MODULE -5

SOLDERING, BRAZING

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METALLURGICAL ASPECTS IN WELDING

Weldability and thermal aspects: Concept of weldability of materials; Thermal Effects in Welding (Distortion, shrinkage and residual stresses in welded structures); Welding defects and remedies.

Allied processes: Soldering, Brazing and adhesive bonding

Advance welding processes: Resistance welding processes, friction stir welding (FSW).

SHRINKAGE AND RESIDUAL STRESSES IN WELDING

The molten metal at the weld joint starts cooling after some time. During this period liquid metal gets transformed to solid. The volume change that takes place results in shrinkage in the weld joint. The weld joint region is subjected to heating and subsequent cooling. This induces residual stresses and deformation occurs in metal. This is attributed to
Non-uniform heating and cooling of metal
Shrinkage of the deposited metal from liquid to solid resulting in warp.

The magnitude of deformation and stresses depend mainly on

- Shape and size of the work piece
- Character of heating zone in welding
- Nature of metal being welded

Welding stresses can be avoided by

- Preheating the work piece before welding to reduce thermal gradients
- Annealing the weld joint.

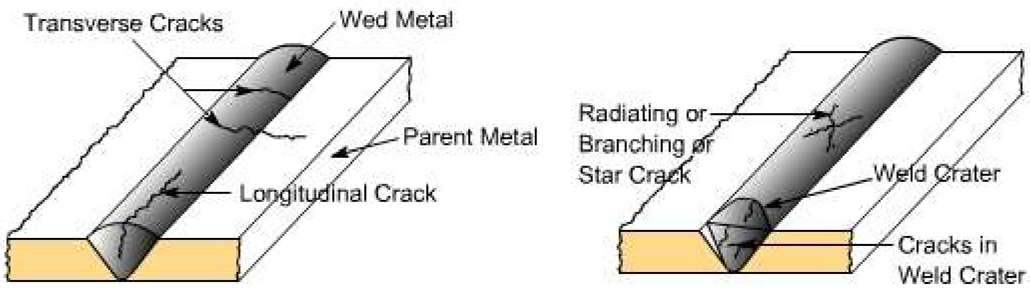
WELDING DEFECTS CAUSES AND REMEDIES:

The defects in the weld can be defined as irregularities in the weld metal produced due to incorrect welding parameters or wrong welding procedures or wrong combination of filler metal and parent metal.

Weld defect may be in the form of variations from the intended weld bead shape, size and desired quality. Defects may be on the surface or inside the weld metal. Certain defects such as cracks are never tolerated but other defects may be acceptable within permissible limits. Welding defects may result into the failure of components under service condition, leading to serious accidents and causing the loss of property and sometimes also life.

Various welding defects can be classified into groups such as cracks, porosity, solid inclusions, lack of fusion and inadequate penetration, imperfect shape and miscellaneous defects.

1. Cracks: Cracks may be of micro or macro size and may appear in the weld metal or base metal or base metal and weld metal boundary. Different categories of cracks are longitudinal cracks, transverse cracks or radiating/star cracks and cracks in the weld crater. Cracks occur when localized stresses exceed the ultimate tensile strength of material. These stresses are developed due to shrinkage during solidification of weld metal.

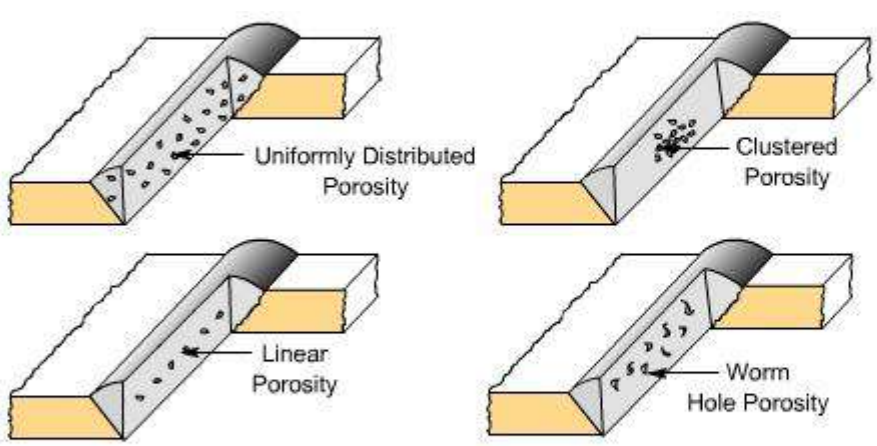


Various Types of Cracks in Welds

Cracks may be developed due to poor ductility of base metal, high sulphur and carbon contents, high arc travel speeds i.e. fast cooling rates, too concave or convex weld bead and high hydrogen contents in the weld metal.

2. Porosity

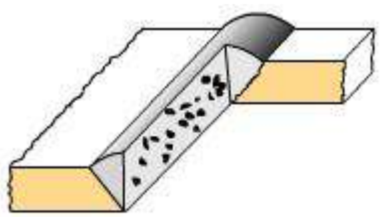
Porosity results when the gases are entrapped in the solidifying weld metal. These gases are generated from the flux or coating constituents of the electrode or shielding gases used during welding or from absorbed moisture in the coating. Rust, dust, oil and grease present on the surface of work pieces or on electrodes are also source of gases during welding. Porosity may be easily prevented if work pieces are properly cleaned from rust, dust, oil and grease .Further, porosity can also be controlled if excessively high welding currents, faster welding speeds and long arc lengths are avoided flux and coated electrodes are properly baked.



Different Forms of Porosities

3. Solid Inclusion

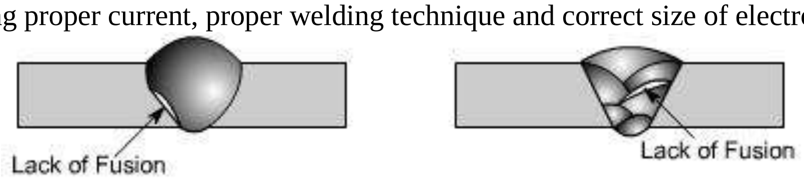
Solid inclusions may be in the form of slag or any other non metallic material entrapped in the weld metal as these may not able to float on the surface of the solidifying weld metal. During arc welding flux either in the form of granules or coating after melting, reacts with the molten weld metal removing oxides and other impurities in the form of slag and it floats on the surface of weld metal due to its low density. However, if the molten weld metal has high viscosity or too low temperature or cools rapidly then the slag may not be released from the weld pool and may cause inclusion. Slag inclusion can be prevented if proper groove is selected, all the slag from the previously deposited bead is removed, too high or too low welding currents and long arcs are avoided.



Slag Inclusion in Weldments

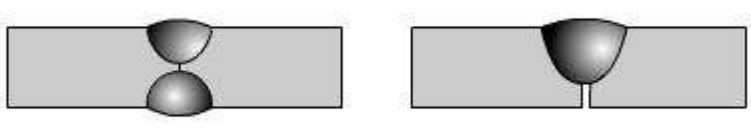
4. Lack of Fusion and Inadequate or incomplete penetration:

Lack of fusion is the failure to fuse together either the base metal and weld metal or subsequent beads in multi pass welding because of failure to raise the temperature of base metal or previously deposited weld layer to melting point during welding. Lack of fusion can be avoided by properly cleaning of surfaces to be welded, selecting proper current, proper welding technique and correct size of electrode.



Types of Lack of Fusion

Incomplete penetration means that the weld depth is not up to the desired level or root faces have not reached to melting point in a groove joint. If either low currents or larger arc lengths or large root face or small root gap or too narrow groove angles are used then it results into poor penetration.



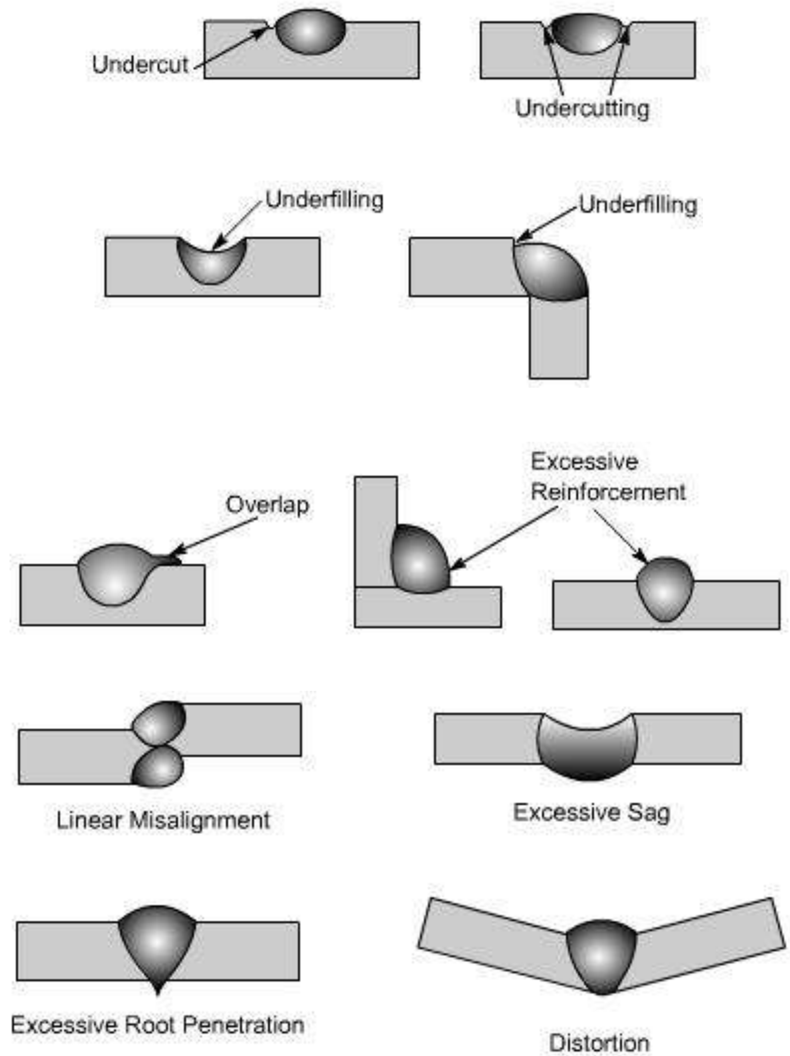
Examples of Inadequate Penetration

5. Imperfect Shape

Imperfect shape means the variation from the desired shape and size of the weld bead.

During undercutting a notch is formed either on one side of the weld bead or both sides in which stresses tend to concentrate and it can result in the early failure of the joint. Main reasons for undercutting are the excessive welding currents, long arc lengths and fast travel speeds.

Under filling may be due to low currents, fast travel speeds and small size of electrodes. Overlap may occur due to low currents, longer arc lengths and slower welding speeds.



Various Imperfect Shapes of Welds

Excessive reinforcement is formed if high currents, low voltages, slow travel speeds and large size electrodes are used. Excessive root penetration and sag occur if excessive high currents and slow travel speeds are used for relatively thinner members.

Distortion is caused because of shrinkage occurring due to large heat input during welding.

SOLDERING AND BRAZING

Definitions:

Soldering: Soldering is a process of uniting two or more metal pieces under heat with the help of a solder and a flux. There are two types:

- Soft soldering
- Hard soldering.

Flux: it is cleaning agent used to prevent oxidation of metals at the soldering point. It helps the solder to melt quickly and allows it to flow freely to unite more firmly.

E.g. zinc chloride, ammonium chloride, hydrochloric acid, borax, rosin, turpentine oil etc.

Solder: generally it is an alloy of lead and tin. It melts at low temperature. For strong joints a mixture of copper and zinc is used which has high melting point.

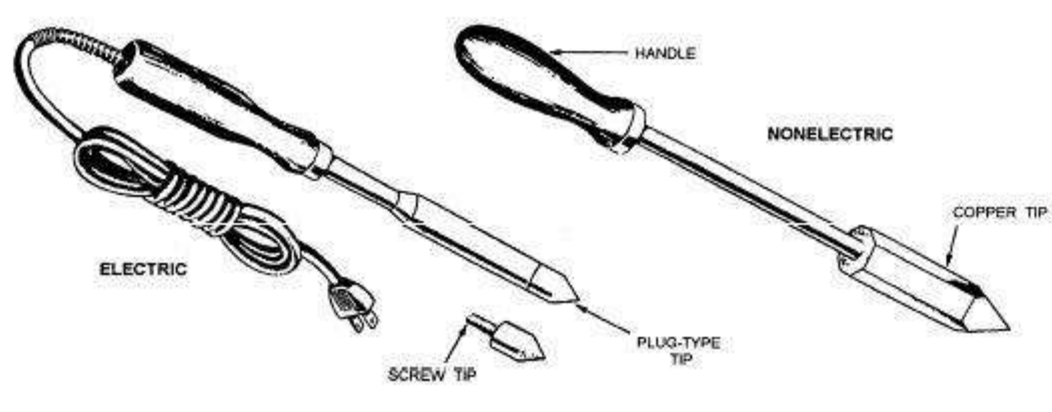


Figure 6-1. Soldering irons.

Classification of solder:

Soft solder: for high joints using various proportions of lead and tin which has low melting point.

Hard solder: for strong joints using a mixture of copper, zinc etc. which has high melting point.

Soft solder: generally it is composed of lead and tin. They are mixed in various proportions to solder different metals at different temperatures. The range of melting point for such solder lies between 150 to 300C. A suitable flux for the particular job is chosen. A small amount of bismuth and cadmium are frequently added to lower the melting point if necessary. Soft solders are used to join the wires and sheet metal works of light jobs which are subjected to light loads and slight shocks. A plain soldering iron is used to heat the metal pieces during the process. Soldering using soft solder is known as soft soldering.

Hard solder: generally it is composed of copper and zinc in 4:1 ratio. A small amount of silver or tin and antimony are frequently added to improve the quality. The range of melting point of such solder is lies between 350 to 900C.the fixtures for such solder will be in paste form. Propane Torch is used to heat the metal pieces during the process. Hard solders are used to make comparatively strong joints compare to soft solder. e.g.: plumbing, heavy sheet metal works etc.

Method of soldering:

The step by step general procedure for soldering is as follows:

The metal parts which are to be soldered must be thoroughly cleaned. The type of job whether light or heavy has to be decided. A good soldering iron has to be selected. In case of light jobs, the tip of the heating head of the soldering iron has to be heated sufficiently. It has to be then cleaned, dipped in flux and the rubbed on the solder to tin the tip. The molten solder has to be then deposited on the joint. In case of heavy jobs, the surface must be tinned first by cleaning, the heating using a blow torch. The job must be dipped in flux. Using a solder iron, the solder has to be applied over the parts. The parts may be then assembled and heated together until the solder melts. In case corrosive flux is used, the soldered job must be washed with water.

Advantages of soldering

It is simple and economical.

Base metals are safe against the metallurgical damages due to low operating temperature.

Brazing:

It is the process of uniting two or more metals of similar or dissimilar type with the help of an alloy in the form of spelter and flux, like borax, ash etc. these are used in tanks, radiators, carbide tips on tool holder etc.

Types of brazing:

It is classified on the basis of actual heating as

- Torch brazing
- Electric brazing
- Immersion brazing.

Method of brazing:

The step by step procedure for brazing is as follows:

The metal parts which are to be brazed must be thoroughly cleaned.

The flux must be applied to the surface.

The parts are to be clamped in the required position.

The flux has to be applied on the surfaces.

The job has to be heated using the blow torch or the furnace etc.

The molten spelter has to be allowed to flow by capillary action into the joint.

The job has to be allowed to cool slowly.

Advantages:

- Even dissimilar metal pieces can be united.
- No metallurgical damage to base metals.
- Provides stronger joints than hard soldering.

Difference between soldering and brazing:

Soldering	Brazing
Solder is used in this process.	Spelter is used in this process.
Joints are not very strong.	Joints are very strong.
Costs less.	Costs more.
Chlorides of zinc and rosin are used as flux.	Ash or borax is used as flux.
Low temperature is sufficient.	High temperature is necessary.

Suitable only for thin similar sheet metals.	Suitable even for thicker similar or dissimilar Metal parts.
Soldered parts are to be cleaned with water.	Brazed parts are to be allowed to cool slowly.

SPECIAL TYPE OF WELDING

RESISTANCE WELDING

Resistance welding is a welding process in which the work pieces are joined by the heat generated due to the resistance offered by the work pieces to the flow of electric current through them. A certain amount of pressure is applied to the work pieces to complete the weld.

Principle

When electric current flows through a material, it offers resistance to the flow of current resulting in heating of the material. The heat generated is used to make a weld between two or more work pieces. Resistance welding is based on the above principle. The heat generated in the material is given by Joules law:

$\mathbf{H = k\, I^2\, RT}$ where H = heat generated in the material in Joules,

I = Flow of current through the material in Amperes,

R = Electrical resistance of the material in Ohms,

T = time for which the electric current flows through the material in seconds,

k = a constant, usually < 1 to account for heat loss through conduction and radiation.

High current is the primary requirement to produce a resistance weld. A step down transformer that converts the high voltage, low current power line to a high current (up to 100,000 A) and low voltage (0.5 - 10 V) power is used for the purpose.

There are at least seven important resistance welding processes, but from the syllabus point of view, spot welding, seam welding, butt welding: and projection welding only have been discussed in this chapter.

Spot Welding

Spot welding is a resistance welding process in which the two overlapping work pieces held under pressure are joined together at one spot (location), Hence the name spot welding. Figure 6.1 (a) shows the details of a resistance spot welding process.

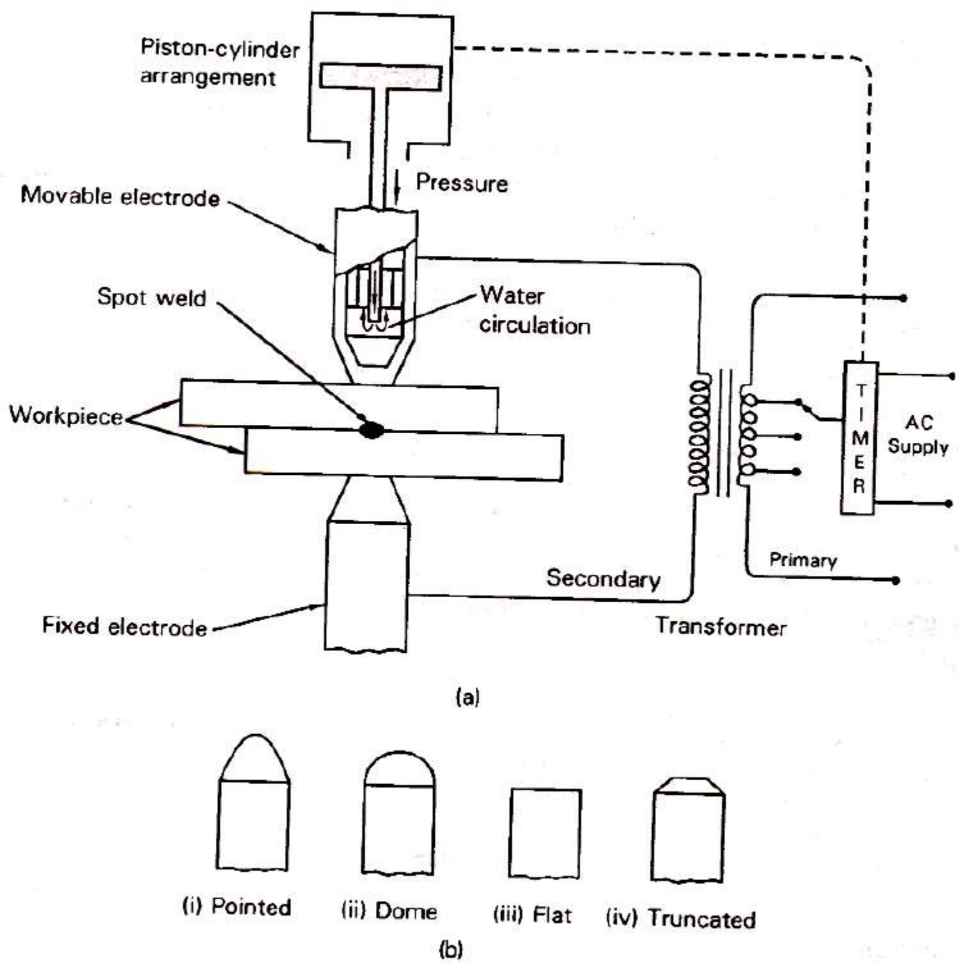
Description and Operation

a) The two work pieces to be joined are cleaned to remove dirt, grease and other oxides either chemically or mechanically to obtain a sound weld.

b) The work pieces are then overlapped and placed firmly between two water cooled cylindrically shaped copper alloy electrodes, which in turn are connected to a secondary circuit

of a step-down transformer. The electrodes carry high currents, and also transmit the force/pressure to the work pieces to complete the weld.
c) In operation, the welding current is switched ON. As the current passes through the electrodes, to the work piece, heat is generated in the air gap at the point of contact of the two work pieces.
d) The heat at this contact point is maximum, with temperature varying from 815 - 930°C, and as a result melts the work pieces locally at the contact point to form a spot weld.

e) In order to obtain a strong bond, external pressure is applied to the work piece, through the electrode, by means of a piston-cylinder arrangement. The current is switched OFF.
In some cases, external pressure is not required, and the holding pressure of the two electrodes is just sufficient to create a good joint.
f) Heat dissipates throughout the work piece, which cools the spot weld causing the metal to solidify, The pressure is released and the work piece is moved to the next location to make another spot weld. In some spot welding machines, the work piece remains stationary while the electrode moves to the next location to make a weld.



Resistance spot welding

Advantages

• Efficient energy use.
• Limited work piece deformation. Also, work piece is not melted to a larger extent. Heat is concentrated only at the spot to be welded.
• High production rates.
• Suitable for automation.
• Filler metals are not required. Hence, no associated fumes or gas. This results in clean weld.

Disadvantages

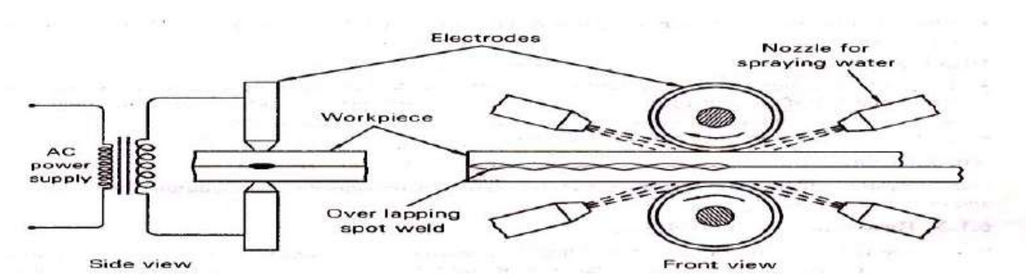
• Weld strength is significantly lower when compared to other processes. This makes the process suitable for only certain applications.
• Silver and copper are difficult to weld because of their high thermal conductivity.

Applications

Spot welding is extensively used for welding steels, and especially in the automotive industry for cars that requires several hundred spot welds made by industrial robots.

Seam Welding

Seam welding is a resistance welding process in which the overlapping work pieces held under pressure are joined together by a series of spot welds made progressively along the joint utilizing the heat generated by the electrical resistance of the work pieces.
Seam welding is similar to spot welding process, but, instead of pointed electrodes, mechanically driven wheel shaped electrodes are used to produce a continuous weld. Figure 6.2 shows the two principal views of a seam welding process:



Seam welding process

Description and Operation

a) The two work pieces to be joined are cleaned to remove dirt, grease and other oxides either. Chemically or mechanically to obtain a sound weld.
b) The work pieces are overlapped and placed firmly between two wheels shaped copper alloy electrodes, which in turn are connected to a secondary circuit of a step-down transformer,
c) The electrode wheels are driven mechanically in opposite directions with the work pieces passing between them, while at the same time the pressure" on the joint is maintained.
d) Welding current is passed in series of pulses at proper intervals through the bearing of the roller electrode wheels (not shown in figure).
e) As the current passes through the electrodes, to the work piece, heat is generated in the air gap at the point of contact (spot) of the two work pieces. This heat melts the work pieces locally at the contact point to form a spot weld.
f) Under the pressure of continuously rotating electrodes and the current flowing through them, a series of overlapping spot welds are made progressively along the joint as shown in the figure.
g) The weld area is flooded with water to keep the electrode wheels cool during welding.

Advantages

• A continuous overlapping weld produced by the process makes it suitable for joining liquid or gas tight containers and vessels.
• Efficient energy use.
• Filler metals are not required. Hence, no associated fumes or gases. This results in clean welds.

Disadvantages

• Requires complex control system to regulate the travel speed of electrodes as well as the sequence of current to provide satisfactory overlapping welds. The welding speed, spots per inch, and the timing schedule are all dependant on each other.
• Difficult to weld metals having thickness greater than 3 mm.

Applications

Used to fabricate liquid or gas tight sheet metal vessels such as gasoline tanks, automobile mufflers, and heat exchangers.

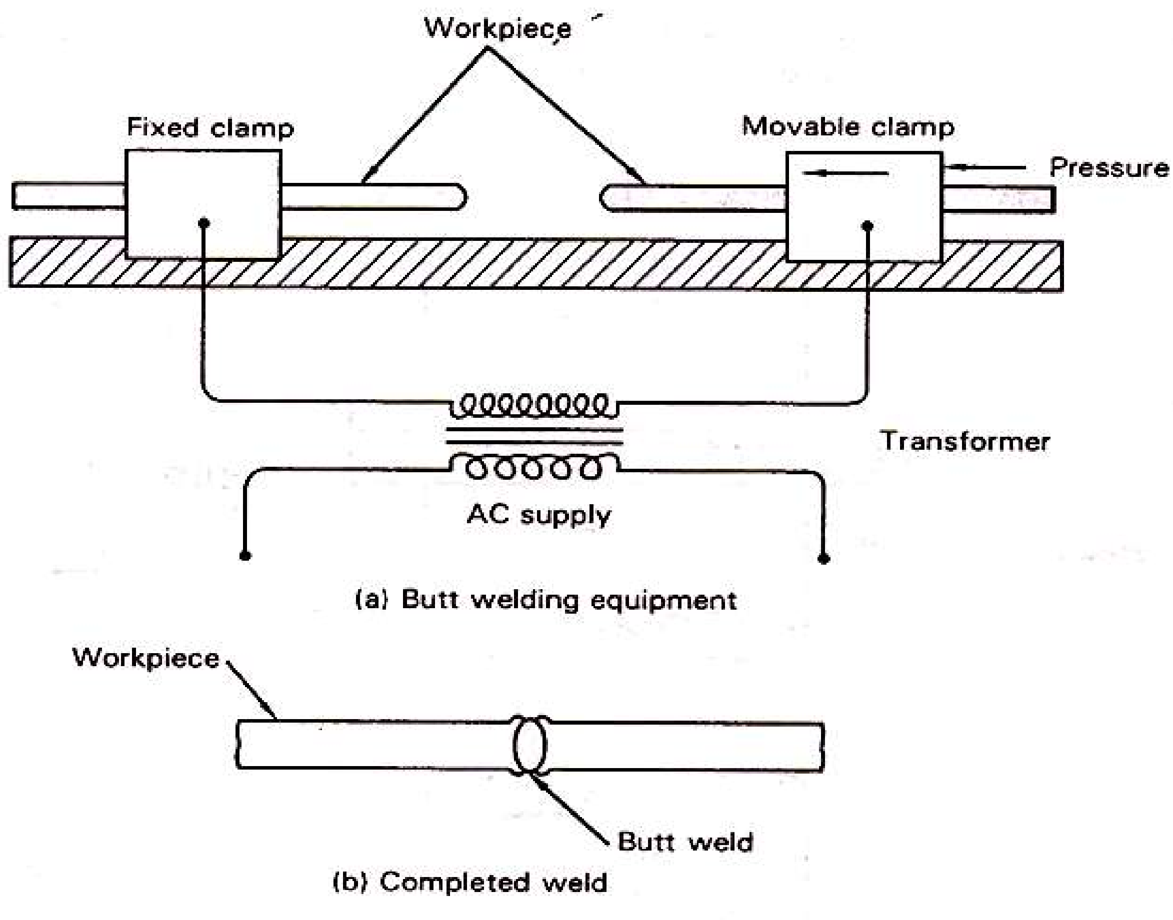
Resistance Butt Welding

Resistance butt welding or upset welding is a resistance welding process in which the two parts to be joined are heated to elevated temperatures and forged (by applying the desired pressure) together at that temperature. Figure 6.3(a) shows the equipment for resistance butt welding process.

Description and Operation

a) The machine used for butt welding consists of two clamps mounted on a horizontal slide. The clamps are made from a conducting material, usually copper alloy, which serve to carry high currents from a step-down transformer.
b) The two work pieces to be joined are cleaned to remove dirt, grease and other oxides either chemically or mechanically to obtain a sound weld.

c) The work pieces are clamped rigidly on the welding machine. By applying external force, the work piece in the movable clamp is brought in tight contact with the surface of the work piece in the fixed clamp.
d) High amperage current is then passed, through the joint which heats the abutting surfaces.
e) When the work pieces reaches a temperature of about 870-930°C, pressure is increased to give a forging squeeze.
f) Upsetting takes place while the current is flowing, and continues until the current is switched OFF.
g) When the metal has cooled, the pressure is released and the weld is completed.
h) The weld joint obtained will be bulged and round due to the squeezing action of the softened metal. Refer figure .This unwanted material can be removed later by machining process.



Resistance butt welding

Advantages
• Joint obtained is clean, since filler metal is not used in this process.
• Produces defect free joint. Oxides, scales and other impurities are thrown out of the weld joint due to the high pressure applied at elevated temperatures.

Disadvantages

• The process is suitable for parts with similar cross-sectional area.
• Joint preparation is a must for proper heating of work pieces to take place.

Applications

Used for producing joints in long tubes and pipes.

PROJECTION WELDING

Projection welding is a resistance welding process in which the work pieces are joined by the heat generated due to the resistance of the work pieces to the flow of electric current through them. The resulting welds are localized at predetermined points by projections, embossments or intersections. Figure (a) shows the resistance projection welding process.

Description and Operation

a) The process uses two flat, large cylindrically shaped water cooled copper electrodes in which one electrode is fixed, while the other to which the pressure is applied is movable. The electrodes are connected to a step-down transformer that provides the required electric current for heating.

b) One of the work pieces contains small projections or embossment (similar to a pimple on a human face) made at a particular location where the joint is to be made.

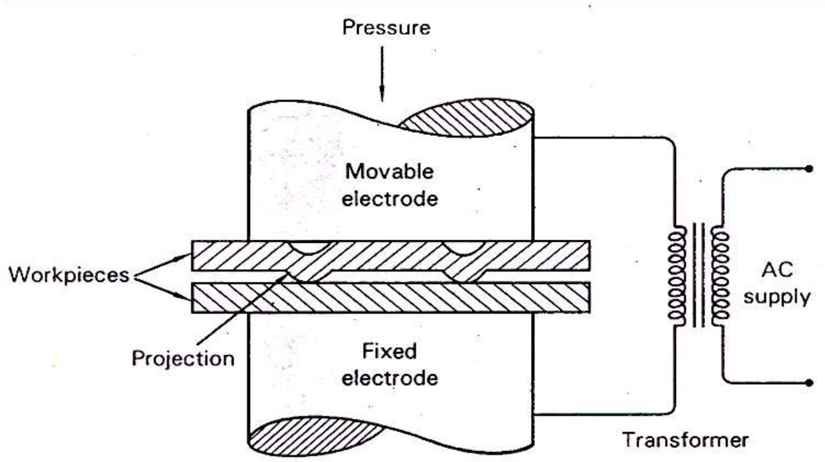
c) The work pieces are cleaned to remove dust, scale and other oxides either chemically or mechanically to obtain a sound weld.

d) The work pieces are then placed between the two electrodes and held firmly under external pressure.

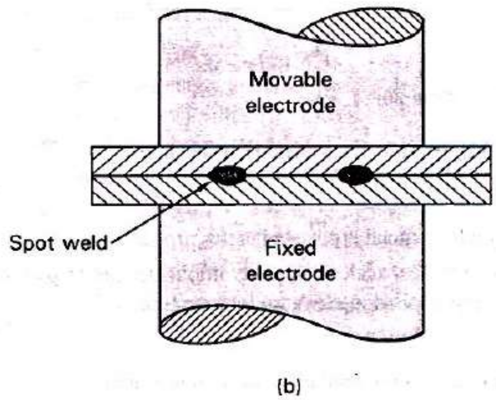
e) When the welding current is made to pass through the electrodes, to the work pieces, maximum heat is generated at the point of contact of the two work pieces, i.e., at the projections.

f) This heat softens and melts the projections causing it to collapse under the external pressure of the electrode thereby forming a spot weld. Refer figure (b).

g) The current is switched OFF and the pressure on the work piece is removed.



(a)



Resistance projection welding

Advantages

• More than one spot weld can be made in a single operation.
• Welding current and pressure required is less.
• Suitable for automation.
• Filler metals are not used. Hence, clean weld joints are obtained.

Disadvantages

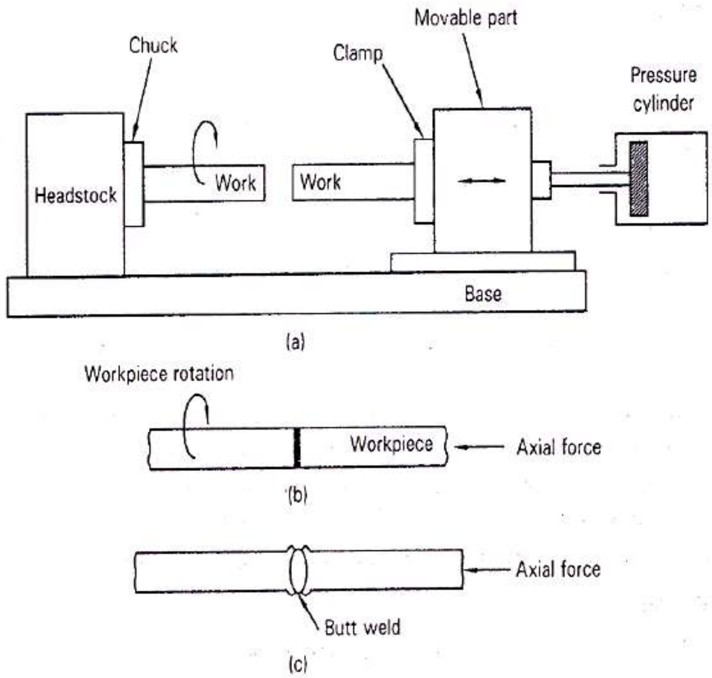
• Projections cannot be made in thin work pieces.
• Thin work pieces cannot withstand the electrode pressure.
• Equipment is costlier.

Applications

A very common use of projection welding is the use of special nuts that have projections on the portion of the part to be welded to the assembly. Also, the process is used for welding parts of refrigerator, condensers, refrigerator racks, grills etc.

FRICTION WELDING

Friction welding is a solid state welding process in which the work pieces are joined by the heat generated due to the friction at the interface of the two work pieces. Figure (a) shows the arrangement for friction welding process.



Friction welding

Description and Operation

a) The machine for friction welding is similar to a lathe, which consists of a chuck held in the spindle of the headstock. The chuck holds one of the work pieces and rotates it at high speeds (around 3000 rpm).

b) The other work piece is held stationary, and in a movable clamp so that it can be brought in contact with the rotating work piece.

c) The work pieces to be joined are prepared to have a smooth square cut surfaces.

d) In operation, the stationary work piece is slowly brought in contact with the rotating work piece under an axial force. Refer figure (b). As the work pieces come in contact with each other, friction is generated at the contact surface resulting in heating of the work pieces.

e) The axial pressure to the stationary work piece is increased until the friction between the surfaces raises the heat to the welding temperature.

f) At this moment, the rotation of the work piece is stopped, but the pressure (force) on-the stationary work piece is maintained, or in some cases increased to complete the weld. Refer figure (c):

g) The weld joint obtained will be bulged due to the squeezing action of the softened metal. The excess metal can be removed by machining.

Advantages

- Process is simple
- Low power requirements.

• Edge preparation is not required. The impurities are thrown away by the friction generated between the two work pieces.
• No filler metal. Hence the joint obtained is clean.
• Dissimilar metals can be easily welded.

Disadvantages

• The process is restricted to tubular parts and butt welds.