Chapter 1

Introduction to Welding Technology

1.1 DEFINITION AND CLASSIFICATION

Welding is a process of permanent joining two materials (usually metals) through localised coalescence resulting from a suitable combination of temperature, pressure and metallurgical conditions. Depending upon the combination of temperature and pressure from a high temperature with no pressure to a high pressure with low temperature, a wide range of welding processes has been developed.

Classification of Welding Process

American Welding Society has classified the welding processes as shown in Fig. 1.1. Various welding processes differ in the manner in which temperature and pressure are combined and achieved.

Welding Processes can also be classified as follows (based on the source of energy):

1. Gas Welding
   — Oxyacetylene
   — Oxy hydrogen
2. Arc Welding
   — Carbon Arc
   — Metal Arc
   — Submerged Arc
   — Inert-gas-Welding
   TIG and MIG
   — Plasma Arc
   — Electro-slag
3. Resistance Welding
   — Spot
   — Seam
   — Projection

— Butt Welding
— Induction Welding

4. Solid State Welding
   — Friction Welding
   — Ultrasonic Welding
   — Explosive Welding
   — Forge and Diffusion Welding
5. Thermo-chemical Welding
   — Thermit Welding
   — Atomic H_2 Welding
   (also arc welding)
6. Radiant Energy Welding
   — Electron Beam Welding
   — Laser Beam Welding

In order to obtain coalescence between two metals there must be a combination of proximity and activity between the molecules of the pieces being joined, sufficient to cause the formation of common metallic crystals.

Proximity and activity can be increased by plastic deformation (solid-state-welding) or by melting the two surfaces so that fusion occurs (fusion welding). In solid-state-welding the surfaces to be joined are mechanically or chemically cleaned prior to welding while in fusion welding the contaminants are removed from the molten pool by the use of fluxes. In vacuum or in outer space the removal of contaminant layer is quite easy and welds are formed under light pressure.

1.2 CONDITIONS FOR OBTAINING SATISFACTORY WELDS

To obtain satisfactory welds it is desirable to have:

- a source of energy to create union by FUSION or PRESSURE
- a method for removing surface CONTAMINANTS
- a method for protecting metal from atmospheric CONTAMINATION
- control of weld METALLURGY

1.2.1 Source of Energy

Energy supplied is usually in the form of heat generated by a flame, an arc, the resistance to an electric current, radiant energy or by mechanical means (friction, ultrasonic vibrations or by explosion). In a limited number of processes, pressure is used to force weld region to plastic condition. In fusion welding the metal parts to be joined melt and fuse together in the weld region. The word fusion is synonymous with melting but in welding fusion implies union. The parts to be joined may melt but not fuse together and thus the fusion welding may not take place.

1.2.2 Surface Contaminants

Surface contaminants may be organic films, absorbed gases and chemical compounds of the base metal (usually oxides). Heat, when used as a source of energy, effectively removes organic films and adsorbed gases and only oxide film remains to be cleaned. Fluxes are used to clean the oxide film and other contaminants to form slag which floats and solidifies above the weld bead protecting the weld from further oxidation.

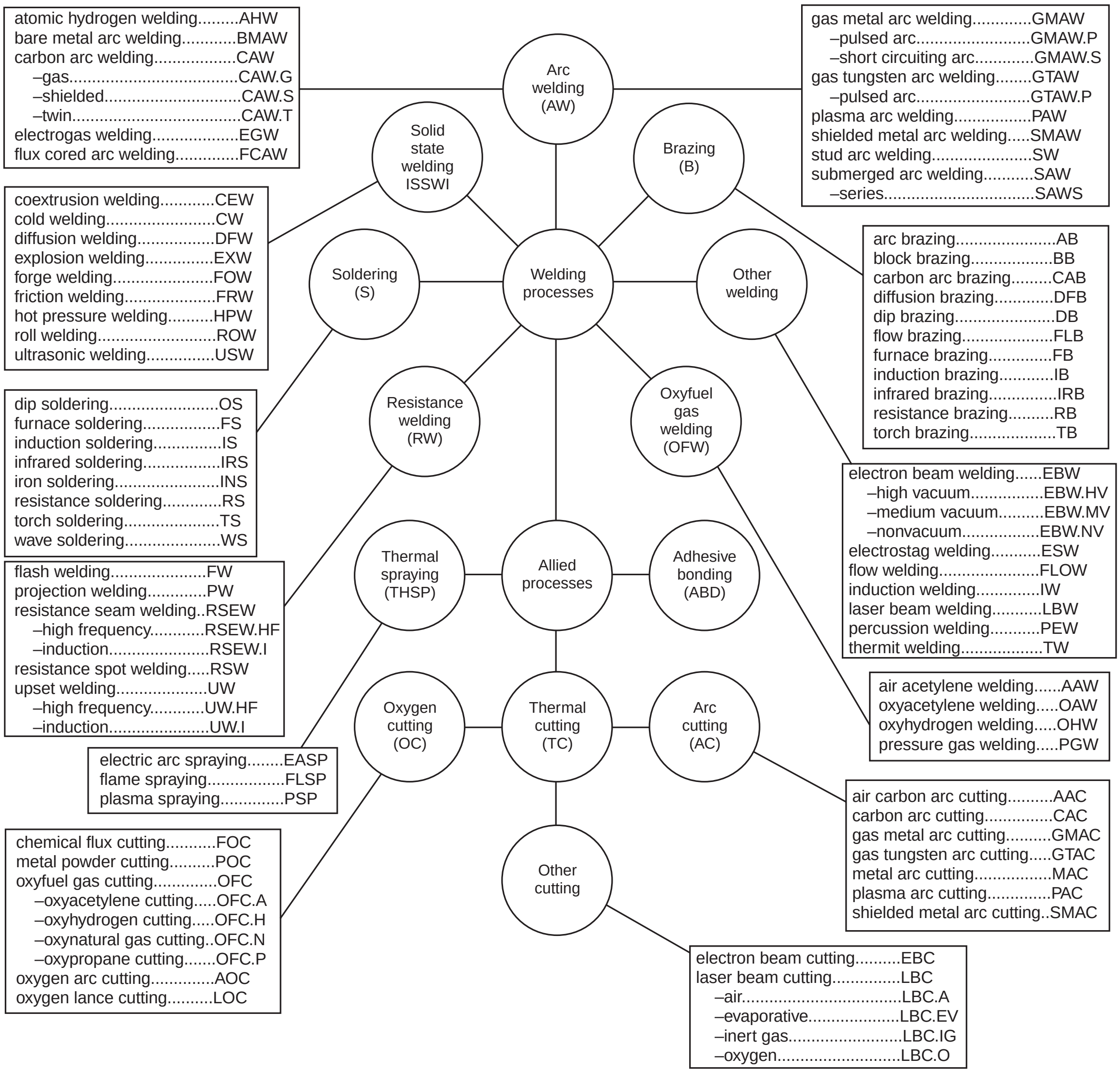

Fig. 1.1 Master Chart of Welding and Allied Processes

1.2.3 Protecting Metal From Atmospheric Contamination

To protect the molten weld pool and filler metal from atmospheric contaminants, specially the oxygen and nitrogen present in the air, some shielding gases are used. These gases could be argon, helium or carbon-dioxide supplied externally. Carbon dioxide could also be produced by the burning of the flux coating on the consumable electrode which supplies the molten filler metal to the weld pool.

1.2.4 Control of Weld Metallurgy

When the weld metal solidifies, the microstructures formed in the weld and the heat-affected-zone (HAZ) region determines the mechanical properties of the joint produced. Pre-heating and post welding heat-treatment can be used to control the cooling rates in the weld and HAZ regions and thus control the microstructure and properties of the welds produced. Deoxidants and alloying elements are added as in foundry to control the weld-metal properties.

The foregoing discussion clearly shows that the status of welding has now changed from skill to science. A scientific understanding of the material and service requirements of the joints is necessary to produce successful welds which will meet the challenge of hostile service requirements.

With this brief introduction to the welding process let us now consider its importance to the industry and its applications.

1.3 IMPORTANCE OF WELDING AND ITS APPLICATIONS

1.3.1 Importance of Welding

Welding is used as a fabrication process in every industry large or small. It is a principal means of fabricating and repairing metal products. The process is efficient, economical and dependable as a means of joining metals. This is the only process which has been tried in the space. The process finds its applications in air, underwater and in space.

1.3.2 Applications of Welding

- Welding finds its applications in automobile industry, and in the construction of buildings, bridges and ships, submarines, pressure vessels, offshore structures, storage tanks, oil, gas and water pipelines, girders, press frames, and water turbines.
- In making extensions to the hospital buildings, where construction noise is required to be minimum, the value of welding is significant.
- Rapid progress in exploring the space has been made possible by new methods of welding and the knowledge of welding metallurgy. The aircraft industry cannot meet the enormous demands for aeroplanes, fighter and guided planes, space crafts, rockets and missiles without welding.
- The process is used in critical applications like the fabrication of fission chambers of nuclear power plants.
- A large contribution, the welding has made to the society, is the manufacture of

household products like refrigerators, kitchen cabinets, dishwashers and other similar items.

It finds applications in the fabrication and repair of farm, mining and oil machinery, machine tools, jigs and fixtures, boilers, furnaces, railway coaches and wagons, anchor chains, earth moving machinery, ships, submarines, underwater construction and repair.

1.4 SELECTION OF A WELDING PROCESS

Welding is basically a joining process. Ideally a weld should achieve a complete continuity between the parts being joined such that the joint is indistinguishable from the metal in which the joint is made. Such an ideal situation is unachievable but welds giving satisfactory service can be made in several ways. The choice of a particular welding process will depend on the following factors.

1. Type of metal and its metallurgical characteristics
2. Types of joint, its location and welding position
3. End use of the joint
4. Cost of production
5. Structural (mass) size
6. Desired performance
7. Experience and abilities of manpower
8. Joint accessibility
9. Joint design
10. Accuracy of assembling required
11. Welding equipment available
12. Work sequence
13. Welder skill

Frequently several processes can be used for any particular job. The process should be such that it is most, suitable in terms of technical requirements and cost. These two factors may not be compatible, thus forcing a compromise. Table 2.1 of chapter 2 shows by "*x*" marks the welding process, materials and material thickness combinations that are usually compatible. The first column in the table shows a variety of engineering materials with four thickness ranges. The major process currently in use in industry are listed across the top of the table. The information given is a general guide and may not necessarily be valid for specific situations.

1.5 WELDING QUALITY AND PERFORMANCE

Welding is one of the principle activities in modern fabrication, ship building and offshore industry. The performance of these industries regarding product quality, delivery schedule and productivity depends upon structural design, production planning, welding technology adopted and distortion control measures implemented during fabrication. The quality of welding depends on the following parameters:

1. Skill of Welder
2. Welding parameters
3. Shielding medium and
4. Working environment
5. Work layout
6. Plate edge preparation
7. Fit-up and alignment
8. Protection from wild winds during-on-site welding
9. Dimensional accuracy
10. Correct processes and procedures
11. Suitable distortion control procedures in place

Selection of Welding Process and Filler Metal:

The welding process and filler metal should be so selected that the weld deposit will be compatible with the base metal and will have mechanical properties similar to or better than the base metal.

Comparison of high energy density welding processes and TIG welding for plate thickness 6 mm.

Parameter	*TIG*	*Plasma*	*Laser*	*EB*
Power input to workpiece	2 kW	4 kW	4 kW	5 kW
Total power used	3 kW	6 kW	50 kW	6 kW
Traverse Speed	2 mm/s	5.7 mm/s	16 mm/s	40 mm/s
Positional Welding	Good penetration	Good penetration	Yes Requires optics to move the beam	Requires mechanism to move the beam
Distortion Shrinkage	Nominal Significant in V-shaped weld	Nominal significant in V-shaped weld	Small Minimum	Minimum Minimum
Special Process Requirements	Normal Light Screening	Normal Light Screening	Safety interlock against misplaced beam reflection	Vacuum chambers, X-ray Screening
Surface Geometry	Underside Protrusion	Underside protrusion	Very fine ripples	Ruffled swarf on back face

■ QUESTIONS

1.1 Define 'Welding'. Explain the meaning and signification of coalescence and fusion in regard to welding. Why is it easier to obtain quality welds in space than in air?

1.2 Explain the conditions for obtaining satisfactory welds. Discuss the importance of welding and state its applications.

1.3 Discuss the factors which are considered in choosing a welding process for a specific application.