SUB : WELDING TECHNOLOGY

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UNIT IV OTHER WELDING PROCESSES 10 hrs.

Radiant energy welding process -Equipment -Electron beam welding -types of guns - Control of beam -Vacuum chambers and work holding systems -Laser beam welding power control-Chilling systems-Focusing elements -Laser beam cutting-Characteristic curves of parameters -Solid phase welding-Ultrasonic welding-Equipment and capabilities -Friction welding, Friction stir welding -Explosive welding - Limitations and applications of the above process -Under water welding -Wet and dry systems-Brazing & soldering -Welding defects

ELEctron Beam Welding

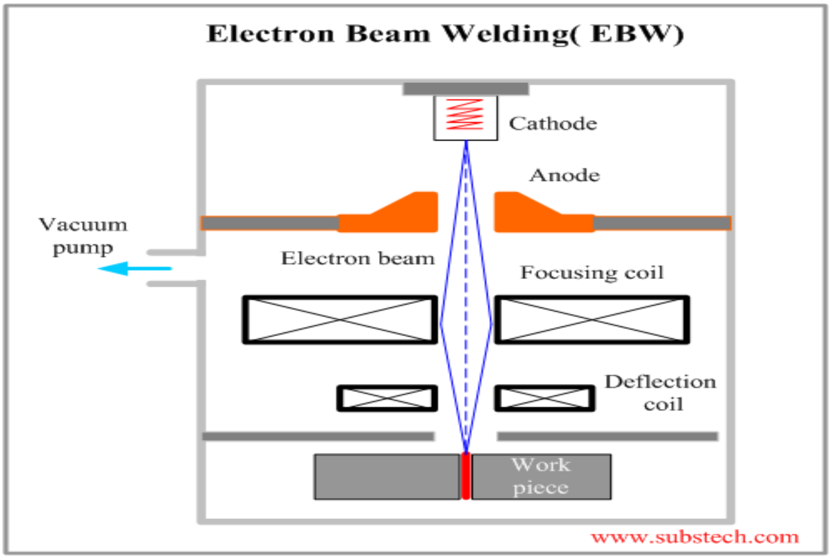
It is a welding process utilizing a heat generated by a beam of high energy electrons. The electrons strike the work piece and their kinetic energy converts into thermal energy heating the metal so that the edges of work piece are fused and joined together forming a weld after Solidification.

The process is carried out in a vacuum chamber at a pressure of about $2*10^{-7}$ to $2*10^{-6}$ psi (0.00013 to 0.0013 Pa). Such high vacuum is required in order to prevent loss of the electrons energy in collisions with air molecules.

The electrons are emitted by a cathode (electron gun). Due to a high voltage (about 150 kV) applied between the cathode and the anode the electrons are accelerated up to 30% - 60% of the speed of light. Kinetic energy of the electrons becomes sufficient for melting the targeted weld. Some of the electrons energy transforms into X-ray irradiation.

Electrons accelerated by electric field are then focused into a thin beam in the focusing coil. Deflection coil moves the electron beam along the weld.

Electron Beam is capable to weld work pieces with thickness from 0.0004” (0.01 mm) up to 6” (150 mm) of steel and up to 20” (500 mm) ofaluminum. Electron Beam Welding may be used for joining any metals including metals, which are hardly weldable by other welding methods: refractory metals (tungsten, molybdenum, niobium) and chemically active metals (titanium, zirconium, beryllium). Electron Beam Welding is also able to join dissimilar metals.



Advantages of Electron Beam Welding (EBW):

- Tight continuous weld;
- Low distortion;
- Narrow weld and narrow heat affected zone;
- Filler metal is not required.

Disadvantages of Electron Beam Welding (EBW):

- Expensive equipment;
- High production expenses;
- X-ray irradiation.

LASER BEAM WELDING

Principles:

Laser is an acronym for light amplification by stimulated emission of radiation. Laser Beam Welding (LBW) is a fusion joining process that produces coalescence of materials with the heat obtained from a concentrated beam of coherent, monochromatic light impinging on the joint to be welded. In the LBM process, the laser beam is directed by flat optical elements, such as mirrors and then focused to a small spot (for high power density) at the workpiece using either reflective focusing elements or lenses. It is a non-contact process, requiring no pressure to be applied. Inert gas shielding is generally employed to prevent oxidation of the molten puddle and filler metals may be occasionally used. The

Lasers which are predominantly being used for industrial material processing and welding tasks are the Nd-YAG laser and 1.06 μm wavelength CO_2 laser, with the active elements most commonly employed in these two varieties of lasers being the neodymium (Nd) ion and the CO_2 molecules respectively.

Laser Types:

Solid-State laser:

It utilizes an impurity in a host material as the active medium. Thus, the neodymium ion (Nd^{+++}) is used as a ‘dopant’, or purposely added impurity in either a glass or YAG crystal and the 1.06 μm output wavelength is dictated by the neodymium ion. The lasing material or the host is in the form of a cylinder of about 150 mm long and 9 mm in diameter. Both ends of the cylinder are made flat and parallel to very close tolerances, then polished to a good optical finish and silvered to make a reflective surface. The crystal is excited by means of an intense krypton or xenon lamp. A simplified schematic arrangement of the rod, lamp and mirrors is as shown in Fig. 4.6.1

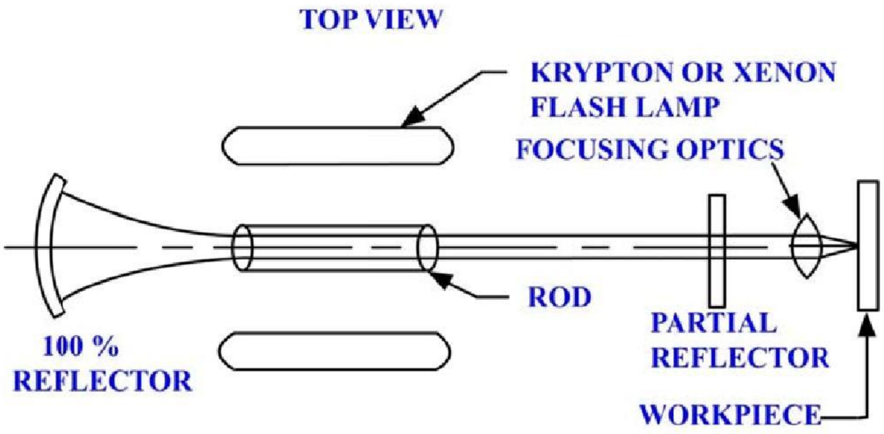


Fig.4.6.1 Schematic of lasant rod, lamp and mirror used in laser beam welding.

Gas Lasers:

The electric discharge style CO_2 gas lasers are the most efficient type currently available for high power laser beam material processing. These lasers employ gas mixtures primarily containing nitrogen and helium along with a small percentage of carbon dioxide, and an electric glow discharge is used to pump this laser medium (i.e., to excite the CO2 molecule). Gas heating produced in this fashion is controlled by continuously circulating the gas mixture through the optical cavity area and thus CO lasers are usually categorized according to the type of gas flow system they employ; slow axial, fast axial or transverse.

Slow Axial Flow Gas Laser:

They are the simplest of the CO_2 gas lasers. Gas flow is in the same direction as the laser resonator's optical axis and electric excitation field, or gas discharge path. These are capable of generating laser beams with a continuous power rating of approximately 80 watts for every meter of discharge length. A folded tube configuration is used for achieving output power levels of 50 to 1000 watts, maximum.

Fast Axial Flow (FAF) Gas Laser:

They have similar arrangement of components as that of slow axial flow gas laser, except that in the case of the FAF Laser, a roots blower or turbo pump is used to circulate the laser gas at high speed through the discharge region and corresponding heat exchangers. The FAF lasers with continuous wave (CW) output power levels of between 500 to 6000 watts are available.

Transverse Flow:

These lasers operate by continuously circulating gas across the resonator cavity axis by means of a high speed fan type blower, while maintaining an electric discharge perpendicular to both the gas flow direction and the laser beam’s optical axis. Transverse flow lasers with output power levels between 1 and 25 kW are available.

LBW Process Advantages:

Major advantages of Laser Beam Welding include the following:

1) Heat input is close to the minimum required to fuse the weld metal, thus heat affected zones are reduced and workpiece distortions are minimized.
2) Time for welding thick sections is reduced and the need for filler wires and elaborate joint preparations is eliminated by employing the single pass laser welding procedures.
3) No electrodes are required; welding is performed with freedom from electrode contamination, indentation or damage from high resistance welding currents.
4) LBM being a non-contact process, distortions are minimized and tool wears are eliminated.

5) Welding in areas that are not easily accessible with other means of welding can be done by LBM, since the beams can be focused, aligned and directed by optical elements.
6) Laser beam can be focused on a small area, permitting the joining of small, closely spaced components with tiny welds.
7) Wide variety of materials including various combinations can be welded.
8) Thin welds on small diameter wires are less susceptible to burn back than is the case with arc welding.
9) Metals with dissimilar physical properties, such as electric resistance can also be welded.
10) No vacuum or X-Ray shielding is required.
11) Laser welds are not influenced by magnetic fields, as in arc and electron beam welds. They also tend to follow weld joint through to the root of the work-piece, even when the beam and joint are not perfectly aligned.
12) Aspect ratios (i.e., depth-to-width ratios) of the order of 10:1 are attainable in LBM.

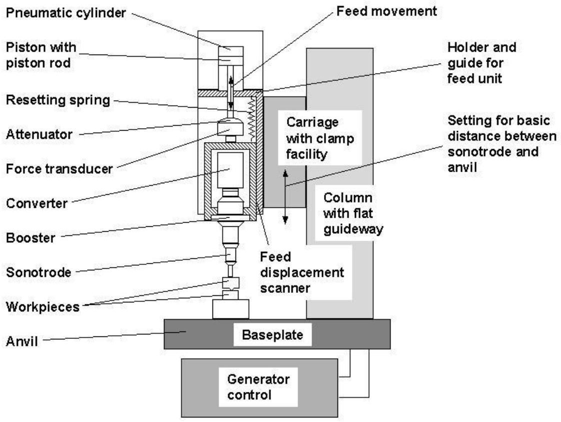
Limitations of the LBM Process:

1) Joints must be accurately positioned laterally under the beam and at a controlled position with respect to the beam focal point.
2) In case of mechanical clamping of the weld joints, it must be ensured that the final position of the joint is accurately aligned with the beam impingement point.
3) The maximum joint thickness that can be welded by laser beam is somewhat limited. Thus weld penetrations of larger than 19 mms are difficult to weld.
4) High reflectivity and high thermal conductivity of materials like Al and Cu alloys can affect the weldability with lasers.

5) An appropriate plasma control device must be employed to ensure the weld reproducibility while performing moderate to high power laser welding.
6) Lasers tend to have fairly low energy conversion efficiency, generally less than 10 percent.
7) Some weld-porosity and brittleness can be expected, as a consequence of the rapid solidification characteristics of the LBM.

Ultrasonic Welding

High frequency vibrations are combined with pressure to join two materials together quickly and securely without producing significant amounts of heat. The vibration that results is at a frequency that is appreciably above the range of human hearing, hence the name ultrasonic.



The ultrasonic machine places pressure on on the component being welded. The ultrasonic horn is activated and vibrates the two pieces together at a rate of 20,000 or 40,000 hertz. Weld cycle times are usually less than 1 second.

Machine Components of Ultrasonic Welding Machine

The generator or power supply provides wall current to the machine.

The base of the machine holds the item being welded within a nest or anvil.

Advantages of Ultrasonic Welding in Manufacturing

1. The ability to weld metals of significantly dissimilar melting points that normally form brittle alloys when joined.

2. Welds can be in close proximity to heat sensitive components, such as electronics or plastic components (some electronics may be too sensitive for ultrasonic).

3. Ultrasonic welds are made without consumables such as glue, solder or filler.

4. Use far less energy usage than traditional joining techniques.

5. Does not produce exorbitant amount of fumes

5) No caustic chemicals

Restrictions of Ultrasonic Welding

Ultrasonic welding is restricted primarily to nonferrous metals and plastics.

The parts cannot be large so it limits the process to smaller components.

FRICTION WELDING

Friction welding is a solid state welding process which produces coalescence of materials by the heat obtained from mechanically-induced sliding motion between rubbing surfaces. The work parts are held together under pressure. This process usually involves the rotating of one part against another to generate frictional heat at the junction. When a suitable high temperature has keen reached, rotational notion ceases. Additional pressure is applied and coalescence occurs.

There are two process variations:

1. In the original process, one part is held stationary and the other part is rotated by a motor which maintains an essentially constant rotational speed. The two parts are brought in contact under pressure for a specified period of time with a specific pressure. Rotating power is disengaged from the rotating piece and the pressure is increased. When the rotating piece stops, the weld is completed. This process can be accurately controlled when speed, pressure, and time are closely regulated.
2. The other variation is inertia welding. A flywheel is revolved by a motor until a preset speed is reached. It, in turn, rotates one of the pieces to be welded. The motor is disengaged from the flywheel and the other part to be welded is brought in contact under pressure with the rotating piece. During the predetermined time during which the rotational speed of the part is reduced, the flywheel is brought to an immediate stop. Additional pressure is provided to complete the weld.

Process

Both methods utilize frictional heat and produce welds of similar quality. Slightly better control is claimed with the original process. The two methods are similar, offer the same welding advantages, and are shown by figure 10-79 below.

There are three important factors involved:

1. The rotational speed which is related to the material to be welded and the diameter of the weld at the interface.
2. The pressure between the two parts to be welded. Pressure changes during the weld sequence. At the start, pressure is very low, but is increased to create the frictional heat. When the rotation is stopped, pressure is rapidly increased so forging takes place immediately before or after rotation is stopped.
3. The welding time is related to the shape and the type of metal and the surface area. It is normally a matter of a few seconds. The actual operation of the machine is automatic. It is controlled by a sequence controller, which can be set according to the weld schedule established for the parts to be joined.

Normally, one of the parts to be welded is round in cross section. This is not an absolute necessity. Visual inspection of weld quality can be based on the flash, which occurs around the outside perimeter of the weld. This flash will usually extend beyond the outside diameter of the parts and will curl around back toward the part but will have the joint extending beyond the outside diameter of the part.

If the flash sticks out relatively straight from the joint, it indicates that the welding time was was too short, the pressure was too low, or the speed too high. These joints may crack.

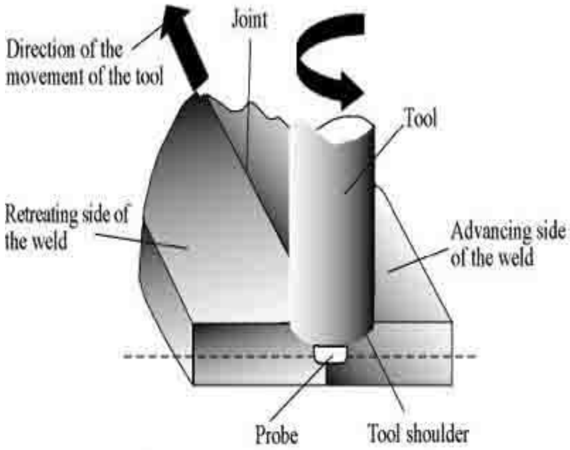
If the flash curls too far back on the outside diameter, it indicates that the time was too long and the pressure was too high.

Between these extremes is the correct flash shape. The flash is normally removed after welding.

- Rotational Speed
- Heating pressure
- Forging pressure
- Time for heating
- Time for braking
- Time for forging

Friction Stir Welding

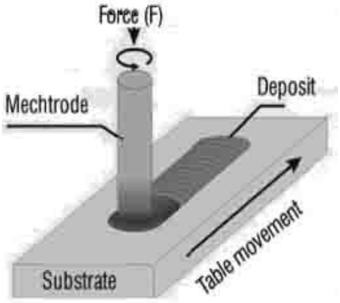
Friction Stir Welding Diagram



Friction stir welding is a cylindrical shouldered tool with a profiled probe. A pin or nib is used. Friction is created between the metal being worked, the nib and the shoulder.

Friction Surfacing

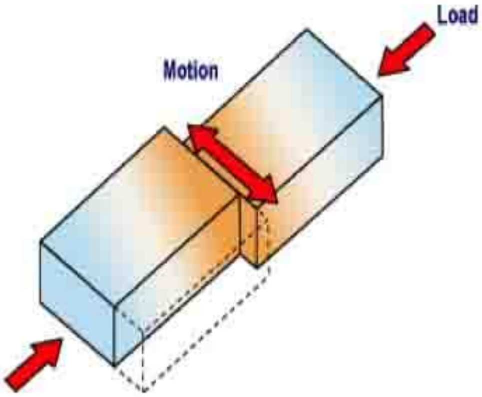
Friction Surfacing



Friction surfacing is a surface coating process. The coating material is Mechtrode, which is rotated under pressure over the substrate

Linear friction welding

In linear friction welding an oscillating chuck is used. It is applied to non-round shapes as compared to spin welding. The material welded has to have high shear strength.



Advantages and Disadvantages

Advantages:

1. Can produce high quality welds in a short cycle time.
2. No filler metal is required and flux is not used.
3. The process is capable of welding most of the common metals. It can also be used to join many combinations of dissimilar metals. Friction welding requires relatively expensive apparatus similar to a machine tool.
4. Easy to operate equipment
5. Not time consuming

6. Low levels of oxide films and surface impurities
7. When compared to resistance butt welding creates better welds at lower cost and higher speed, lower levels of electric current are required
8. Small heat affected zone when comparing the process to conventional flash welding.
9. When compared to flash butt welding, less shortening of the component.
10. No need to use gas, filler metal or flux. No slag that can cause weld imperfections.

Disadvantages:

1. Process limited to angular and flat butt welds.
2. Only used for smaller parts.
3. Complicated when used for tube welding.
4. Hard to remove flash when working with high carbon steel.
5. Requires a heavy rigid machine in order to create high thrust pressure.

WET UNDERWATER WELDING

employing a waterproof electrode. Other processes that are used include flux cored arc welding and friction welding.In each of these cases, the welding power supply is connected to the welding equipment through cables and hoses.

The process is generally limited to low carbon equivalent steels, especially at greater depths, because of hydrogen-caused cracking.

In dry underwater welding the weld is performed at the prevailing pressure in a chamber filled with a gas mixture sealed around the structure being welded. For this process, gas tungsten arc welding is often used, and the resulting welds are generally of high integrity.

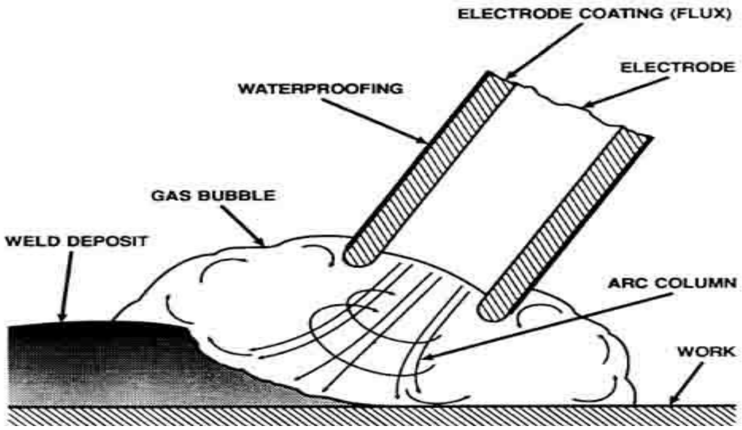
The applications of underwater welding are diverse – it is often used to repair and construct ships, offshore platforms, and pipelines. Steel is the most common material welded. In terms of underwater cutting, oxygen-arc cutting with exothermic electrodes and steel tublular electrodes are also used.

Due to the danger and demands on the body, welders or cutters often work 1 month on and 3 months off.

he welding arc does not behave underwater as it does on the surface and the activity of the gas bubble is particularly important to successful completion of the underwater weld.

When the arc is struck, the combustion of the electrode and the detachment of water creates a gas bubble or envelope As the pressure within the bubble increases, it is forced to leave the arc and meet with the surrounding water while another bubble forms to take its place. See example above.

Then, as this pressure head becomes greater than the capillary force, the bubble breaks down. Therefore, if the electrode is too far from the work, the weld will be destroyed as the gases explode and blow through. If the travel speed is too slow, the bubble will collapse around the weld and destroy the possibility of producing an effective weld.



EXPLOSIVE WELDING

The process of explosive cladding, or explosive welding, has been understood for decades. Although academia has acknowledged explosive welding as a novel and fascinating process, with several specific exceptions, industry has been slow to realize its potential and the possible composites that it makes available. More recently, explosive welding manufacturers, such as

PA&E's Bonded Metals Division, formerly known as Northwest Technical Industries (NTI), have characterized and defined many aspects of the process and have made efforts to inform design engineers of the many composite possibilities that explosive bonding allows.

A composite can be designed and fabricated to combine desirable properties of very different metals. This process allows the designers to optimize the performance of the composite for high temperature, cryogenic, high strength, thermal or electrical conductivity, enhanced mechanical properties, corrosion resistance, or any other application.