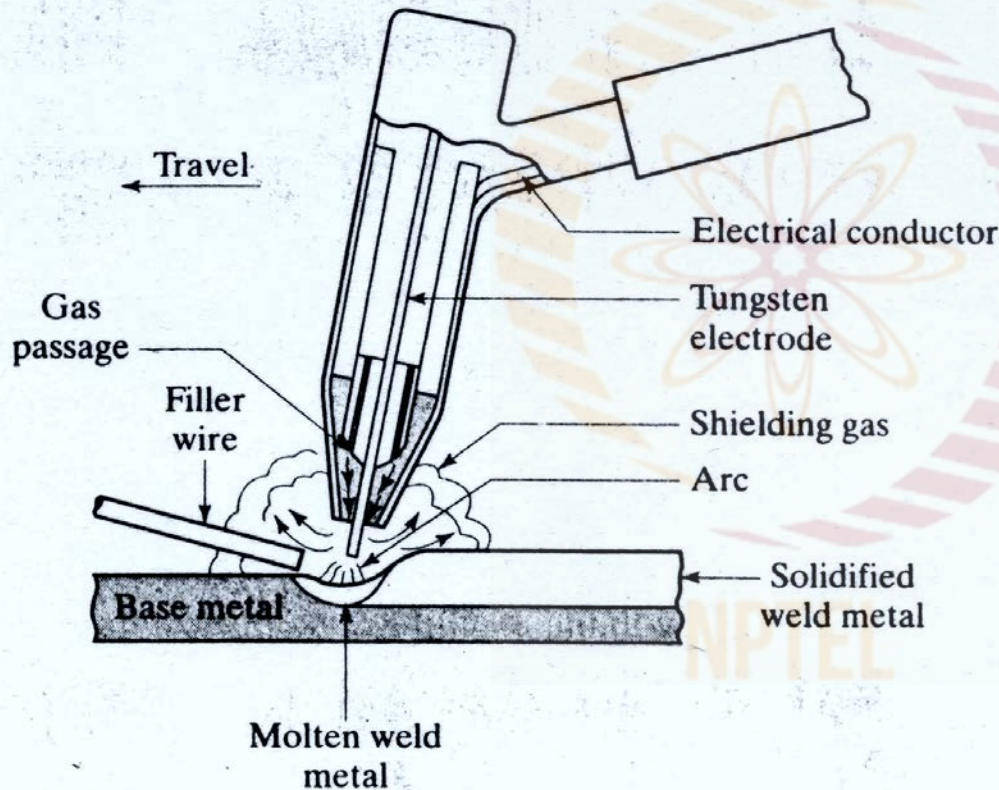


Gas Tungsten Arc Welding (GTAW)

Uses a nonconsumable tungsten electrode and an inert gas for arc shielding

- Melting point of tungsten = 3410°C (6170°F)
- Also called *TIG welding* (Tungsten Inert Gas welding)
 - In Europe, called "WIG welding"
- Used with or without a filler metal
 - When used, filler metal is added to weld pool from separate rod or wire
- Applications: aluminum and stainless steel most common

Tungsten-Inert Gas Welding (TIG)



- Shielding gas usually Ar, He or Ar+He
- AC or DC mode of operation
 - AC preferred for Al and Mg because cleaning action of AC removes oxide and improves weld quality
- GTAW produces very clean welds since no flux is employed
- Particularly attractive for reactive metals (Al, Mg and Ti), and high temperature refractory metals

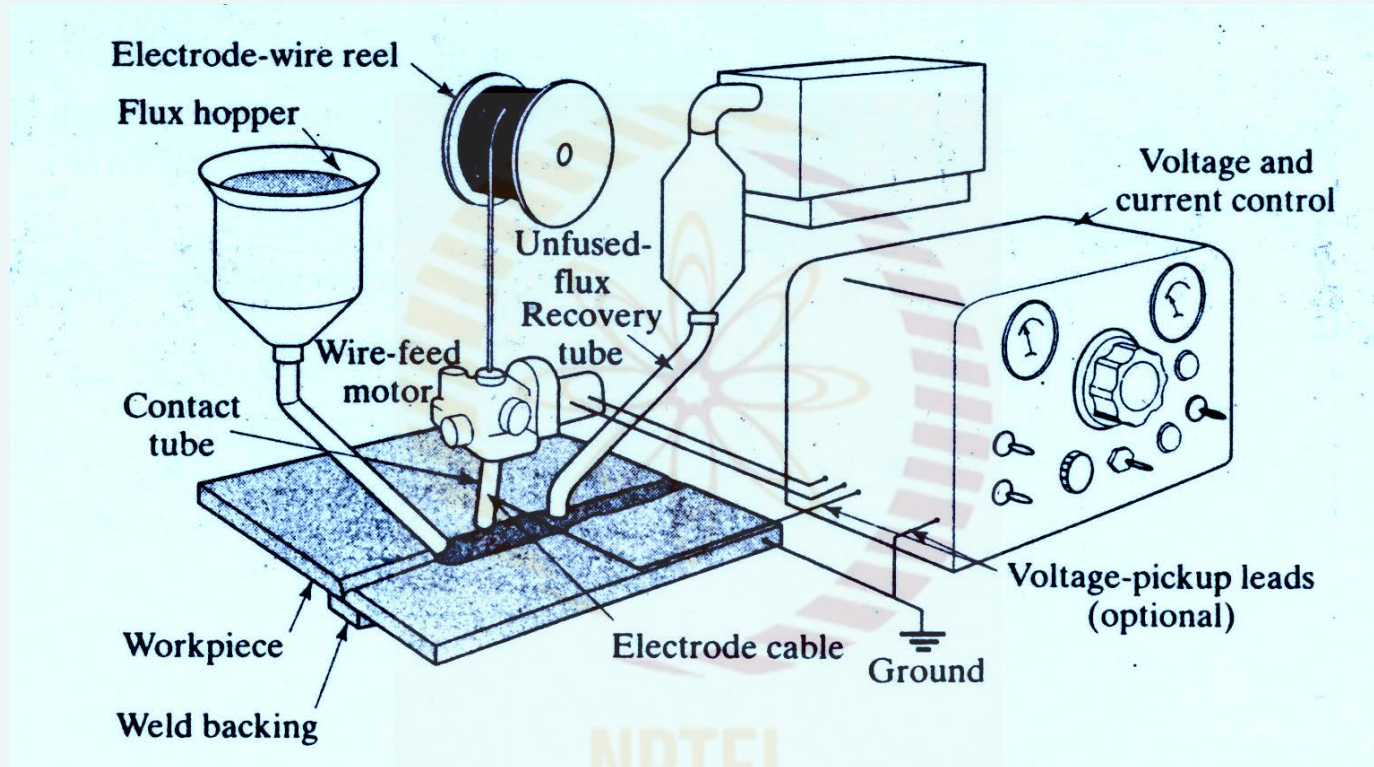
Advantages and Disadvantages of GTAW (TIG welding)

- **Advantages:**
 - High quality welds for suitable applications
 - No spatter because no filler metal through arc
 - Little or no postweld cleaning because no flux
- **Disadvantages:**
 - Generally slower and more costly than consumable electrode AW processes

NPTEL

Liquid State (Fusion) Welding

2. Submerged Arc Welding:



- Weld arc is shielded by a *granular flux*
- Flux: Lime, SiO_2 , MnO_2 , CaF_2
- Flux fed into weld zone by gravity

Liquid State (Fusion) Welding

Submerged Arc Welding

- Thick layer of flux covers molten metal, Prevents oxidation, sparks
 - Reduces weld metal spatter.
 - Increases deposition efficiency
 - Acts as thermal insulator; promotes deep penetration

Electrode wire: 1.5 – 10 mm; Current: 300 – 2000 A

- Limited to welds in a flat or horizontal position because flux is fed by gravity
- Can weld a wide variety of C, alloy and stainless steel sheet or plate often at speeds as high as 5 m/min
- Quality of weld is very high, with good toughness, ductility and uniformity of properties.

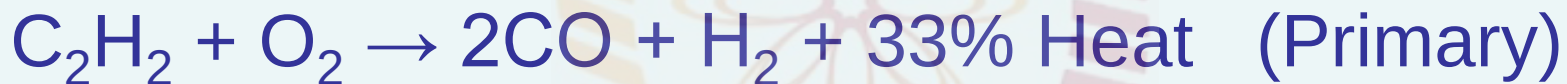
Typical applications

Thick plate welding for ship building and pressure vessels

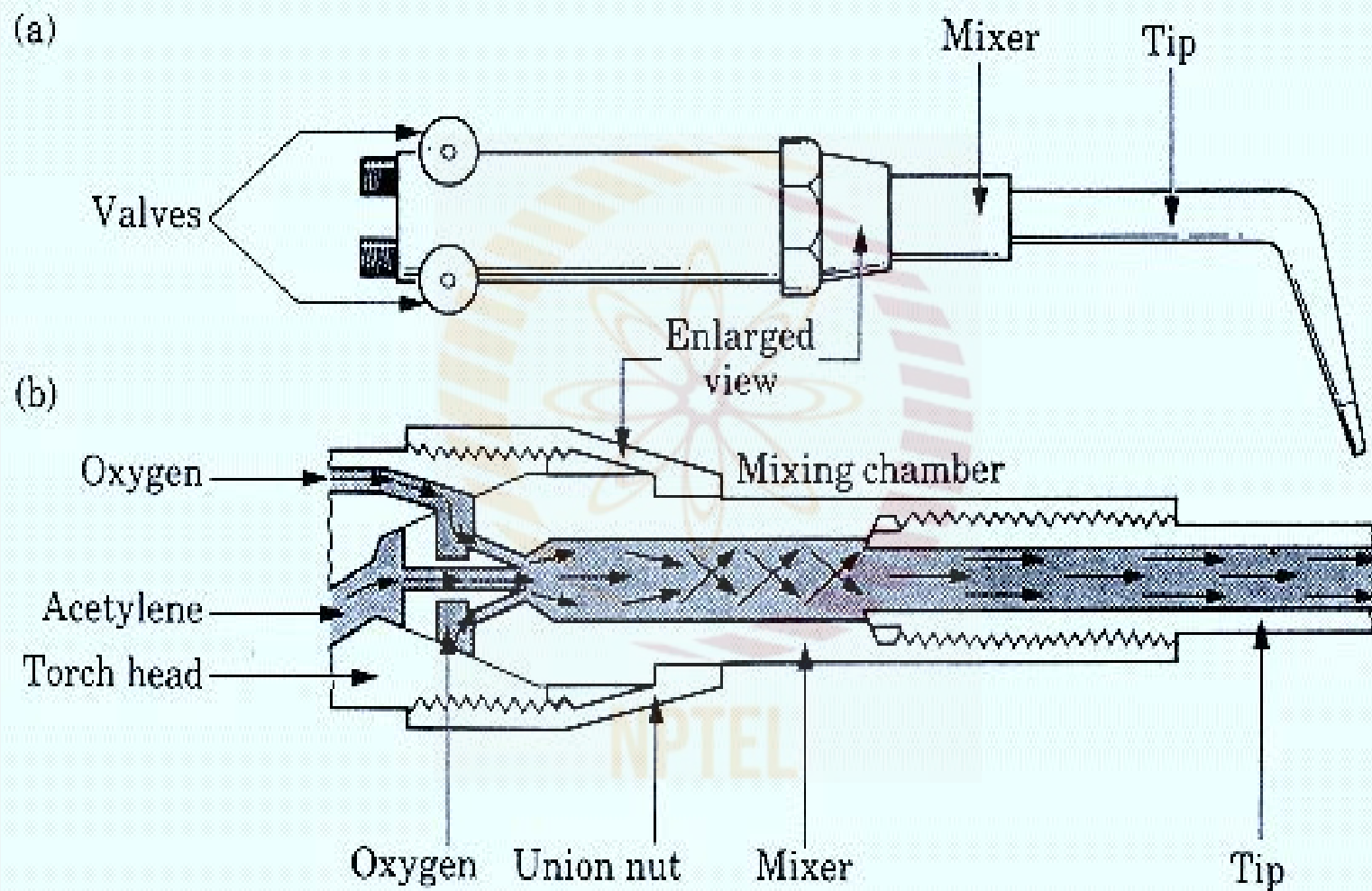
Liquid State (Fusion) Welding

GAS WELDING

- Acetylene most common fuel
- Developed in the early 1900s
- Reactions



- Temperatures up to 3300° C achieved
- Used for structural sheet metal fabrication, automotive bodies, repair work



Liquid State (Fusion) Welding

GAS WELDING

Types of Flame

Depends on acetylene-oxygen ratio

- **Neutral flame**
 - Used for most operations
- **Oxidizing flame**
 - Harmful for steels. Excess O_2 reacts with C
 - Used for Cu and Cu-based alloy because it forms a protective oxide film
- **Reducing/Carburizing flame**
 - Lower temperatures
 - Soldering, Brazing, Flame hardening

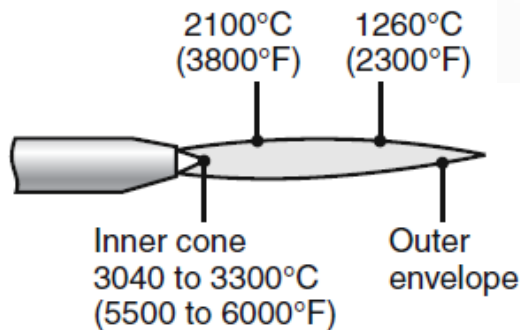
Types of Flame

There are three different flame types depending on the relative proportion of oxygen and acetylene in the flame.

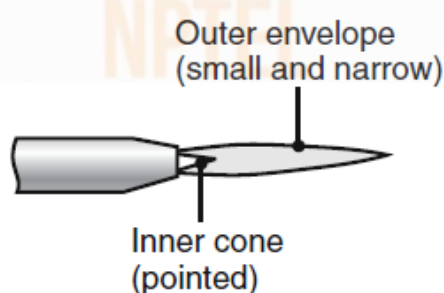
At a ratio of **1:1** (i.e. there is no excess oxygen) the flame is considered to be **neutral**.

With a greater oxygen supply, the flame is known as **oxidizing** flame. It can be harmful (especially for steels) because it oxidizes the metal.

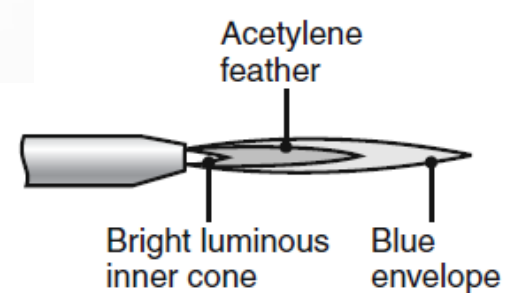
If the oxygen is insufficient for combustion, the flame is known as **reducing** or **curburizing** flame (i.e. excess acetylene).



(a) Neutral flame



(b) Oxidizing flame



(c) Carburizing (reducing) flame

- **Filler Metals**
 - Bare
 - Flux coated
- Metals at high temperatures tend to react chemically with elements in the air - oxygen and nitrogen.
- Oxides and nitrides destroy the strength and toughness of the weld joint.

- **Flux retards oxidation by**
 - **Generating a gaseous shield around the weld zone**
 - **Dissolves and removes oxides in the form of “slag”. Slag protects metal against oxidation as it cools**
- **Advantages**
 - **Low cost**
 - **Portable**
 - **Versatile**
 - **Economical for low quantities**

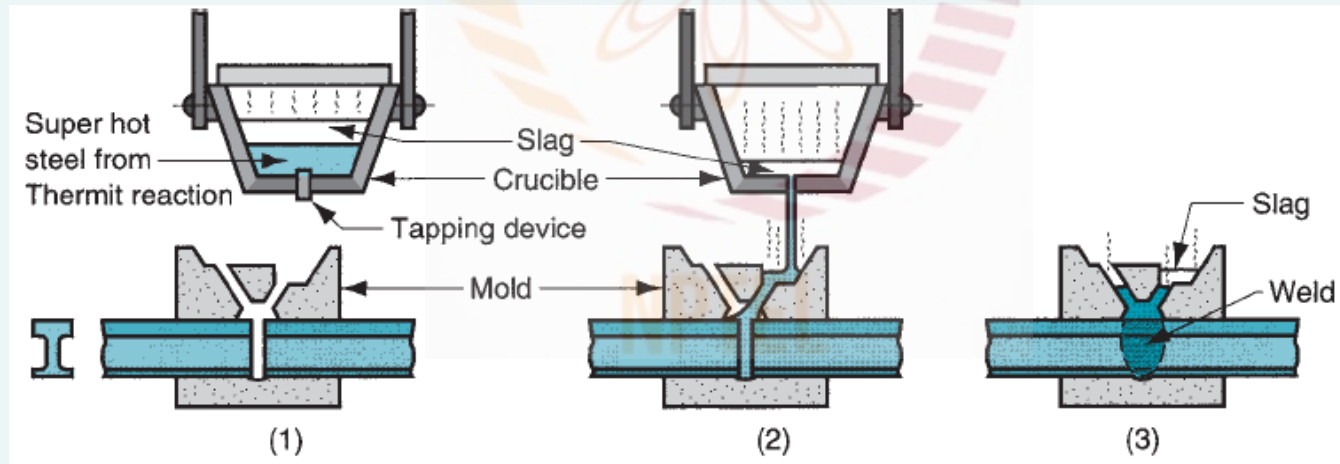
- **An arc is an electric current flowing between two electrodes through an ionized column of gas.**
- **Arc is generated by electrons liberated from cathode and moving towards the anode**
- **About 70% of the heat is liberated at the anode by the striking electrons**
- **Anode temperature can reach 5000 – 30000° C**

Thermit Welding

Thermit is the trademark name of Thermite, a mixture of aluminium powder and iron oxide that produces an exothermic reaction when ignited.

Thermit welding is a fusion welding process in which the heat for coalescence is produced by superheated molten metal from the chemical reaction of Thermit.

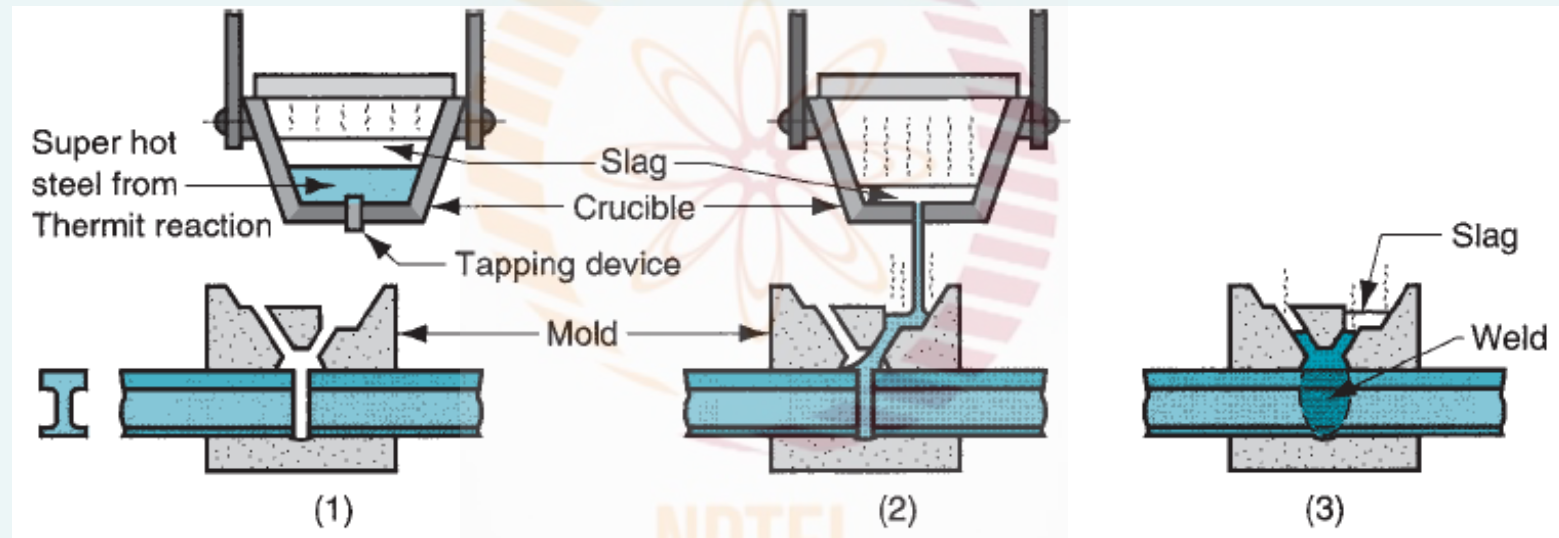
Finely mixed powders of aluminium and iron oxide (in a 1:3 mixture), when ignited at a temperature of 1300°C , produce the following chemical reaction:



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

Thermit Welding (Contn.)

- Aluminium oxide is a by-product of the reaction which floats on top of the molten iron as slag and protects it from oxidation. This process is used to join railroad rails



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

Solid-Liquid State Welding

BRAZING AND SOLDERING

- Join materials that cannot withstand high temperatures
- Join parts that are delicate and intricate
- Join two or more materials with very different characteristics, properties, thicknesses, and cross-sections

Solid-Liquid State Welding

BRAZING AND SOLDERING

- Filler metal is placed at or between the surfaces to be joined
- Temperature is raised to melt the filler metal but not the workpiece
- Molten metal fills the closely fitting space by capillary action
- Upon cooling and solidification of the filler metal, a strong joint is obtained.
- Temperature of operation differentiates brazing from soldering

Solid-Liquid State Welding

BRAZING AND SOLDERING

Process Capabilities

Brazing

- Joining process in which a filler metal is melted and distributed by capillary action between faying surfaces of metal parts being joined
- Filler metal T_m greater than 450°C (840°F) but less than T_m of base metal(s) to be joined
- Dissimilar metals can be assembled with good joint strength
 - Typical products: carbide drill bits and carbide inserts on steel shank
 - Intricate lightweight shapes can be joined with little distortion

Solid-Liquid State Welding

BRAZING AND SOLDERING

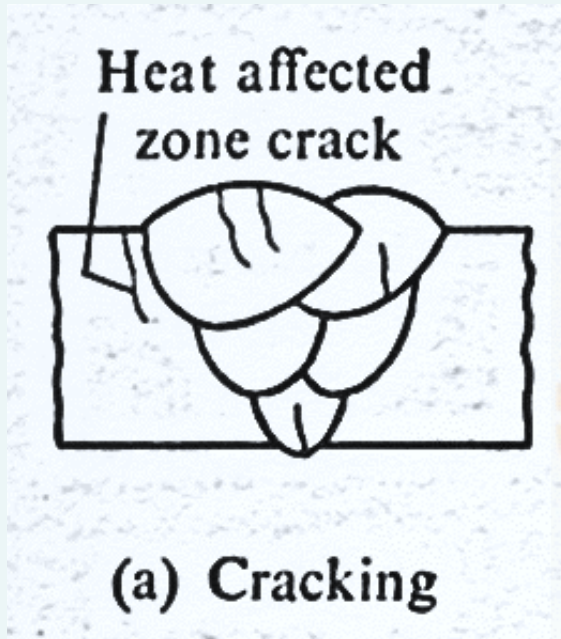
Soldering

- Joining process in which a filler metal with T_m less than or equal to 450°C (840°F) is melted and distributed by capillary action between faying surfaces of metal parts being joined
- No melting of base metals, but filler metal wets and combines with base metal to form metallurgical bond
- Used extensively in the electronics industry
- Because solders do not generally have enough strength, they are not used for load bearing (structural) applications
- Can join various metals and thicknesses
 - Cu, Ag, Au are easy to solder
 - Al, SS are difficult to solder because of their, strong, thin oxide film.

Advantages of Brazing Compared to Welding

- Any metals can be joined, including dissimilar metals
- Can be performed quickly and consistently, permitting high production rates
- Multiple joints can be brazed simultaneously
- In general, less heat and power required than FW
- Problems with HAZ in base metal near joint are reduced
- Joint areas that are inaccessible by many welding processes can be brazed, since capillary action draws molten filler metal into joint

Welding Defects



Cracking

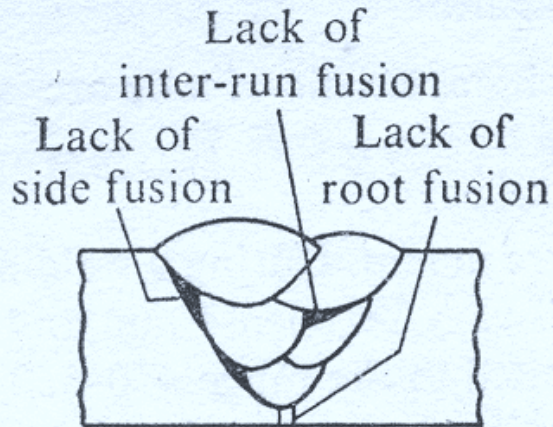
Causes: Temperature gradients that cause thermal stresses in the weld zone.

Prevention:

- Change the weld design to minimize stresses from shrinkage during cooling
- Change welding process parameters, procedure and sequences.
- Preheat components being welded
- Avoid rapid cooling of the components after welding

Welding Defects

Incomplete Fusion or Penetration



(b) Lack of fusion

Produces poor weld beads due to insufficient heat input.

Prevention:

- Raise the temperature of the base metal
- Clean the weld area prior to welding
- Adequate shielding gas
- Change the design of joints and type of electrode

Welding Defects

Porosity



(c) Porosity

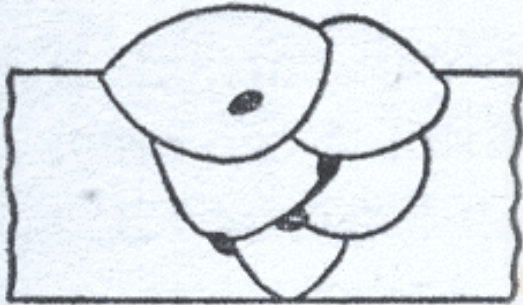
Caused by trapped gases during solidification of the weld area, chemical reactions during welding or contaminations.

Prevention:

- Proper selection of electrodes and filler material
- Preheating the weld area
- Proper cleaning and preventing contaminants from entering the weld zone.

Welding Defects

Slag Inclusion



(d) Slag inclusion

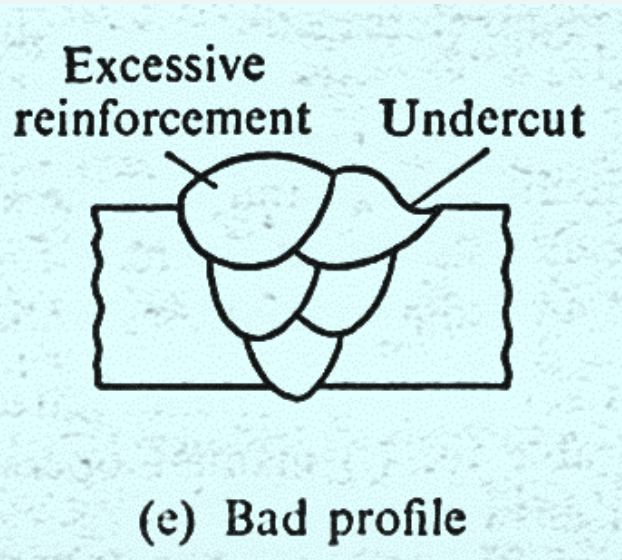
Inclusions are compounds such as oxides, fluxes and electrode coating materials that are trapped in the weld zones.

Prevention:

- Clean the weld bead surface before the next layer is deposited.
- Provide adequate shielding gas
- Change the type of electrode

Welding Defects

Bad Profile

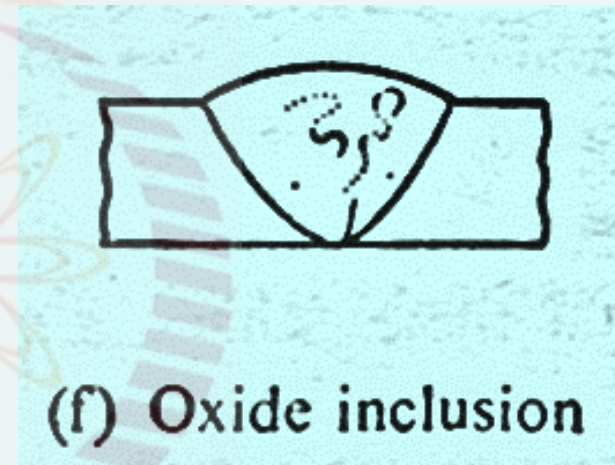


Due to under filling/overfilling and melting away of base metal.

Prevention:

- Improve welding technique.
- Select proper electrode/filler material.

Oxide Inclusion



Similar to slag inclusion.

The NPTEL logo is a circular emblem. It features a central stylized flower or sunburst design. Surrounding this center are concentric circles of radiating lines, some solid and some dashed, in shades of orange and yellow. The word "NPTEL" is written in a bold, sans-serif font at the bottom of the emblem.

Thank you for your Attention

Prof. Sounak K. Choudhury Mechanical
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