The d.c. supply should have an open-circuit voltage of about 70V and drooping voltage-ampere characteristics. A high-frequency pilot arc circuit is employed to start the arc [Fig. 48.35 (b)].

(d) Method of Welding

Welding with plasma arc jet is done by a process called 'keyhole' method. As the plasma jet strikes the surface of the workpiece, it burns a hole through it. As the torch progresses along the work-piece, this hole also progresses along with but is filled up by the molten metal as it moves along. obviously, 100 percent penetration is achieved in this method of welding. Since plasma jet melts a large surface area of the base metal, it produces a weld bead of wineglass design as shown in Fig. 48.36. The shape of the bead can be changed by changing the tip of the nozzle of the torch. Practically, all welding is done mechanically.



Plasma arc welding



Fig. 48.36

(e) Applications

1. Plasma arc welding process has many aerospace applications.
2. It is used for welding of reactive metals and thin materials.
3. It is capable of welding high-carbon steel, stainless steel, maraging steel, copper and copper alloys, brass alloys, aluminium and titanium.
4. It is also used for metal spraying.

5. It can be modified for metal cutting purposes. It has been used for cutting aluminium, carbon steel, stainless steel and other hard-to-cut steels. It can produce high-quality cross-free aluminium cuts 15 cm deep.

(f) Disadvantages

1. Since it uses more electrical equipment, it has higher electrical hazards.
2. It produces *ultra-violet and infra-red* radiations necessitating the use of tinted lenses.
3. It produces high-pitched noise (100 dB) which makes it necessary for the operator to use ear plugs.

48.35. Electroslag Welding

(a) General

It is a metal-arc welding process and may be considered as a further development of submerged-arc welding.

This process is used for welding joints of thick sections of ferrous metals in a single pass and without any special joint preparation. Theoretically, there is no upper limit to the thickness of the weld bead. It is usually a vertical uphill process.

It is called *electroslag* process because heat is generated by passing current through the molten slag which floats over the top of the metal.

(b) Welding Equipment

As shown in Fig. 48.37, two water-cooled copper shoes (or dams) are placed on either side of the joint to be welded for the purpose of confining the molten metal in the joint area. The electrode is fed into the weld joint almost vertically from special wire guides. There is a mechanical device which raises the shoes and wire-feed mechanism as the weld continues upwards till it is completed. An a.c. welding machine has 100 percent duty cycle and which can supply currents upto 1000 A if needed.

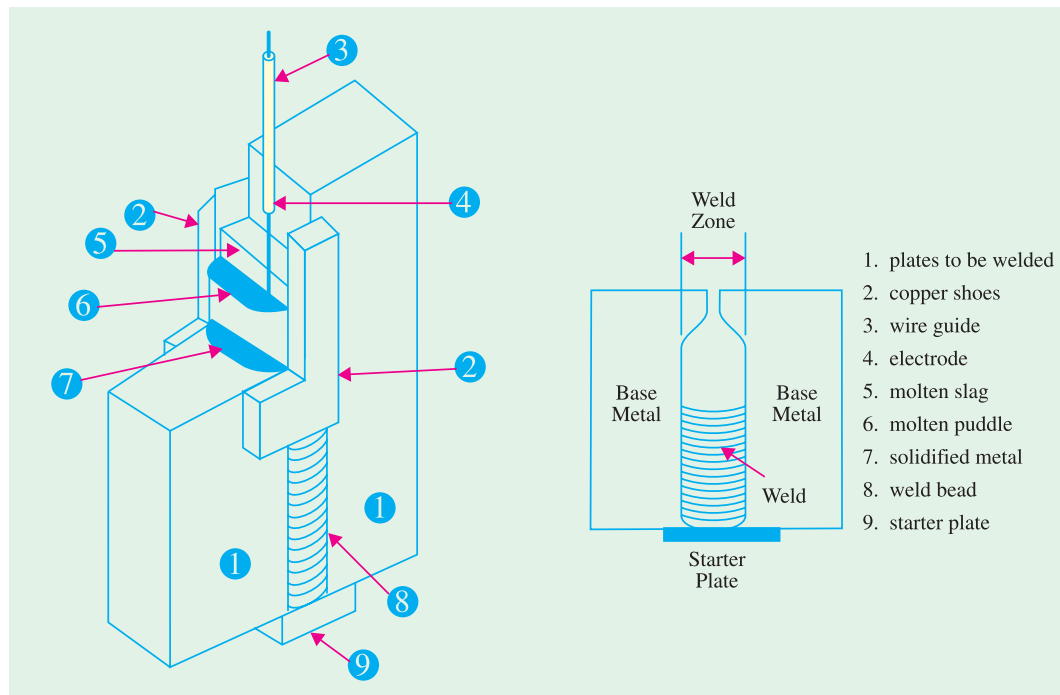


Fig. 48.37

(c) Welding Process

The electroslag process is initiated just like submerged arc process by starting an electric arc beneath a layer of granular welding flux. When a sufficient thick layer of hot flux or molten slag is formed, arc action stops and from then onwards, current passes from the electrode to workpiece through the molten slag. At this point, the process becomes truly electroslag welding. A starting plate is used in order to build up proper depth of conductive slag before molten pool comes in contact with the workpieces.

The heat generated by the resistance to the flow of current through the molten slag is sufficient to melt the edges of the workpiece and the filler electrode. The molten base metal and filler metal collect at the bottom of the slag pool forming the weld pool. When weld pool solidifies, weld bead is formed which joins the faces of the base metal as shown in Fig. 48.33 (b).

As welding is continued upwards, flux flows to the top in the form of molten slag and cleanses the impurities from the molten metal. A mechanism raises the equipment as the weld is completed in the uphill vertical position.

(d) Advantages

1. It needs no special joint preparation.
2. It does welding in a single pass rather than in costly multiple passes.
3. There is theoretically no maximum thickness of the plate it can weld.
4. There is also no theoretical upper limit to the thickness of the weld bead. Weld beads upto 400 mm thick have been performed with the presently-available equipment.
5. This process requires less electrical power per kg of deposited metal than either the submerged arc welding process or the shield arc process.
6. It has high deposit rate of upto 20 kg of weld metal per hour.
7. It has lower flux consumption.
8. Due to uniform heating of the weld area, distortion and residual stresses are reduced to the minimal amounts.

However, for electroslag welding, it is necessary to have only a square butt joint or a square edge on the plates to be welded.

(e) Applications

It is commonly used in the fabrication of large vessels and tanks. Low-carbon steels produce excellent welding properties with this process.

48.36. Electrogas Welding

This process works on the same basic principle as the electroslag process but has certain additional features of submerged arc welding. Unlike electroslag process, the electrogas process uses an inert gas for shielding the weld from oxidation and there is a continuous arc (as in submerged arc process) to heat the weld pool.

48.37. Electron Beam Welding

In this process, welding operation is performed in a vacuum chamber with the help of a sharply-focussed beam of high-velocity electrons. The electrons after being emitted from a suitable electrode are accelerated by the high anode voltage and are then focussed into a fine beam which is finally directed to the workpiece. Obviously, this process needs no electrodes. The electron beam produces intense local heat which can melt not only the metal but can even boil it. A properly-focussed electron beam can completely penetrate through the base metal thereby creating a small hole whose walls are molten. As the beam moves along the joint, it melt the material coming in contact with it. The molten metal flows back to the previously-melted hole where it fuses to make a perfect weld for the entire depth of penetration.

Electron-beam welding has following advantages :

1. It produces deep penetration with little distortion.
2. Its input power is small as compared to other electrical welding devices.
3. Electron-beam weld is much narrower than the fusion weld.
4. It is especially suitable for reactive metals which become contaminated when exposed to air because this process is carried out in vacuum.
5. It completely eliminates the contamination of the weld zone and the weld bead because operation is performed in a vacuum chamber.
6. It is especially suited to the welding of beryllium which is being widely used in the fabrication of industrial and aerospace components.
7. Its high deposition rate produces welds of excellent quality with only a single pass.
8. It is the only process which can join high temperature metals such as columbium.

At present, its only serious limitations are that it is extremely expensive and is not available in portable form. However, recently a non-vacuum electron-beam welder has been developed.



Electron beam welding facility

48.38. Laser Welding

It uses an extremely concentrated beam of coherent monochromatic light *i.e.* light of only one colour (or wavelength). It concentrates tremendous amount of energy on a very small area of the workpiece to produce fusion. It uses solid laser (ruby, sapphire), gas laser (CO_2) and semiconductor laser. Both the gas laser and solid laser need capacitor storage to store energy for later injection into the flash tube which produces the required laser beam.

The gas laser welding equipment consists of (i) capacitor bank for energy storage (ii) a triggering device (iii) a flash tube that is wrapped with wire (iv) lasing material (v) focussing lens and (vi) a worktable that can rotate in the three X, Y and Z directions.

When triggered, the capacitor bank supplies electrical energy to the flash tube through the wire. This energy is then converted into short-duration beam of laser light which is pin-pointed on the workpiece as shown in Fig. 48.38. Fusion takes place immediately and weld is completed fast.

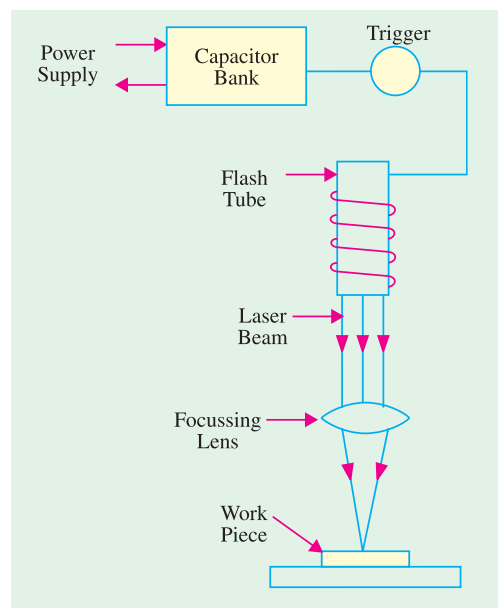


Fig. 48.38

Since duration of laser weld beam is very short (2 ms or so), two basic welding methods have been adopted. In the first method, the workpiece is moved so fast that the entire joint is welded in a single burst of the light. The other method uses a number of pulses one after the other to form the weld joint similar to that formed in electric resistance seam welding (Art 48.31).

Laser welding is used in the aircraft and electronic industries for lighter gauge metals.

Some of the advantages of laser welding process are as follows :

1. It does not require any electrode.
2. It can make welds with high degree of precision and on materials as thin as 0.025 mm.
3. It does not heat the workpiece except at one point. In fact, heat-affected zone is virtually non-existent.
4. Liquidus is reached only at the point of fusion.
5. It can produce glass-to-metal seals as in the construction of klystron tubes.
6. Since laser beam is small in size and quick in action, it keeps the weld zone uncontaminated.
7. It can weld dissimilar metals with widely varying physical properties.
8. It produces minimal thermal distortion and shrinkage because area of heat-affected zone is the minimum possible.
9. It can easily bond refractory materials like molybdenum, titanium and tantalum etc.

However, the major disadvantage of this process is its slow welding speed. Moreover, it is limited to welding with thin metals only.

Tutorial Problem No. 48.1

1. Describe various types of electric arc welding processes.
(J.N. University, Hyderabad, December 2002/January 2003)
2. Compare resistance welding and arc welding.
(J.N. University, Hyderabad, December 2002/January 2003)
3. Briefly explain the different methods of electric welding and state their relative merits.
(J.N. University, Hyderabad, December 2002/January 2003)
4. Give the comparison between A.C. and D.C. welding.
(J.N. University, Hyderabad, December 2002/January 2003)
5. Explain the different methods of electric welding and their relative advantages.
(J.N. University, Hyderabad, December 2002/January 2003)

OBJECTIVE TESTS – 48

1. The basic *electrical* requirement in arc welding is that there should be
 - (a) coated electrodes
 - (b) high open-circuit voltage
 - (c) no arc blow
 - (d) d.c. power supply.
2. Welding is not done directly from the supply mains because
 - (a) it is customary to use welding machines
 - (b) its voltage is too high
 - (c) its voltage keeps fluctuating
 - (d) it is impracticable to draw heavy currents.
3. A.C. welding machine cannot be used for welding
 - (a) MIG
 - (b) atomic hydrogen
 - (c) resistance
 - (d) submerged arc.
4. In electric welding, arc blow can be avoided by
 - (a) using bare electrodes
 - (b) welding away from earth ground connection
 - (c) using a.c. welding machines
 - (d) increasing arc length.

5. In DCSP welding
 - (a) electrode is the hottest
 - (b) workpiece is relatively cool
 - (c) base metal penetration is deep
 - (d) heavily-coated electrodes are used.
6. Overhead welding position is thought to be the most
 - (a) hazardous
 - (b) difficult
 - (c) economical
 - (d) useful.
7. The *ultimate* aim of using electrode coating is to
 - (a) provide shielding to weld pool
 - (b) prevent atmospheric contamination
 - (c) improve bead quality
 - (d) cleanse the base metal.
8. In electrode-positive welding of the total heat is produced at the electrode.
 - (a) one-third
 - (b) two-third
 - (c) one-half
 - (d) one-fourth.
9. Submerged arc process is characterised by
 - (a) deep penetration
 - (b) high welding current
 - (c) exceptionally smooth beads
 - (d) all of the above.
10. The major disadvantage of carbon arc welding is that
 - (a) there is occurrence of blow holes
 - (b) electrodes are consumed fast
 - (c) separate filler rod is needed
 - (d) bare electrodes are necessary.
11. In atomic hydrogen welding, electrodes are long-lived because
 - (a) two are used at a time
 - (b) arc is in the shape of a fan
 - (c) of a.c. supply
 - (d) it is a non-pressure process.
12. Unlike TIG welding, MIG welding
 - (a) requires no flux
 - (b) uses consumable electrodes
 - (c) provides complete protection from atmospheric contamination
 - (d) requires no post-weld cleansing.
13. The major power supply used in MIG welding is
 - (a) a.c. supply
 - (b) DCSP
 - (c) electrode-negative
 - (d) DCRP.
14. MIG welding process is becoming increasingly popular in welding industry mainly because of
 - (a) its easy operation
 - (b) its high metal deposit rate
 - (c) its use in both ferrous and non-ferrous metals.
 - (d) both (a) and (b).
15. A weld bead of wineglass design is produced in welding.
 - (a) plasma arc
 - (b) electron beam
 - (c) laser
 - (d) MAG.
16. Spot welding process basically depends on
 - (a) Ohmic resistance
 - (b) generation of heat
 - (c) application of forging pressure
 - (d) both (b) and (c).
17. Electric resistance seam welding uses electrodes.
 - (a) pointed
 - (b) disc
 - (c) flat
 - (d) domed.
18. Projection welding can be regarded as a mass production form of welding.
 - (a) seam
 - (b) butt
 - (c) spot
 - (d) upset.
19. In the process of electroslog welding, theoretically there is no upper limit to the
 - (a) thickness of weld bead
 - (b) rate of metal deposit
 - (c) slag bath temperature
 - (d) rate of slag consumption.
20. High temperature metals like columbium can be easily welded by welding.
 - (a) flash
 - (b) MIG
 - (c) TIG
 - (d) electron beam.
21. During resistance welding heat produced at the joint is proportional to
 - (a) I^2R
 - (b) kVA
 - (c) current
 - (d) voltage
22. Grey iron is usually welded by welding
 - (a) gas
 - (b) arc

- (c) resistance
(d) MIG
23. The metal surfaces, for electrical resistance welding must be.....
(a) lubricated
(b) cleaned
(c) moistened
(d) rough
24. In a welded joint poor fusion is due to which of the following?
(a) Improper current
(b) High welding speed
(c) Uncleaned metal surface
(d) Lack of flux
25. For arc welding, D.C. is produced by which of the following?
(a) motor-generator set
(b) regulator
(c) transformer
(d) none of the above
26. welding process uses consumable electrodes.
(a) TIG
(b) MIG
(c) Laser
(d) All of the above
27. Which of the following equipment is generally used for arc welding?
(a) single phase alternator
(b) two phase alternator
(c) three phase alternator
(d) transformer
28. Which of the following is not an inert gas?
(a) argon
(b) carbon dioxide
(c) helium
(d) all of the above
29. Electronic components are joined by which of the following methods?
(a) brazing
(b) soldering
(c) seam welding
(d) spot welding
(e) none of the above
30. Resistance welding cannot be used for
(a) dielectrics
(b) ferrous materials
(c) non-ferrous metals
(d) any of the above
31. Electric arc welding process produces temperature upto
(a) 1000°C
(b) 1500°C
(c) 3500°C
(d) 5550°C
32. Increased heat due to shorter arc is harmful on account of
(a) under-cutting of base material
(b) burn through
(c) excessive porosity
(d) all of the above
33. Arc blow results in which of the following?
(a) Non-uniform weld beads
(b) Shallow weld puddle given rise to weak weld
(c) Splashing out of metal from weld puddle
(d) All of the above defects
34. Inseam welding
(a) the work piece is fixed and disc electrodes move
(b) the work piece moves but rotating electrodes are fixed
(c) any of the above
(d) none of the above
35. In arc welding major personal hazards are
(a) flying sparks
(b) weld spatter
(c) harmful infrared and ultra-violet rays from the arc
(d) all of the above
36. In spot welding composition and thickness of the base metal decides
(a) the amount of squeeze pressure
(b) hold time
(c) the amount of weld current
(d) all above
37. Helium produces which of the following?
(a) deeper penetration
(b) faster welding speeds
(c) narrower heat affected zone in base metal
(d) all of the above
38. Due to which of the following reasons aluminium is difficult to weld?
(a) it has an oxide coating
(b) it conducts away heat very rapidly
(c) both (a) and (b)
(d) none of the above
39. Welding leads have
(a) high flexibility
(b) high current handling capacity
(c) both (a) and (b)
(d) none of the above
40. Air craft body is
(a) spot welded

- (b) gas welded
(c) seam welded
(d) riveted
41. For arc welding current range is usually
(a) 10 to 15 A
(b) 30 to 40 A
(c) 50 to 100 A
(d) 100 to 350 A
42. Spot welding is used for
(a) thin metal sheets
(b) rough and irregular surfaces
(c) costings only
(d) thick sections
43. Galvanising is a process of applying a layer of
(a) aluminium
(b) lead
(c) copper
(d) zinc
44. A seamless pipe has
(a) steam welded joint
(b) spot welded joint
(c) arc welded joint
(d) no joint
45. Motor-generator set for D.C. arc welding has generator of
(a) series type
(b) shunt type
(c) differentially compound type
(d) level compound type
46. Plain and butt welds may be used on materials upto thickness of nearly
(a) 5 mm
(b) 10 mm
(c) 25 mm
(d) 50 mm
47. In argon arc welding argon is used as a
(a) flux
(b) source of heat
(c) agent for heat transfer
(d) shield to protect the work from oxidation
48. During arc welding as the thickness of the metal to be welded increases
(a) current should decrease, voltage should increase
(b) current should increase, voltage remaining the same
(c) current should increase, voltage should decrease
(d) voltage should increase, current remaining the same
49. In D.C. arc welding
(a) electrode is made positive and workpiece negative
(b) electrode is made negative and workpiece positive
(c) both electrode as well as workpiece are made positive
(d) both electrode as well as workpiece are made negative
50. The purpose of coating on arc welding electrodes is to
(a) stabilise the arc
(b) provide a protecting atmosphere
(c) provide slag to protect the molten metal
(d) all of the above
51. 50 percent duty cycle of a welding machine means
(a) machine input is 50 percent of rated input
(b) machine efficiency is 50 percent
(c) machine work on 50 percent output
(d) machine works for 5 minutes in a duration of 10 minutes

ANSWERS

- | | | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1. (b) | 2. (d) | 3. (a) | 4. (c) | 5. (c) | 6. (a) | 7. (c) | 8. (b) | 9. (d) |
| 10. (a) | 11. (c) | 12. (b) | 13. (d) | 14. (d) | 15. (a) | 16. (d) | 17. (b) | 18. (c) |
| 19. (a) | 20. (d) | 21. (a) | 22. (a) | 23. (b) | 24. (a) | 25. (a) | 26. (b) | 27. (d) |
| 28. (b) | 29. (b) | 30. (a) | 31. (d) | 32. (d) | 33. (d) | 34. (c) | 35. (d) | 36. (d) |
| 37. (d) | 38. (c) | 39. (d) | 40. (c) | 41. (d) | 42. (a) | 43. (d) | 44. (d) | 45. (d) |
| 46. (c) | 47. (d) | 48. (b) | 49. (b) | 50. (d) | 51. (d) | | | |