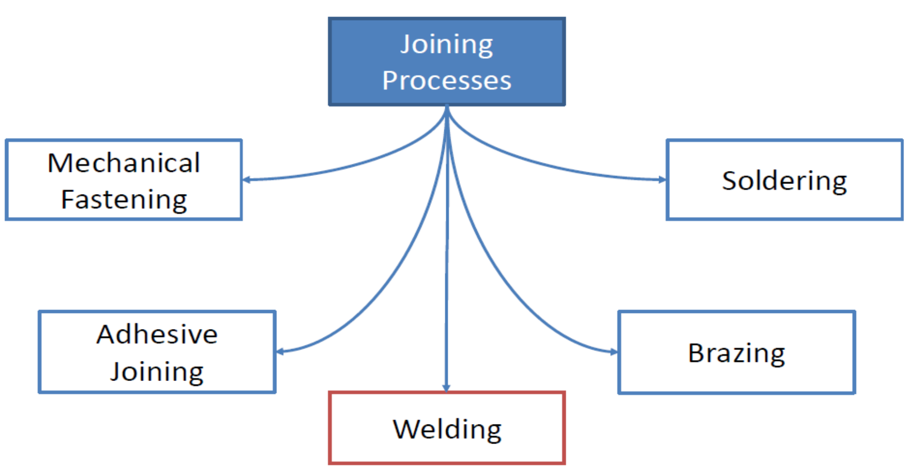
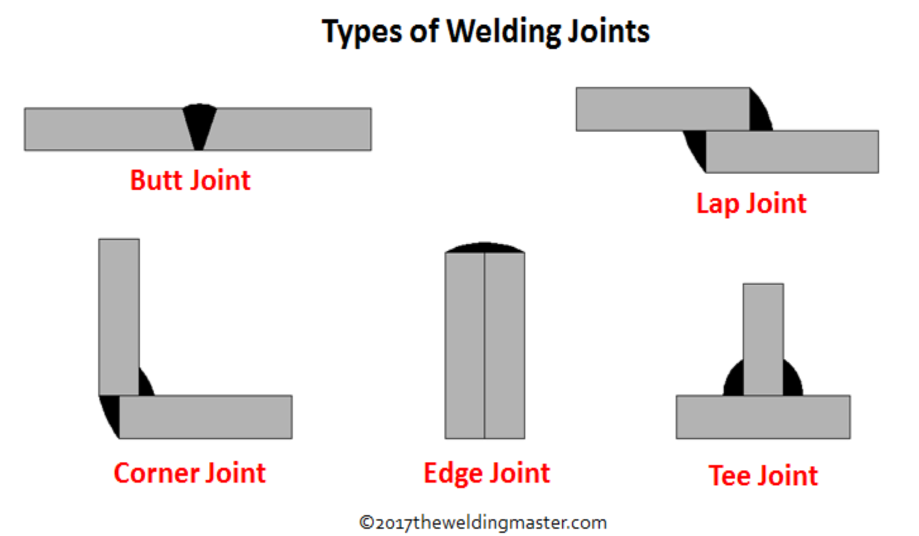
Introduction to Welding

WELDING

- **Welding** is a process in which two or more parts are **joined permanently** at their touching surfaces by a suitable **application of heat and/or pressure**.
- Often a **filler material** is added to **facilitate coalescence**. The assembled parts that are joined by welding are called a **weldment**.
- Welding is primarily used in metal parts and their alloys.

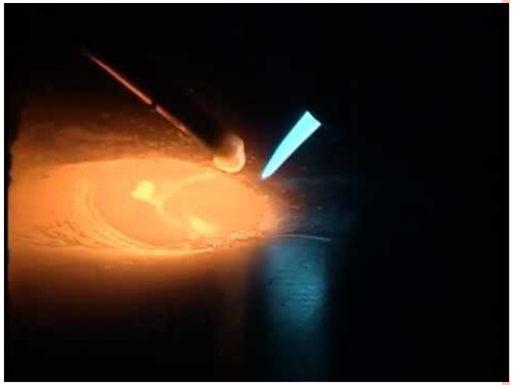
Classification of Joining Processes





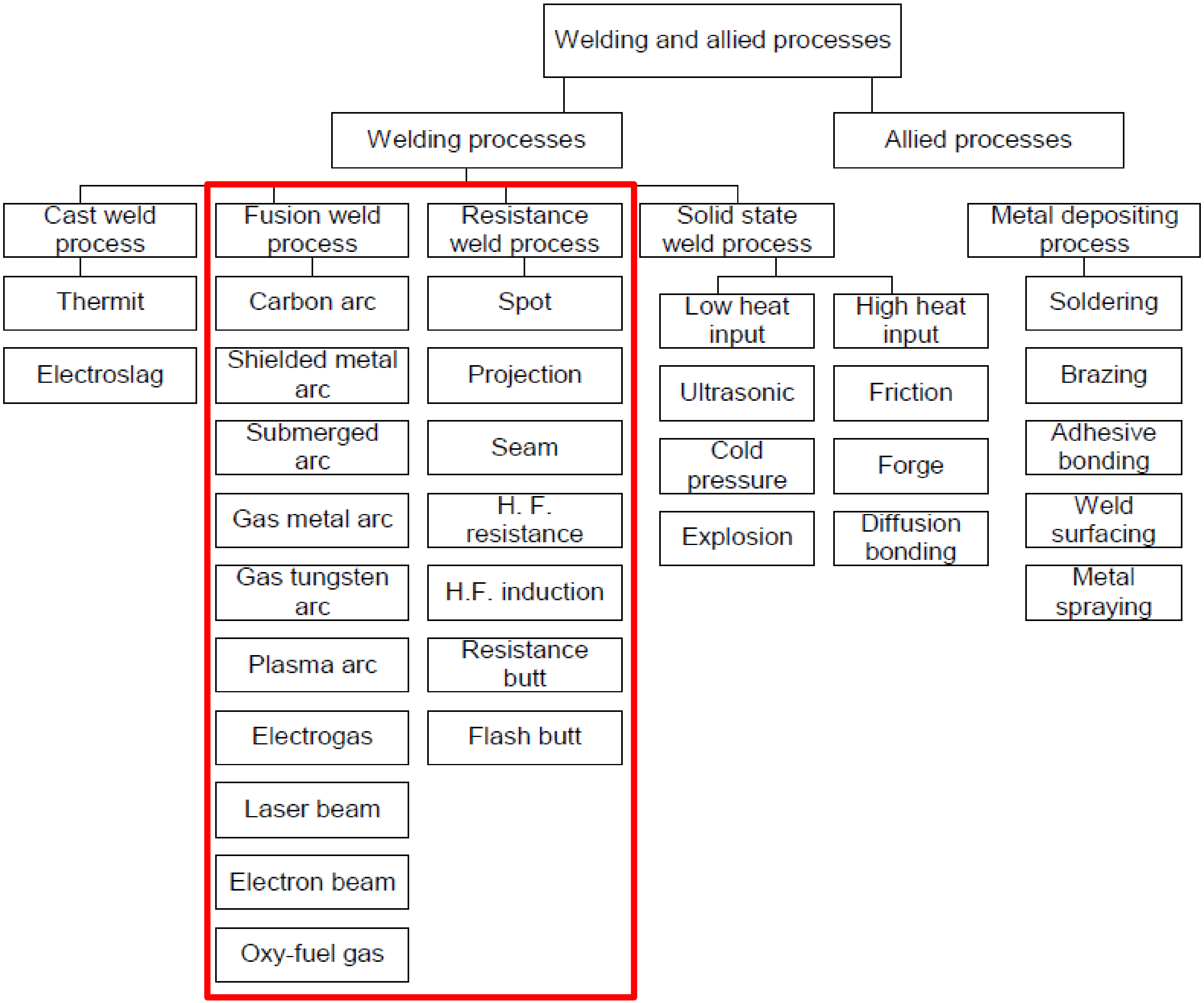
Welding processes are classified into two major groups

- **Fusion welding:**
  - In this process, **base metal is melted** by means of **heat**.
  - Often, in **fusion welding** operations, a **filler metal** is added to the **molten pool** to facilitate the process and provide bulk and strength to the joint.
  - Commonly used **fusion welding processes** are:
    - Arc welding, Resistance welding, Oxy-Fuel welding, Electron Beam welding and Laser Beam welding.



- **Solid-state welding:**
  - In this process, **joining of parts** takes place by application of **pressure alone** or a **combination of heat and pressure**.
  - **No filler metal** is used.
  - Commonly used solid-state welding processes are:
    - Diffusion welding, Friction welding, Ultrasonic welding.

Classification of Welding



- A **weld joint** developed by **melting the surfaces** and subsequently undergoes solidification (**without using any filler** metal) is called **"autogenous weld"**. Thus, the composition of the autogenous weld metal corresponds to the base metal only.
- However, **autogenous weld** can be **crack sensitive** when solidification temperature range of the base metal to be welded is significantly high **(750°C to 1000 °C)**.

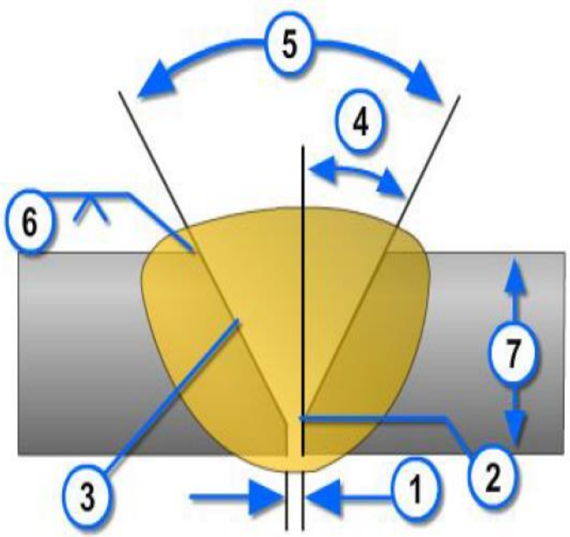
Filler Materials not Used:

- Laser beam welding
- Electron beam welding
- Resistance welding,
- Friction stir welding

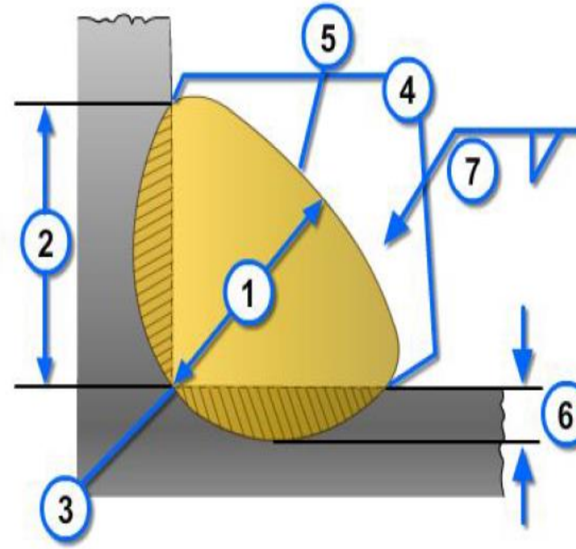
- Some of the welding processes are **inherently designed** to produce a weld joint by **applying heat for melting both base metal & filler metal**.
- These processes are mostly used for **welding of thick plates** (> 5mm) with comparatively **higher deposition** rate.

- Metal inert gas welding: (with filler)
- Submerged arc welding: (with filler)
- Flux cored arc welding: (with filler)
- Electro gas/slag welding: (with filler)

GROOVE WELD

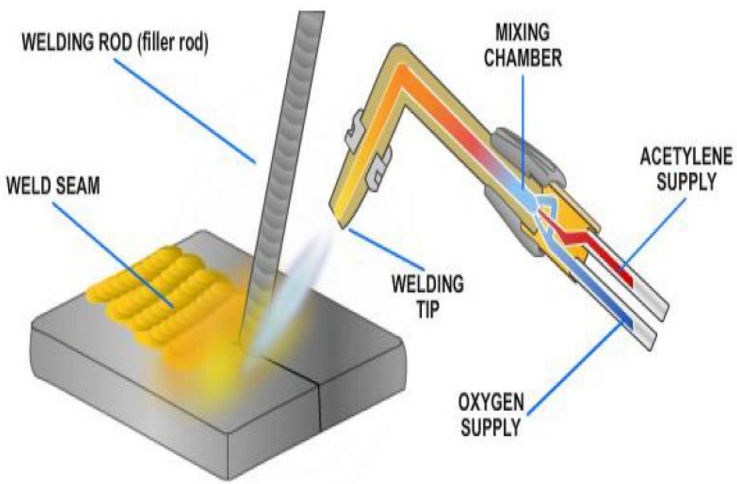


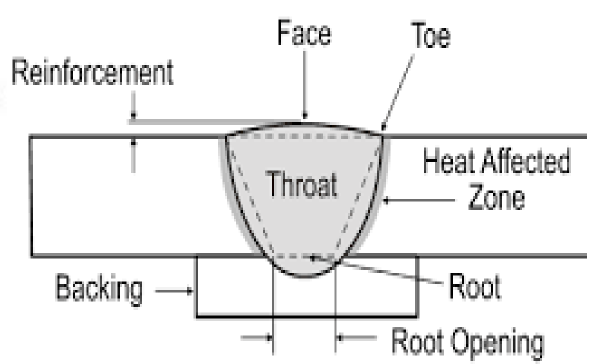
FILLET WELD

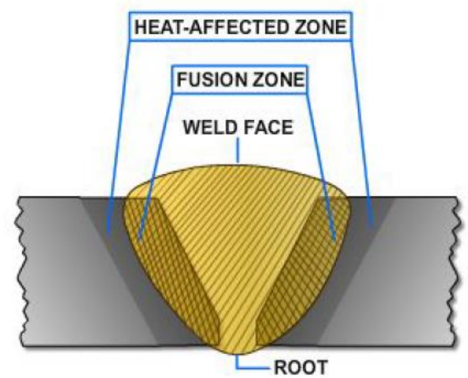


1. ROOT OPENING (RO): The separation between the members to be joined at the root of the joint.
2. ROOT FACE (RF): Groove face adjacent to the root of the joint.
3. GROOVE FACE: The surface of a member included in the groove.
4. BEVEL ANGLE (A): The angle formed between the prepared edge of a member and a plane perpendicular to the surface of the member.
5. GROOVE ANGLE (A): The total included angle of the groove between parts to be joined by a groove weld.
6. SIZE OF WELD(S): The joint penetration (depth of bevel plus the root penetration when specified). The size of a groove weld and its effective throat are one and the same.
7. PLATE THICKNESS(T): Thickness of plate welded.

1. ACTUAL THROAT OF A FILLET WELD: The shortest distance from the root of the fillet weld to its face.
2. LEG OF A FILLET WELD: The distance from the root of the joint to the toe of the fillet weld.
3. ROOT OF A WELD: The points at which the back of the weld intersects the base metal surfaces.
4. TOE OF A WELD: The junction between the face of a weld and the base metal.
5. FACE OF WELD: The exposed surface of a weld on the side from which the welding was done.
6. DEPTH OF FUSION: The distance that fusion extends into the base metal or previous pass from the surface melted during welding.
7. SIZE OF WELDS(S): Leg length of the fillet.

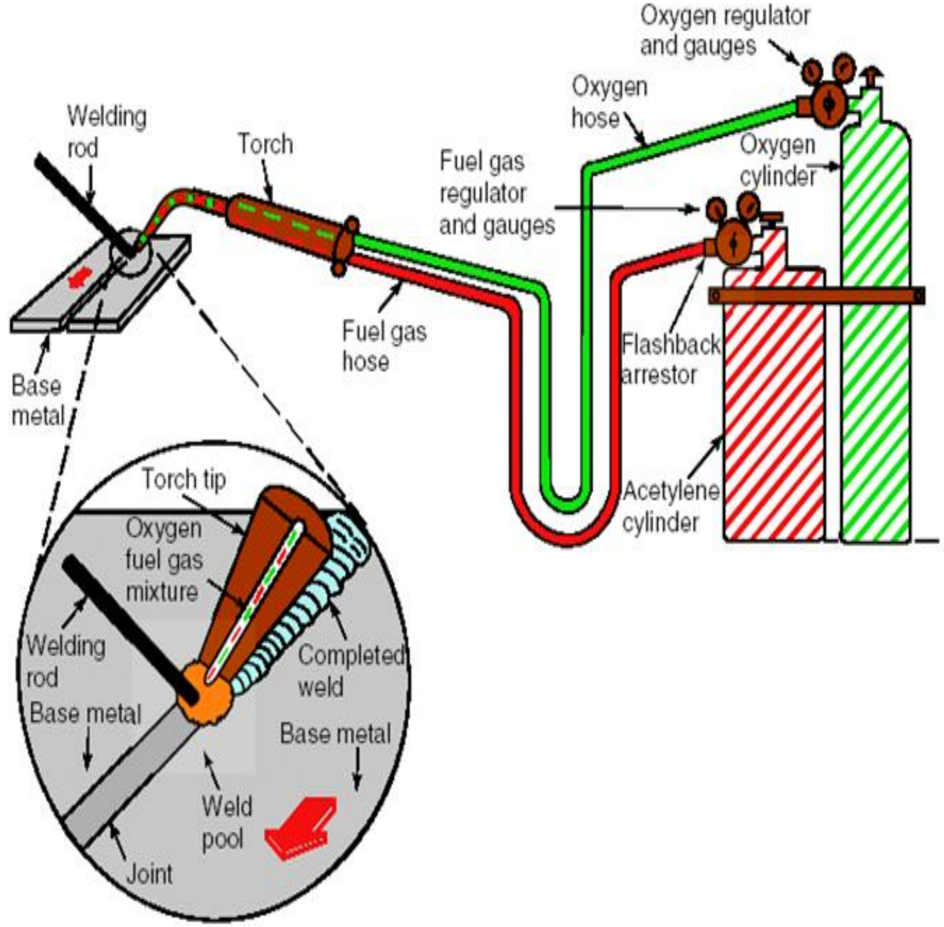






OXY-FUEL GAS WELDING (OFW)

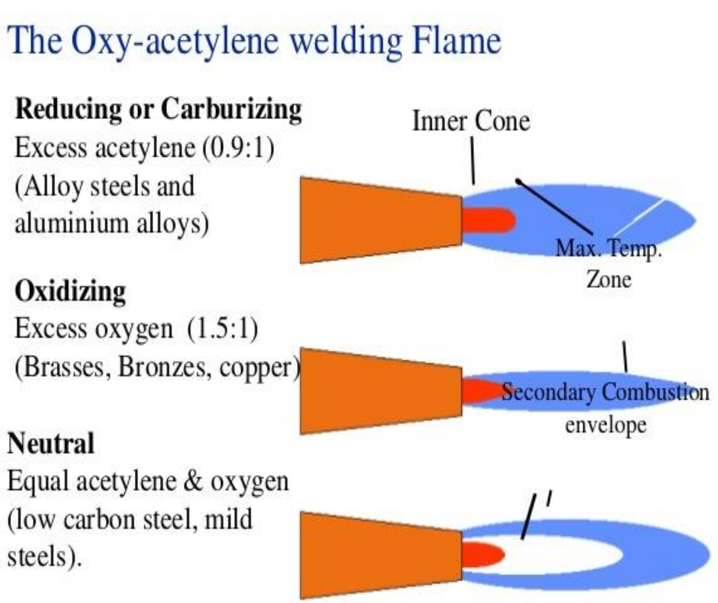
- This process is also known as **oxy-acetylene welding**. Heat is supplied by the **combustion of acetylene in a stream of oxygen**.
- Both **gases are supplied to the torch** through flexible hoses. Heat from this torch is **lower and far less concentrated** than that from an **electric arc**.

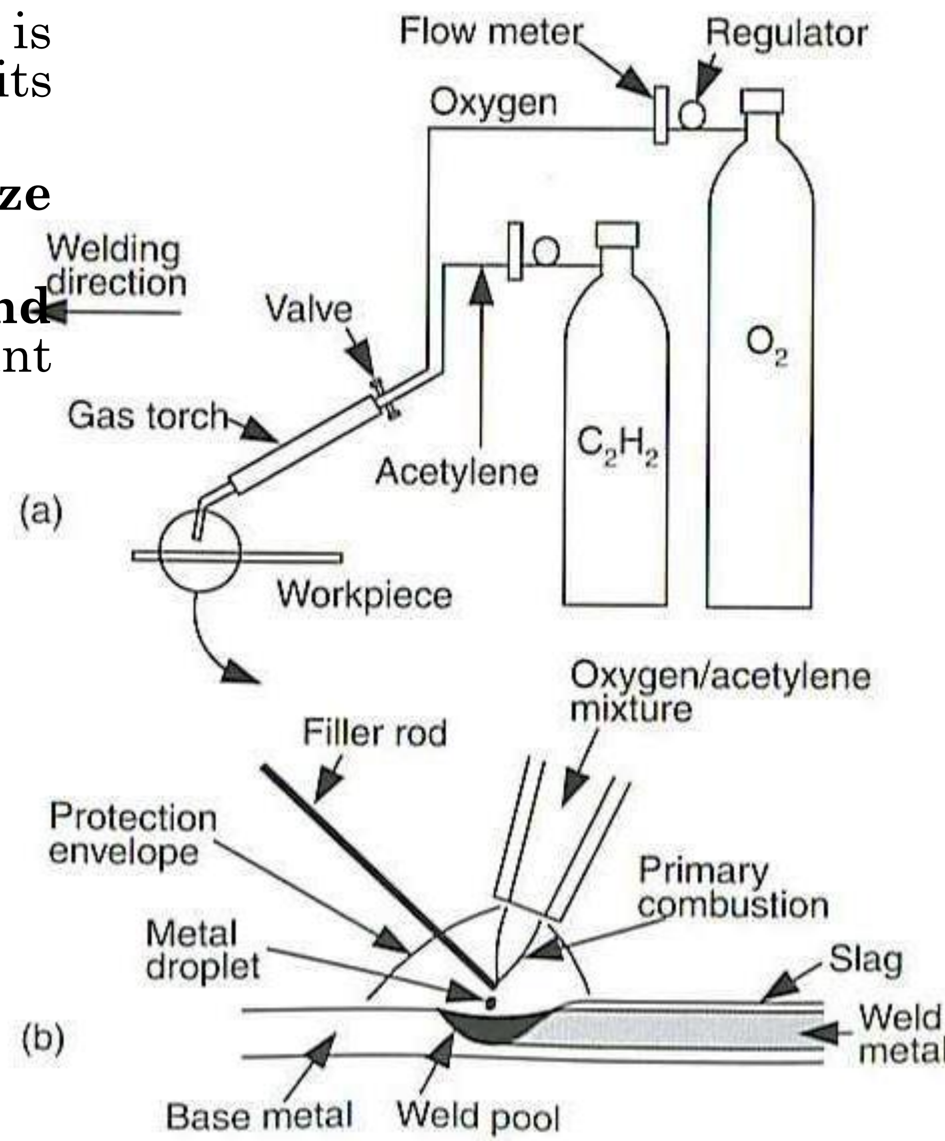


Equipment's:

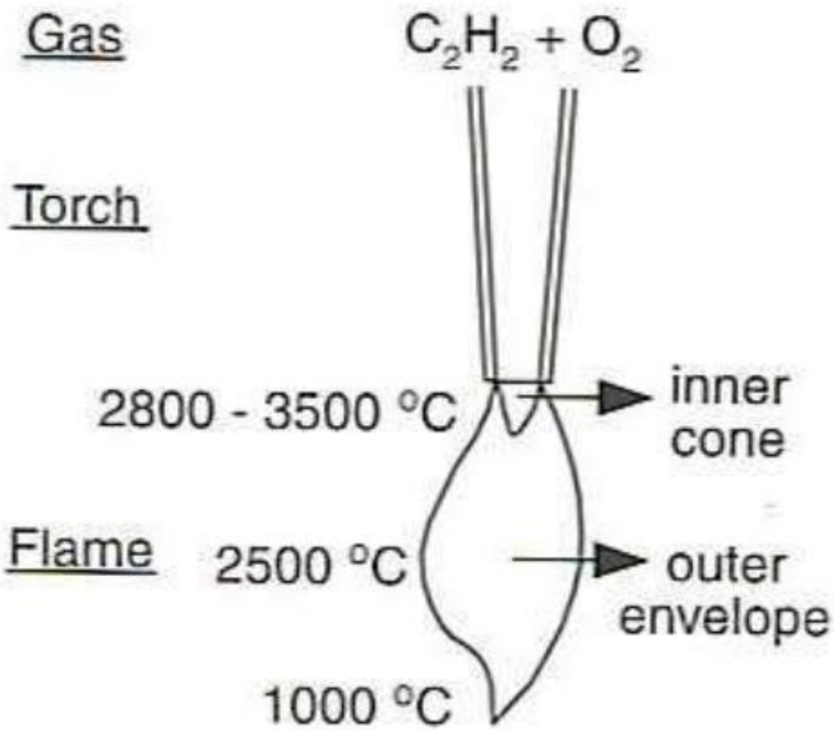
- Gas Cylinders
    - Oxygen – 125 kg/cm^2
    - Acetylene – 16 kg/cm^2
- Regulators
- Working pressure- oxygen 1 kg/cm^2
- Working pressure - acetylene 0.15 kg/cm^2
- Working pressure varies depending upon the **thickness of the work pieces** welded.
- Pressure Gauges, Hoses, Welding torch Check valve, Non return valve

- **Gas welding** is a welding process that **melts and joins** metals by **heating them with a flame** caused by a reaction of **fuel gas and oxygen**.
- The most commonly used method is **Oxyacetylene welding**, due to its **high flame temperature**.
- The flux may be used to **deoxidize and cleanse** the weld metal.
- The **flux melts, solidifies and forms a slag skin** on the resultant weld metal.





Chemical reactions and temperature distribution in a neutral oxyacetylene



Primary combustion in inner cone (2/3 total heat) :

$2C_2H_2 + 2O_2$ (from cylinder)

$\longrightarrow 4CO + 2H_2$

Secondary combustion in outer envelope (1/3 total heat) :

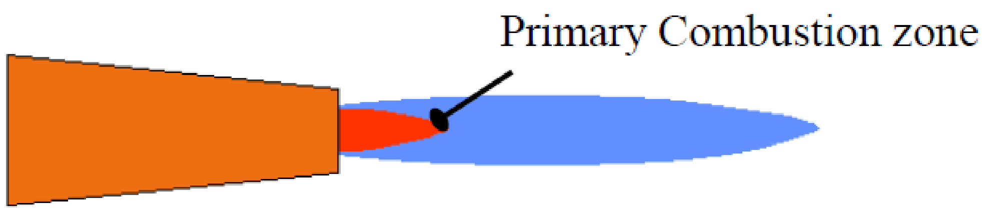
$4CO + 2O_2$ (from air) $\longrightarrow 4CO_2$

$2H_2 + O_2$ (from air) $\longrightarrow 2H_2O$

The secondary combustion is also called the protection envelope since CO and H_2 here consume the O_2 entering from surrounding air, thereby protecting the weld from oxidation.

- The inner zone **(Primary combustion Zone)** is the **hottest part** of the flame.
- The welding should be performed so as the **point of the inner zone** should be just above the joint edges.

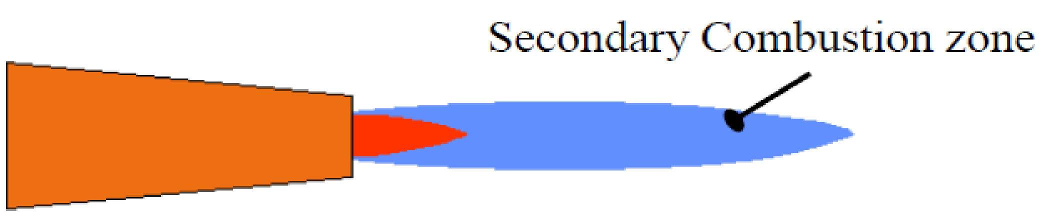
$$C_2H_2 + O_2 \longrightarrow 2CO + H_2$$



The outer zone the **secondary combustion envelope** performs two functions

- Preheats the joint edges
- Prevents oxidation by using some of the surrounding oxygen from weld pool for combustion and gives off **carbon dioxide** and **water vapour**

$$CO + H_2 + O_2 \longrightarrow CO_2 + H_2O$$



- **Advantages:**
  - Simple equipment
  - Portable
  - Inexpensive
  - Easy for maintenance and repair
  - Great for **brazing dissimilar metals** together.

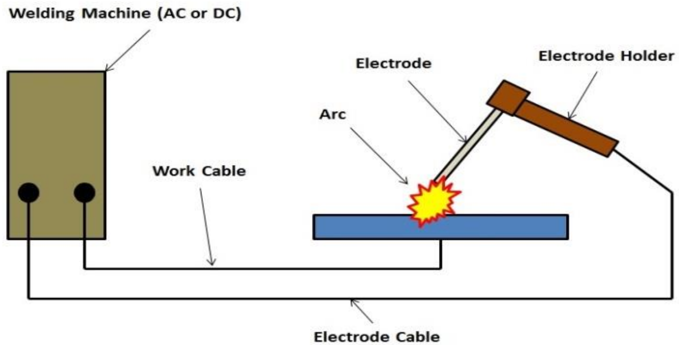
- **Disadvantages:**
  - Limited power density
  - Very low welding speed
  - High total heat input per unit length
  - Large heat affected zone
  - Severe distortion
  - Not recommended for welding reactive metals such as titanium and zirconium.

Arc Welding

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 piece**.

- Permanent joining of two or more metal parts
- Mostly **without the application of pressure** and with (or) without the **use of filler metals** depending upon the **base plate thickness**
- Final welded joint has unit **strength approximately** equal to that of the **base material.**

- **Electric energy** from the **arc produces temperatures** of **~ 4400 °C**, **hot enough to melt** any metal
- Most Arc Welding processes **add filler metal** to increase volume and strength of weld joint
- **Flux material** is used to prevent **oxidation**, which **decomposes under the heat of welding** and releases a **gas that shields the arc** and the hot metal.
- Second method employs an **inert or nearly inert gas** to form a **protective envelope** around the arc and the weld. **Helium, argon, and carbon dioxide -** used gases.



Basic Arc Welding Circuit Diagram

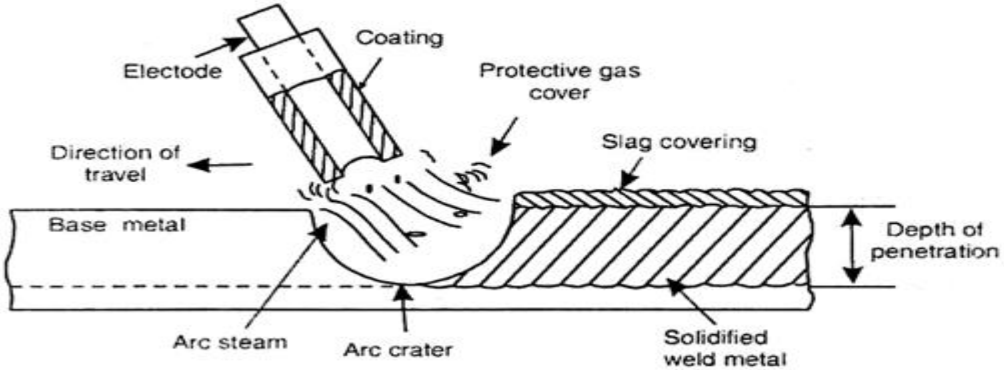
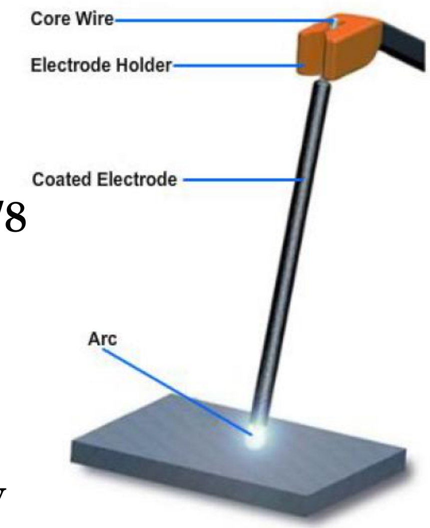


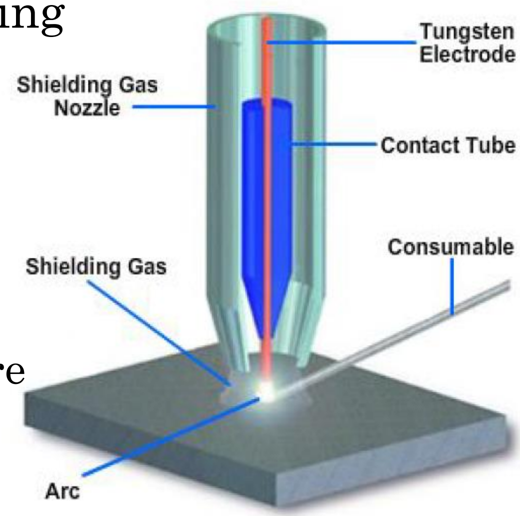
Fig. 7.14. Cut away view of the arc welding with a coated electrode.

Two Basic Types of AW Electrodes

- **Consumable** – consumed during welding process
  - Source of **filler metal** in arc welding
  - Forms of **consumable electrodes**
  - **Welding rods** (a.k.a. sticks) are **9 to 18 inches** and **3/8 inch** or less in diameter and must be **changed frequently**
  - **Weld wire** can be continuously **fed from spools** with long lengths of wire, avoiding frequent interruptions
  - In both **rod and wire forms**, electrode is consumed by the arc and **added to weld joint** as filler metal



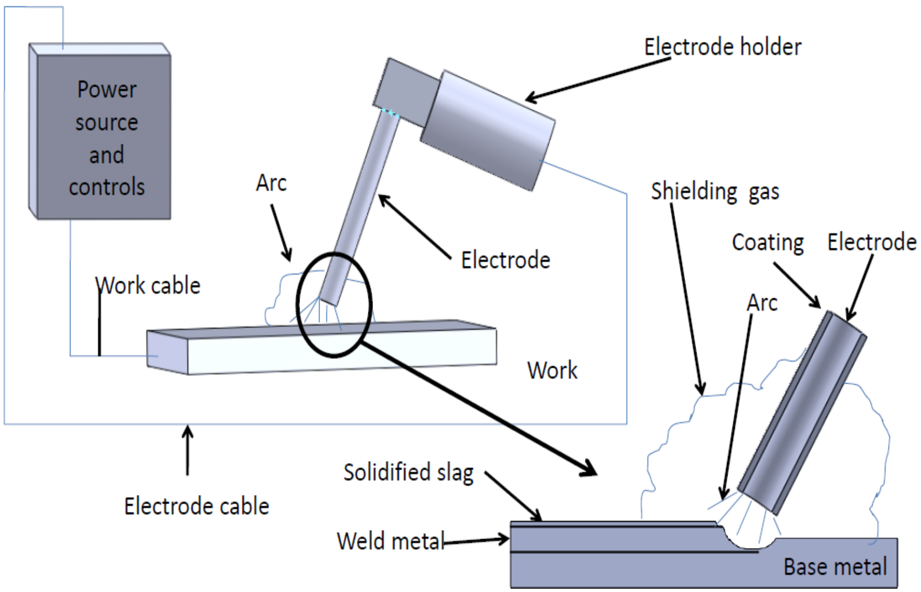
- **Non-Consumable** – not consumed during welding process
  - Filler metal must be **added separately** if it is added
  - Made of **tungsten** which resists melting
  - **Gradually depleted** during welding (vaporization is principal mechanism)
  - Any **filler metal must be supplied** by a separate wire fed into weld pool

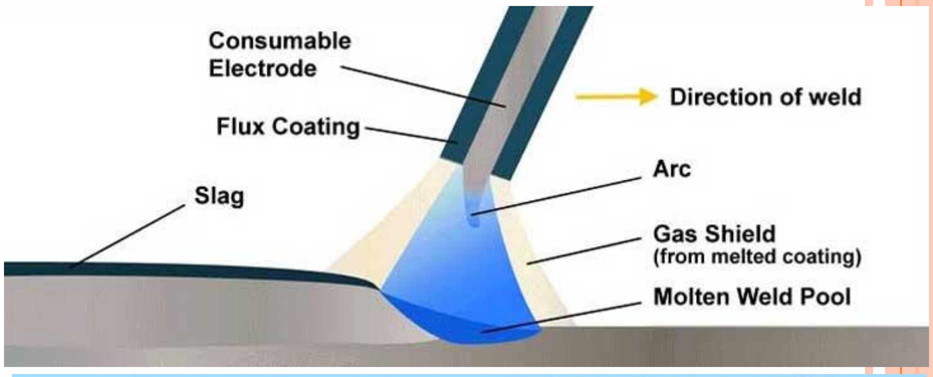


Shielded-Metal Arc (SMAW) or Stick Welding

- In this process, **coalescence is produced** by heating the work piece with an electric arc setup between a **flux-coated electrode** and the **workpiece**. The electrode is in a **rod form coated** with **flux**.

Shielded metal arc welding





Advantages of Arc welding

- The process gives **high deposition rates**.
- Welding speed is **high**.
- Wire consumption is low.
- The consumption of electrical energy is low, as a **maximum of 97 % of heat energy** can be utilized.
- Any length can be welded without any interruption.
- **High-quality Welds** are achieved with no fusion defects, no porosity and slag inclusions.

Disadvantages of Arc welding

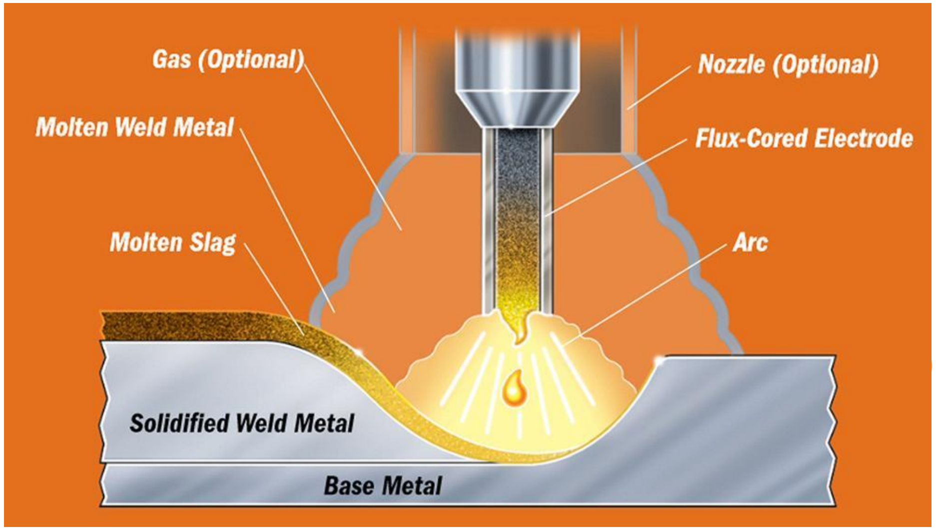
- **Arc is invisible**, it can be controlled only by measuring arc voltage and current.
- It can be used only in the down hand welding position.

Applications

- Sustainable connections within buildings & bridges.
- Arc welds bonds heat shields, exhaust systems and hydraulic lines to the chassis.
- Metal furniture pieces like office desks, file cabinets and shelving units are often welded.
- Heating, ventilation and air conditioning units are usually constructed using this welding process.

Arc Shielding

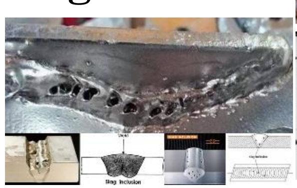
- At **high temperatures** in AW, **metals are chemically reactive** to oxygen, nitrogen, and hydrogen in air
  - **Mechanical properties** of joint can be **degraded** by these reactions
  - To protect operation, **arc must be shielded** from surrounding air in AW processes
- Arc shielding is accomplished by:
  - Shielding gases, e.g., argon, helium, CO_2
  - Flux

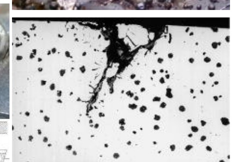


Role of a Flux: Protection, Deoxidation, Stabilization and Metal Addition

Constituent	Role
Iron oxide	Slag former, arc stabilizer
Titanium oxide	Slag former, arc stabilizer
Calcium fluoride	Slag former, fluxing agent
Potassium silicate	Arc stabilizer, Binder
Magnesium oxide	Fluxing agent
Cellulose	Gas former
Calcium carbonate	Gas former, Arc stabilizer
Ferro-manganese, Ferro-chrome	Alloying changes
Ferro-silicon	Deoxidizer

- **Flux** prevents **formation of oxides** and other **contaminants** in welding, or dissolves them and facilitates removal
- Provides **protective** atmosphere for welding
- **Stabilizes** arc
- **Reduces spattering**

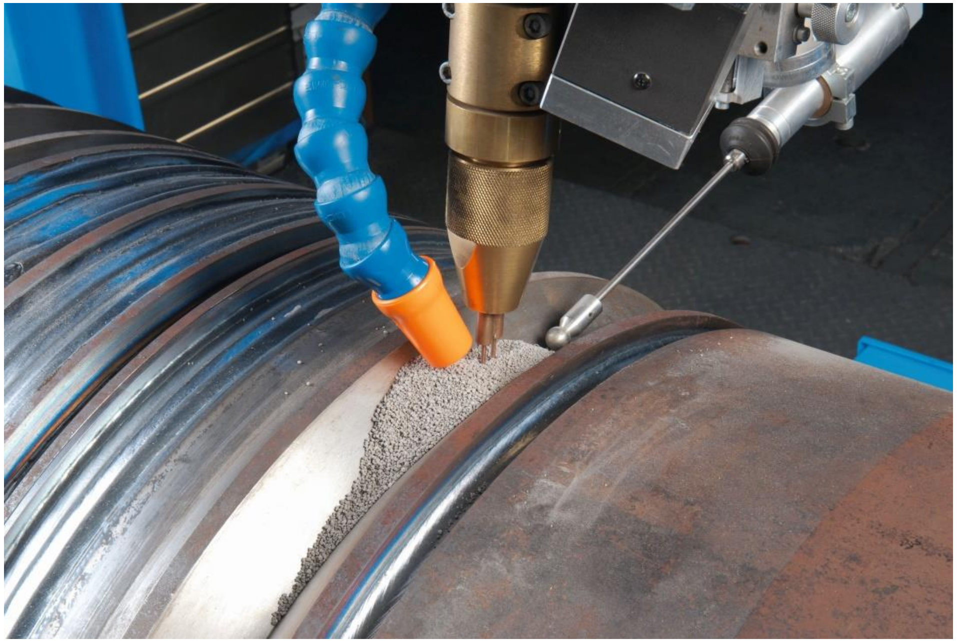


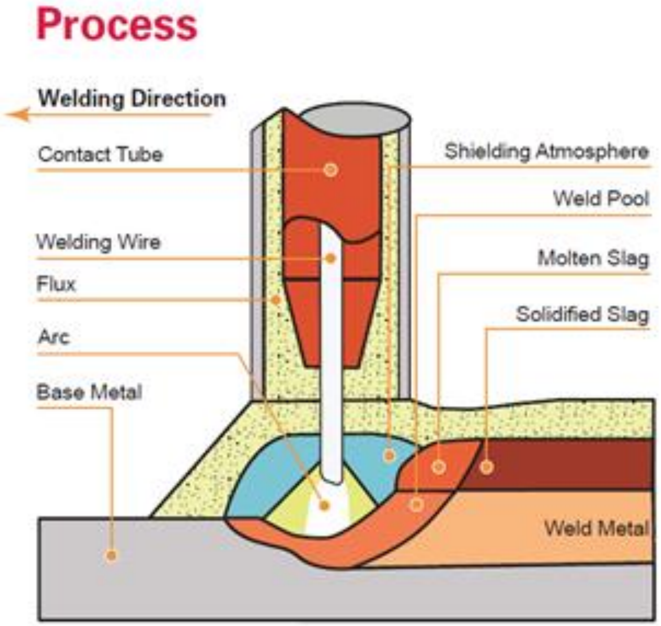


- **Flux Application:**
  - **Pouring granular flux** onto welding operation
  - **Stick electrode** coated with **flux material** that melts during welding to cover operation
  - **Tubular electrodes** in which flux is contained in the core and released as electrode is consumed

Submerged Arc Welding (SAW)

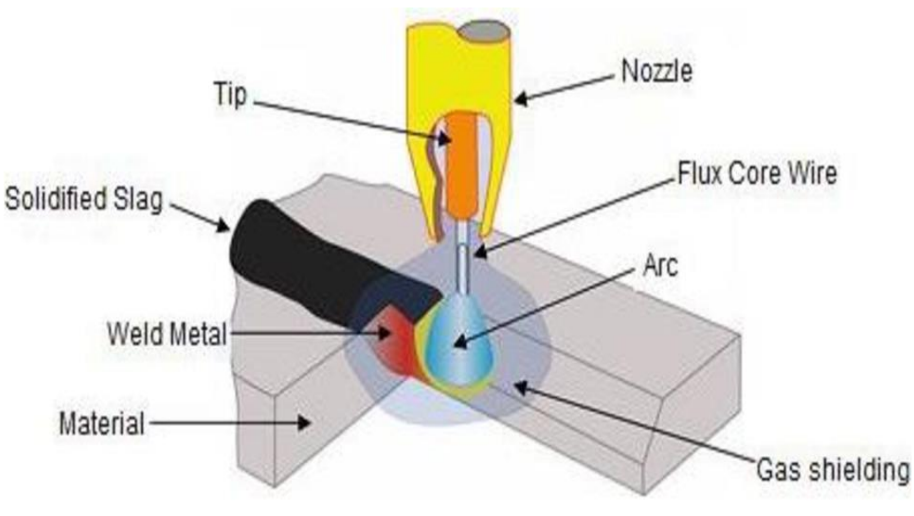
- In this process, coalescence is produced by heating the workpiece with an electric arc setup between the **bare electrode and the work piece**.
- Molten pool remains completely hidden under a **blanket of granular material** called flux.
- The electrode is in a **wire form** and is **continuously fed** from a reel. **Movement of the weld gun**, dispensing of the flux and picking up of **surplus flux granules** behind the gun are usually **automatic**.

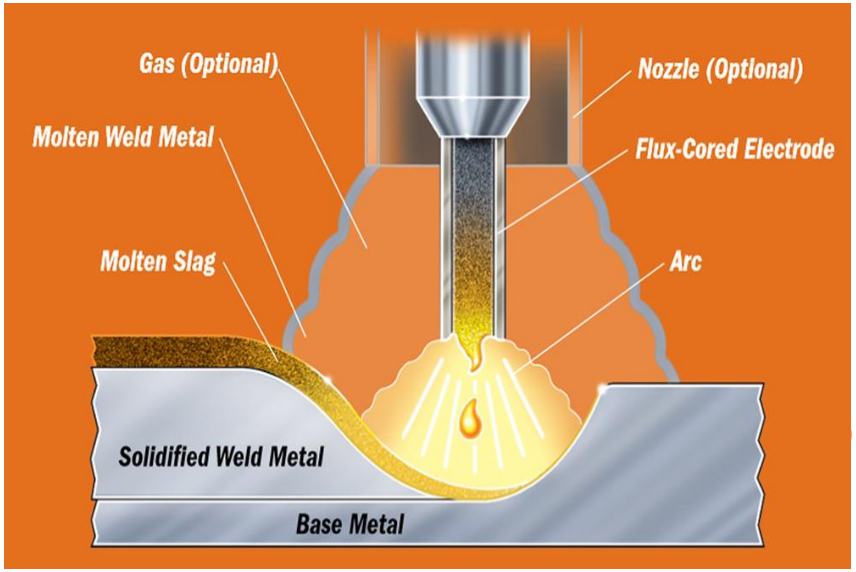




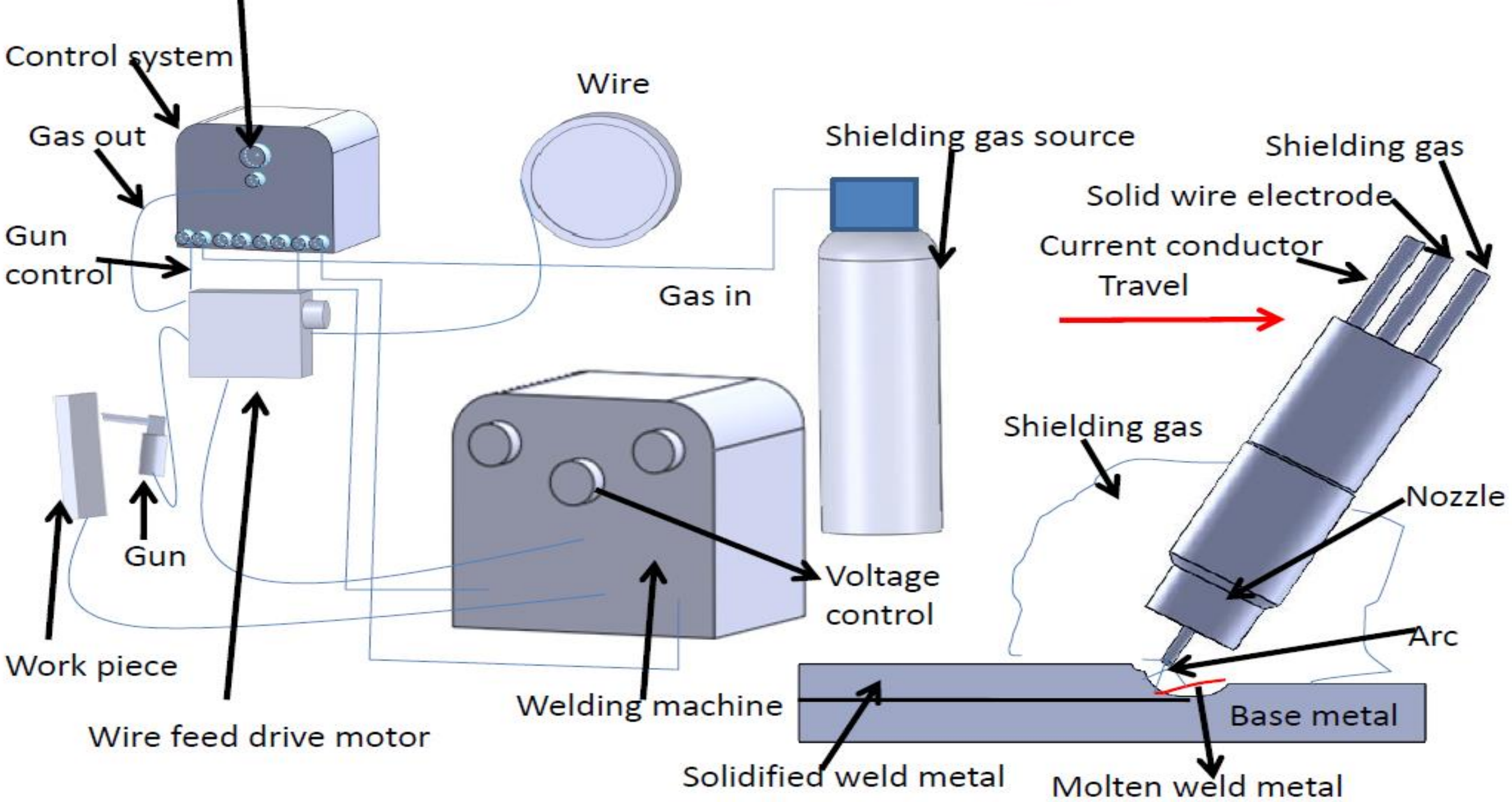
Flux-Cored Arc Welding (FCAW)

- This process is similar to the **shielded-arc stick welding** process with the main difference being the **flux is inside the welding** rod.
- **Tubular, coiled and continuously fed electrode** containing **flux inside the electrode** is used, thereby, saving the cost of changing the welding.
- Sometimes, **externally supplied gas** is used to assist in shielding the arc.



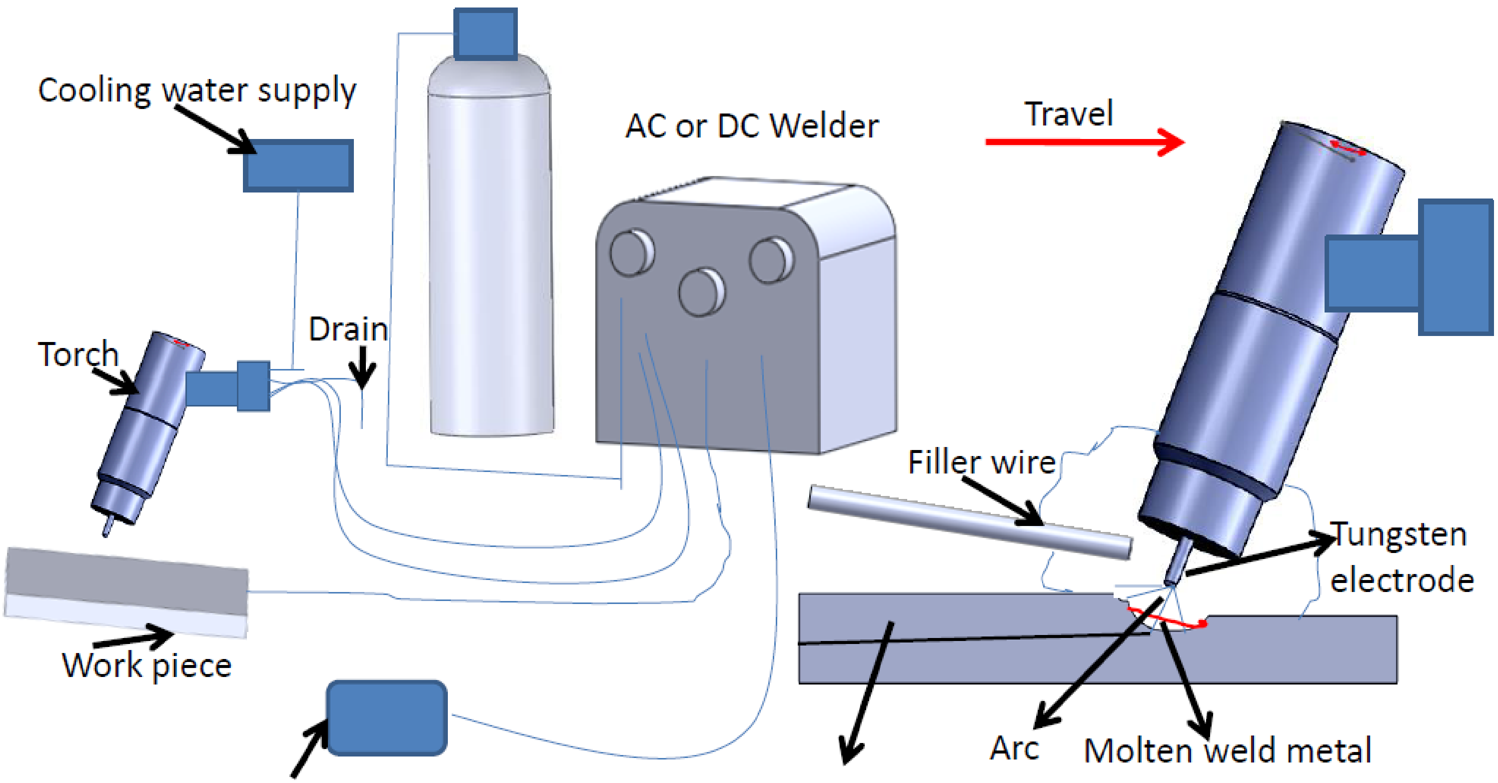


Gas metal arc welding



- In this process, an **inert gas such as argon, helium,** carbon dioxide or a **mixture of them** are used to **prevent atmospheric contamination** of the weld.
- The **shielding gas** is allowed to **flow through the weld** gun.
- The electrode used here is in a **wire form**, **fed continuously** at a fixed rate.
- The **wire is consumed** during the process and thereby **provides filler metal**.

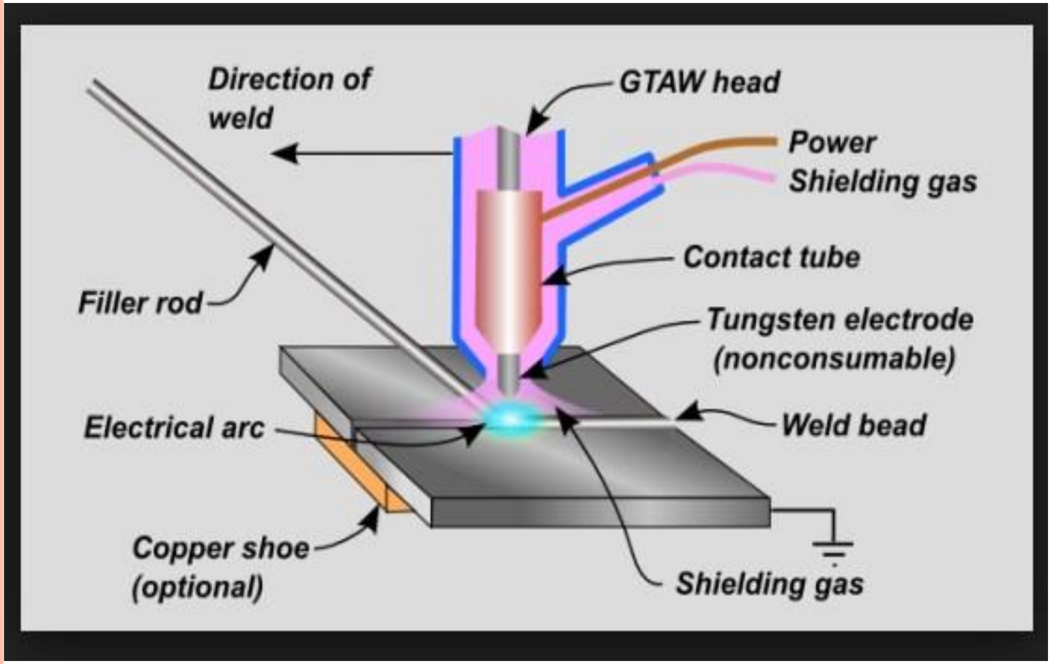
Gas tungsten arc welding

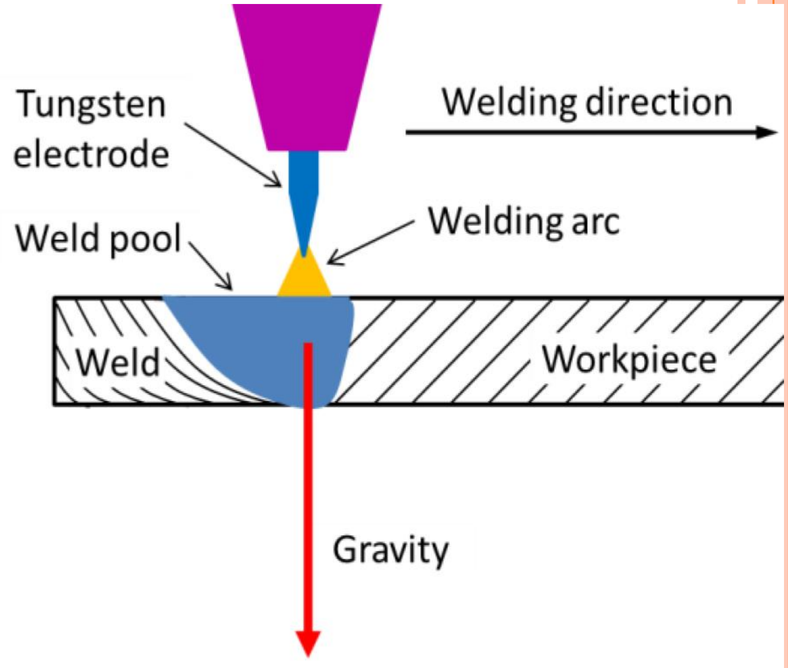


- In **gas tungsten arc welding** (GTAW), **inert gases** are used to **shield the tungsten from contamination**.
- It also shields the **fluid metal** (created from the arc) from the **reactive gases in air** which can **cause porosity** in the **solidified weld puddle**.
- Inert gases are also used in gas metal arc welding (GMAW) for welding **non-ferrous metals**.

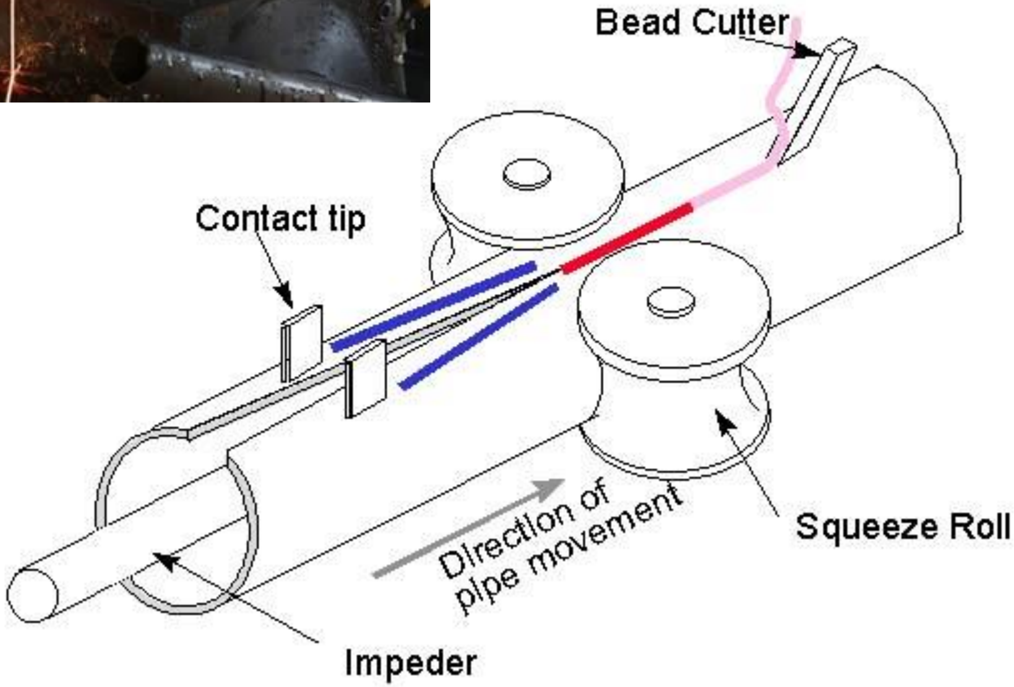
Gas-Tungsten Arc Welding (GTAW)

- This process is also known as **tungsten–inert gas** (TIG) **welding**. This is similar to the **Gas-Metal Arc Welding** process.
- Difference being the electrode is **non consumable** and **does not provide filler metal** in this case.
- A **gas shield** (usually **inert gas**) is used as in the GMAW process. If the filler metal is required, an **auxiliary rod** is used.





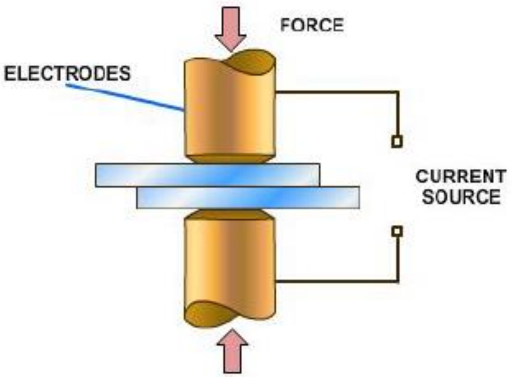
ELECTRICAL RESISTANCE WELDING

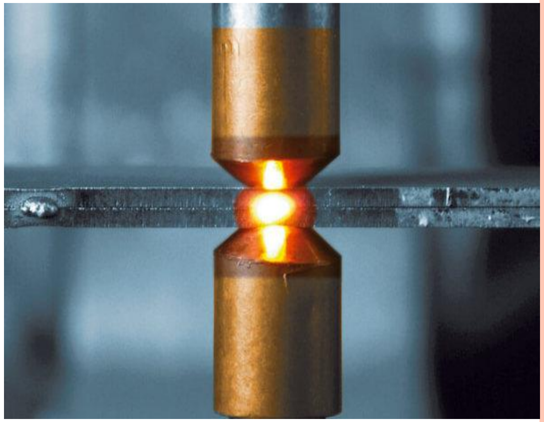


ELECTRICAL RESISTANCE WELDING

Introduction

- **Resistance welding** uses the application of **electric current and mechanical pressure** to create **a weld between two pieces** of metal.
- **Weld electrodes** conduct the **electric current** to the two pieces of metal as **they are forged** together.
- The **welding cycle** must first develop **sufficient heat to raise** a small volume of metal to the molten state.
- This **metal then cools while under pressure** until it has adequate strength to **hold the parts** together.
- The **current density and pressure** must be sufficient to produce a **weld nugget**, but not so high as to expel molten metal from the weld zone.

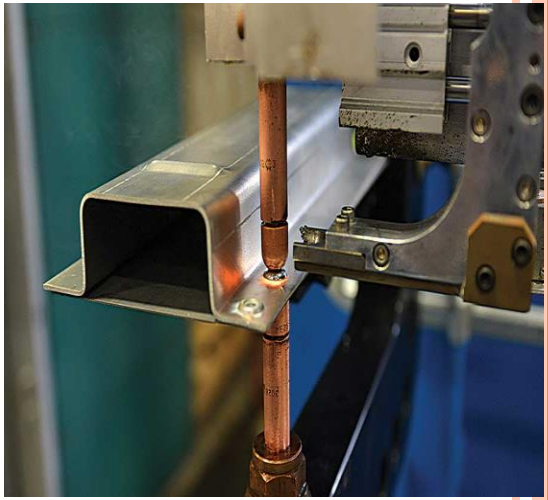


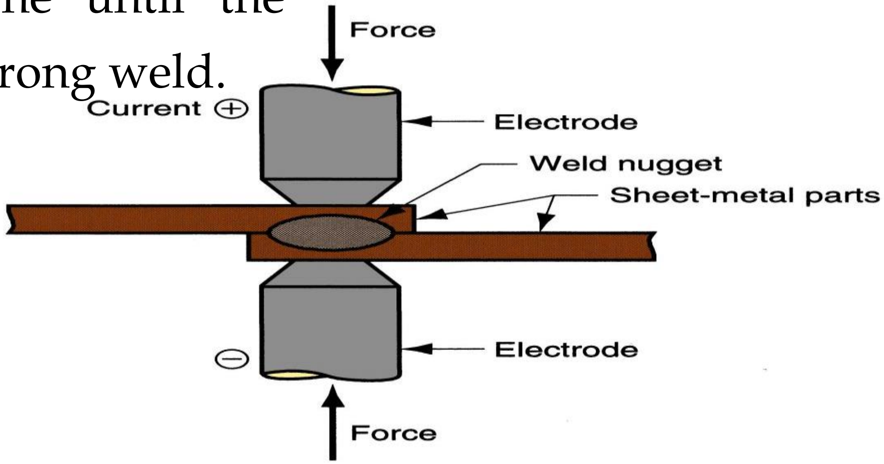


ELECTRICAL RESISTANCE WELDING

Operating Principle

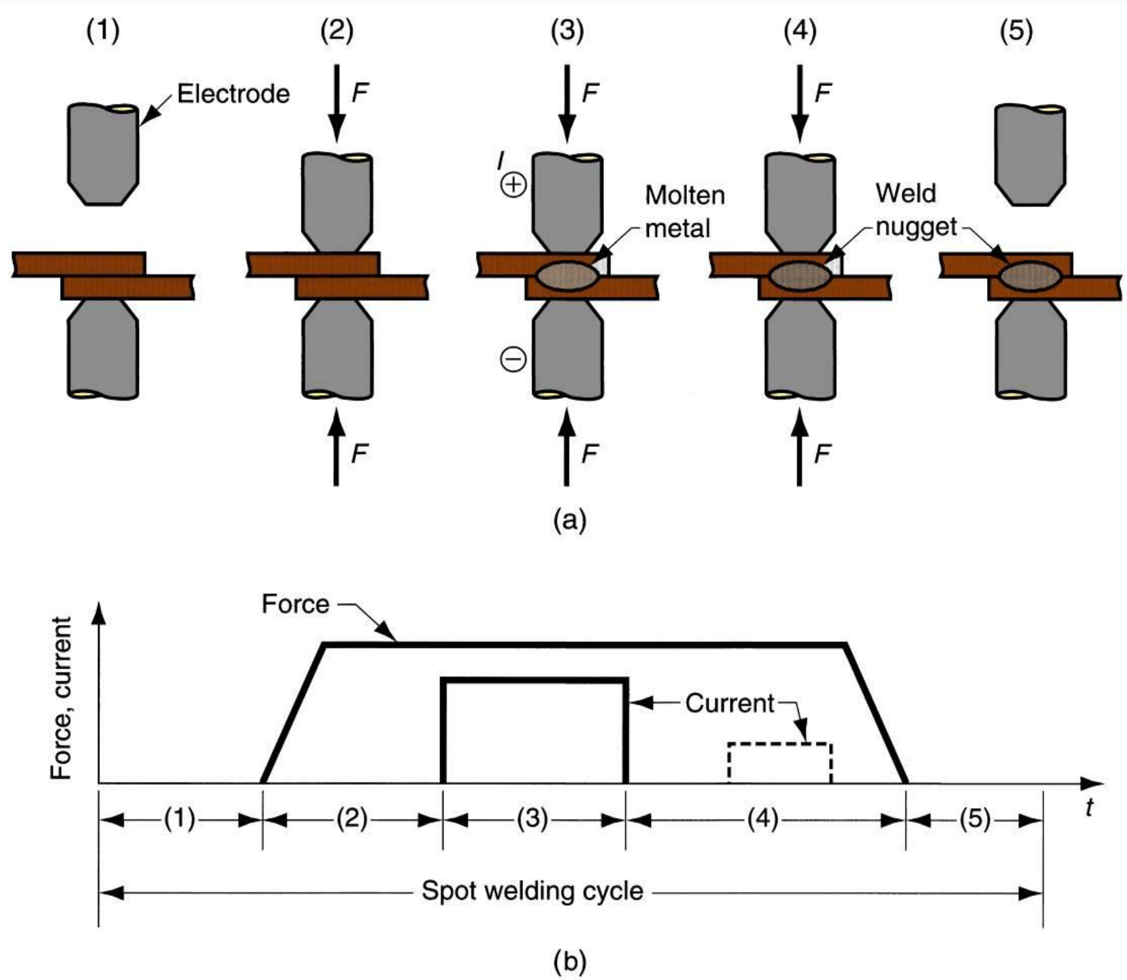
- Parts to be welded (**usually sheet metal**) are placed in between two **opposing copper electrodes**
- When **alternating current (A/C)** is passed through the **electrodes** ,the electrical resistance at the **metal joints becomes very high**.
- **Heat generated by electrical resistance** to current flow at junction to be welded by **means of applying pressure** to squeeze parts between electrodes
- **Pressure is applied** to the contact zone until the current is turned off in order to obtain a strong weld.





Schematic illustration of Electrical Resistance Welding

ELECTRICAL RESISTANCE WELDING



Operating Principle in Detail

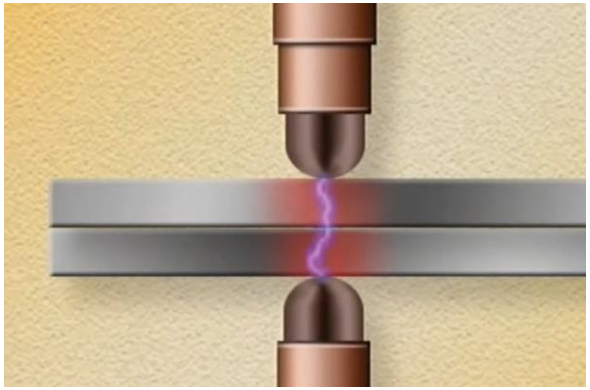
Parts inserted between electrodes

Electrodes close, force applied

Current on

Current off

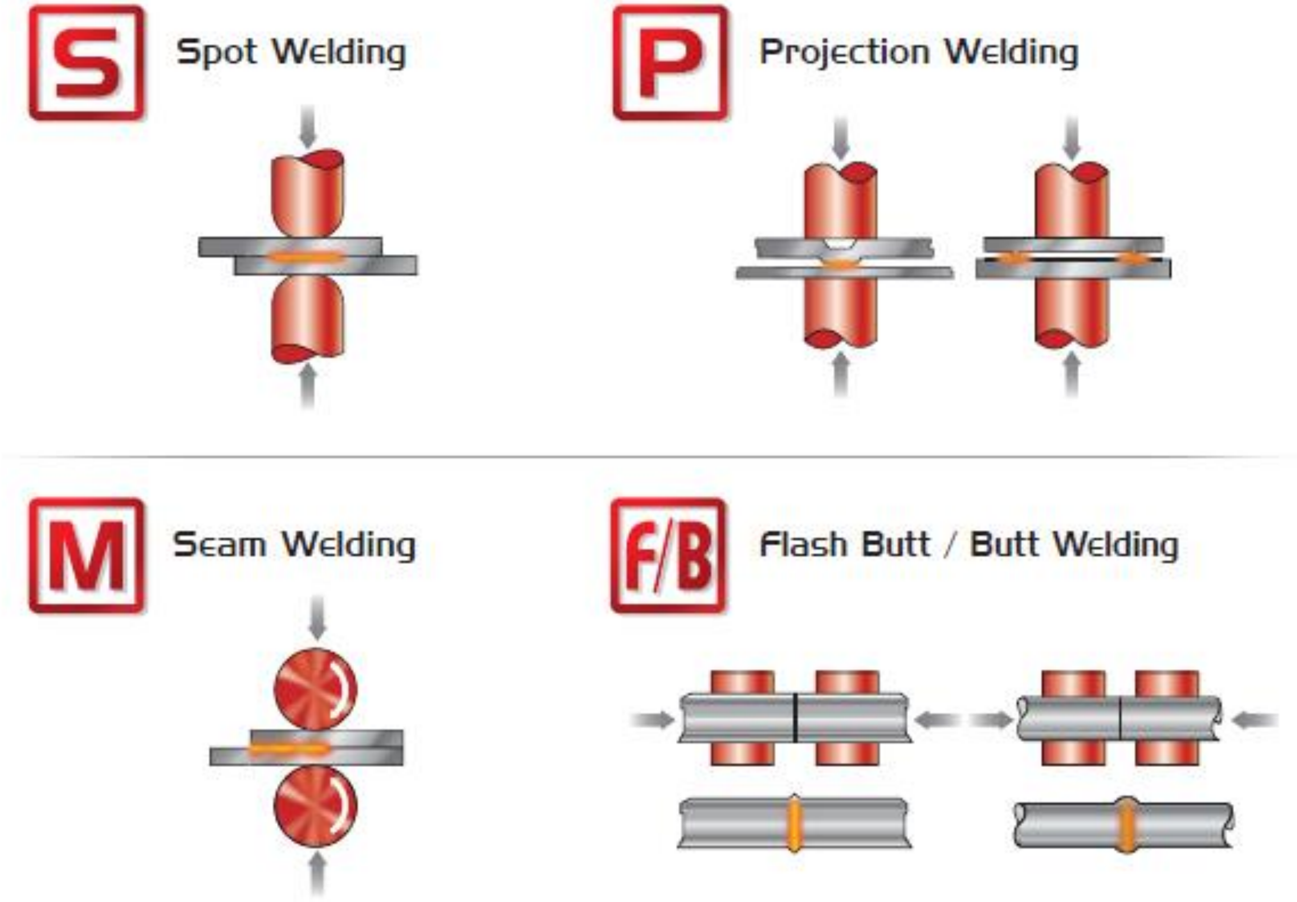
Electrodes opened



Electrical Resistance Welding Process

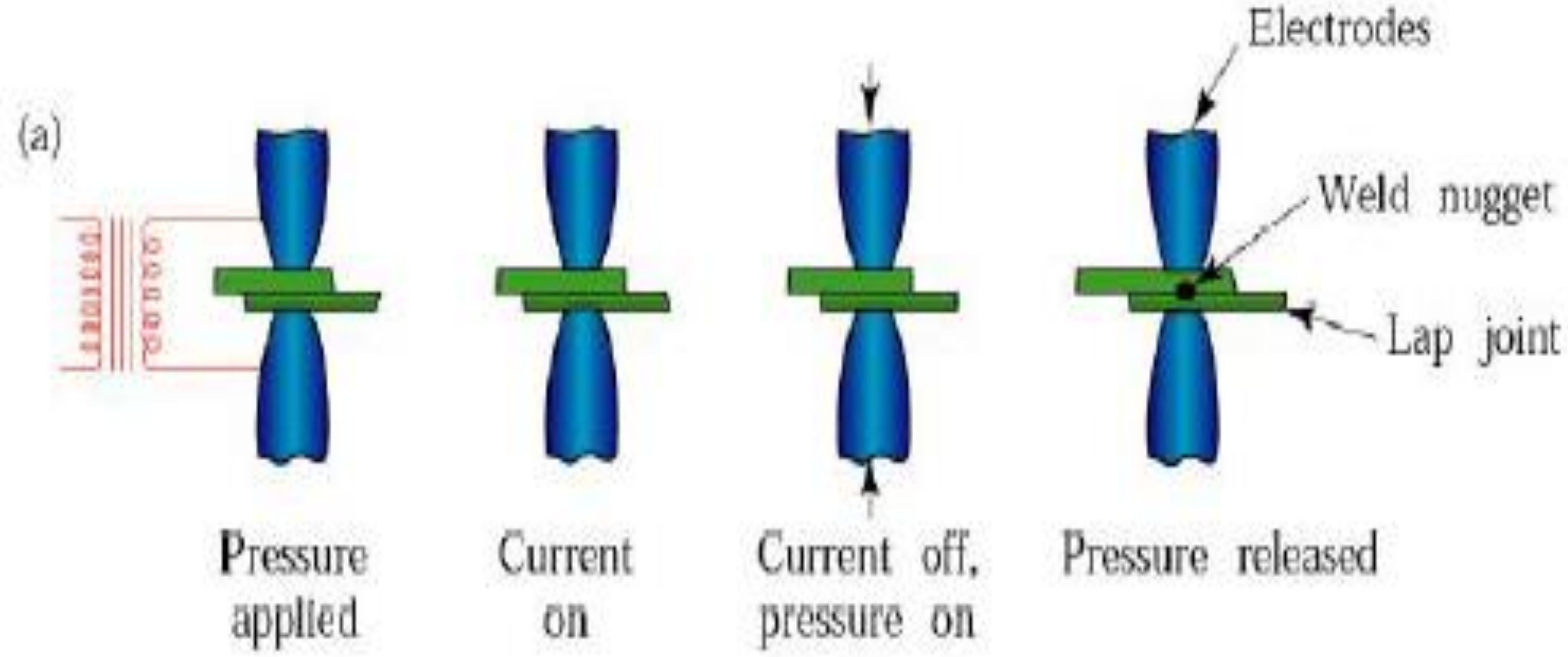
ELECTRICAL RESISTANCE WELDING

Types of Resistance Welding



ELECTRICAL RESISTANCE WELDING

- Resistance Spot Welding Process Detail



ELECTRICAL RESISTANCE WELDING

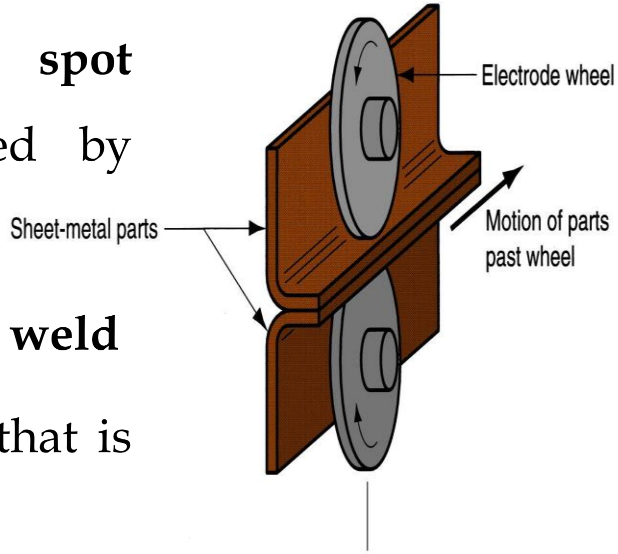
Operating Principle

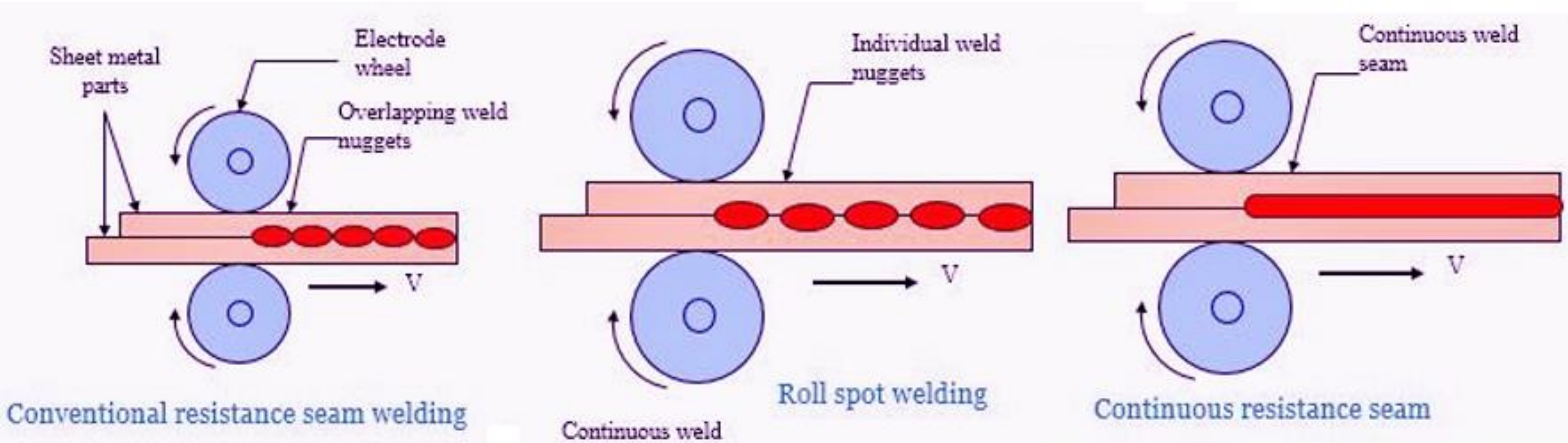
- **Resistance welding process** in which fusion of faying **surfaces of a lap joint** is achieved at one location by opposing electrodes
- Used to **join sheet metal** parts using a **series of spot** welds
- Widely used in mass production of automobiles, appliances, metal furniture, and other products made of sheet metal

ELECTRICAL RESISTANCE WELDING

Resistance Seam Welding

- Resistance Seam Welding is modification of **spot welding wherein the electrodes** are replaced by **rotating wheels** or rollers
- The electrically conducting rollers **produce a spot weld**
- RSEM can produce a **continuous seam & joint** that is liquid and gas tight

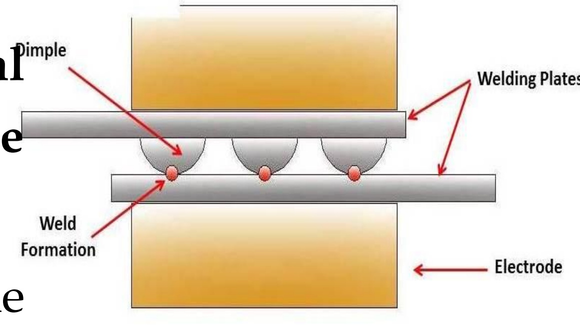




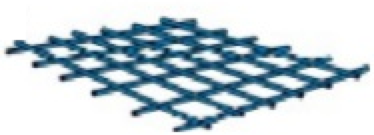
ELECTRICAL RESISTANCE WELDING

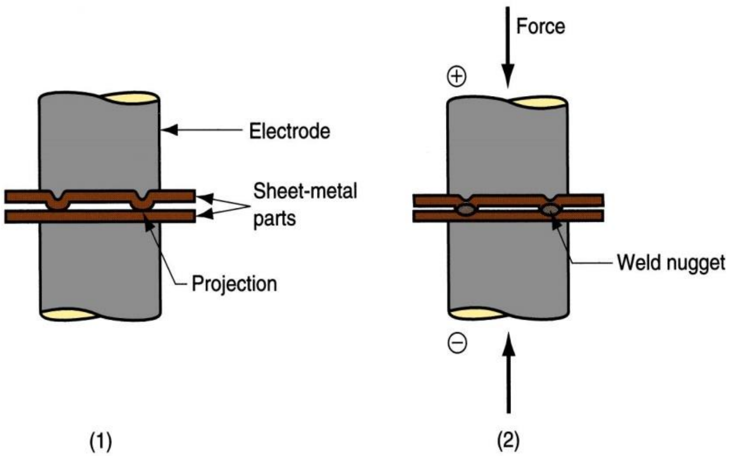
Resistance Projection Welding

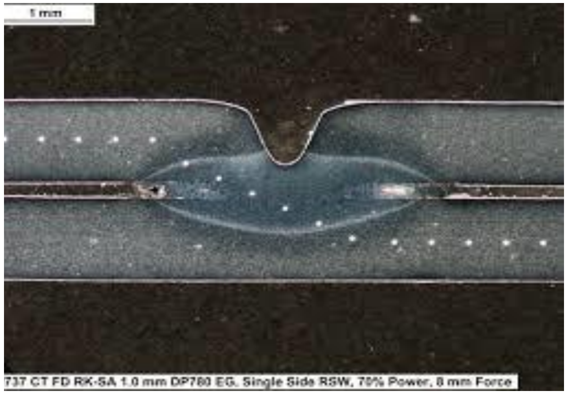
- RPW is developed by introducing **high electrical resistance** at a joint by embossing **one or more projections** on the surface to be welded
- The **electrodes exert pressure** to compress the projections
- **Nuts and bolts** can be welded **to sheet and plate** by this process
- Metal baskets, oven grills, and shopping carts can be made by RPW



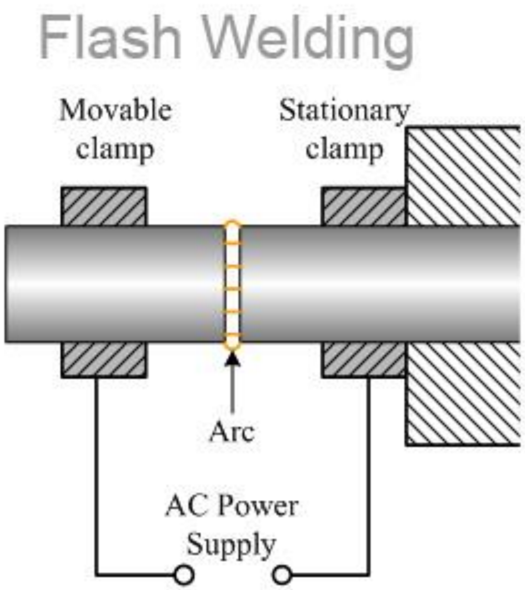
Projection Welding

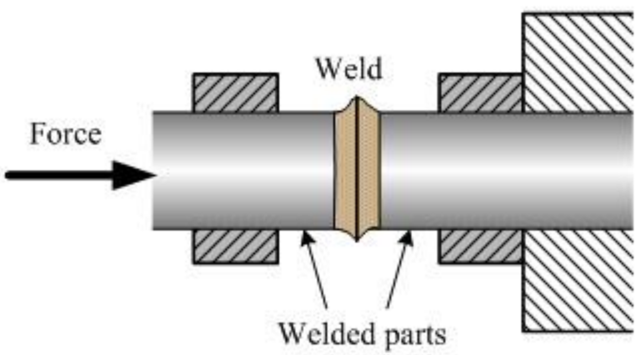


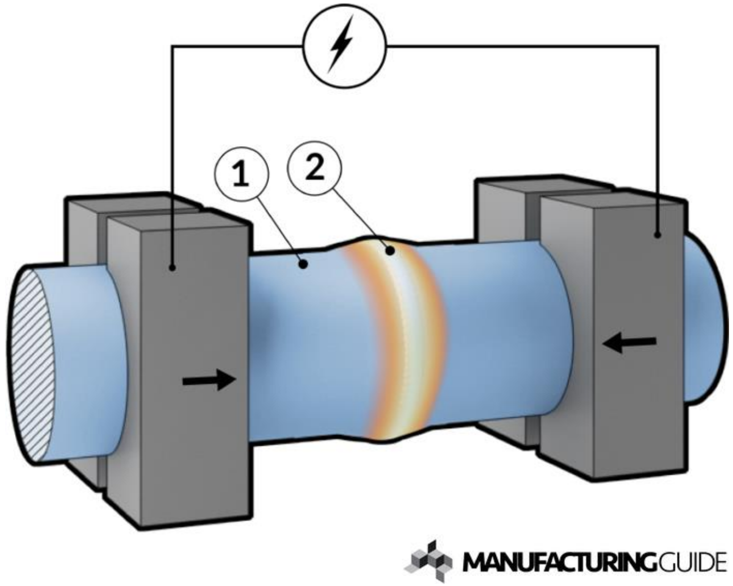


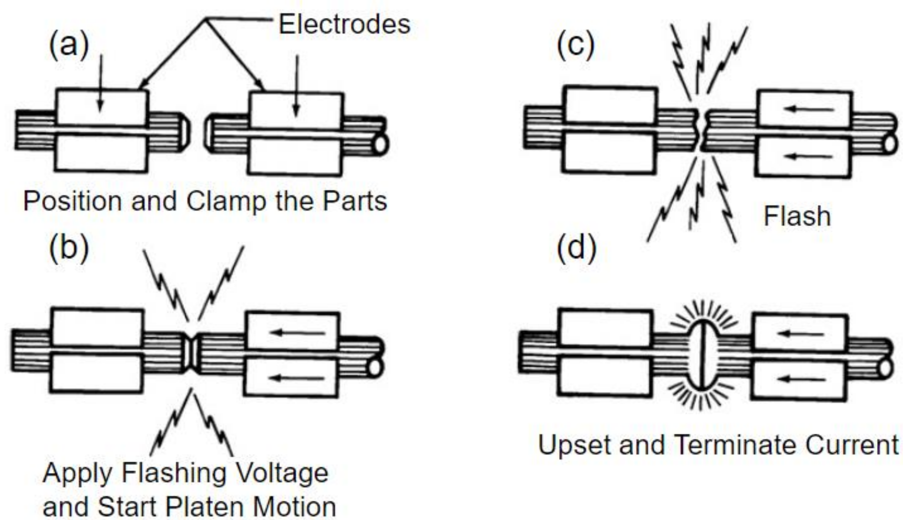


Flash Welding









ELECTRICAL RESISTANCE WELDING

Heat Generated in the weld may be expressed as

- $Q = K R I^2 T$

Where,

- ***K:*** **constant less than 1 related to heat losses.**
- ***I*** **: Current.**
- ***R*****: Resistance of ionized air gap.**
- ***T :*** **Welding time.**

ELECTRICAL RESISTANCE WELDING

Process Parameters

- The welding current
- Welding temperatures
- Electrode materials
- Electrode geometry
- Electrode pressing force
- Weld current and weld time.

ELECTRICAL RESISTANCE WELDING

Advantages

- High speed welding
- Easily automated
- Suitable for high rate production
- Economical

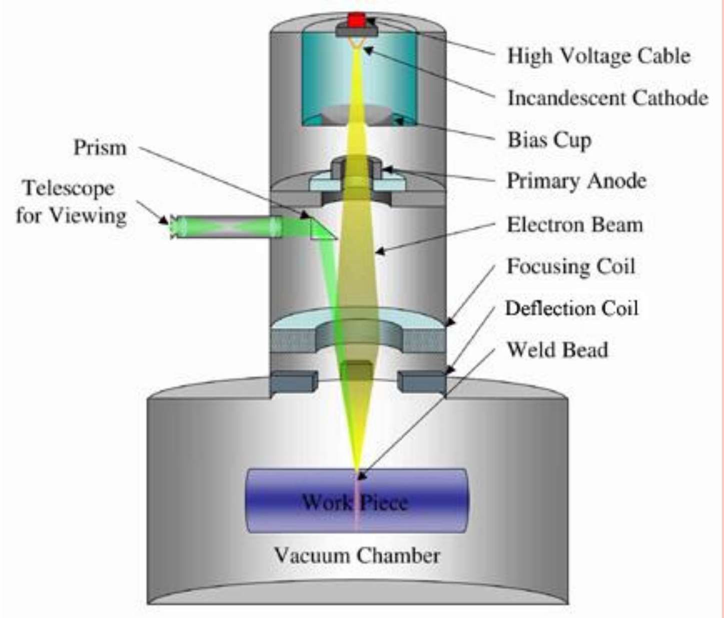
Limitations

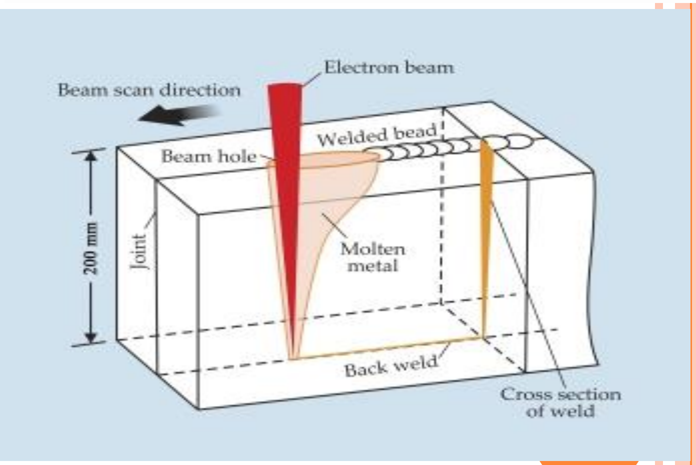
- Initial equipment costs
- Lower tensile and fatigue strengths
- Lap joints add weight and material

Applications

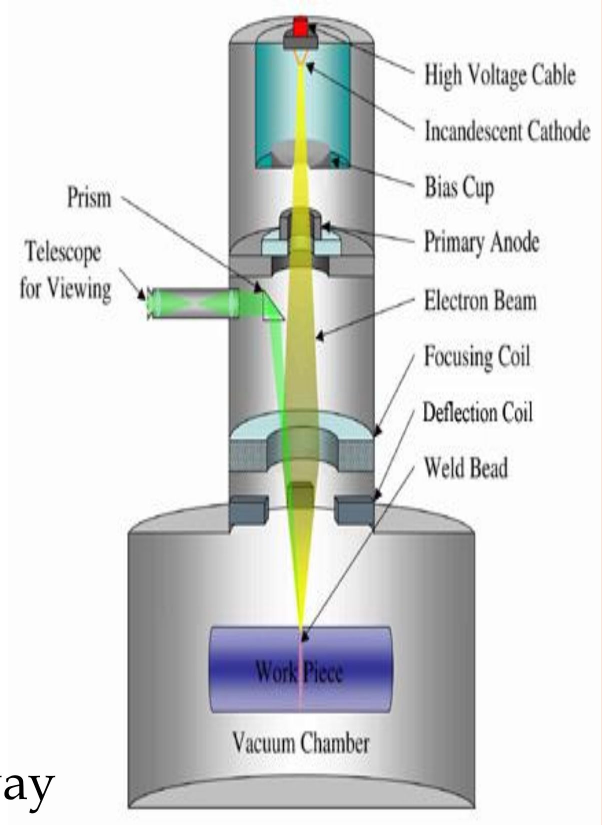
- Industries: automotive, aircraft, farm equipment, petroleum and natural gas

ELECTRON BEAM WELDING





ELECTRON BEAM WELDING



- **Electron beam machining (EBW)** is a fusion welding process that uses **high velocity stream of electrons focused on work piece surface to weld** material by melting and vaporization
- In electron-beam welding (EBW), **electrons are accelerated to a velocity** nearly three - fourths that of light (~200,000 km/sec).

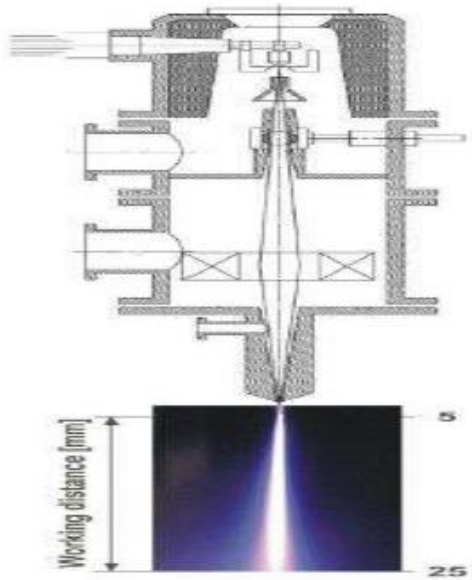
How it Works

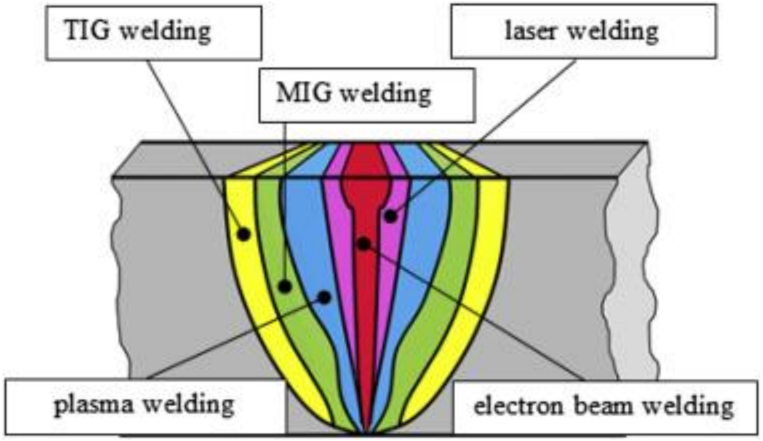
- An electron beam machine works in much the same way as a cathode ray tube in a television.
  - A **cathode** section generates an **electron beam**.
  - An **anode** section **accelerates the beam**.
  - The **lens system** converges and **deflects** the electron beam to the desired position.

ELECTRON BEAM WELDING

Operating principle

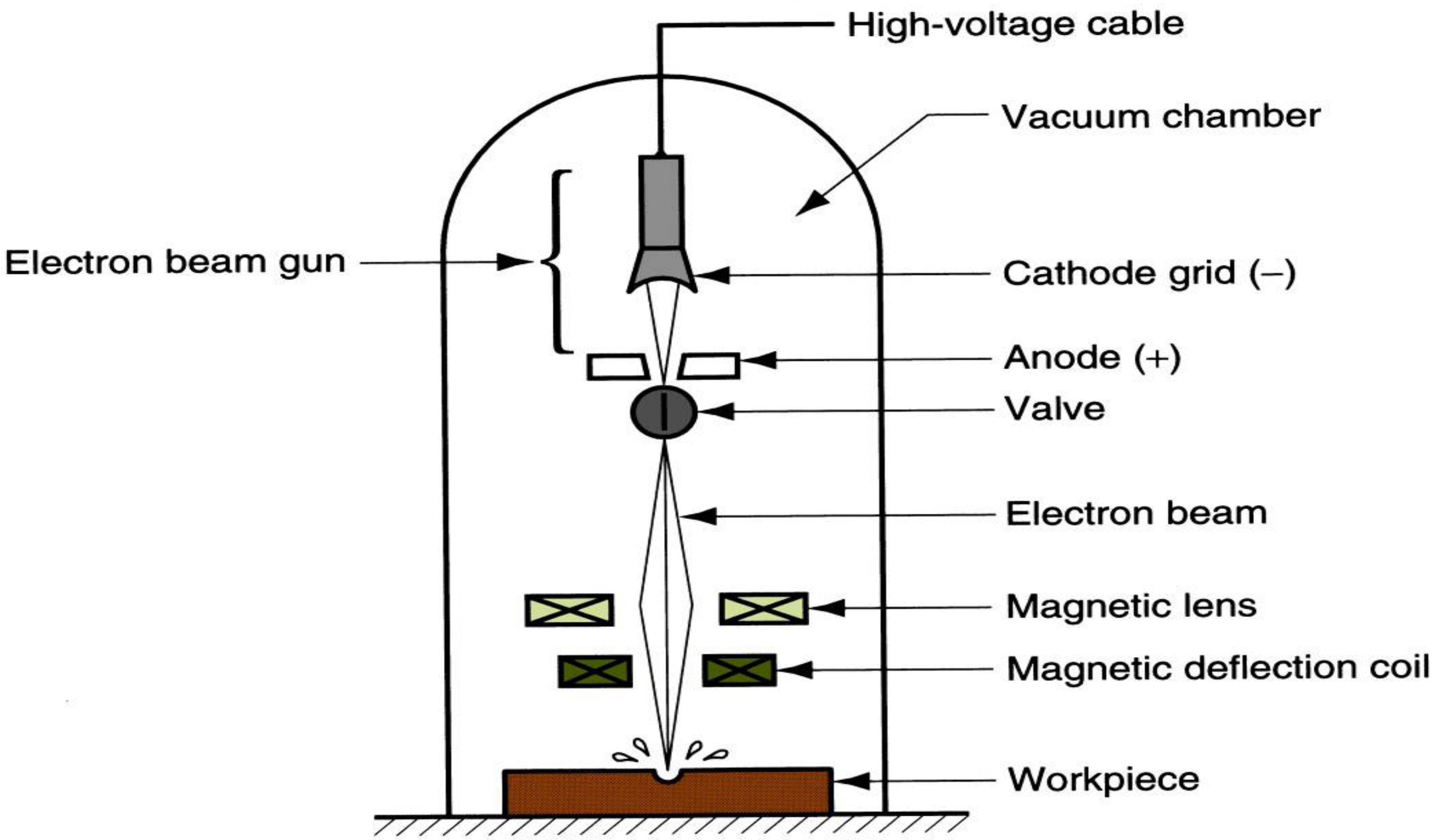
- A **high velocity stream of electrons** is directed against a precisely **limited area** of the work piece; on impact, the **kinetic energy of the electrons** is converted into **thermal energy that melts** and joins the materials to be weld.
- The process is performed in a **vacuum chamber to reduce the scattering of electrons** by gas molecules in the atmosphere.





ELECTRON BEAM WELDING

Equipment



Schematic illustration of the Electron Beam Welding Process

ELECTRON BEAM WELDING

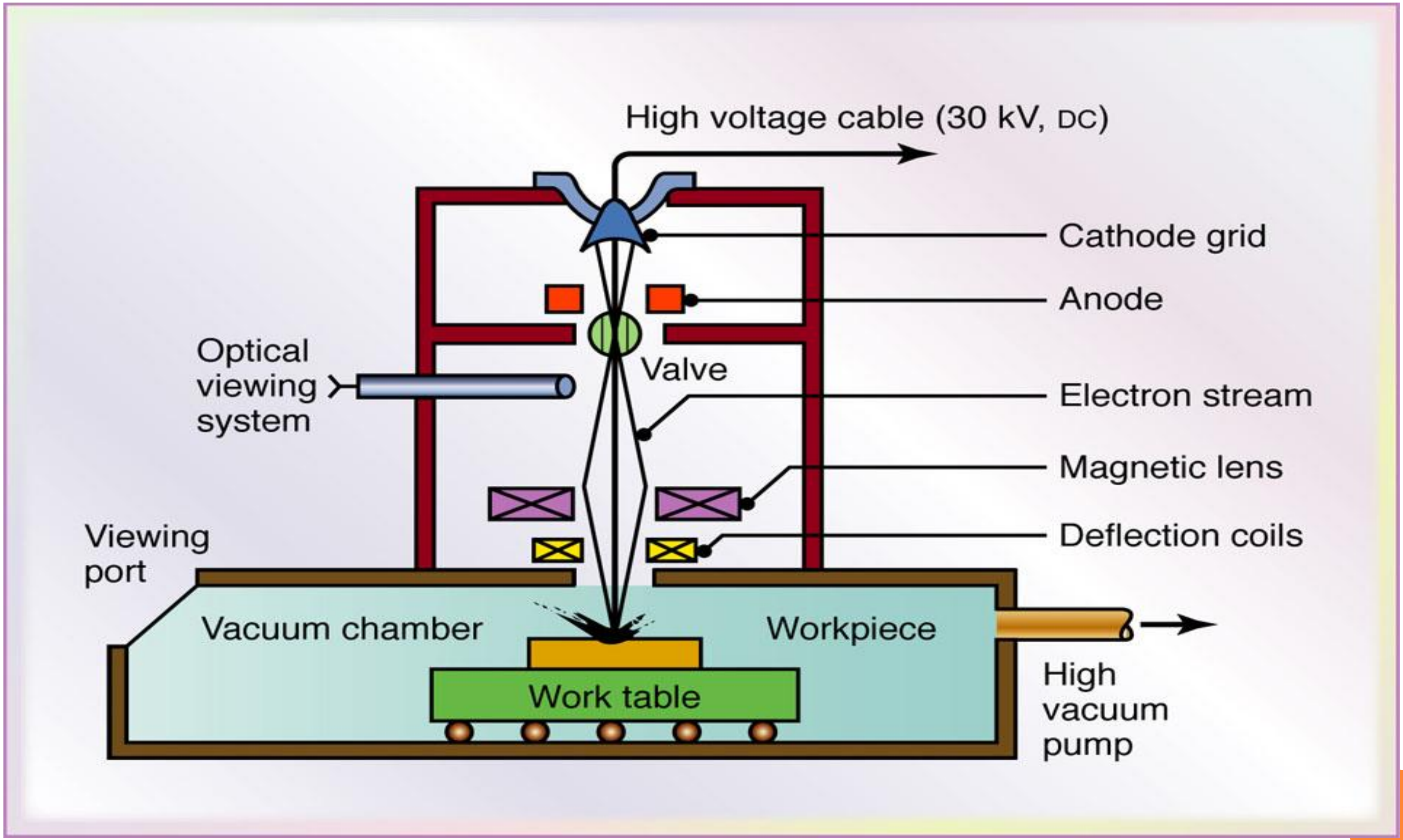
Sub systems of the Equipment

Electron Gun

- The **electron beam** is formed inside of an **electron gun**, which has
  - **Cathode** – Hot **tungsten filament** emitting electrons
  - **Grid Cup** – Element which is **negatively biased** with respect to the filament
  - **Anode** – a neutral element through which the accelerated electron pass

ELECTRON BEAM WELDING

Overall setup



ELECTRON BEAM WELDING

Sub systems of the Equipment

Magnetic Lens

- Used to **focus the electron beam** to any **desired diameter** to less than 0.00254 cm **at a precise location** on the work piece

Vacuum Chamber

- It prevents **collision of electrons with gas molecules** which would **scatter or diffuse** the electron beam
- It prevents the possibility of an **arc discharge** between the electrons

ELECTRON BEAM WELDING

Process Parameters

- Processing material
- Power supply
- Beam current (A)
- pulse duration (μs)
- Lens Current
- Focusing length
- Beam Deflection
- Safety characteristics

ELECTRON BEAM WELDING

Process capabilities

- A range of materials such as stainless steel, nickel and cobalt alloys, copper, aluminium, titanium, ceramic, leather and plastics can be processed by this method
- This is mainly used to weld metals about 0.1 to 1.4 mm in thicknesses up to 10 mm can be made
- Aspect ratios as large as 15:1 (Depth:width) can be achieved in most materials

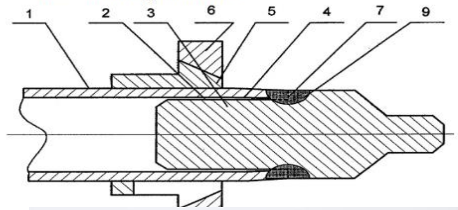
ELECTRON BEAM WELDING

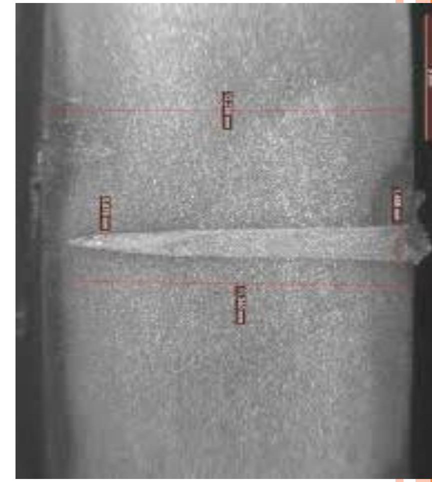
Applications

- The metals about 0.5 to 1.5mm thick can be welded
- It is used to weld non-metallic materials and alloys.
- It is used to weld dissimilar metals
- Electron beam machining is being used extensively in the electronic. aerospace and automotive industries.
- Welding of cams
- Suitable for large scale production

- Space
  - **Titanium tanks**
  - Sensors
- Nuclear
  - **Fuel housing**
  - Parts of structure
  - Valves
  - Instrumentations
- Automotive
  - **Transmission parts**
  - Gears
  - Parts of turbocharger
- Aerospace
  - Jet engine components
  - Parts of structures
  - Transmission parts
  - Sensors

Method of electron-beam welding of covers of heat-emitting elements



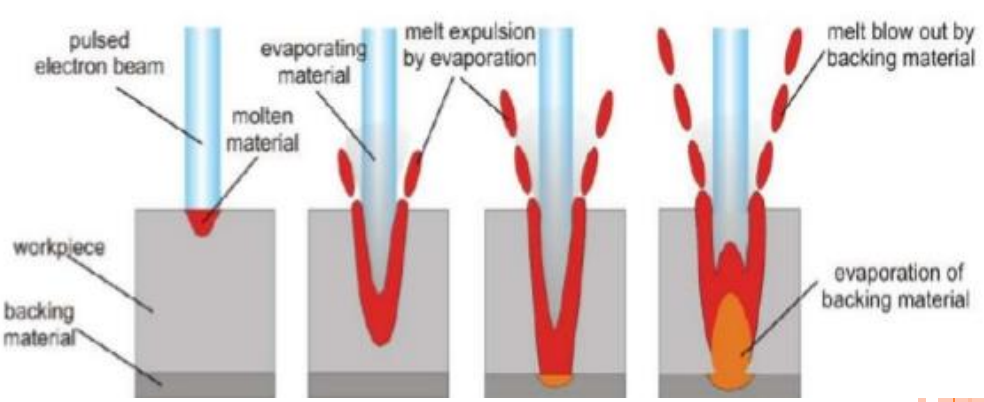


Spiral bevel gears are flight critical components used in helicopter drive systems and aircraft engines. These parts, which rotate at high speeds and operate at high loads, require virtually defect free welds. NADCAP approved electron beam welding is the process of choice for aerospace gears.

ELECTRON BEAM WELDING

<u>Advantages</u>

- Single pass welding of joints (0.05 mm to 200 mm) in single pass;
- Hermetic seals of components retaining a vacuum.
- Cost-effective welding process for large production in automatic mode.
- Low distortion
- Low contamination in vacuum
- Narrow melt zone (MZ) and narrow heat affected zone (HAZ);
- Welding of all metals even with high thermal conductivity;
- Welding of metals with dissimilar melting points;
- Uses no filler metal
- EB Micro-Machining

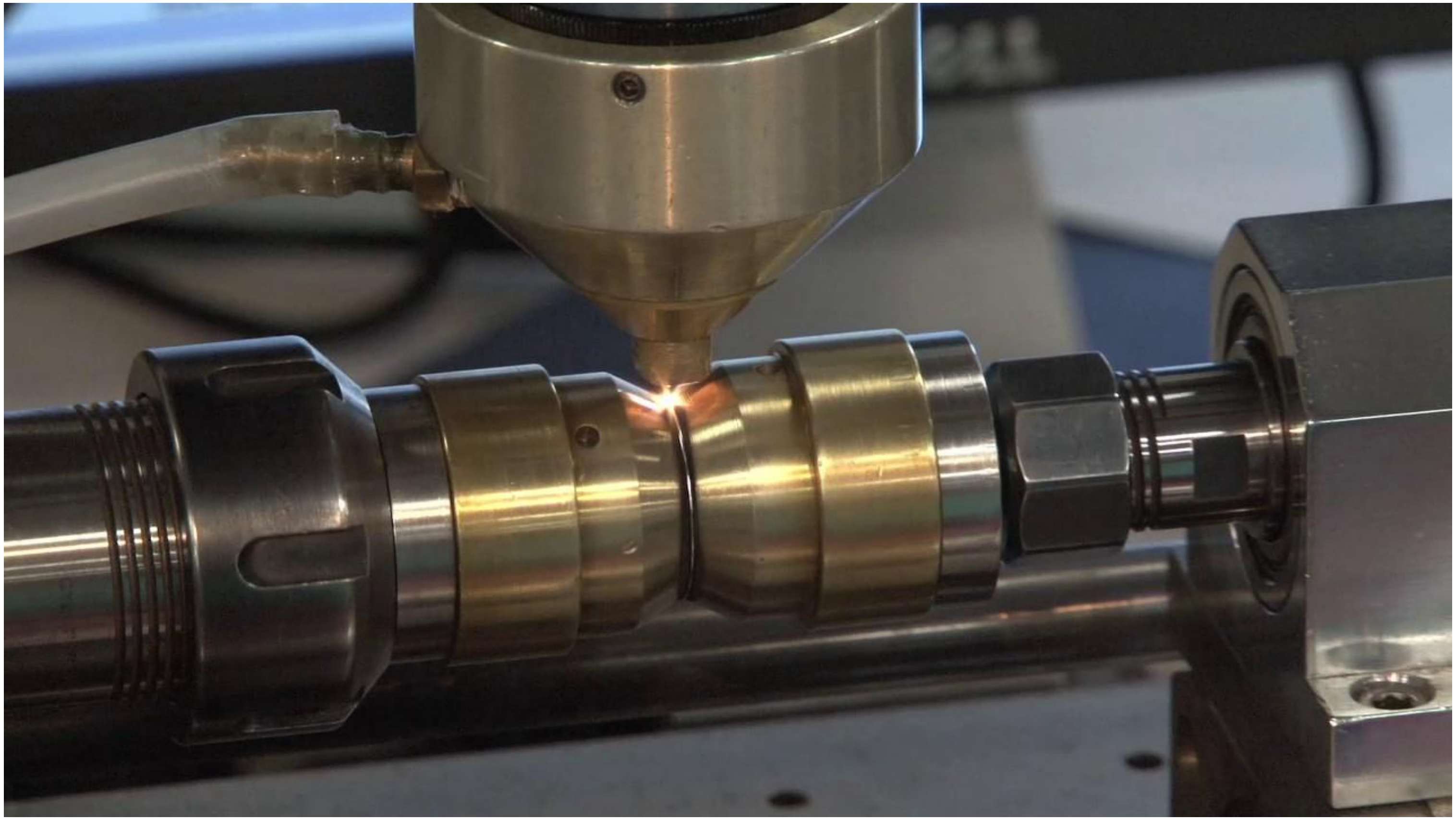


ELECTRON BEAM WELDING

Limitations

- High equipment cost
- Work chamber size constraints
- Time delay when welding in vacuum
- High weld preparation costs
- X-rays produced during welding
- Rapid solidification rates can cause cracking in some materials

MANUFACTURING TECHNOLOGY



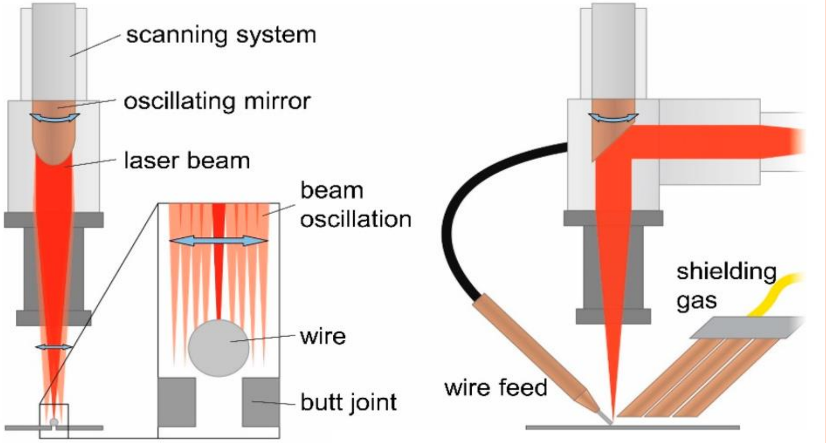
LASER BEAM WELDING

LASER BEAM WELDING

LASER

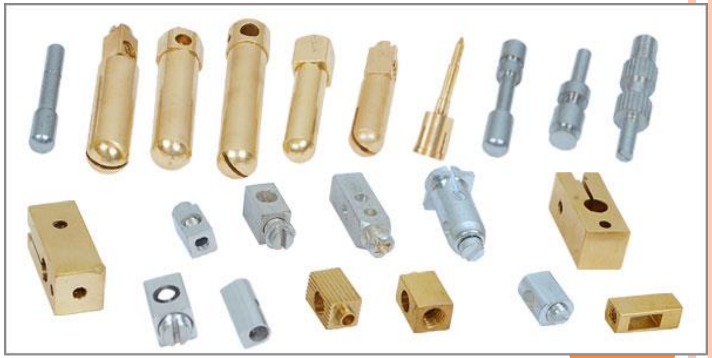
- **LASER**: **"Light Amplification by Stimulated Emission of Radiation"**
- Focused laser beam has **high power density**.
  - Useful for welding, cutting, heat treating, Etc…
- Materials processing lasers
  - Gas (CO_2)
  - Solid-state lasers (Yttrium aluminum garnet-YAG)

LASER BEAM WELDING



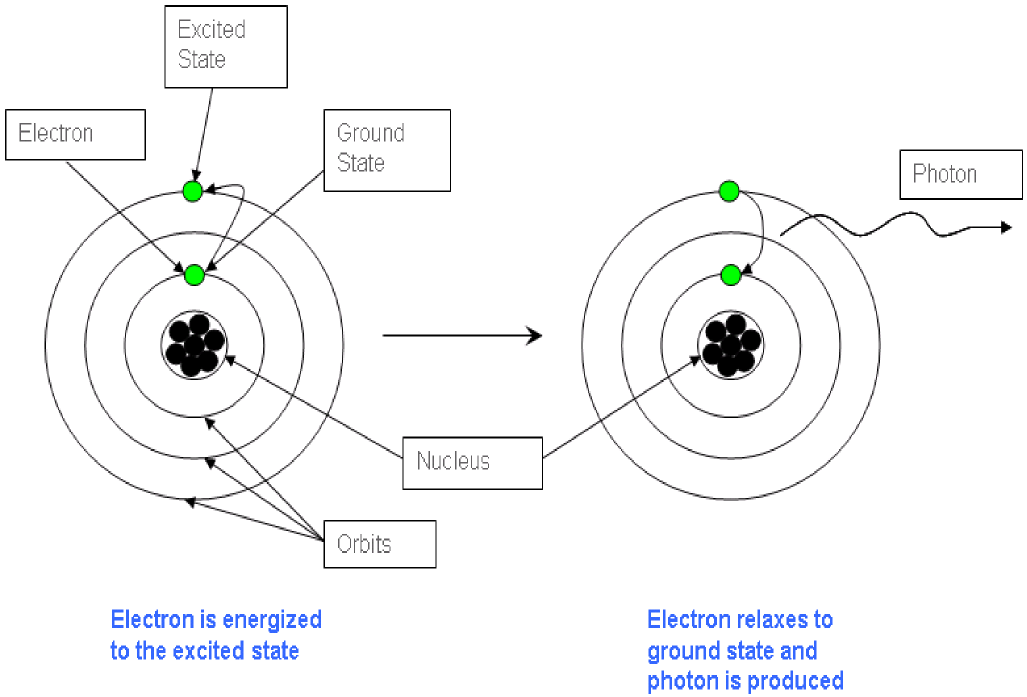
Introduction

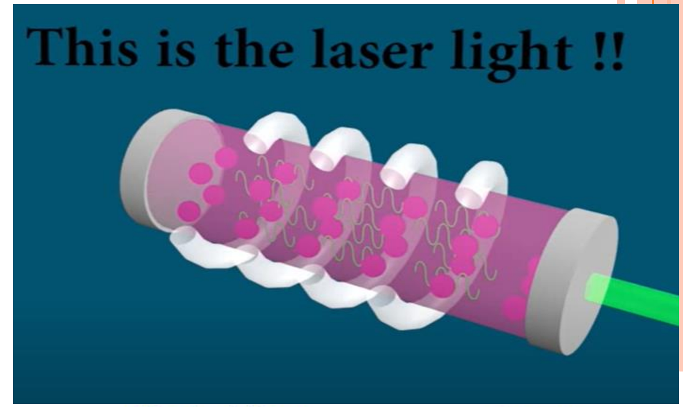
- **Laser-beam welding** is a fusion welding process that utilizes a **high-energy, coherent light beam** to melt and join the particles on the surface of metallic and non-metallic work pieces.
- Lasers can be used to **cut, drill, weld and mark**
- LBW is particularly suited to weld all type of materials .
- It can be used to perform precision welding on all microelectronic substrates such as ceramic, silicon, diamond, and graphite

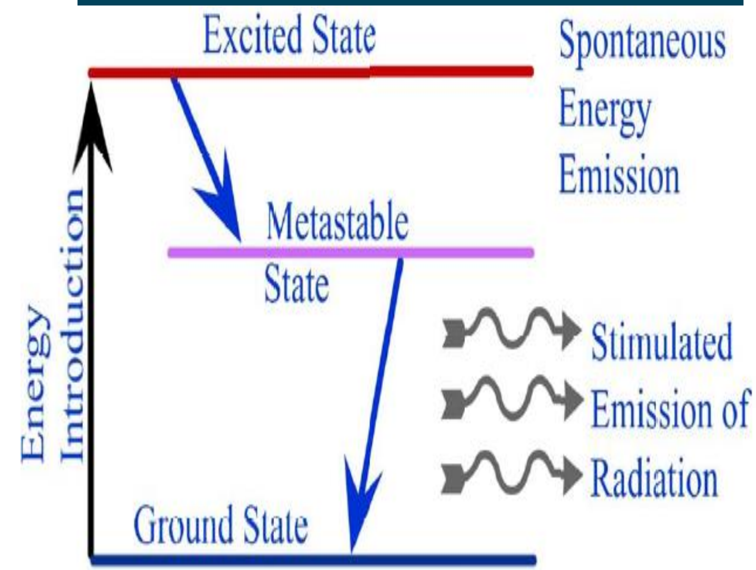


LASER BEAM WELDING

Photon Emission Model







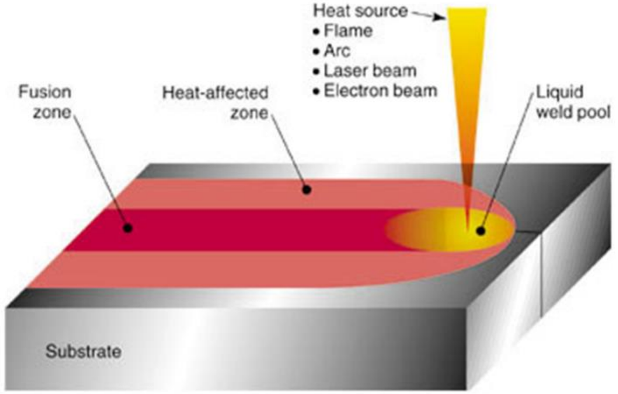
- **Add energy** to **make electrons "jump" to higher energy orbit**
- **Electron "relaxes"** and moves to equilibrium **at ground-state energy level**
- **Emits a photon** in this process
- **Two mirrors** reflect the photons back and forth and **"excite" more electrons**
- **One mirror** is partially reflective to **allow some light to pass through** creating a narrow laser beam

LASER BEAM WELDING

Operating principle

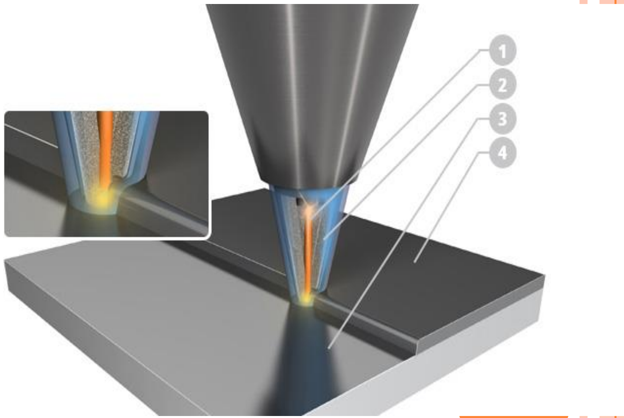
- Uses **light energy** from a laser to **join materials** by **melting** and **solidification**
- **Energy is concentrated** optically and in terms of time
- Light beam pulsed so that the released energy results in an impulse against the work surface, producing evaporation and melting

LASER BEAM WELDING



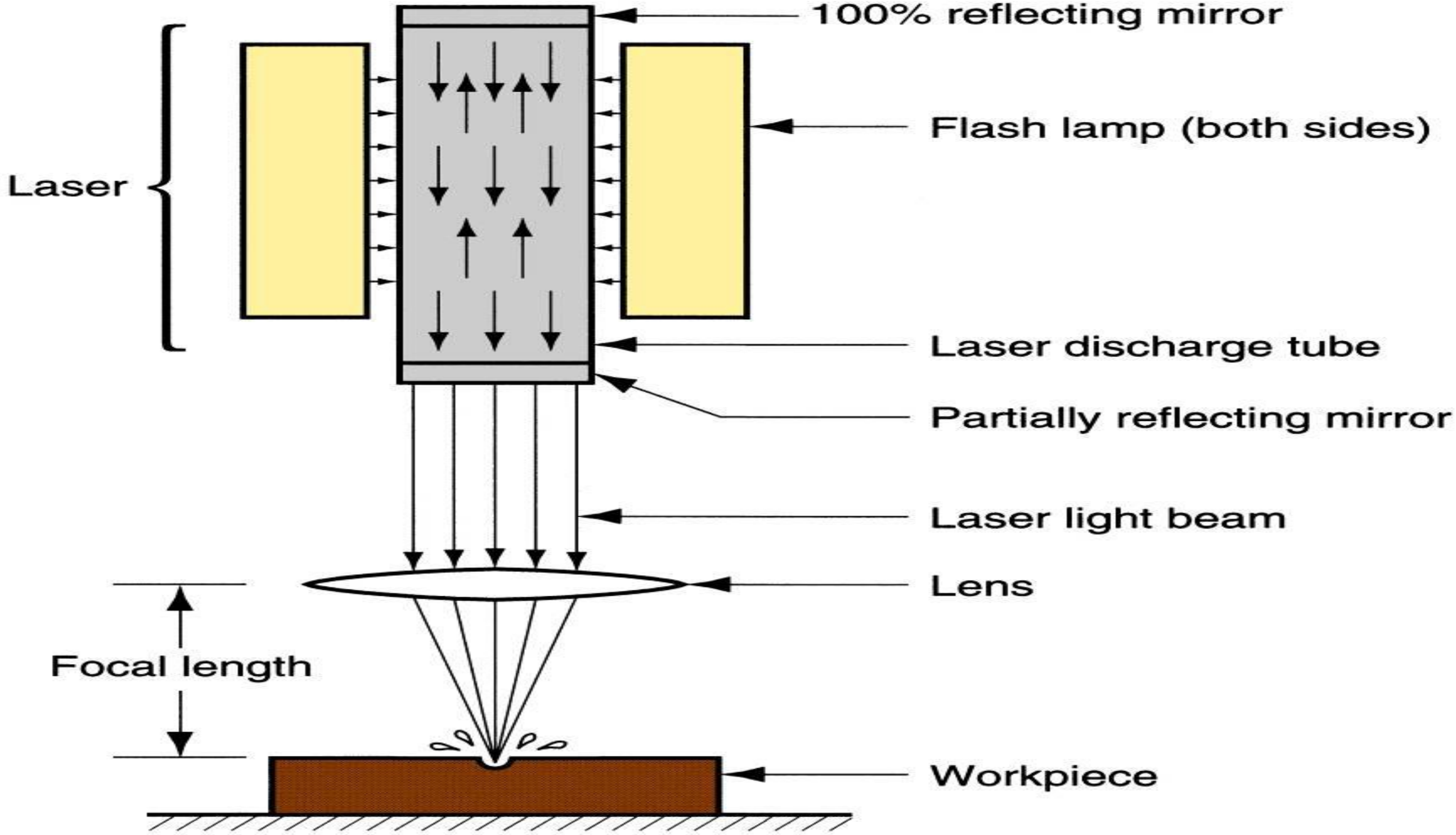
Operating principle in detail

- The **focal spot is targeted** on the work piece surface which will be welded.
- At the surface the **large concentration of light energy** is converted into **thermal energy**.
- The surface of the work piece starts melting and progresses through it by surface conductance.
- Finally the **molten area solidifies** and weld product obtained.



LASER BEAM WELDING

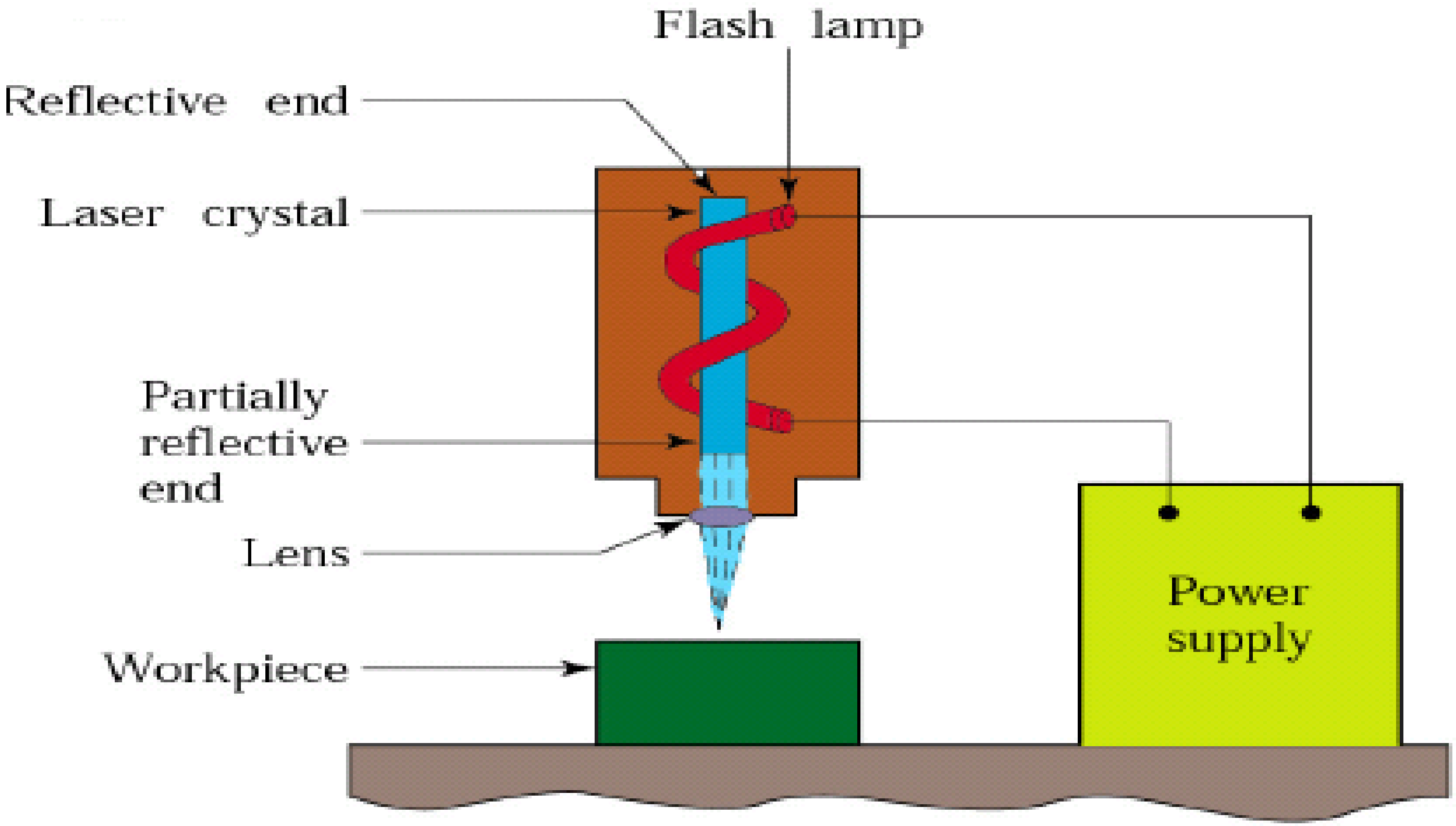
Equipment



Schematic illustration of the Laser Beam Process

LASER BEAM WELDING

Overall setup



LASER BEAM WELDING

Sub systems of the Equipment

Flash Lamp

- A **gas filled light emitting system** emits an intense flash or white light with a **power source of 250W -1000W**. Life time of lamp mainly depends upon the **energy input** and the **current pulse shape**

Reflecting mirrors

- **Two mirrors reflect** the **photons back and forth** and "**excite**" more **electrons**
- **One mirror is partially reflective** to allow some light to pass through: creates narrow laser beam

Optical lenses

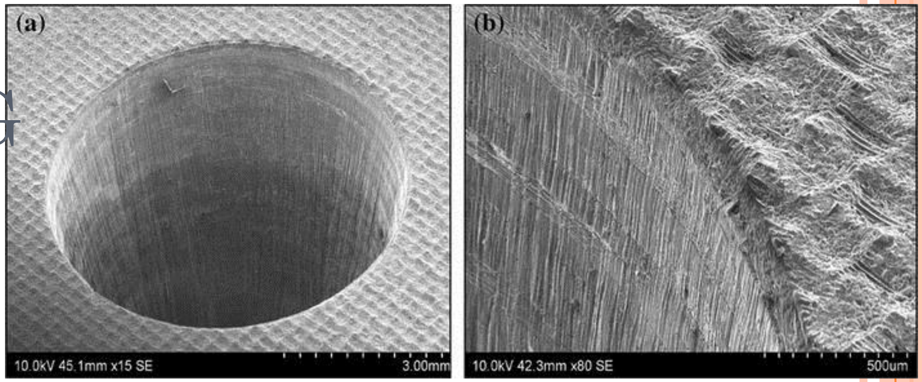
- Used **to focus laser beam** in to small intense spot on the work piece

LASER BEAM WELDING

Process Parameters

- Processing material
- Power supply
- pulse current (A)
- pulse duration (μs)
- pulse off time (μs)
- Focusing length
- Light density
- Safety characteristics

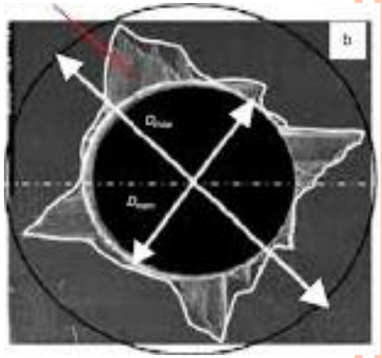
LASER BEAM WELDING



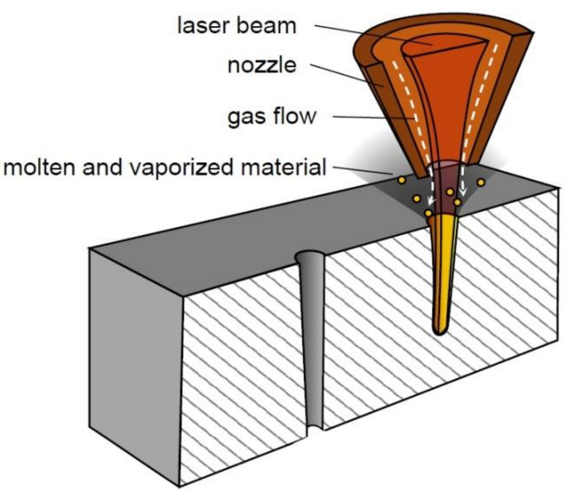
Process capabilities

Laser beam drilling

- **In drilling, energy transferred** (e.g., via a Nd:YAG laser) into the work piece melts the material at the **point of contact**, which subsequently changes into a **plasma and leaves the region**.

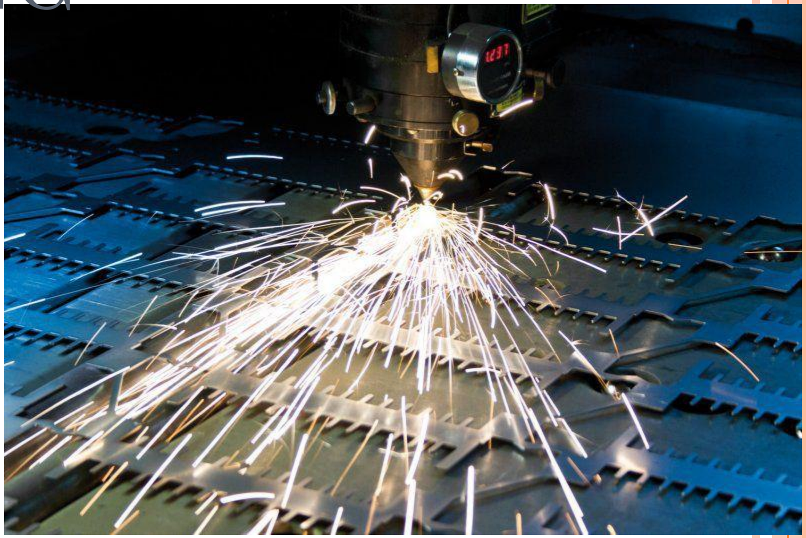


- A **gas jet** (typically, oxygen) can further facilitate this phase transformation and departure of material removed.



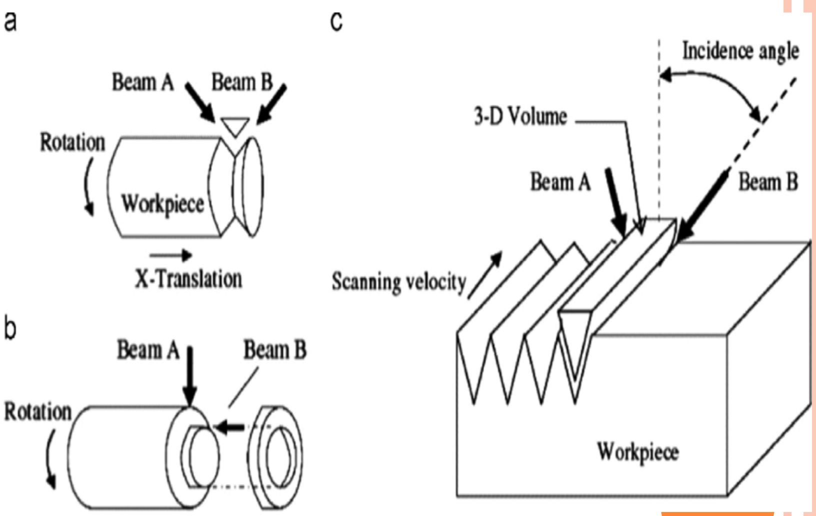
- Laser drilling should be targeted for **hard materials and hole geometries** that are difficult to achieve with other methods.

LASER BEAM WELDING



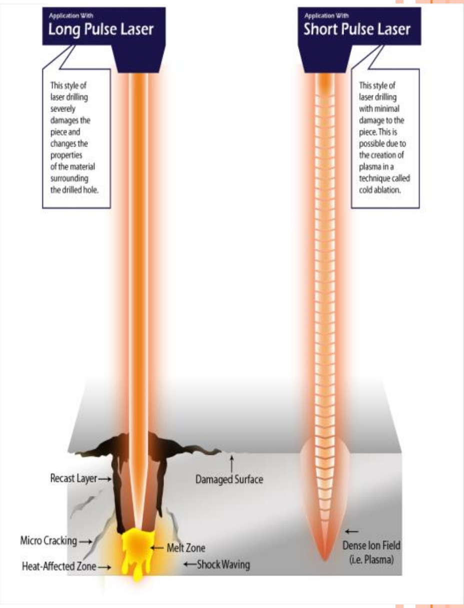
Laser beam milling

- A **laser spot reflected** onto the surface of a workpiece travels along a prescribed trajectory and cuts into the material.
- Continuous-wave mode (CO_2) gas lasers are very suitable for laser cutting providing high-average power, yielding high material-removal rates, and **smooth cutting surfaces.**



Applications

- The metals about 0.5 to 1.5mm thick can be welded
- It is used to weld non-metallic materials and alloys.
- It is used to weld dissimilar metals
- Laser beam machining is being used extensively in the electronic, aerospace and automotive industries.



LASER BEAM WELDING

Advantages

- Single pass weld penetration up to 3/4" in steel
- High Travel speed
- Materials need not be conductive
- No filler metal required
- Low heat input produces low distortion
- Does not require a vacuum
- Sticky materials are also be weld by this process.
- High accuracy.
- No cutting lubricants required
- No tool wear
- Narrow heat effected zone

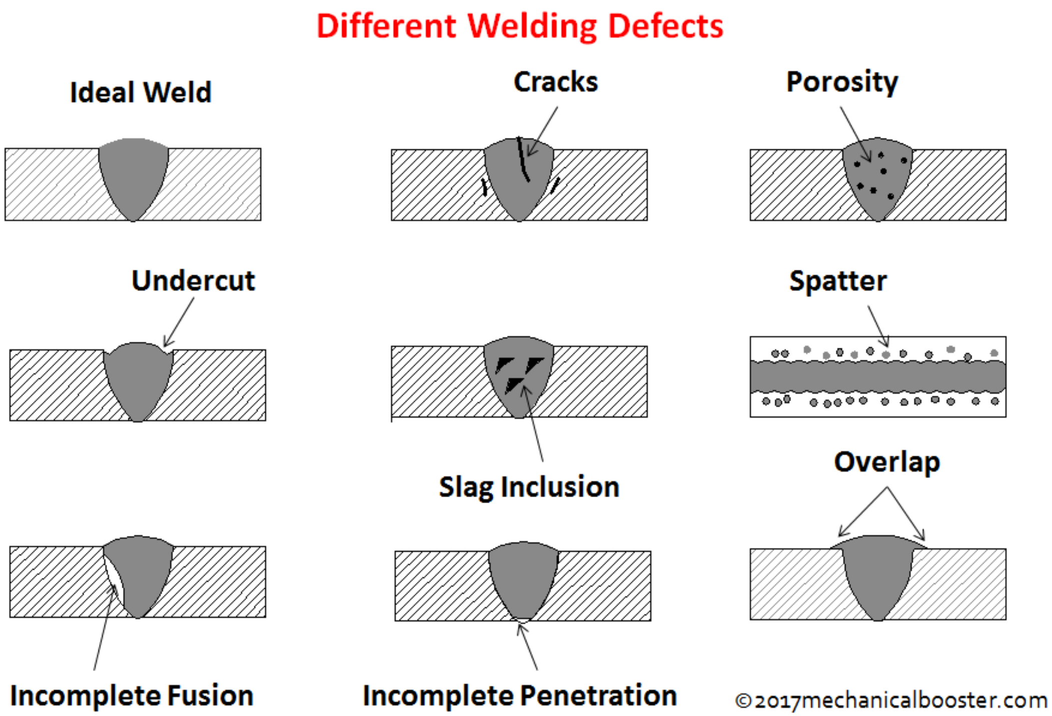
LASER BEAM WELDING

Limitations

- Un-Economic on high volumes compared to stamping
- High capital cost
- High maintenance cost
- Assist or cover gas required
- Part fit-up and joint tracking are critical
- Not portable
- Metals such as copper and aluminum have high reflectivity and are difficult to laser weld
- High cooling rates may lead to materials problems

TYPES OF DEFECTS

- Slag Inclusion
- Undercut
- Porosity
- Incomplete fusion
- Overlap
- Underfill
- Spatter
- Excessive Convexity
- Excessive Weld Reinforcement
- Incomplete Penetration
- Excessive Penetration



External Welding Defects

Weld Crack:

- Welding cracks can be present at the surface, inside of the weld material or at the heat affected zones.

Undercut:

- When the base of metal melts away from the weld zone, then a groove is formed in the shape of a notch

Spatter:

- Metal drops are expelled from the weld and remain stuck to the surface

Porosity:

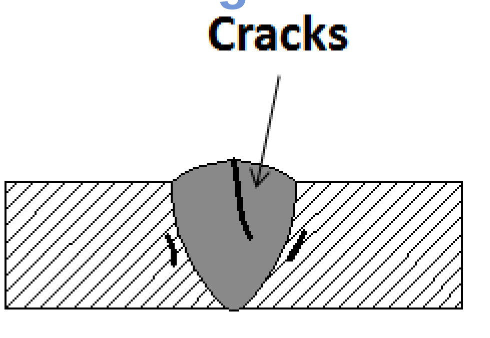
- The gas or small bubbles gets trapped in weld zones

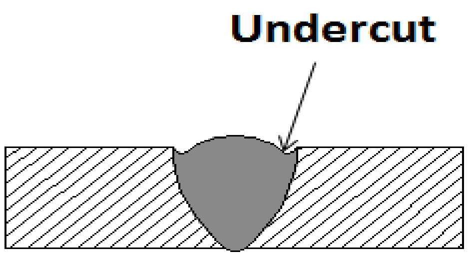
Overlap:

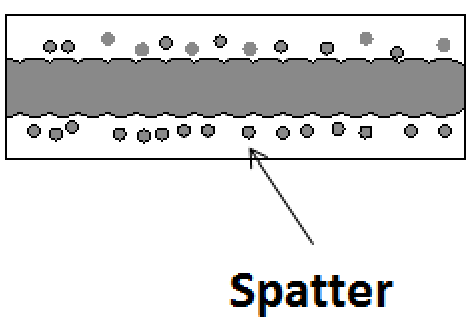
- Weld face extends beyond the weld toe

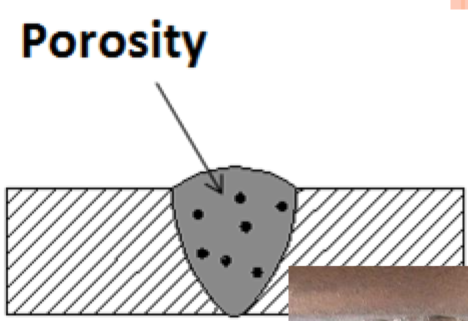
Crater:

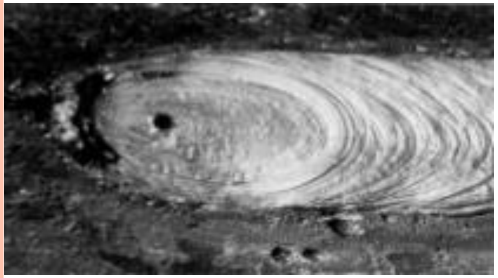
- Shrinkage cavity at end of weld run, where arc is terminated

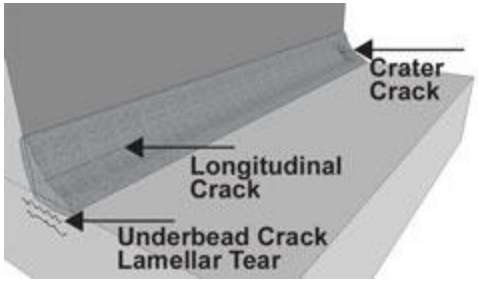




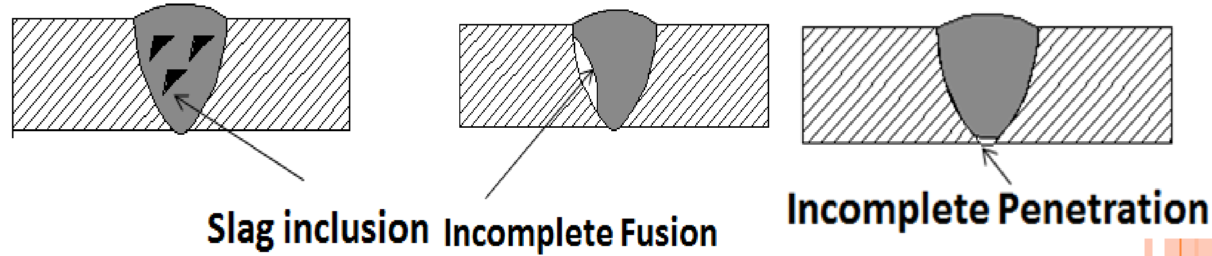








Internal Welding Defects



Slag Inclusion:

- Slag is formed on the surface of the weld or between the welding turns. Any slag in the weld, affects the toughness and metal weldability.

Incomplete Fusion:

- Incomplete fusion occurs when the welder does not accurately weld the material and the metal pre solidifies leading to a gap

Necklace Cracking:

- Weld does not penetrate properly. Therefore, the molten metal does not flow into the cavity

Incomplete Penetration:

- Occur only in the butt welds where the groove of the metal is not filled completely