UNIT 3

Welding Process: Arc Welding, Resistance Welding, Oxyfuel Gas Welding, Thermit welding, electron beam welding, Fusion-Welding Processes, Solid-State Welding, Weld Quality, Weldability, Brazing, Soldering, Adhesive Bonding, defects in welding.

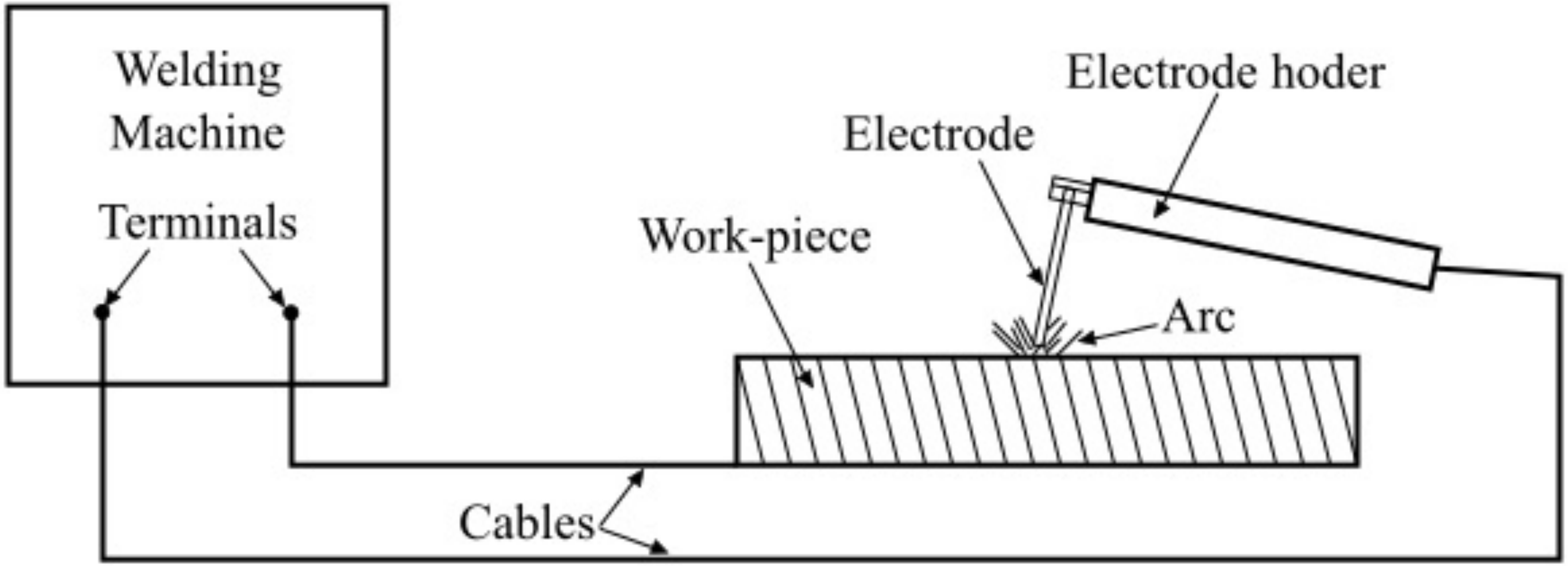
Welding

Welding is metallurgical fusion process, where two parts to be joined by the application of heat and pressure

Arc Welding

- Arc Welding (AW)A fusion welding process in which coalescence of the metals is achieved by the heat from an electric arc between an electrode and the work
- Electric energy from the arc produces temperatures 10,000 F (5500 C), hot enough to melt any metal
- Most AW processes add filler metal to increase volume and strength of weld joint

Arc Welding



Electric Arc Welding

Working Principle of Electric Arc Welding

- The process of electric arc welding is based on the principle that, when electric current is passed through an air gap from one electric conductor to another, then an electric arc is produced which generates a very intense and concentrated heat.
- The temperature of the arc between two conductors is approximately 3500 °C to 4000 °C. This high temperature generates intense heat in the arc at the point of welding, which melts a small portion of metal in the work-piece.
- The electric arc keeps this molten metal pool agitated and the base metal is thoroughly mixed with melted electrode metal, after that the metal pool cools down under a protective cover of slag left by the electrode. On cooling, a strong weld join is formed between the two metal pieces.
- A simplified circuit of electric arc welding is shown in the figure.

Working Principle of Electric Arc Welding

- In electric arc welding, either AC or DC current is obtained from a welding power supply. Here, one terminal is connected to the electrode mounted on an electrode holder, which is held by the welder, while the other terminal is connected to the workpiece and the circuit is completed through an air gap between the electrode and the work-piece.
- The length of the air gap (i.e., distance between electrode tip and the surface of the work-piece) is about 3 mm to 6 mm. The welding is done by creating an electric arc between the electrode and the workpiece. The temperature of the arc is very high (about 3500 °C to 4000 °C) and the metal in contact with the arc becomes molten which enables a weld to be melt. The electrode is then moved slowly in the desired direction to complete the weld.

Advantages of Arc Welding

- The electric arc welding is the suitable welding process for high speed welds.
- Apparatus required for arc welding is very simple and portable.
- The electric arc welding gives superior temperature at the point of welding.
- Electric arc welding can work on both AC and DC supply.
- It is inexpensive to install.

Disadvantages of Arc Welding

- Toxic fumes need ventilation or respirators
- More waste than with other processes
- Requires practice to achieve a high skill level
- Burn through on thin materials

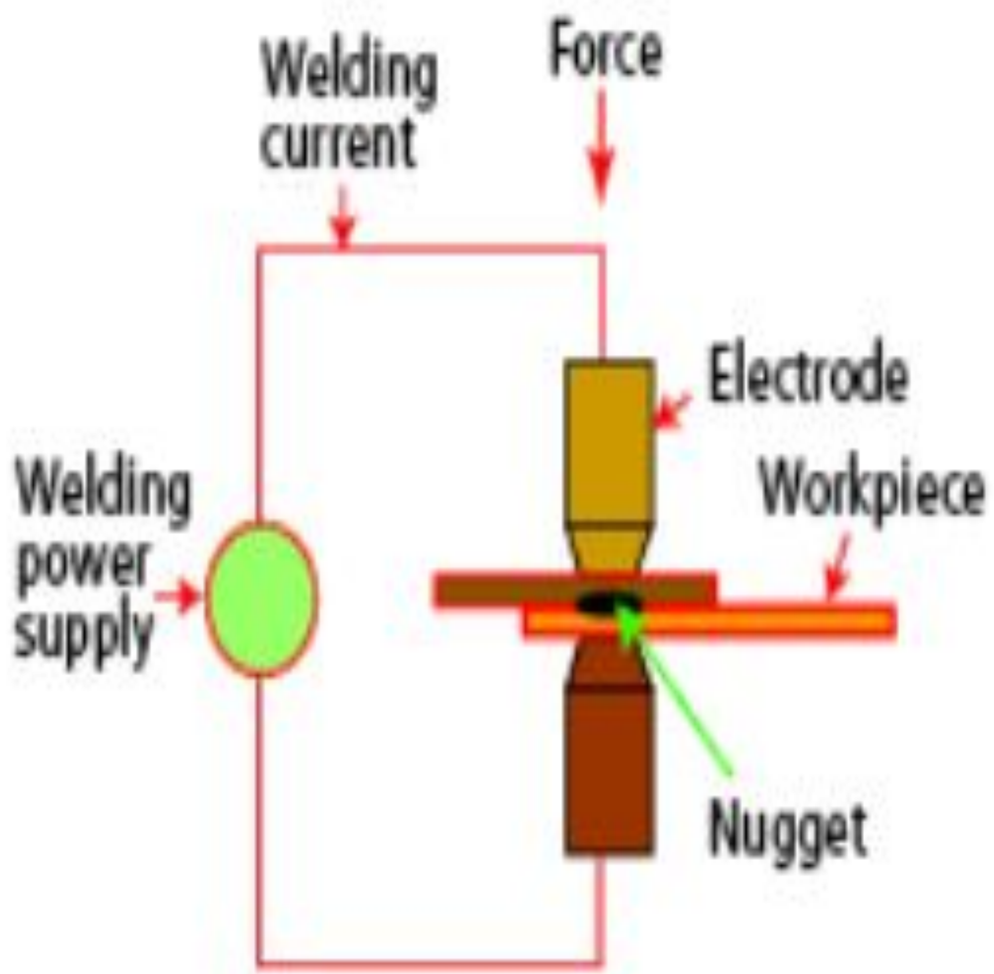
Applications of Arc Welding

- Arc welding is used in repairing of broken parts of machines.
- It is used for welding of cast iron or steel housings and frames.
- Arc welding is used in various industries such as automotive industries, construction industries, mechanical industries, etc.
- Arc welding is also used for welding process in shipbuilding.

Resistance welding

Resistance welding can be defined as; it is a liquid state welding method where the metal-to-metal joint can be formed within a liquid state otherwise molten state. This is a thermoelectric method where heat can be generated at the It is a thermo-electric process in which heat is generated at the edge planes of welding plates because of electric resistance and a weld joint can be created by applying low-pressure to these plates. This type of welding uses electric resistance to generate heat. This process is very efficient with pollution free but the applications are limited because of the features like equipment cost is high, and material thickness is limited.

Resistance Welding



Resistance Welding Working Principle

Resistance Spot Welding, like all Resistance Welding Processes, creates welds using heat generated by resistance to the flow of welding current between the faying surfaces, as well as force to push the work pieces together, applied over a defined period of time.

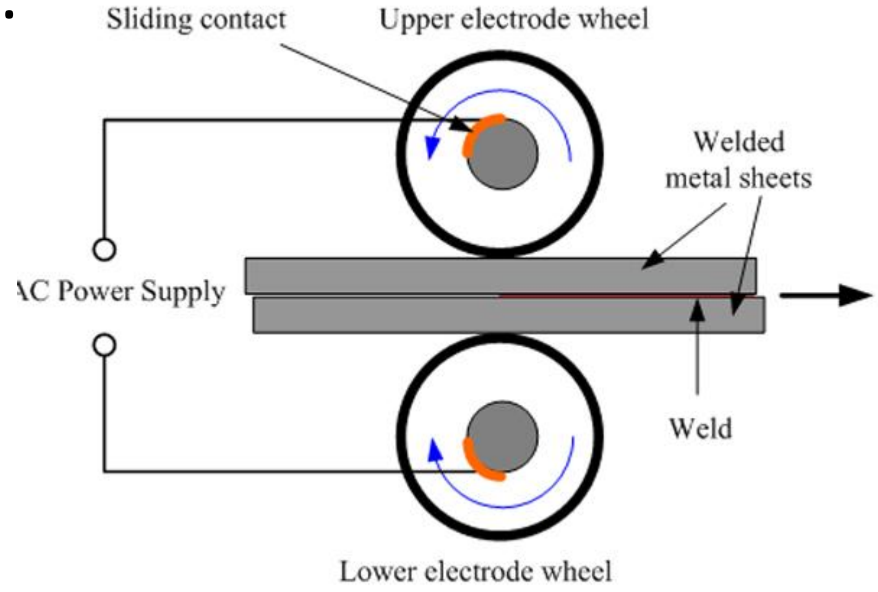
Resistance Spot Welding uses the face geometries of the welding electrodes themselves to focus the welding current at the desired weld location, as well as to apply force to the work pieces. Once sufficient resistance is generated, the materials set down and combine, and a weld nugget is formed.

Types of Resistance Welding

1. Resistance Spot Welding
2. Resistance Seam Welding
3. Projection Welding
4. Flash Welding
5. Upset Welding

Resistance Seam Welding

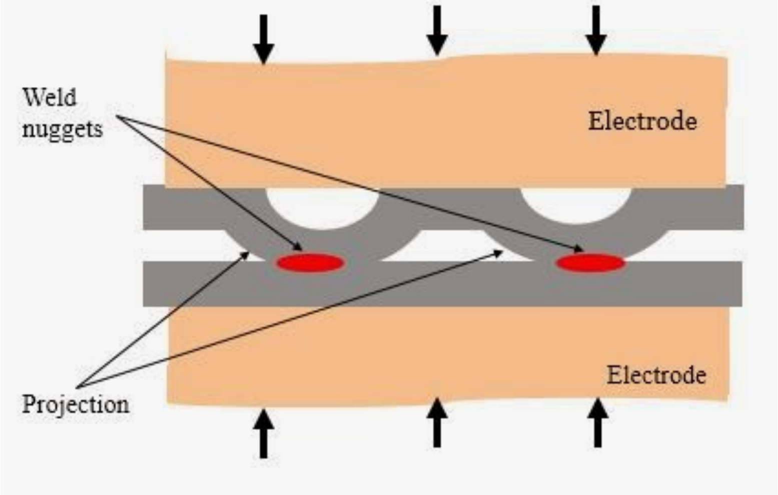
Resistance Seam Welding is a subset of Resistance Spot Welding using wheel-shaped electrodes to deliver force and welding current to the parts. The difference is that the work piece rolls between the wheel-shaped electrodes while weld current is applied. Depending on the particular weld current and weld time settings, the welds created may be overlapping, forming a complete welded seam, or may simply be individual spot welds at defined intervals.



https://www.youtube.com/watch?v=n5bssD7GTlc

Projection Welding

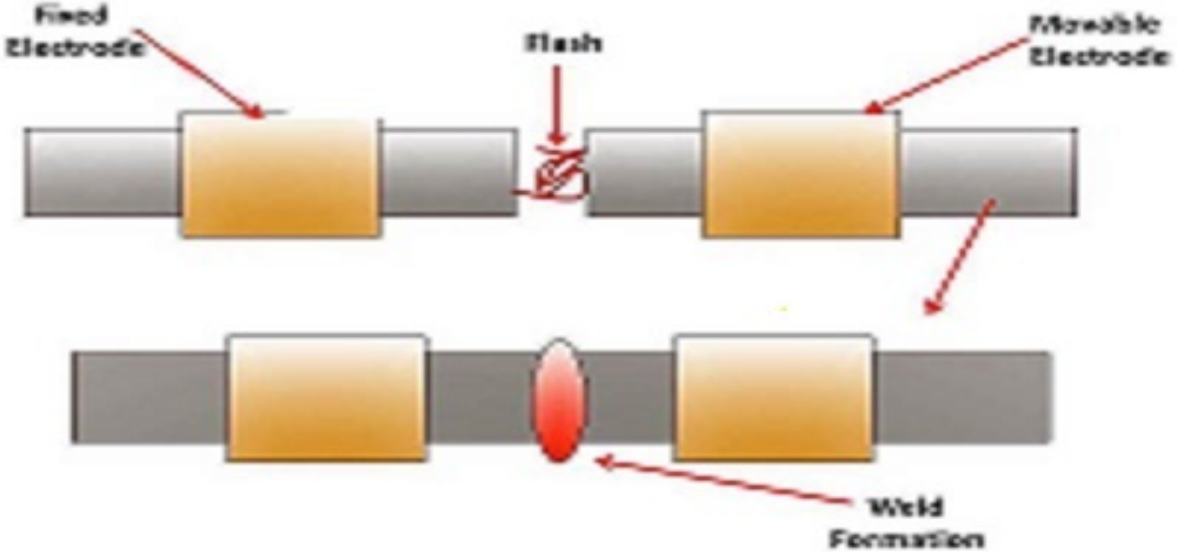
- Projection Welding uses heat generated by resistance to the flow of welding current, as well as force to push the work pieces together, applied over a defined period of time.
- Projection Welding localizes the welds at predetermined points by using projections, embossments or intersections, all of which focus heat generation at the point of contact. Once the weld current generates sufficient resistance at the point of contact, the projections collapse, forming the weld nugget.
- Solid Projections are often used when welding fasteners to parts. Embossments are often used when joining sheet or plate material.



https://www.youtube.com/watch?v=vS9X1uFH_tc

Flash Welding

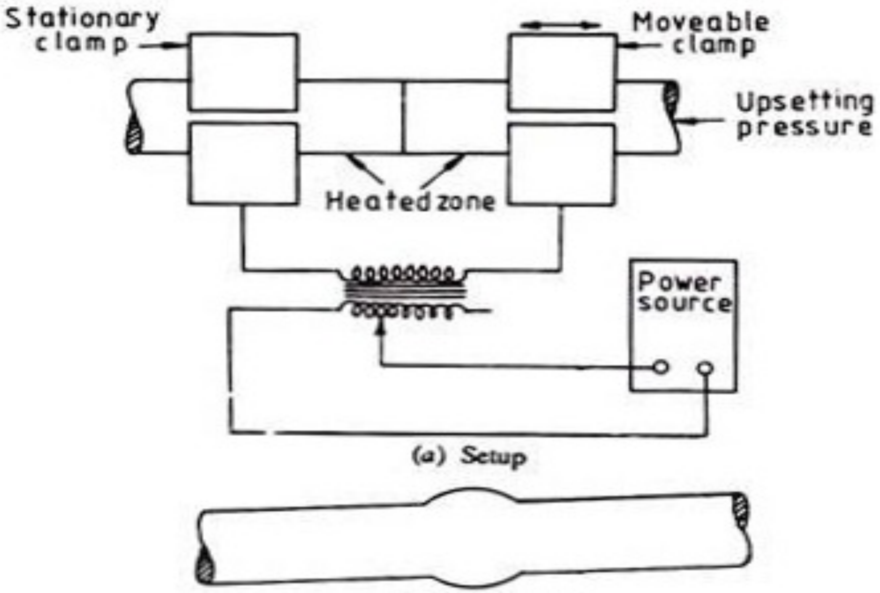
- Flash Welding uses heat generated by resistance to the flow of welding current, as well as force to push the work pieces together, applied over a defined period of time. Flash Welding is a Resistance Welding Process which generates resistance using flashing action. This action is created using very high current density at very small contact points between the workpieces. At a predetermined point after the flashing process has begun, force is applied to the workpiece, and they are moved together at a controlled rate. Rapid upset created by this force expels oxides and impurities from the weld.



https://www.youtube.com/watch?v=vInbzT6CmmQ

Upset Welding

Upset Welding uses heat generated by resistance to the flow of welding current, as well as force to push the work pieces together, applied over a defined period of time. While similar to Flash Welding, in Upset Welding the workpieces are already in firm contact with one another, so no flashing occurs. Pressure is applied before the current is started, and is maintained until the process is complete.



(a) Setup

(b) Finished weld

https://www.youtube.com/watch?v=nBUrnwqeLXA

Resistance Welding Advantages

- This method is simple and does not necessary high expert labor.
- The resistance welding metal thickness is 20mm, & thinness is 0.1 mm
- Automated simply
- The rate of production is high
- Both related, & different metals can be weld.
- Welding speed will be high
- It does not need any flux, filler metal & protecting gases.
-

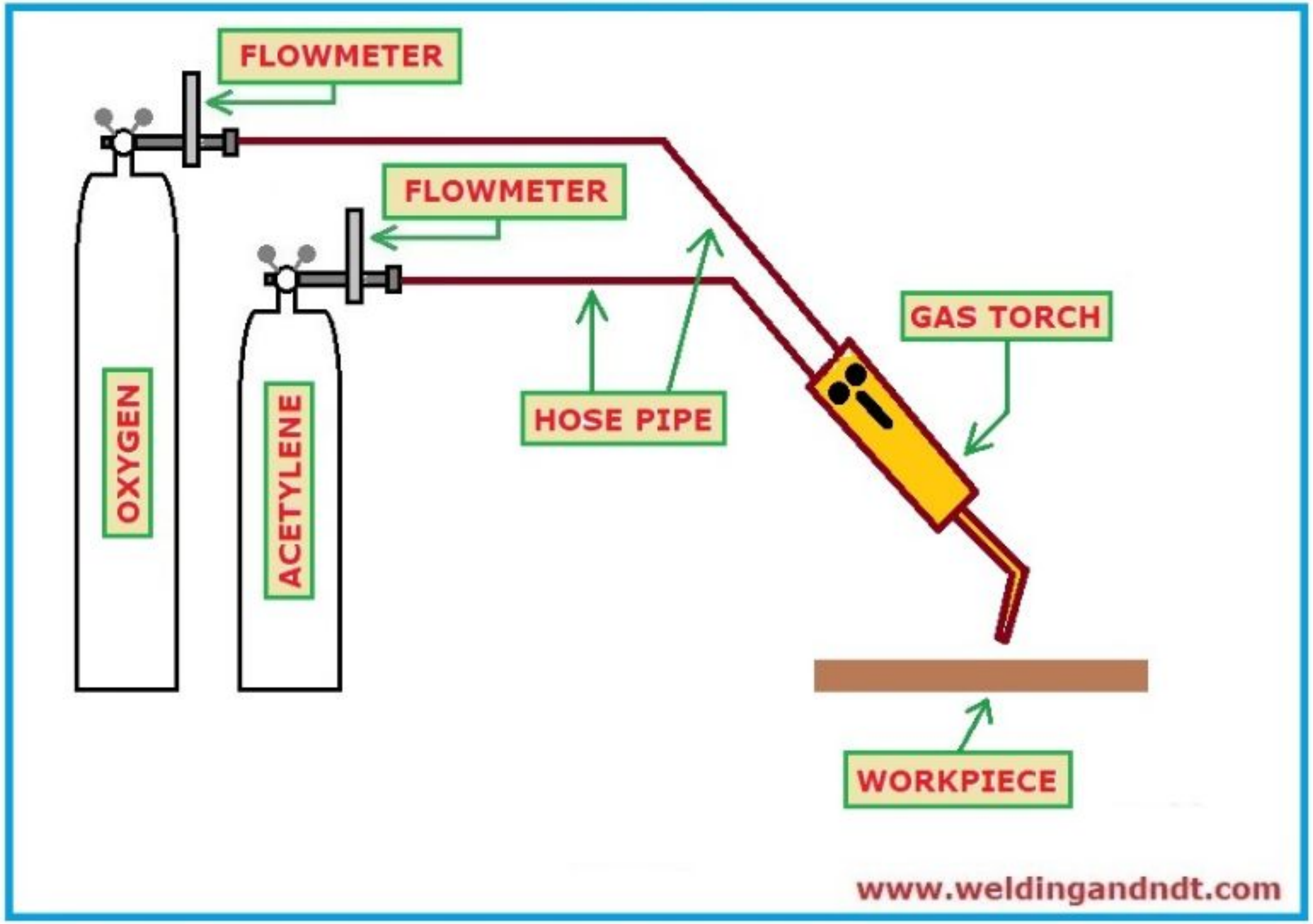
Resistance Welding Disadvantages

- Tools cost will be high.
- The work section thickness is limited because of the current requirement.
- It is less proficient for high-conductive equipment.
- It consumes high electric-power.
- Weld joints contain small tensile & fatigue power.

Resistance Welding Applications

- This type of welding can be widely used within automotive industries, making of nut as well as a bolt.
- Seam welding can be utilized to generate leak prove joint necessary within little tanks, boilers, etc.
- Flash welding can be used for welding tubes and pipes

(OFW) Oxy-Fuel Welding (Gas Welding/Oxy-Acetylene Welding)



Process of OFW

Oxy-fuel welding (OFW) is also known as Gas welding or Oxy-fuel gas welding. The term ‘Oxy-fuel’ is used to denote a combination of Oxygen and a Fuel gas, means **it’s a process in which Oxygen and a fuel (combustible gas) both are required**. Most commonly used fuel gas is Acetylene and thus the name Oxy-Acetylene welding (OAW) is also used for this process, when Acetylene is used as a fuel gas. Apart from Oxy-Acetylene welding, other common variants of Oxyfuel gas welding are

- **Air Acetylene welding (AAW)**
- **Oxy Hydrogen welding (OHW)**
- **Pressure gas welding (PGW)**

The required heat for welding is generated by a flame caused by the chemical reaction between oxygen and the fuel gas (Acetylene). Fuel gas and Oxygen are combined in a mixing chamber, provided in the welding torch itself. Additional filler metal can be used with this process. A flux may be used to protect the molten weld pool. Flux deoxidizes and cleanses the weld metal. The flux melts, solidifies, and forms a slag on the weld metal.

ADVANTAGES OF OXY-FUEL GAS WELDING

- Equipment is cheaper than other welding processes, easy to learn and use
- It’s very portable and can be transported anywhere very easily
- Since no electricity is required, hence can be used at locations where power sources are not available.
- The equipment is very versatile and can also be used for metal cutting, preheating, postheating and surfacing.
- The welder can control the heat input, temperature, weld bead size and shape very efficiently.
- Very useful for maintenance related work

DISADVANTAGES OF OXY-FUEL GAS WELDING

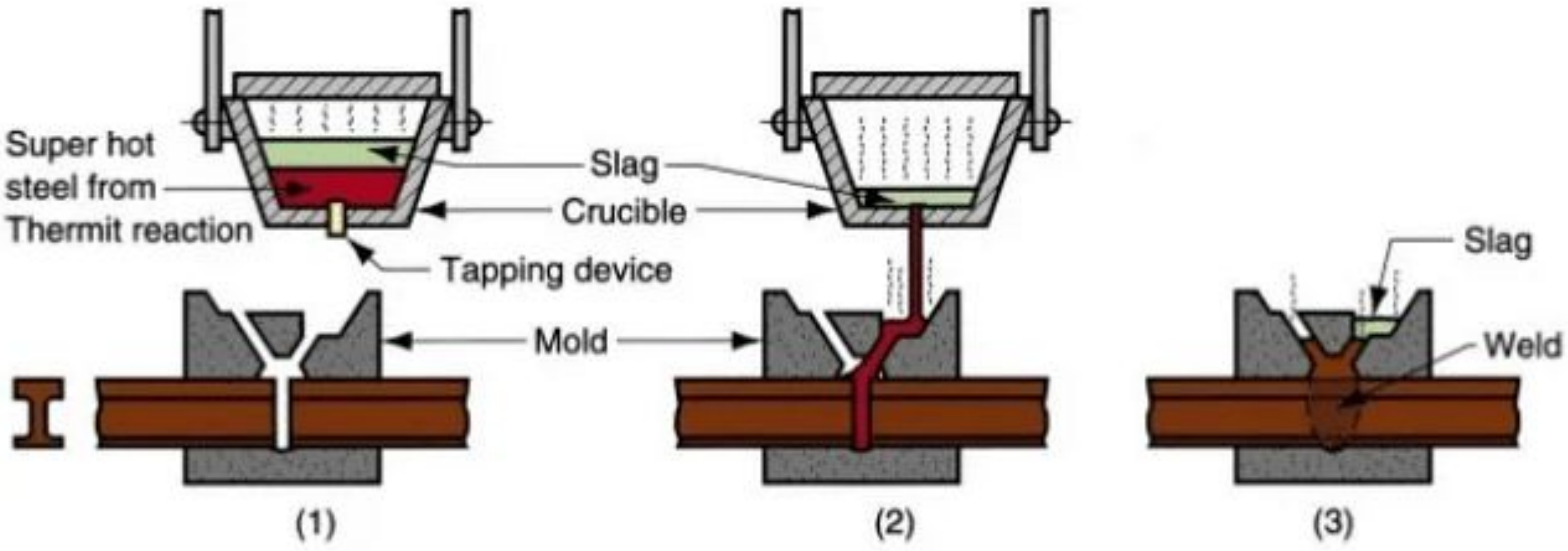
- Slow welding if compared to other arc welding processes, hence less productive
- Not good for reactive metals and thick metals
- Large heat affected zone (HAZ)
- Due to the presence of combustible gas (Acetylene or Hydrogen), lots of Safety precautions needed because these gases are highly flammable and can explode if catches fire.

Thermit Welding

Thermite Welding is a chemical welding process using molten metal to join the conductors permanently. It uses heat to join or merge two metals with the help of an exothermic reaction to form one mass or whole.

It is also known as Exothermic welding, exothermic bonding and thermit welding since it uses exothermic reactions for its task. The process requires no external source of heat or current since it employs an exothermic reaction of the powder consists of aluminium and the oxide of a metal such as iron which is called thermite composition which was due to the result of the chemical combination of the aluminium with the oxygen of the oxide

Thermit Welding



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

Principle of Thermit Welding

Thermite welding is a chemical welding process in a liquid state, through which the joints are formed in molten state. It combines the process of welding and casting in which the molten iron is poured at the welding plates so that it can form a permanent strong joint.

The molten state of iron is created without application of any external heat. In thermite welding, a mixture of aluminium and iron oxide is used in ratio 1:3 by weight therefore the common thermite is composed of iron oxide (78%) and aluminium powder (22%).

Working of Thermit Welding

- In the first place, we clean both the work pieces which are to be welded.
- Now a wax pattern is made round the weld cavity.
- A mould handle clamp is used to fix the moulding flask round the joint.
- Now the moulding sand is packed around the wax pattern to form a mould in which the molten metal will get poured and it involves the gating system consisting of sprue, runner, and gates.
- Now this mould is heated to get rid of the wax pattern.
- This will start the thermite reaction which liberates an enormous amount of heat and forms a molten state of iron oxide which flows from crucible to the sand mould.
- This molten metal obtained from the thermite reaction fills the weld cavity and fuses the parent metal to make a permanent joint and then it is allowed to cool down.
- After removing the flask, machining is done to get rid of the welding burr or other extra metal.

Advantages of Thermit Welding

- It does not require any external energy input, so it can be used in areas where electrical power is not available.
- It is very simple to join two similar or dissimilar metals together quickly
- No power supply which is costly is required making the process cheap
- The joint formed between the steel rail and the copper conductor has an excellent current-carrying capacity and the ability to withstand corrosion, when Aluminium reduces copper oxide powder to form a metallurgical bond.

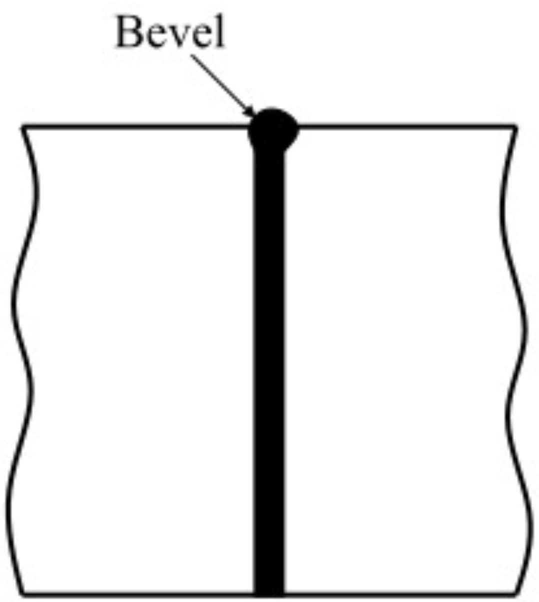
Disadvantages of Thermit Welding

- It is essential to use thermite welding for parts of heavy sections of ferrous metals and not economical for welding cheap metals and light parts.
- It requires a supply of replaceable moulds and the rate of welding is also very slow and may contain gas and slag inclusion
- It suffers from a lack of repeatability, and can be impeded by damp or bad weather conditions if it is performed outdoors.
- When the temperature is high, it may cause a change in the grain structure and the weld metal can get distorted.

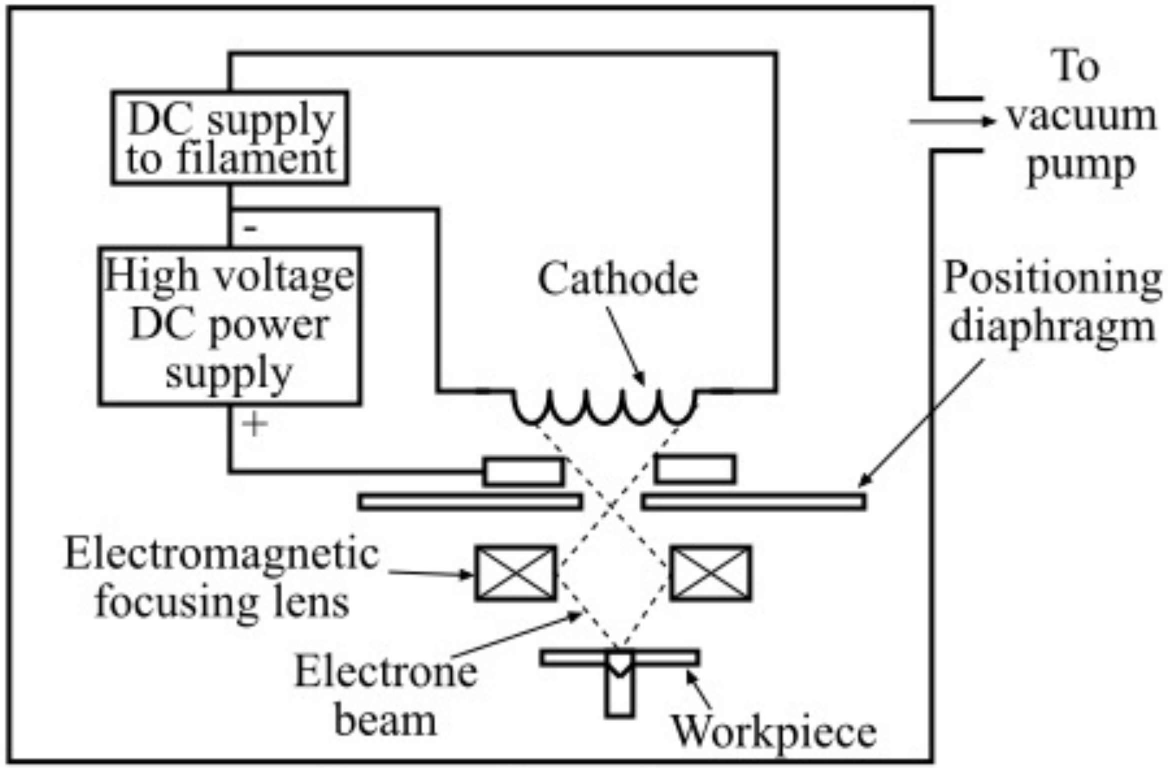
Applications of Thermit Welding

- Thermit Welding is used for fixing heavy castings and gears. It is used in welding of very huge cast and produced parts and large sections such as locomotive rails, ship hulls or joining railroad rails, steel wires and steel pipes.
- It is also used to weld a wide range of metals, which includes stainless steel, cast iron, common steel, brass, bronze, and Monel. The thermite welding process is also utilised to weld electrical conducting joints, particularly to supply electrical continuity for railroad signal systems.
- Aluminium reduces copper oxide powder to form a metallurgical bond between the steel rail and the copper conductor.

Electron beam welding



Electro-Beam Welding



Electrone Beam Gun

Working Principle of Electron Beam Welding

- In electron beam welding, when a cathode in a vacuum is heated by a filament, it emits a beam of high velocity electrons. These electrons are further accelerated by voltage and are converged by an electromagnetic coil. When the electron beam strikes the workpiece, the kinetic energy of the electrons is converted into heat. This heat energy generated is then utilized for welding process.
- For a typical electron beam welding machine, the diameter of the beam spot is about 0.2 mm. The electron beam welding allows less distortion, as the heat applied to the area around the weld is low.

Advantages of Electron Beam Welding

- The electron beam welding process eliminates the atmospheric contamination of both the weld zone and the weld bead, as it is performed in the vacuum.
- Electron beam welding consumes low power, therefore, its operating cost is low.
- It produces narrow electron beam that reduces the distortion of the workpiece.
- Electron beam welding is the only process that can be used to join high temperature metals like columbium.
- Electron beam welding has high deposition rate. Therefore, its single pass can produce welds of excellent quality.
- Electron beam welding produces deep penetration with very less distortion

Disadvantages of Electron Beam Welding

- The initial outlay for equipment is expensive. With these costs in mind, a company will need a large work-flow in order to justify the investment. It is usually more cost effective to outsource your EBW requirements unless you have a large volume throughput over a long period of time.
- Due to the complex technical equipment, expert operators are essential. If you are starting with a clean piece of paper, you will need to invest in professional training and employ experienced qualified welding engineers.
- The size of the components to be welded is limited by the size of the vacuum chamber at your disposal.
- Safety standards are exceptionally strict as x-rays and radiation are both present during the welding process.

Applications of Electron Beam Welding

- The adjustment of penetration can be controlled by controlling the electron beam output, thus the electron beam welding is applicable to a wide variety of base materials, from thick to thin sheets.
- Metals having high melting points like tungsten can also be welded by using the electron beam welding.
- Electron beam welding can be used for active metals such as titanium which may oxidize during the welding process.
- Electron beam welding is widely used in various industrial applications such as for welding of electronic components, bridges, aircraft parts, ship's shells, etc.

Fusion welding

- Fusion welding processes are all those welding processes where faying surfaces of parent part as well as filler material melt down during welding for weld bead formation. So heat is always associated with these processes.
- External application of pressure is not required for these processes, except for resistance welding group where substantial contact pressure needs to be maintained during welding for sound joining. Filler material may or may not be applied.

Advantages of fusion welding processes

- Filler material can be applied easily. So a large lacuna can be filled.
- No need to apply external pressure, so primary shape of the components does not matter (a suitable shape is required to uniformly apply pressure).
- Joint design and edge preparation are not crucial as these parameters affect only achievable penetration.
- More than two components can easily be welded at a step.

Disadvantages of fusion welding processes

- The process is associated with distortion and residual stress generation as it involves melting and solidification.
- Palpable heat affected zone (HAZ) exists in the welded components. HAZ is always considered as the weak portion in welded assembly.
- Mechanical properties of parent materials are also severely affected by intense heating.
- Joining dissimilar metals by fusion welding is challenging task, especially if the metals have substantially different melting point and coefficient of thermal expansion.

Classification of welding processes

Welding	
Fusion welding	**Solid-state welding**
1. Arc welding (SMAW, GMAW, TIG, SAW, FCAW, ESW, etc.) 2. Gas welding (AAW, OAW, OHW, PGW) 3. Resistance welding (RSW, RSEW, PW, PEW, FW, etc.) 4. Intense energy beam welding (PAW, EBW, LBW)	1. Cold Welding (CW) 2. Roll Welding (ROW) 3. Pressure Welding (PW) 4. Diffusion Welding (DFW) 5. Friction Welding (FRW) 6. Friction Stir Welding (FSW) 7. Forge Welding (FOW), etc.

Solid-State Welding

- In all those welding processes where melting of faying surfaces of parent materials don’t take place are called solid-state welding. Unlike fusion welding, here application of heat is not necessary.
- However, application of pressure is required for getting a sound joint and thus it is also termed as Pressure welding.
- It is worth nothing that sometime base materials are heated to an elevated temperature while joining by solid-state welding process; however, temperature always remains below melting point.

Advantages of solid-state welding processes

- Because of no melting and solidification, these processes provide comparatively lower level of distortion and residual stress generation.
- Heat affected zone (HAZ) is also narrower.
- It provides sumptuous weld appearance.
- Mechanical properties of parent materials remain intact as no fusion takes place.
- Easy to join dissimilar metals.

Disadvantages of solid-state welding processes

- It requires special type of joint design, edge preparation and/or surface finish.
- Primary shape of the components is crucial factor as pressure is needed to apply (a suitable shape is required to apply pressure uniformly).
- Joining more than two components at a time is difficult; in some cases it is impossible.
- Application of filler material is not possible. So wider root gap cannot be filled.

Weld Quality

- Weld quality, concept, meaning, definition, importance, and factors affecting it. If the strength of the weld obtained is equal to the strength of base metal and weld does not contain any defect than its called good weld.
- To ensure quality welds, it is important to have a quality weld inspection program in place. In order to do so, a company must understand how to evaluate weld characteristics, determine weld quality.
- If the strength of weld obtained is equal to the strength of base metal and weld does not contain any defect then it is called a good weld
- The weld quality is directly related to weld design, magnitude of residual stresses & strain set up by welding heat, layout of welded joint, quality of base metal and quality of work preparation and fit ups.

FACTORS AFFECTING WELD QUALITY

1. poor design
2. incorrect dimensions.
3. Incorrect shape of weld

Weldability in Welding

"the capacity of a metal to be welded under the fabrication conditions imposed into a specific, suitably designed structure and to perform satisfactorily in the intended service."

Weldability is considered as ease of accomplishing a satisfactory weld joint and can be in determined from quality of the weld joint, effort and cost required for developing the weld joint.

Factors Affecting Weldability

- **Metallurgy –** The science of heating or manipulating metals to produce desired properties or shapes in them.
- **Welding Process –** There are more than 67 welding processes. Various factors set them apart: how the heat and pressure are applied, how much heat and pressure are used, and the type of equipment employed.
- **Joint Design –** The combination of the dimensions required for the welded joint and the geometry of the joint.
- **Weld Preparation –** Weld preparation is a set of techniques to execute prior to welding to prevent defects in the weld. For example, one practice is to clean base metal before welding.
- **Melting Point –** The temperature that must be reached for a solid substance to melt or fuse. When a metal has a medium melting point, it has better weldability.
- **Electrical Resistance –** A metal's opposition, or resistance, to the flow of electrical current. Metals with a high electrical resistance require more heat energy to weld and this makes them have poor weldability.

Soldering

- Soldering is one of the oldest and most popular techniques used for joining similar or dissimilar metals. It uses a filler material to join parent materials that remain solid.
- It is a low-temperature analog to brazing which uses filler alloys with melting temperatures below 450 °C (840 °F).
- This process may or may not require a fluxing agent. The filler metals melt at low temperatures so there is minimum part distortion and heat damage to sensitive parts. The filler metal is called solder which when solidifies, is then bonded to the metal parts to join them.
- The most commonly used solder is tin alloy and lead. Soldering is extensively used in the electronics industry for joining wires, capacitor, resistor, etc. with the joining plate.

Advantages of soldering

1. Dissimilar metals can be joined.
2. It is simple, low cost, flexible, economical, and user-friendly.
3. The life of the solder will be more.
4. Low amount of power is required to heat the soldering iron.
5. The soldering can be done at low temperature, and controlling is very easy.
6. Soldered joints can be dismantled

Disadvantages of Soldering

1. The soldering process can not join heavy sections. It is suitable for small parts only.

2. Solders are costlier, and soldering requires proper solder to get strong bonding.

3. Skilled labor is required for soldering.

Brazing

Brazing is yet another metal joining process in which two or metals are joined together by heating and melting a filler metal, which then bind the two pieces together and join them.

It can be applied to a wide variety of materials, including metals, ceramics, glasses, plastic, and composite materials. Although it is not as strong as fusion welding, it is the strongest form of metal bonding without melting the parent metal of the components being joined together.

So this process requires more heat input than other soldering operations such as mechanical fastening, adhesive bonding, solid state joining, welding and so on. This process can also be used to join dissimilar metals such as silver, gold, copper, aluminum, etc.

Brazing is necessarily done at temperature above 450 °C but below the critical temperature of metal.

Advantages of Brazing

1. The brazing is an economical and straightforward process.
2. A brazing process can join dissimilar metals.
3. Low gauge or thin section plates are joined very easily, but such workpieces can not be joined by welding.
4. Metals with different thickness can be joined easily.
5. Joints produced with brazing process are better in appearance because stresses will not be induced, no metallurgical damages and distortion of the plate will take place.

Disadvantages of Brazing

1. Heavy sections can be joined by a brazing process. It is suitable for small and thin section plates only.
2. Skilled labor is required for brazing.
3. Brazing results in low strength joints compared to welding.

Difference between Brazing vs. Soldering

Brazing	Soldering
Filler metal boiling point is above 450°C.	Filler metal boiling point is below 450°C
The filler metals may be of copper, aluminum, nickel, silver	The filler metals are made up from of tin and lead.
The flux used may be borax or boric acid	The flux used is usually rosin, zinc chloride, aluminum chloride
The brazing produces stronger joints than soldering	The soldering process produces less stronger joints compared to brazing
The brazing gives better accuracy, and joints may have a good aesthetic appearance.	The soldering does not give accuracy in the workpiece
Brazing is used in radiators, containers and other tanks, pipe fittings, heat exchangers.	Soldering is used in electronic circuit board connections

Adhesive Bonding Process

- Adhesive bonding is a process of joining materials in which an adhesive (liquid or a semi solid state material) is placed between the faying surfaces of the workpiece / parts (adherents) to be joined. Either heat or pressure or both are applied to get bonding.

Adhesive Bonding Process Steps

(a) preparation of the surfaces:

The workpiece surfaces are cleaned by chemical etching or mechanical abrasion. Grinding, filing, wire brushing, sanding and abrasive blasting are some of the mechanical cleaning methods. Next the prepared surfaces are tested by their affinity to be wetted by water. It is called water-break test. Smooth spread of water is an indication that the surface is chemically clean while the collection of droplets indicates the possibility of oil film in the surface.

Adhesive Bonding Process Steps

(b) application of the adhesive on to the mating surfaces

Adhesives are applied on to the workpiece surface by hand brushing, spraying, roller casting, knife coating and dipping. They are also applied as sheet or tape type coating to the surface. The adhesive are either applied as one thick layer on one of the workpiece surface, or as a thin layer on surfaces of both the workpiece.

(c) assembly of workpieces / parts and curing the joint.

After the application of the adhesive, the workpieces are assembled and held together by means of clamps, tools, tack welds, or other fixtures. During the assembly process, sufficient care should be taken so that the open time of the adhesive is not exceeded, the parts are put together in the proper sequence, the bonding is performed under specified environmental conditions, and the parts are held together until cured.

Advantages of the adhesive bonded joints

- Fast and cheap joining technique
- The adherents are not affected by heat
- Uniform stress distribution
- Possibility to join large structures
- Ability to join different materials
- Possibility to join very thin adherents
- Gas proof and liquid tight joints
- No crevice corrosion
- No contact corrosion
- Good damping properties
- High dynamic strength

Disadvantages of the adhesive bonded joints

- Limited stability to heat
- High strength adhesives are often brittle
- Long term use may alter the properties
- Cleaning and surface preparation of the adherents is necessary in many cases
- Specific clamping devices are often required to fix the joint
- Difficult disassembly of joined parts

Applications of Adhesive Bonded Joints

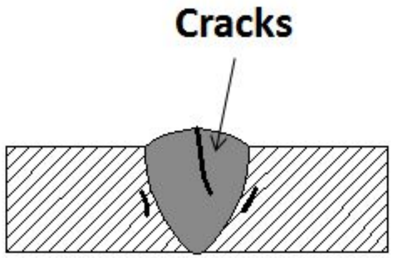
- Bonding of metal to non-metals especially plastics is the major application of adhesive bonding.
- Used as an alternative to riveting for aircraft structures.
- Widely applicable in fastening of stiffeners to the aircraft skin and in assembling honeycomb structures in aircraft,
- Using extensively in the fabrication of aircraft internal structures and providing the smooth surface for supersonic planes.,
- Useful in automobile industry for attaching brake lining to shoes, automatic transmission bands, and stiffeners,
- Find applications in the fabrication of railway coaches, boats, refrigerators, storage tanks, and microwave reflectors for radar and space communications.

Welding defects

Weld Crack: The most serious type of welding defect is a weld crack and it's not accepted almost by all standards in the industry. It can appear on the surface, in the weld metal or the area affected by the intense heat.

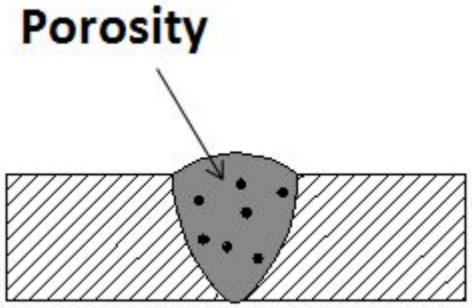
There are different types of cracks, depending on the temperature at which they occur:

- Hot cracks. These can occur during the welding process or during the crystallization process of the weld joint. The temperature at this point can rise over 10,000C.
- Cold cracks. These cracks appear after the weld has been completed and the temperature of the metal has gone down. They can form hours or even days after welding. It mostly happens when welding steel.
- Crater cracks. These occur at the end of the welding process before the operator finishes a pass on the weld joint. They usually form near the end of the weld. When the weld pool cools and solidifies, it needs to have enough volume to overcome shrinkage of the weld metal.

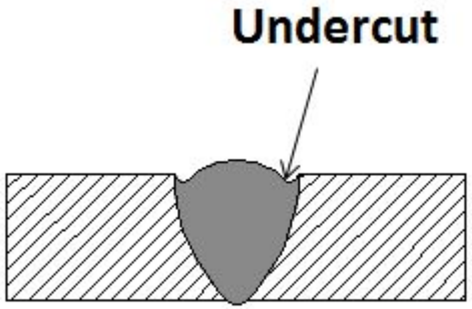


Welding defects

- **Porosity:** Porosity occurs as a result of weld metal contamination. The trapped gases create a bubble-filled weld that becomes weak and can with time collapse.

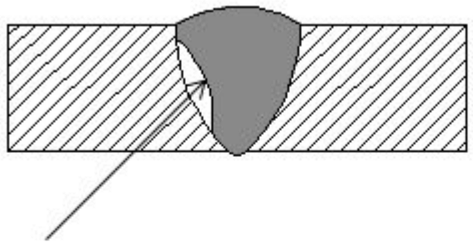


- **Undercut:** This welding imperfection is the groove formation at the weld toe, reducing the cross-sectional thickness of the base metal. The result is the weakened weld and work piece



Welding defects

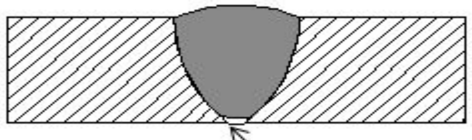
- **Incomplete Fusion:** This type of welding defect occurs when there's a lack of proper fusion between the base metal and the weld metal. It can also appear between adjoining weld beads. This creates a gap in the joint that is not filled with molten metal.



Incomplete Fusion

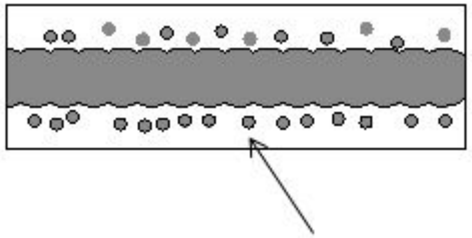
Welding defects

- **Incomplete Penetration:** Incomplete penetration occurs when the groove of the metal is not filled completely, meaning the weld metal doesn't fully extend through the joint thickness.



Incomplete Penetration

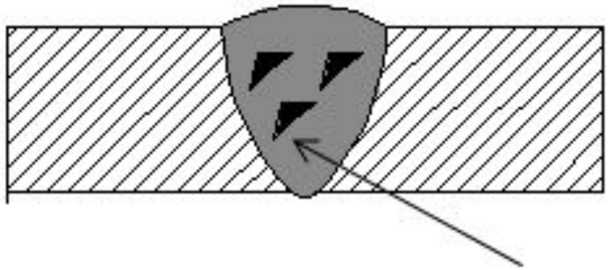
- **Spatter:** Spatter occurs when small particles from the weld attach themselves to the surrounding surface. It's an especially common occurrence in gas metal arc welding. No matter how hard you try, it can't be completely eliminated. However, there are a few ways you can keep it to a minimum.



Spatter

Welding defects

- **Slag Inclusion:** Slag inclusion is one of the welding defects that are usually easily visible in the weld. Slag is a vitreous material that occurs as a byproduct of stick welding, flux-cored arc welding and submerged arc welding. Is can occur when the flux, which is the solid shielding material used when welding, melts in the weld or on the surface of the weld zone.



Slag inclusion