

3.1 CLASSIFICATION OF WELDING PROCESSES

Apart from technical factors, welding processes can also be classified on the fundamental approaches used for deposition of materials for developing a joint. This chapter presents the classification of welding processes as welding processes and allied process used for developing a joint

There is another way of classifying welding and allied processes which is commonly reported in literature. Various positive processes involving addition or deposition of metal are first broadly grouped as welding process and allied welding processes as under:

1. Welding processes

- Cast weld processes
- Fusion weld processes
- Resistance weld processes
- Solid state weld processes

2. Allied welding processes

- Metal depositing processes
- Soldering
- Brazing
- Adhesive bonding
- Weld surfacing
- Metal spraying

This approach of classifying the welding process is primarily based on the way metallic pieces are united together during welding such as:

- i. Availability and solidification of molten weld metal between components being joined are similar to that of casting: Cast weld process.
- ii. Fusion of faying surfaces for developing a weld: Fusion weld process
- iii. Heating of metal only to plasticize then applying pressure to forge them together: Resistance weld process
- iv. Use pressure to produce a weld joint in solid state only: Solid state weld process

3.2 CAST WELDING PROCESS

Those welding processes in which either molten weld metal is supplied from external source or melted and solidified at a very low rate during solidification like castings. Following are two common welding processes that are grouped under cast welding processes:

Thermite welding

Electro Slag Welding (ESW)

In case of thermite welding, weld metal is melted externally using exothermic heat generated by chemical reactions and the melt is supplied between the components to be joined while in electroslag welding weld metal is melted by electrical resistance heating and then it is allowed to cool very slowly for solidification similar to that of casting.

Comments on classification based on cast weld processes

This classification is true for thermite welding where like casting melt is supplied from external source but in case of electroslag welding, weld metal obtained by melting of both electrode and base metal and is not supplied from the external source. Therefore, this classification is not perfect.

3.3 FUSION WELD PROCESSES

Those welding processes in which faying surfaces of plates to be welded are brought to the molten state by applying heat and cooling rate experienced by weld metal in these processes are much higher than that of casting. The heat required for melting can be produced using electric arc, plasma, laser and electron beam and combustion of fuel gases. Probably this is un-disputed way of classifying few welding processes. Common fusion welding processes are given below:

1. Carbon arc welding, 2. Shielded metal arc welding, 3. Submerged arc welding, 4. Gas metal arc welding, 5. Gas tungsten arc welding, 6. Plasma arc welding, 7. Electro gas welding, 8. Laser beam welding, 9. Electron beam welding, 10. Oxy-fuel gas welding

3.4 RESISTANCE WELDING PROCESSES

Welding processes in which heat required for softening or partial melting of base metal is generated by electrical resistance heating followed by application of pressure for developing a weld joint. However, flash butt welding begins with sparks between components during welding instead of heat generation by resistance heating.

Resistance welding processes

1. Spot welding, 2. Projection welding, 3. Seam welding, 4. High frequency resistance welding, 5. High frequency induction welding, 6. Resistance butt welding, 7. Flash butt welding, 8. Stud welding

3.5 SOLID STATE WELDING PROCESS

Welding processes in which weld joint is developed mainly by application of pressure and heat through various mechanism such as mechanical interaction, large scale interfacial plastic deformation and diffusion etc.. Depending up on the amount of heat generated during welding these are further categorized as under:

Solid state welding process

1. Low heat input processes, 2. Ultrasonic welding, 3. Cold pressure welding, 4. Explosion welding, 5. High heat input processes, 6. Friction welding, 7. Forge welding, 8. Diffusion welding

There are many ways to classify the welding processes however, fusion welding and pressure welding criterion is the best and most accepted way to classify all the welding processes. The flow chart is showing classification of welding and allied processes for better understanding of nature of a specific process (Chart 3.1).

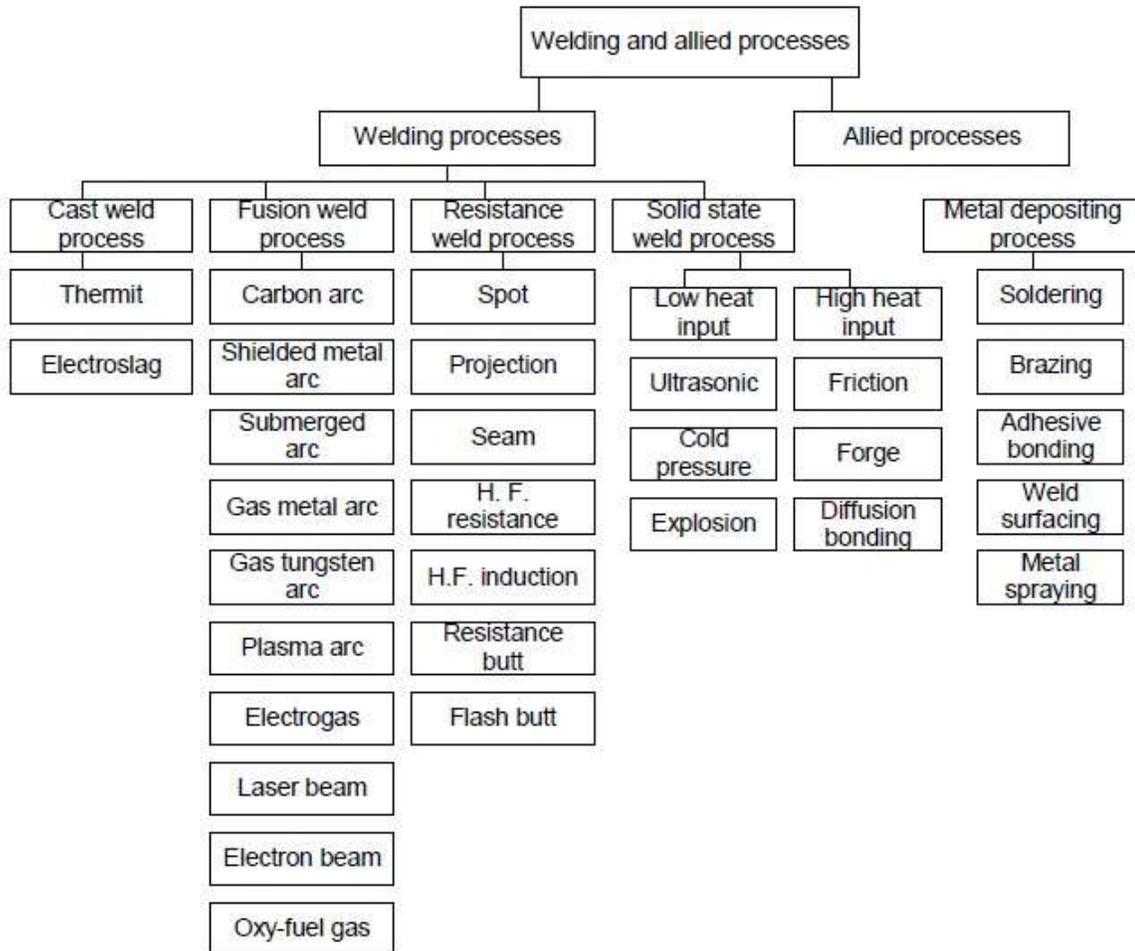


Chart 3.1 Classification of Welding and Allied Processes

GAS TUNGSTEN ARC WELDING

This chapter describes different types of tungsten electrodes used in TIG(Tungsten Inert Gas) welding process besides selection of polarity and methods of initiating welding arc for TIGW process.

4.1 ELECTRODE FOR TIG TORCH

The electrode for tungsten inert gas welding process can be pure (uncoated) or coated with Zr, La or Th. However, pure tungsten electrode offers shorter life than coated electrodes because of rapid wear and tear of the pure tungsten electrode owing to thermal damage caused by their low current carrying capacity. The damage to electrode primarily occurs due to the fact that tungsten carbide (formed during steel welding of reaction between W and C) has lower melting point than tungsten.

Particles generated from pure tungsten electrode due to thermal damage cause contamination of the weldment as tungsten particles inclusions therefore; pure tungsten electrodes are not used for critical welding applications.

Pure tungsten electrodes are frequently coated oxides of Th, Zr, La, and Ce. These oxides are expected to perform two important functions a) increasing arc stability and b) increasing the current carrying capacity of the electrodes.

Increase in arc stability of tungsten electrode in presence of the oxides of thorium, cerium, zirconium and lanthanum is primarily attributed to lower work function of these oxides than pure tungsten. Work function of pure tungsten electrode is 4.4eV while that of Zr, Th, La and Ce is 4.2, 3.4, 3.3 and 2.6 eV respectively. Lower the work function of the electrode material easier will be emission of electrons in the gap between electrode and work piece which in turn will improve the arc stability even at low arc voltage, and welding current.

Addition of the oxides of thorium, cerium, zirconium and lanthanum helps to increase the current carrying capacity of pure tungsten electrode up to 10 folds. Size of tungsten electrode is generally specified on the basis of its diameter as it largely determines the current carrying capacity of a given electrode material. The current carrying capacity of an electrode is also influenced by cooling arrangement in a welding torch (air/water cooled), type of power source (DCEP/DCEN, AC), electrode extension beyond collets, nozzle diameter and shielding gas. Typical electrodes for

TIG welding and suitable type of current are given below.

2% Cerium coated electrodes: Good for both AC and DC welding

1.5–2% Lanthanum coated electrode: Gives excellent low current starts for AC and DC welding

2% Thorium coated electrode: Commonly used for DC welding and is not preferred for AC.

4.2 TYPE OF WELDING TORCH

Air cooled welding torch offers lower current carrying capacity than water cooled due to the fact that water cooling reduces overheating of the electrode during welding by extracting the heat effectively from the electrode.

4.2.1 TYPE OF WELDING CURRENT AND POLARITY

Current carrying capacity of an electrode with DCEN polarity is found to be higher than DCEP and AC because DCEN generates lesser (30% of arc power) heat in tungsten electrode side compared to the DCEP and AC. Therefore, electrodes with

DCEN polarity offer longer life with same level of welding current conversely higher current capacity for the same life. Size of welding electrode for DCEP (for the same current and life) should be larger than that for DCEN owing to higher heat generation at anode than cathode for the same welding current. Current carrying capacity of electrode for AC welding is generally found between that in case of DCEP and

DCEN as continuous change in polarity during the AC welding allows the somewhat cooling of electrode when electrode is negative for one half of the cycle.

The selection of polarity for GTAW is primarily determined by the type of metal to be welded. The DCEN polarity is preferred for welding of steel, and nickel alloys and other metals where cleaning action is not very crucial for developing successful weld joints. The application of DCEP polarity is not common and is preferred for shallow penetration welding application like thin sheet welding. AC is commonly used for welding of aluminum and magnesium to get advantage of cleaning action and avoiding overheating of tungsten electrode.

4.2.2 ELECTRODE DIAMETER AND WELDING CURRENT

The diameter of tungsten electrode is usually found in a range of 0.3-8 mm and length varies from 75 to 610 mm. The selection of electrode material and diameter is governed by the section thickness of the material to be welded. Thick plates demand greater heat input so high welding current which in turn dictates the selection of large diameter electrodes. Excessive welding current causes erosion of electrodes and tungsten inclusion due to thermal damage. Erosion of electrode reduces the electrode life. Low welding current results in erratic wandering of welding arc over the tip of electrode, which reduces the arc stability. However, wandering of the arc at low current can be corrected by tapering the electrode tip (included angle 30-120°).

Taper angle affects the penetration and weld bead width. Low taper angle results in deeper the penetration and narrower the bead than high angle taper.

4.3 TIG ARC INITIATION

Direct work piece touch start method of initiating TIGW arc is not considered as a good approach because it generally leads to many undesirable effects a) contamination of tungsten electrode, b) partial melting of electrode tip (due to short circuiting) so reduction in life of the electrode and c) formation of tungsten inclusions which deteriorate the mechanical performance of weld joint. Therefore, alternative methods of TIG arc initiation have been developed over the years so as to

avoid undesirable effects of touch start method. Three methods are commonly used for initiating TIG welding arc a) use of carbon block as scrap material, b) use of high frequency high voltage unit and c) use of low current pilot arc.

4.3.1 CARBON BLOCK METHOD

This method is based on the principle similar to that of touch start method where tungsten electrode is brought in contact of a scrap material or carbon block placed in area which is close to the region where arc is to be applied during welding. However, this method doesn't necessarily prevent electrode contamination but reduces tendency for the same.

4.3.1 High frequency unit

This method is based on field emission principle by applying high frequency (100- 2000 KHz) and high voltage (3000-5000V) pulse to initiate the welding arc. The high voltage pulse ensures the availability of electrons in arc gap by field emission and ionization of gases between the electrode and work piece required to initiate the arc.

This method is mainly used in automatic TIG welding process. Absence of contact between electrode and work piece reduces the electrode contamination hence increases life of the electrode.

4.3.1 Pilot arc method

Pilot arc method is based on the principle of using low current for initiating the arc 50 to reduce adverse effects of high heat generation in form of electrode contamination and electrode melting during the arc initiation (Fig. 15.1). For this purpose, an additional power source can be used to strike the arc between the tungsten electrode and auxiliary anode (fitted in nozzle) using low current called pilot arc. This pilot arc is then brought close to base metal to be welded so as to ignite the main arc between electrode and work piece. Once the main arc is established auxiliary powersource is taken off.

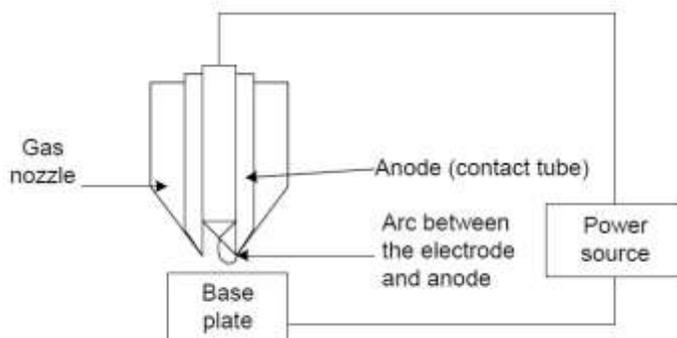


Fig. 4.1 Schematic showing the mechanism of pilot arc initiation method

4.4 MAINTENANCE OF TIG WELDING ARC

Arc maintenance in TIG welding with DC power supply does not create any problem.

However, in case of AC TIG welding, to have smooth and stable welding arc, methods like use of high OCV, imposing the high frequency and high voltage pulse at the moment when current is zero can be used so that arc is not extinguished.

15.5 Pulse TIG Welding

Pulse TIG is a variant of tungsten inert gas welding. In this process, welding current is varied between a high and a low level at regular time intervals. This variation in welding current between high and low level is called pulsation of welding current

(Fig. 4.2). High level current is termed as peak current and is primarily used for melting of faying surfaces of the base metal while low current is generally called background current and it performs two functions 1) maintenance of the welding arc while generating very low heat and 2) allows time for solidification of the weld pool by dissipating the heat to base metal. This feature of current pulsation associated with this process effectively reduces net heat input to the base metal during welding which in turn facilitates a) easy welding especially of thin sheets and b) refinement of grain structure of the weld. Reduction in net heat input using arc pulsation decreases undesirable effects of comparatively high heat input of conventional TIG welding such as melt through, wrapping/buckling and fit-up.

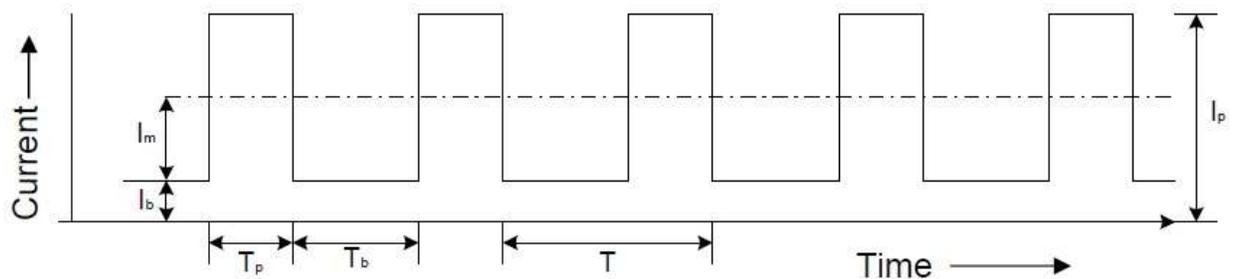


Fig. 4.2 Schematic showing parameters related with the pulse current and time.

Where I_p , I_b & I_m are peak current, base current and mean current respectively while T_p , T_b & T show pulse current duration, base current duration and total cycle time for one pulse i.e. sum of pulse and base current period (in ms).

4.5.1 PROCESS PARAMETERS OF PULSE TIG WELDING

Important variables in this variant of TIG welding are peak current, background current, peak current duration (pulse duration) and duration of background current.

Peak and background current can be controlled independently depending upon the characteristics of the base metal to be welded such as thickness, materials etc.