Welding Processes Classification Based On The Technological Criteria

Welding is a process of joining metallic components with or without application of heat, with or without pressure and with or without filler metal. A range of welding processes have been developed so far using single or a combination above factors namely heat, pressure and filler. Welding processes can be classified on the basis of following techological criteria:

- Welding with or without filler material
- Source of energy for welding
- Arc and non-arc welding
- Fusion and pressure welding

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2.1 Classification of welding processes on the basis of technical factors

2.1.1 Welding with or without filler material

A weld joint can be developed just by melting of edges (faying surfaces) of plates or sheets to be welded especially when thickness is lesser than 5 mm thickness. A weld joint developed by melting the fating surfaces and subsequently solidification only (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^{o} - 100^{o}C). Following are typical welding processes in which filler metal is generally not used to produce a weld joint.

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

However, for welding of thick plates/sheets using any of the following processes filler metal can be used as per needs according to thickness of plates. Application of autogenous fusion weld in case of thick plates may result in concave weld or under fill like discontinuity in weld joint. The composition of the filler metal can be similar to that of base metal or different one accordingly weld joints are categorized as homogeneous or heterogeneous weld, respecting.

In case of autogenous and homogeneous welds, solidification occurs directly by growth mechanism without nucleation stage. This type of solidification is called epitaxial solidification. The autogenous and homogeneous welds are considered to be of lesser prone to the development of weld discontinuities than heterogeneous weld because of a uniformity in composition and (b) if solidification largely occurs at a constant temperature. Metal systems having wider solidification temperature range show issues related with solidification cracking and partial melting tendency. The solidification in heterogeneous welds takes place in conventional manner in two stages i.e. nucleation and growth. Following are few fusion welding processes where filler may or may not be used for developing weld joints:

- Plasma arc welding
- Gas tungsten arc welding
- Gas welding

Some of the welding processes are inherently designed to produce a weld joint by applying heat for melting base metal and filler metal both. These processes are mostly used for welding of thick plates (usually > 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)

Comments on classification of welding processes based on with/without filler

The gas welding process was the only fusion welding process earlier using which joining could be achieved with or without filler material. The gas welding

performed without filler material was termed as autogenous welding. However, with the development of tungsten inert gas welding, electron beam, laser beam and many other welding processes, such classification created confusion as many processes were falling in both the categories.

2.1.2 **Source of energy for welding**

Almost all weld joints are produced by applying energy in one or other form to develop atomic/metallic bond between metals being joined and the same is achieved either by melting the faying surfaces using heat or applying pressure either at room temperature or high temperature (0.5^{o} to 0.9^{o} Tm). Based on the type of energy being used for creating metallic bonds between the components to be welded, welding processes can be grouped as under:

- Chemical energy: Gas welding, explosive welding, thermite welding
- Mechanical energy: Friction welding, ultrasonic welding
- Electrical energy: Arc welding, resistance welding
- Radiation energy: Laser beam welding, electron beam welding

Comments on classification of welding processes based on source of energy

Energy in various forms such as chemical, electrical, light, sound, mechanical energies etc. are used for developing weld joints. However, except chemical energy all other forms of energies are generated from electrical energy for welding. Hence, categorization of the welding processes based on the source of energy criterion also does not justify classification properly.

2.1.3 **Arc or Non-arc welding**

Metallic bond between the plates to be welded can be developed either by using heat for complete melting of the faying surfaces then allowing it to solidify or by apply pressure on the components to be joined for mechanical interlocking. All those welding processes in which heat for melting the faying surfaces is provided after establishing an arc either between the base plate and an electrode or

between electrode & nozzle are grouped under arc welding processes. Another set of welding processes in which metallic bond is produced using pressure or heat generated from sources other than arc namely chemical reactions or frictional effect etc., are grouped as non-arc based welding processes. Welding processes corresponding to each group are given below.

- Arc based welding processes
  - Shielded Metal Arc Welding: Arc between base metal and covered electrode
  - Gas Tungsten Arc Welding: Arc between base metal and tungsten electrode
  - Plasma Arc Welding: Arc between base metal and tungsten electrode
  - Gas Metal Arc Welding: Arc between base metal and consumable electrode
  - Flux Cored Arc Welding: Arc between base metal and consumable electrode
  - Submerged Arc Welding: Arc between base metal and consumable electrode

- Non-arc based welding processes
  - Resistance welding processes: uses electric resistance heating
  - Gas welding: uses heat from exothermic chemical reactions
  - Thermit welding: uses heat from exothermic chemical reactions
  - Ultrasonic welding: uses both pressure and frictional heat
  - Diffusion welding: uses electric resistance/induction heating to facilitate diffusion
  - Explosive welding: involves pressure

Comments on classification of welding processes based on arc or non arc based process

Arc and non-arc welding processes classification leads to grouping of all the arc welding processes in one class and all other processes in non-arc welding processes. However, welding processes such as electro slag welding (ESW) and

flash butt welding were found difficult to classify in either of the two classes as ESW process starts with arcing and subsequently on melting of sufficient amount flux, the arc extinguishes and heat for melting of base metal is generated by electrical resistance heating by flow of current through molten flux/metal. In flash butt welding, tiny arcs i.e. sparks are established during initial stage of the welding followed by pressing of components against each other. Therefore, such classification is also found not perfect.

2.1.4 Pressure or Fusion welding

Welding processes in which heat is primarily applied for melting of the faying surfaces are called fusion welding processes while other processes in which pressure is primarily applied (with little or no application of heat for softening of metal up to plastic state) for developing metallic bonds are termed as solid state welding processes.

- Pressure welding
    - Resistance welding processes (spot, seam, projection, flash butt, arc stud welding)
    - Ultrasonic welding
    - Diffusion welding
    - Explosive welding
- Fusion welding process
    - Gas Welding
    - Shielded Metal Arc Welding
    - Gas Metal Arc Welding
    - Gas Tungsten Arc Welding
    - Submerged Arc Welding
    - Electro Slag/Electro Gas Welding

Comments on classification of welding processes based on Fusion and pressure welding

Fusion welding and pressure welding is most widely used classification as it covers all processes in both the categories irrespective of heat source and welding with or without filler material. In fusion welding, all those processes are included in which molten metal solidifies freely while in pressure welding, molten metal if any is retained in confined space (as in case of resistance spot welding or arc stud welding) and solidifies under pressure or semisolid metal cools under pressure. This type of classification poses no problems and therefore it is considered as the best criterion.

References and books for further reading

- Metals Handbook-Welding, Brazing and Soldering, American Society for Metals, 1993, 10th edition, Volume 6, USA.
- Richard Little, Welding and Welding Technology, McGraw Hill, 2001, 1st edition.
- H Cary, Welding Technology, Prentice Hall, 1988, 2nd edition.
- S V Nadkarni, Modern Arc Welding Technology, Ador Welding Limited, 2010, New Delhi.
- R S Parmar, Welding process and technology, Khanna Publisher, New Delhi
- Welding handbook, American Welding Society, 1987, 8th edition, volume 1 & 2, USA.
- http://www.substech.com/dokuwiki/doku.php?id=classification_of_welding_processes
- http://www.newagepublishers.com/samplechapter/001469.pdf
- http://www.typesofwelding.net
- http://books.google.co.in/books?id=PSc4AAAAIAAJ&pg=PA1&lpg=PA1&dq=classification+of+welding+processes&source=bl&ots=G9EbFzqzBa&sig=T1EqGIMpChzzqwSZJJeuD9PlaKQ&sa=X&ei=qlsyUO_XCMnZrQfn8oHoCQ&sqi=2&ved=0CCIQ6AEwBA#v=onepage&q=classification%20of%20welding%20processes&f=false

- http://www.kobelcowelding.com/20100119/handbook2009.pdf
- http://me.emu.edu.tr/me364/ME364_combining_fusion.pdf

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