Welding Technology

Unit – 1

Metal Joining Process

Introduction

- Welding which is the process of joining two metallic components for the desired purpose, can be defined as the process of joining two similar or dissimilar metallic components with the application of heat, with or without the application of pressure and with or without the use of filler metal.
- Heat may be obtained by chemical reaction, electric arc, electrical resistance, frictional heat, sound and light energy. If no filter metal is used during welding then it is termed as "Autogenously Welding Process."
- The assembled parts that are joined by welding are called a weldment. .

General Applications:

- Welding is vastly being used for construction of transport tankers for transporting oil, water, milk and fabrication of welded tubes and pipes, chains, LPG cylinders and other items. Steel furniture, gates, doors and door frames, body and other parts of white goods items such as refrigerators, washing machines, microwave ovens and many other items of general applications are fabricated by welding.
- **Pressure Vessels:**

One of the first major use of welding was in the fabrication of pressure vessels. Welding made considerable increases in the operating temperatures and pressures possible as compared to riveted pressure vessels.

- **Bridges:**

Early use of welding in bridge construction took place in Australia . This was due to problems in transporting complete riveted spans or heavy riveting machines necessary for fabrication on site to remote areas. The first all welded bridge was erected in UK in 1934. Since then all welded bridges are erected very commonly and successfully.

- **Ship Building :**

Ships were produced earlier by riveting. Over ten million rivets were used in 'Queen Mary' ship which required skills and massive organization for riveting but welding would

have allowed the semiskilled/ unskilled labor and the principle of pre-fabrication. Welding found its place in ship building around 1920 and presently all welded ships are widely used. Similarly submarines are also produced by welding.

- **Building Structures:**

Arc welding is used for construction of steel building leading to considerable savings in steel and money. In addition to building, huge structures such as steel towers etc also require welding for fabrication.

- **Aircraft and Spacecraft:**

Similar to ships, aircrafts were produced by riveting in early days but with the introduction of jet engines welding is widely used for aircraft structure and for joining of skin sheet to body.

Space vehicles which have to encounter frictional heat as well as low temperatures require outer skin and other parts of special materials. These materials are welded with full success achieving safety and reliability.

- **Railways:**

Railways use welding extensively for fabrication of coaches and wagons, wheel tyres laying of new railway tracks by mobile flash butt welding machines and repair of cracked/damaged tracks by thermit welding.

- **Automobiles:**

Production of automobile components like chassis, body and its structure, fuel tanks and joining of door hinges require welding.

- **Electrical Industry:**

Starting from generation to distribution and utilization of electrical energy, welding plays important role. Components of both hydro and steam power generation system, such as penstocks, water control gates, condensers, electrical transmission towers and distribution system equipment are fabricated by welding. Turbine blades and cooling fins are also joined by welding.

- **Electronic Industry:**

Electronic industry uses welding to limited extent such as for joining leads of special transistors but other joining processes such as brazing and soldering are widely being used. Soldering is used for joining electronic components to printed circuit boards.

Robotic soldering is very common for joining of parts to printed circuit boards of computers, television, communication equipment and other control equipment etc.

- **Nuclear Installations:**

Spheres for nuclear reactor, pipe line bends joining two pipes carrying heavy water and other components require welding for safe and reliable operations.

- **Defence Industry:**

Defence industry requires welding for joining of many components of war equipment. Tank bodies fabrication, joining of turret mounting to main body of tanks are typical examples of applications of welding.

- **Micro-Joining:**

It employs the processes such as micro-plasma, ultrasonic, laser and electron beam welding, for joining of thin wire to wire, foil to foil and foil to wire, such as producing junctions of thermocouples, strain gauges to wire leads etc.

- Apart from above applications welding is also used for joining of pipes, during laying of crude oil and gas pipelines, construction of tankers for their storage and transportation. Offshore structures, dockyards, loading and unloading cranes are also produced by welding.

Classification of Welding Processes I

- **Welding processes can be classified on the basis of following technological criteria:**

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

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”.
- 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.
- 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.

- **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)

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.
- Same is achieved either by melting the faying surfaces using heat or applying pressure either at room temperature or high temperature (0.5o to 0.9o 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

Arc or Non-arc welding

- 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.
- **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

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

Classification of Welding Processes II

- Apart from technical factors, welding processes can also be classified on the fundamental approaches used for deposition of materials for developing a joint.

- **Welding processes**

- Cast weld processes

- Fusion weld processes

- Resistance weld processes

- Solid state weld processes

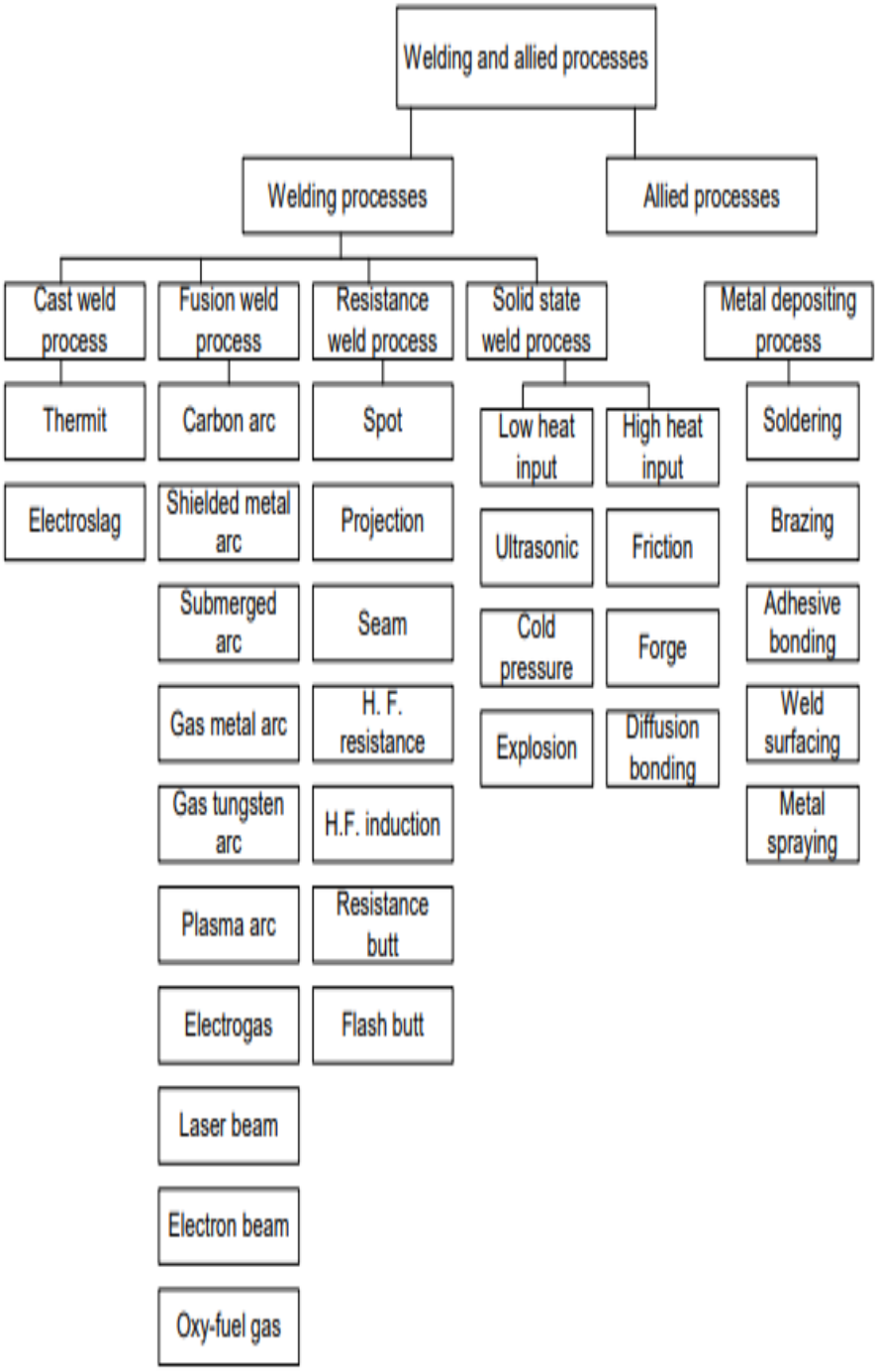
- **Allied welding processes**

- **Cast weld processes-** Those welding processes in which either molten weld metal is supplied from external source or melted and solidified at very low rate during solidification like castings.

- **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.

- **Resistance weld 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.

- **Solid state weld processes -** Welding processes in which weld joint is developed mainly by application of pressure and heat through various mechanism such as mechanical interacting, large scale interfacial plastic deformation



Classification of Welding Processes

Advantages

- Welding is more economical and is much faster process as compared to other processes (riveting, bolting, casting etc.)
- Welding, if properly controlled results permanent joints having strength equal or sometimes more than base metal.

- Large number of metals and alloys both similar and dissimilar can be joined by welding.
- General welding equipment is not very costly.
- Portable welding equipment can be easily made available.
- Welding permits considerable freedom in design.
- Welding can join welding jobs through spots, as continuous pressure tight seams, end-to-end and in a number of other configurations.
- Welding can also be mechanized.

Disadvantages

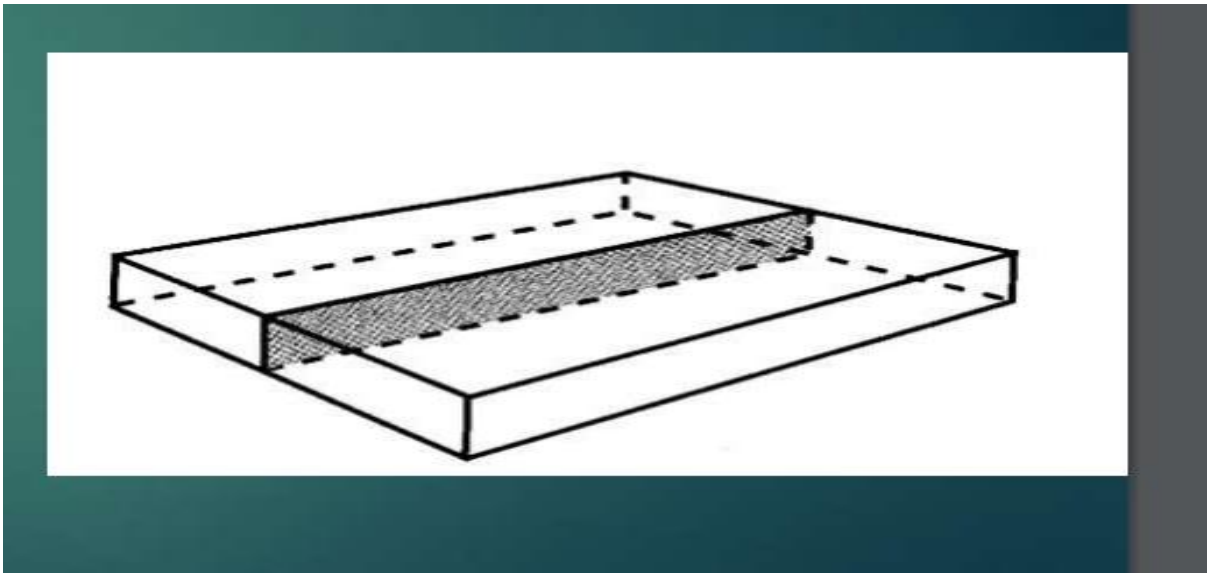
- It results in residual stresses and distortion of the work pieces.
- Welded joint needs stress relieving and heat treatment.
- Welding gives out harmful radiations (light), fumes and spatter.
- Jigs and fixtures may also be needed to hold and position the parts to be welded
- Edges preparation of the welding jobs are required before welding
- Skilled welder is required for production of good welding
- Heat during welding produces metallurgical changes as the structure of the welded joint is not same as that of the parent metal.

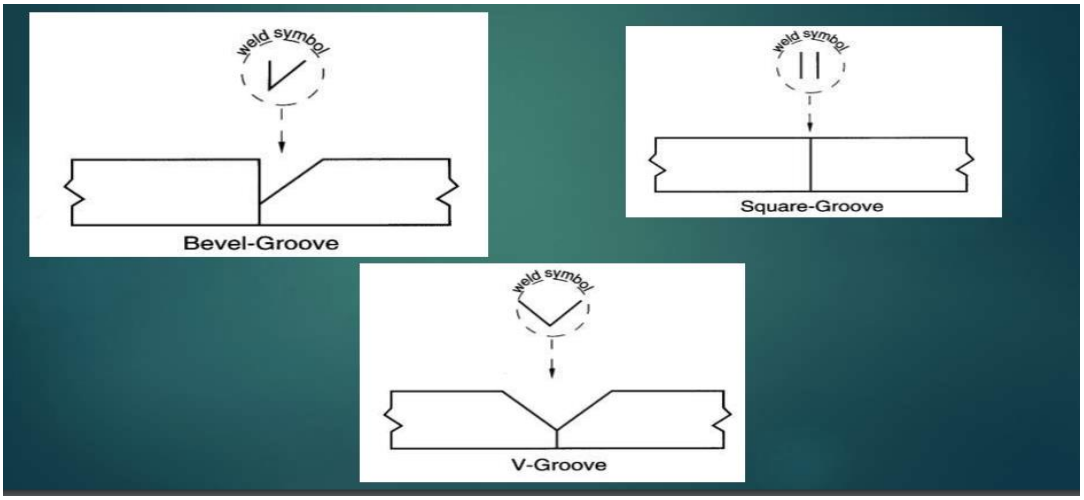
Various Types of Welding Joints

- Five Basic Welded Joints

➢ **Butt Joint**

Butt joint- a joint between two members aligned approximately in the same plane.

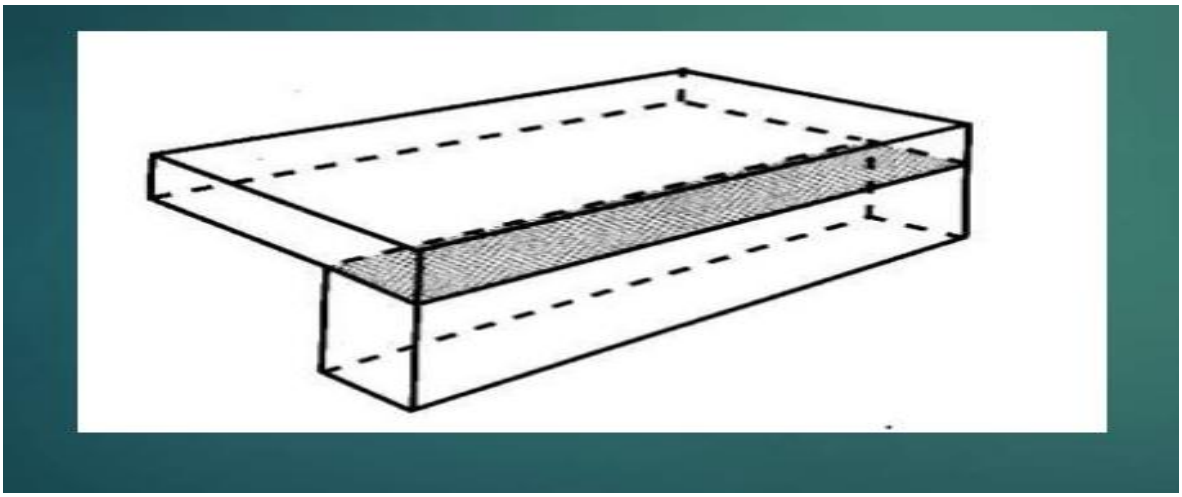


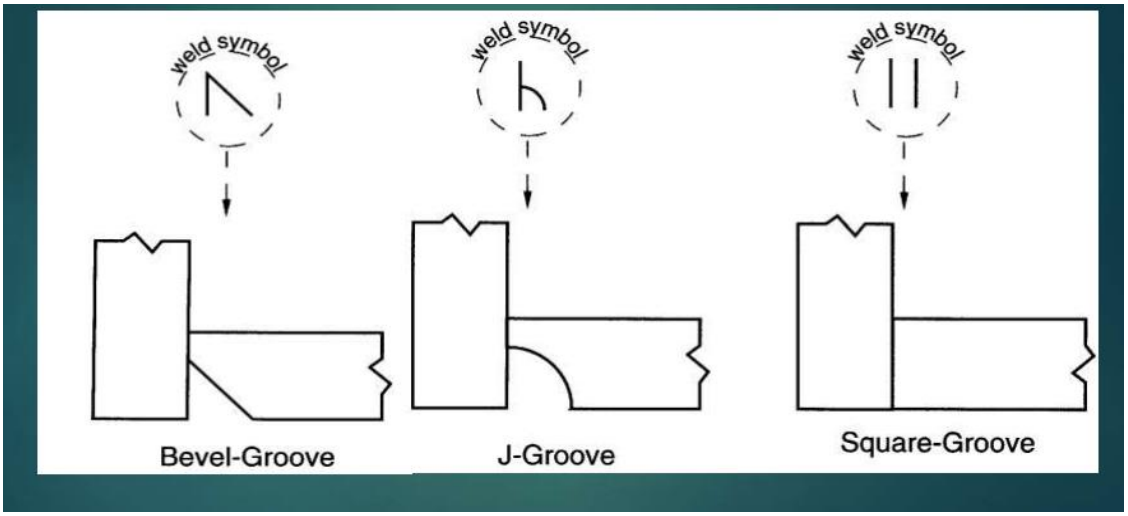


Different Edge Shapes and Symbols for some Butt-Joints

- **Corner Joint**

Corner joint - a joint between two members located at right angles to each other.

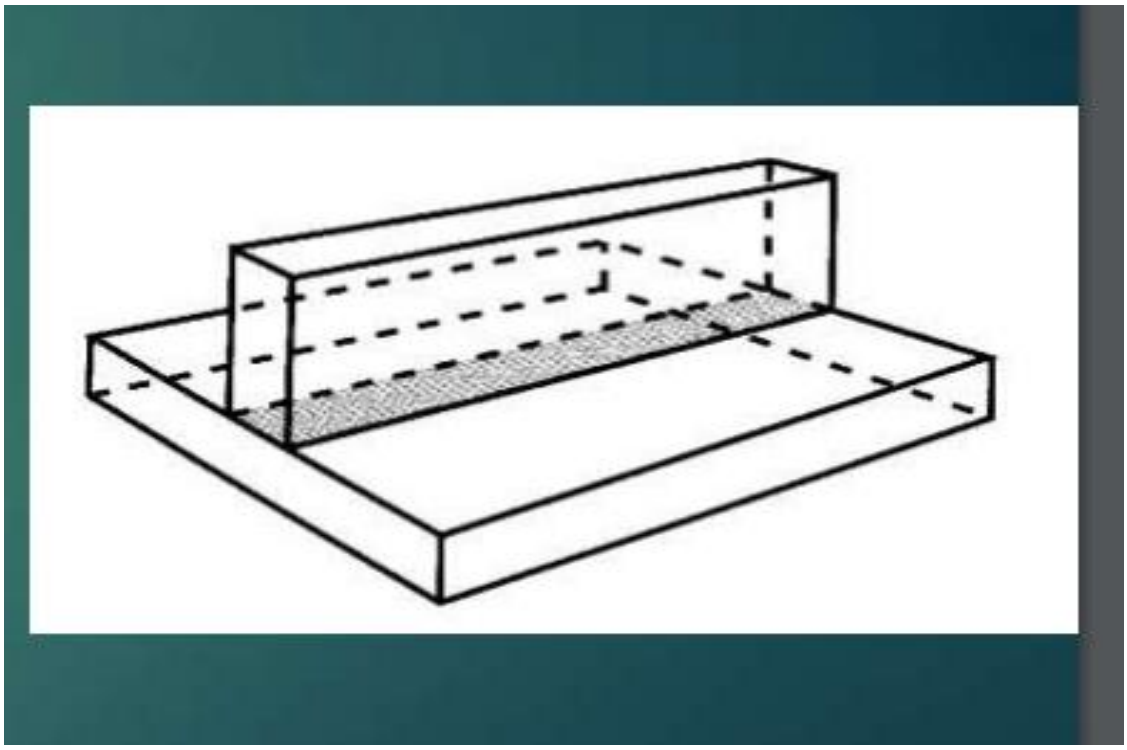


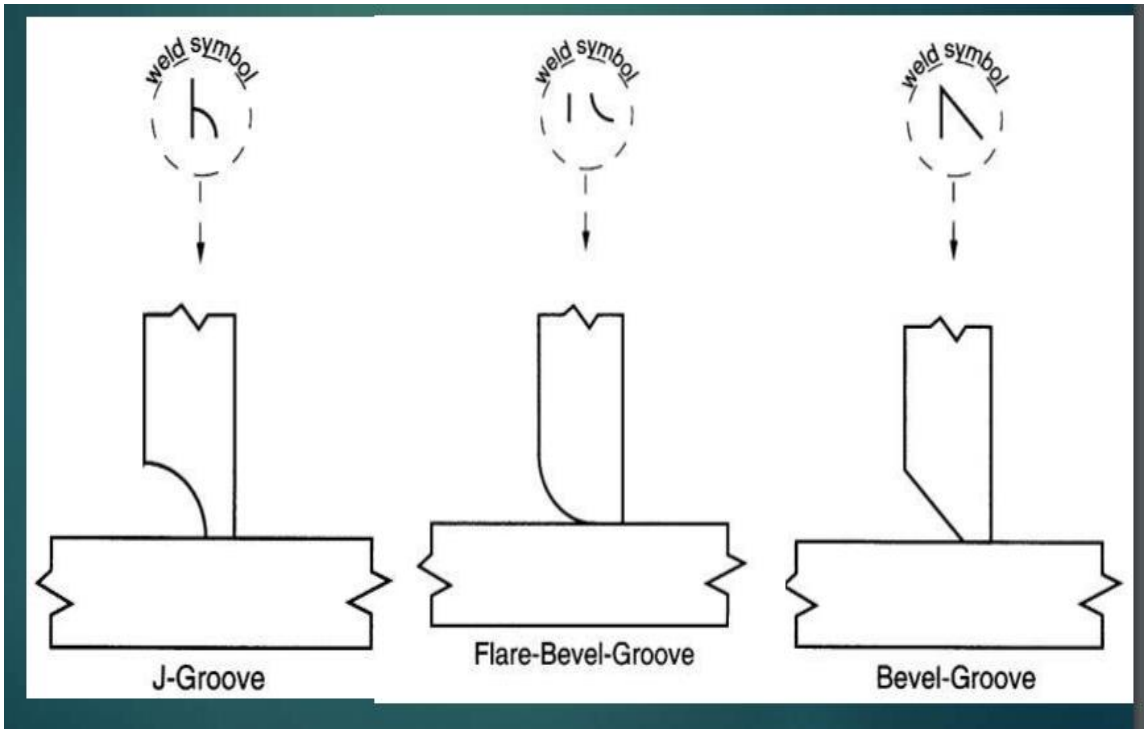


Some Different Edge Shapes and Symbols for Corner Joints

- **T – Joint**

T- joint - a joint between two members located approximately at right angles to each other in the form of a T.

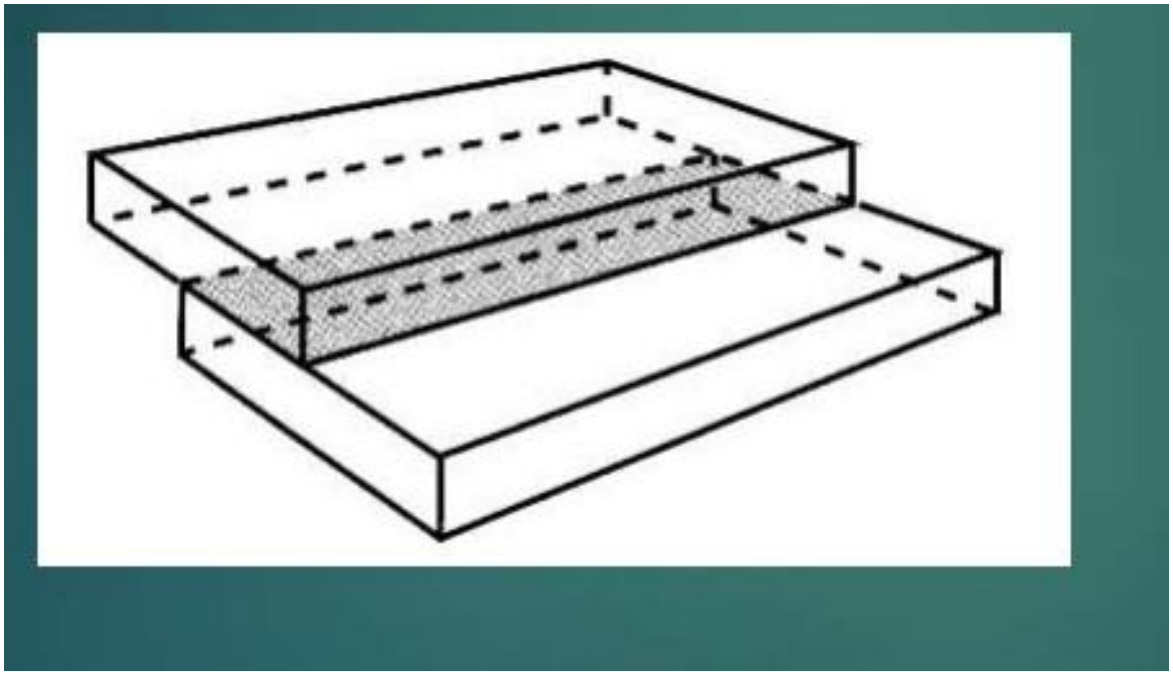


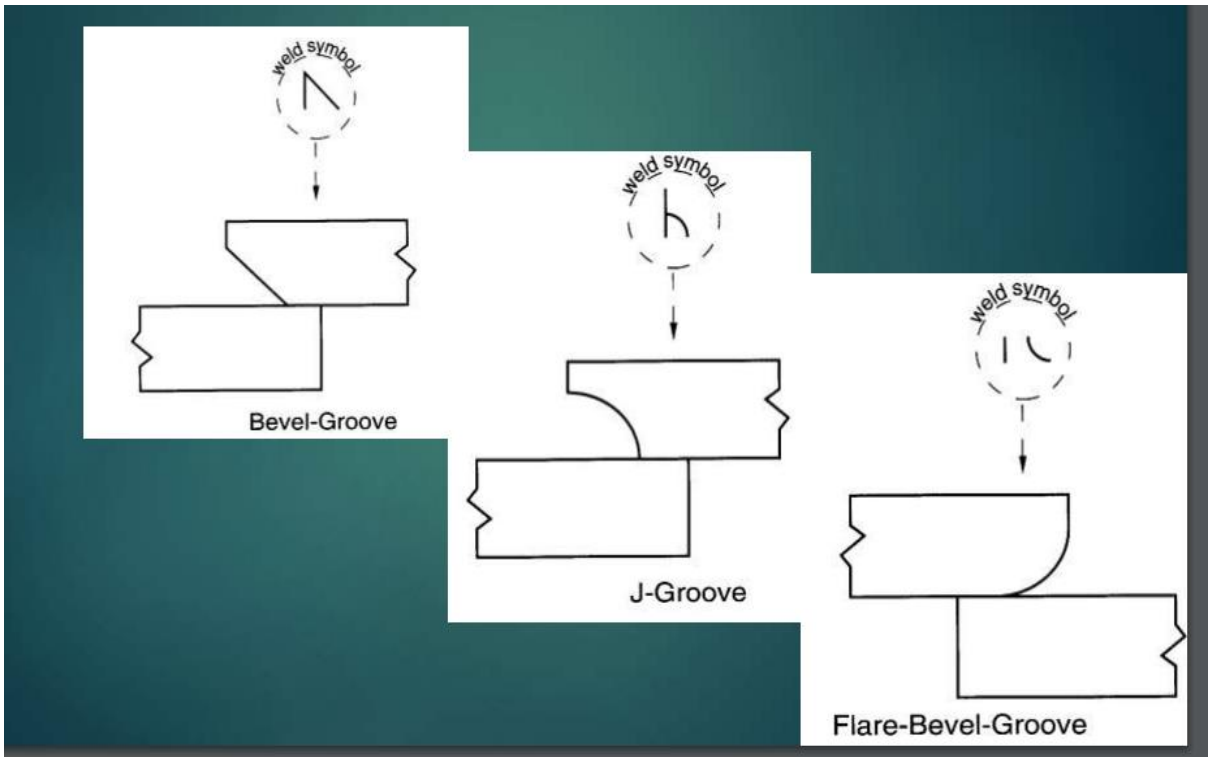


Some Different Edge Shapes and Symbols for T-Joint

- **Lap Joint**

Lap Joint- a joint between two overlapping members.

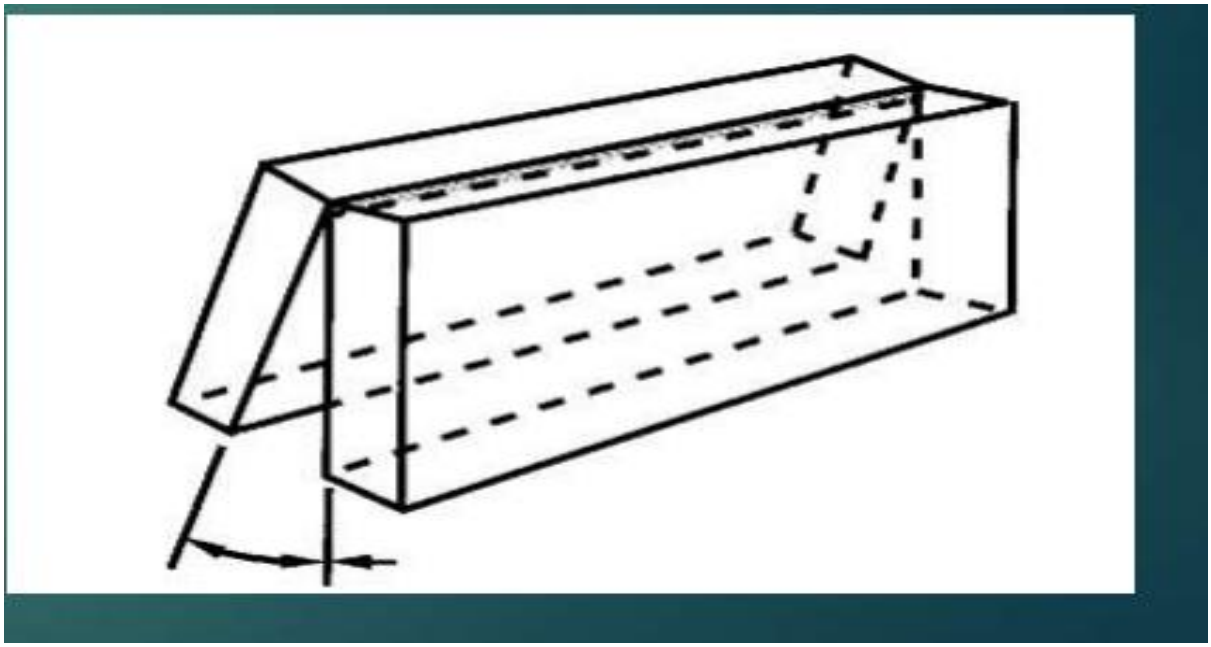


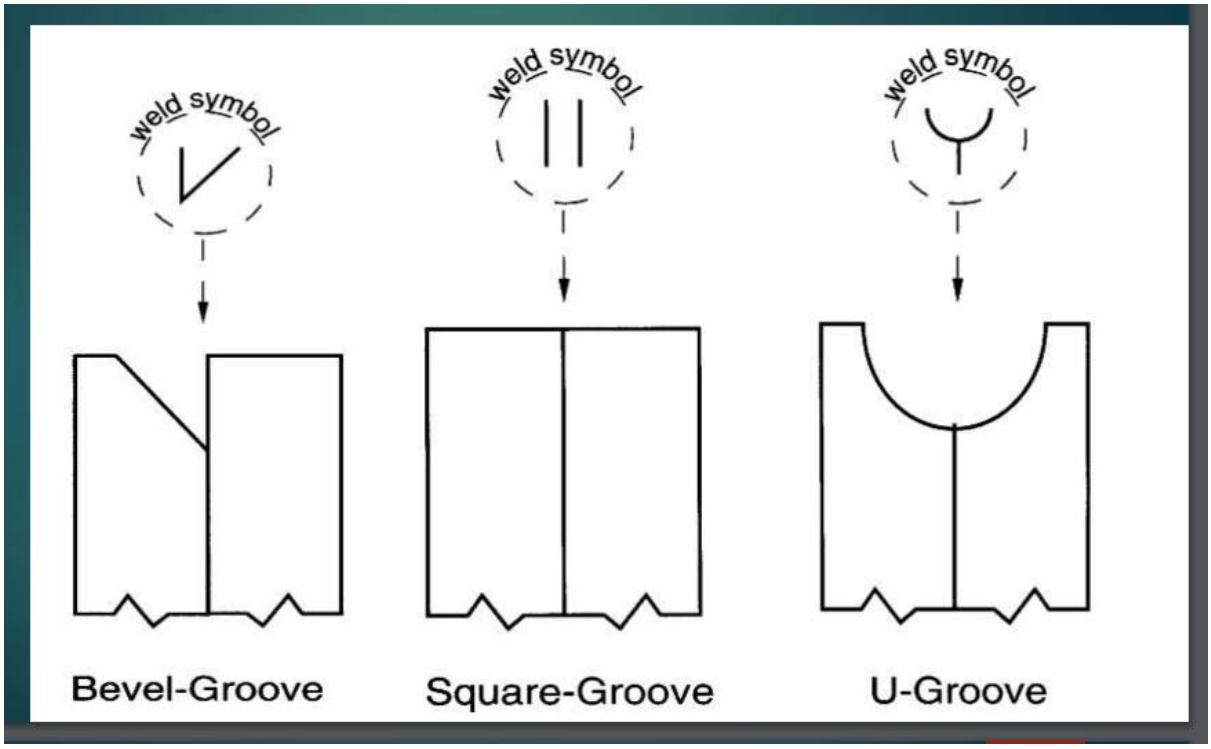


Some Different Edge Shapes and Symbols for Lap Joints

- Edge Joint

Edge joint- a joint between the edges of two or more parallel or nearly parallel members.



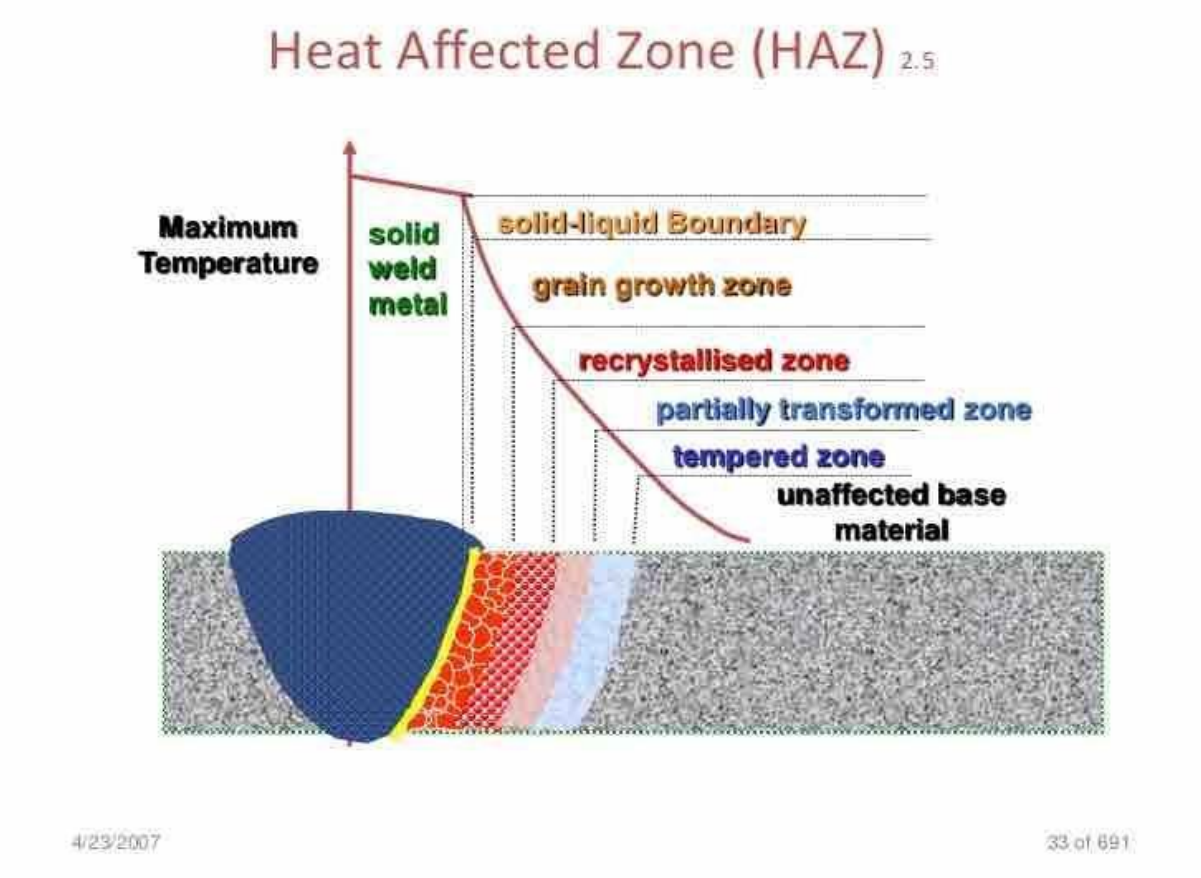


Some Different Edge Shapes and Symbols for Edge Joints

Heat Affected Zone

- **The Heat-Affected Zone (HAZ)** refers to a non-melted area of metal that has experienced changes in its material properties as a result of exposure to high temperatures.
- The alterations in material properties are usually a result of welding or high-heat cutting procedures.
- The HAZ is identified as the area between the weld or cut and the base metal.
- These areas can vary in size and severity depending on the properties of the materials involved, the intensity and concentration of heat, and the process employed.

Heat Affected Zone



What are the Causes of Heat-Affected Zone

- During welding operations, the HAZ may range from small to large depending on the rate of heat input.
- Welding processes with high rates of heat input (i.e. fast heating) have faster cooler rates compared to welding processes with low rates of heat input (i.e. slow heating) and thus, have smaller HAZs.
- Conversely, a process with low rates of heat input will result in a larger HAZ.
- The size of a HAZ also increases as the speed of the welding process decreases.
- HAZ problems can be mitigated by performing a pre- and/or **post- weld heat treatment.**

What are the Effects of Heat-Affected Zones

- Because the HAZ experiences sufficient heat for a long enough period of time, the layer undergoes microstructure and property changes that differ from the parent metal.
- These property changes are usually undesirable and ultimately serve as the weakest part of the component.
- For example, the microstructural changes can lead to residual stresses, reduced material strength, increased brittleness, and decreased resistance to **corrosion** and/or **cracking**. As a result, many failures occur in the HAZ

Commonly Welded Base Metals

- Steels.
- Stainless steels.
- **Aluminium** and its **alloys**.
- **Nickel** and its **alloys**.
- **Copper** and its **alloys**.
- **Titanium** and its **alloys**.
- **Cast iron**.
- Iron