

## Basics of Mechanical Engineering-2

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Week 08

Lecture 29

Basics of Welding (Part 6 of 7)

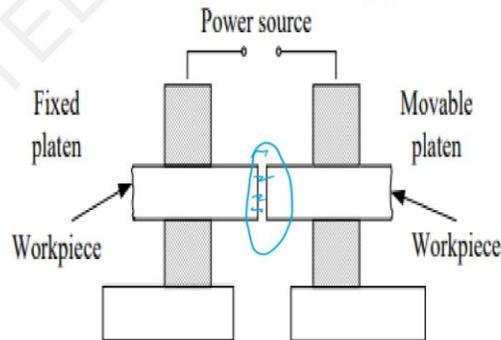
### Percussion Welding



- Percussion welding (PEW) is a resistance welding process wherein coalescence is produced simultaneously over the entire area of abutting surfaces by heat obtained from an arc produced by a rapid discharge of electrical energy, with pressure percussively (rapidly) applied during or immediately following the electrical discharge.

#### Principle of Operation

- Cleaned work pieces are clamped with light force to bring ends together.
- An arc is struck by ionizing the gap or making contact to establish current.
- Welding force is applied to extinguish the arc and form the weld as the parts cool.



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Percussion welding, or PEW, is a type of welding. It is a resistance welding process wherein coalescence is produced simultaneously over the entire area of the abutted surfaces. So, we are talking about heat obtained from an arc produced by rapid discharge. So, there will be an arc which occurs due to rapid discharge. The key terminology here is rapid discharge of electrical energy.

With pressure applied percussively during or immediately following the electric discharge. This is also part of a resistance welding process. Where heat is applied, then a flat plate, a moving plate, tries to hit and weld. The principle of operation is almost the

same: clean the workpiece. An arc is struck, weld forces are applied, and then welding happens.

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## Percussion Welding



### Advantages:

- Fusion confined to the surface with minimal flash or upset.
- Heat treated or cold worked metals can be welded without annealing.

### Disadvantages:

- Limited to butt welded joints only.
- Joint size is limited to 1.5 to 3 sq. cm due to arc control difficulties.

### Applications:

- Primarily used for Aluminum and alloys.
- Also used for copper alloys, low carbon steel, stainless steel, and Copper to Molybdenum.



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The advantages and disadvantages are clearly stated. The applications include extensive use in aluminum and aluminum alloys. Please note that the resistance welding process is extensively used for thermal welding. For highly thermally conductive materials. We will always opt for this resistance welding process or another suitable welding process.

Where we use an intermediate phase without affecting the parental material. It is primarily used for aluminum and its alloys. It is also used for copper alloys, low carbon steel, stainless steel, and copper to molybdenum. It is for similar and dissimilar material joining. The melting process produces coalescence at temperatures below the melting point of the base material being joined.

So you have material A and material B. It can be similar or dissimilar, okay. Joining between these two occurs at a temperature of the weld. It is less than the melting point of the parental material. The weld is carried out without the addition of a filler but with the application of pressure.

## Solid State Welding

- A solid state welding process produces coalescence at temperatures below the melting point of the base metal being joined.
- The welding is carried out without the addition of a filler metal but with the application of pressure.
- At least one of the metal to be joined should be highly ductile and should exhibit extreme work hardening.



The next classification of the welding process is solid-state welding. A solid-state welding process produces coalescence at temperatures below the melting point of the base metal being joined. The welding is carried out without the addition of a filler material but with the application of pressure. At least one of the materials should be highly ductile and should exhibit extreme work-hardening behavior.

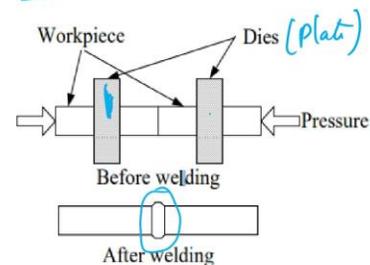
## Cold Welding



- Cold or contact welding is a solid-state process where joining occurs without fusion or heating at the interface.
- A metal oxide layer exists on the surface, which is partially removed during cold working.
- When two surfaces are pressed together, the oxide forms fragments, and plastic deformation occurs, leading to metal-to-metal contact and fusion.
- The ductility of the metal ensures a true fusion condition.

### Principle of Operation

- The parts to be welded are first cleaned and clamped in a die with some initial extension.
- A forging force is then applied to complete welding



Cold welding process. Cold or contact welding is a solid-state process where joining occurs without fusion or heating of the substrate.

So, what happens here? We have a moving die or a moving plate. It can be a fixed moving plate, it can be a moving platen, it can be there. And then, what happens here? We try to bring these two close to each other and apply huge pressure.

This huge pressure leads to joining. A metal oxide layer exists on the surface, which is partially removed by cold working. That means when you get very close, you have a surface just above the metal, and you will have an oxide layer. Now, this oxide layer is removed. When the oxide layer is removed, the nascent layer comes into contact.

When we apply pressure between these two, joining occurs. When two surfaces are pressed together, the oxide fragments and plastic deformation occurs. This leads to metal-to-metal contact and fusion. The ductility of the metal ensures a true fusion condition. So, the parts to be welded are cleaned, then the die is clamped.

Then the forging force is applied such that they form the weld. So here, if you see, there is no heat applied; there is not much heat, which is the dominant phenomenon here.

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## Cold Welding



### Advantages

- Total absence of applied heating.
- Dissimilar metals can be joined.

### Disadvantages

- Needs a lot of surface preparation.
- At least one of the metals is required to be ductile without excessive work hardening.

### Applications:

- Welding and manufacturing metal wires (aluminum, copper, gold, silver, platinum).
- Joining reels for continuous wire drawing.
- Cladding and joining metals.
- Joining metals in explosive areas.

So, in the total absence of applied heat, dissimilar materials can be joined. See, joining dissimilar materials even today is a very big challenge. Thin, fragile metals can be joined.

When you go to thick, it is very difficult. So, that is why people try to do cladding also. Dissimilar or disadvantages require a lot of surface preparation. At least one of the metals should exhibit ductility without excessive work hardening. So the applications are manufacturing metal wires like aluminium, copper, gold, silver, platinum can be done. So joining reels of continuous wire is done. Cladding and joining of metals are possible.

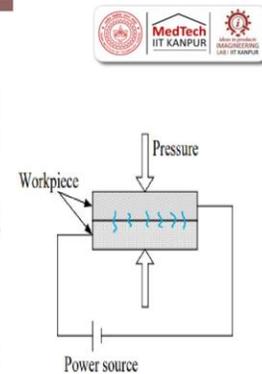
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## Diffusion Welding

- Diffusion welding is a solid-state process where pressure is applied to two clean work pieces at elevated temperatures below their melting points.
- Bonding occurs through the mutual diffusion of atoms at the interface, without macroscopic deformation or relative motion of the work pieces.

### Principle of Operation:

- Metal-to-metal contact is required, with high pressure (350 to 700 kg/cm<sup>2</sup>) applied to break the surface oxide layer.
- Temperature up to 1100°C is used for diffusion and grain growth, completing the weld.
- The atoms within the attractive force field form a high-strength joint.
- To prevent contamination, the process is often conducted in a vacuum.



The other welding process under solid state is the diffusion welding process. So diffusion welding is a solid-state process where pressure is applied to clean workpieces at elevated temperatures below their melting point. You try to join these two.

It is diffusion. Diffusion means why is heat used because there is a diffusion which is happening between the metal pieces. The bonding occurs through a mutual diffusion of atoms at the interface. Without macroscopic deformation or relative motion of the workpiece. So, a metal to metal contact is required.

The temperatures up to 1100 degrees can be done. The atoms with the attractive force field forms a high strength to prevent the contamination. The process is often conducted in vacuum. Diffusion welding process happens in vacuum. In electronic components, majority of the welding process happens by diffusion process.

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## Diffusion Welding



### Advantages:

- Dissimilar materials may be welded (Metals, Ceramics, Graphite, glass).
- Welds of high quality are obtained without pores, inclusions, chemical segregation and distortion.
- No limitation of work piece thickness.

### Disadvantages:

- Time consuming process with low productivity requiring thorough surface preparation.
- The mating surfaces must be precisely fitted to each other.
- Relatively high initial investments in equipment.

### Applications:

- Reactor components, rocket engines, rotor hubs, missiles, bombers, space shuttles.
- Used for joining titanium, zirconium, nickel alloys, and composite materials.



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So again, all the advantages, disadvantages are listed. So the most important applications are reactive components, rocket engine parts, rotor hubs, missiles, bombers, space shuttles. They all use diffusion welding process. So in strategic application, diffusion welding process is very important. Why at all diffusion welding process?

Because when you want to make a complex shape, you cannot make it with any single manufacturing process. So we make it piecemeal and join it.

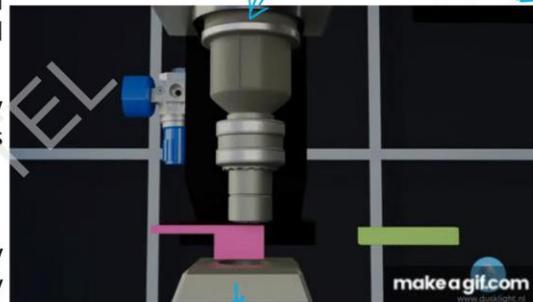
## Ultrasonic Welding



- Ultrasonic welding is a solid state welding process where in coalescence is produced between a wide range of similar and dissimilar combinations of metals.
- By the local application of high frequency vibratory energy in very short cycle times without melting the materials being joined.

### Principle of Operation:

- A power supply converts low-frequency electrical energy into high-frequency electrical pulses.
- The pulses are transformed into mechanical vibrations by a transducer.
- A coupling system applies these vibrations with clamping force to the weld interface.



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The next one is the ultrasonic welding process. There is a fixed plate here. This is a fixed plate. The workpiece is held. The workpiece can be similar material, dissimilar material, thin material, or slightly thicker. Thicker means I am talking about 3 millimeters, 4 millimeters. That itself is too large. We generally talk about 0.1 millimeter to 1 or 1.5 millimeters.

So this is one end. The other end is attached to an ultrasonic horn. This ultrasonic horn vibrates at 21 kilohertz. With an amplitude of maybe 6 to 20 microns. So, the top surface of the plate is pressed by the ultrasonic horn.

Ultrasonic welding is a solid state welding process. Wherein the coalescence is produced between a wide range of similar and dissimilar material combination. By a local application of high frequency, 21 kilohertz, with a very short cycle time, kilohertz are there. So cycle time is very less, then with an amplitude of 6 to 20 microns is applied. So the surfaces are cleaned, and then the nascent surface come in contact, the joining happens.

So the operation, the power supply converts the low frequency energy into a high frequency energy pulse. The pulse are transformed into a mechanical vibration by a transducer. So once there is a vibration, there is a heat, the cleaning happens and the heating happens, so diffusion happens.

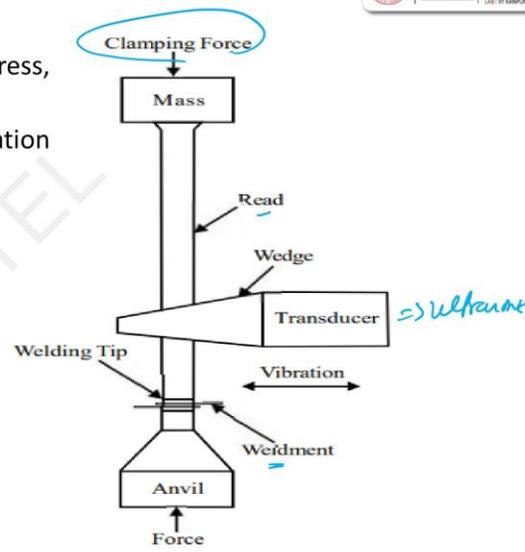
## Ultrasonic Welding

- The clamping force generates uniform stress, radiating from the dimpling point.
- Stress distribution shifts during the vibration cycle, alternating sides of the clamp point.

### Welding Equipment

The ultrasonic welding equipment consists of

- Power supply. ✓
- Transducer. ✓
- The coupling system. ✓
- The clamping system. ✓



So here is the clamping force. The clamping force is given by a mass. So this is the the holding right. This is the read this is the wedge where you are trying to give a transducer which is ultrasonic. And there is a vibration which is given you can do it along the axis horizontal. To the axis vertical to the axis inclined at an axis you can try all these things. So, transducer is kept vibration happens.

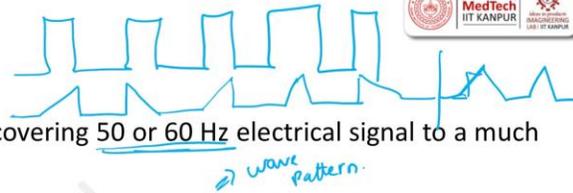
So, the weld tip is there. So, you have weldability, then there is an anvil. So, mass anvil force is there. So, it is pressed together, and then the welding happens.

# Ultrasonic Welding



## Power Supply:

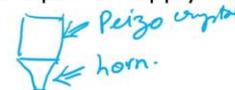
- The USM power supply is responsible for covering 50 or 60 Hz electrical signal to a much higher frequency signal. *21 kHz*
- This is accomplished through the use of a frequency generator and amplifier.
- The frequency generators used for various welding applications are capable of operating at frequencies from 10 to 75 KHz



## Transducer:

- The role of the transducer is to convert the electrical energy from the power supply into mechanical energy that will perform the welding.

*Piezo Crystal*



## The Coupling System:

- The coupling systems transmit the high frequency vibrations from the transducers to the work piece.



So, in the ultrasonic weld, power supply is very important; low frequency to high frequency has to be done. There is a transducer. The transducer is basically a piezoelectric material. We will see that, a coupling system, and a clamping system. So, these are all the parts of welding equipment, like in your AC power supply, you have a transformer. We are also trying to look at some details of the welding equipment. So, the power supply is responsible for converting 50 or 60 hertz to a very high frequency of 21 kHz.

So, it is done by a function generator and an amplifier. In the function generator, you can also try to have wave patterns. See, the function generator will do something like this. It is activated. Now, these are all square pulses.

So, you can also try to have a sawtooth. You can try to have a tuck like this. Whatever you can try to change like this, or you can also try to change and play with it. You can also try to have something like a trapezium type. That is also possible.

So, this is one square. You can have a rectangle, you can have a triangle. You can have it so you can start like this and try to have a triangle type, right? These are all different wave patterns which are generated by the function generator. The amplitude is only 6 to 20 microns. So, the frequency generator used for various welding operations is capable of operating between 10 hertz to 75 kilohertz. The role of the transducer is to convert electrical energy from the power supply into mechanical energy.

This is done by the piezo crystals. The piezo crystal which is there—so you apply voltage, it expands. So now, the piezo crystal can be oriented in many directions. You can do it perpendicular, you can do it along. You can cut the piezo crystal at an angle so that you get whatever you want.

So, a piezo crystal is used; the same piezo crystal is also used for force measurement. So, in force measurement, mechanical energy is converted into electrical energy. Here, electrical energy is converted into mechanical energy. The coupling system transmits the high-frequency vibration from the transducer to the workpiece. This is where we use the horn.

So, what happens is this is a function generator; the function generator is attached to a horn, which is called the horn. This is the function generator, or these are piezo crystal materials. Why is there a horn? Because this horn amplifies the small signal, whatever is there, to a large amplitude. So, the coupling system transmits the high-frequency vibration from the transducer to the workpiece.

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## *Ultrasonic Welding*

### **Advantages:**

- No critical surface preparation, and no defects from arc, gases, or filler metals.
- Can join dissimilar metals with different melting points and causes minimal surface deformation.
- Short welding cycle, low energy consumption, and material properties remain unchanged.

### **Disadvantages:**

- Limited to thin materials (3 mm for aluminum, 1 mm for harder metals).
- Materials may weld to the tip and anvil, shortening equipment lifespan due to fatigue.
- Hard materials fatigue under welding stress.

### **Applications:**

Joining electrical and electronic components, thermatic sealing of materials and devices, welding aluminium wire and sheet, and fabricating nuclear fuel elements.



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So, the advantages are no critical surface preparation is required. Joining of dissimilar materials is possible, with short weld cycles and low power consumption as the advantages. So, joining of electrical and electronic components, hermetic sealing of

materials and devices, welding aluminum wire and sheet, and fabrication of nuclear fuel elements can occur under the ultrasonic welding process.

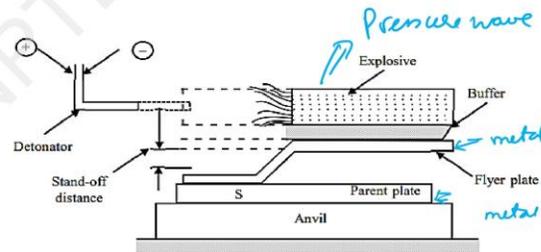
## Explosive Welding



- Explosive welding is a solid state welding process where in coalescence is effected by high velocity movement produced by a controlled detonation.

### Principle of Operation

- Welding is achieved by detonating an explosive layer on one piece, generating kinetic energy that causes plastic deformation and removes surface contaminants, resulting in a high-quality joint.



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<https://tristatefabricators.com/types-of-welding/>

The other process, which is completely different, is the explosive welding process. In the explosive welding process, what we do is we try to keep dissimilar materials. So, you can see here this is a parent plate, this is a flyer plate, okay. The flyer plate is one of two plates: the base plate or one metal, and this can be the other metal, okay? Same material or dissimilar material. So, now on top of this flyer plate, we try to place an explosive. In the explosive, what happens is it tries to create a pressure wave.

When it explodes, it creates a pressure wave. This pressure wave is kept inside a container or something. So the wave tries to push the flyer plate against the parent plate. So there is a settlement happening between the flyer plate and the parent plate. This leads to joining.

So here it will be, by and large, surface joining. Surface-to-surface is a solid-state welding process. Wherein coalescence is affected by a high-velocity movement produced by a controlled detonation. So, this is a very powerful process; generally, people try to use it for very large surfaces. And for very complex surfaces, if you want to cover them, they use this explosive welding process.

Welding is achieved by detonating an explosive layer on one piece, generating kinetic energy that causes plastic deformation. It removes surface contamination, resulting in a high-quality joining. This is again used in the aerospace industry.

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## Explosive Welding



### Advantages:

- Welds heat-treated metals without affecting microstructures and bond large surfaces.
- High joint strength and can clad a wide range of thicknesses.
- Foils can be bonded to heavier plates.



### Disadvantages:

- Use of explosives is restricted in industrial areas due to noise and vibrations.
- Metals must have ductility and impact resistance.
- Metals thicker than 62 mm require high explosive loads for joining.

### Applications:

Joining dissimilar metals, die-casting components, and fabricating heat exchangers and pressure vessels. It also clads pipes and tubes.



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Welding heats metals without affecting the microstructure, and the bond layer surface is achieved because we are able to join them. The disadvantage is that the use of explosives is restricted in industrial areas.

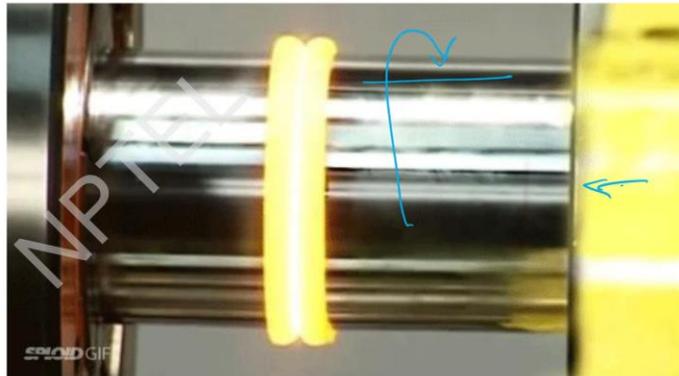
Joining of dissimilar materials, die-cast components, and fabricated heat exchangers and pressure vessels has also been tried. Cladding of pipes and tubes is also possible. So pipes—so you have a large-area pipe. Then you have another large-area pipe. Suppose, let us assume this is one pipe.

This is the other pipe. So you want to do pipe-to-pipe joining. Many times, we try to expand this pipe and push this. If it is a long pipe, it is very difficult. So what we do is we keep this as a loose fit.

This is pushed into it, and then inside it, we keep an explosive so that it gets pushed, and then it tries to join. So, dissimilar pipe joining is very efficiently done here.

## Friction Welding

- Friction welding, also known as “*inertia welding*”, is a solid-state process where two cylindrical parts are brought into contact with friction pressure, causing heating and forming a joint when pressure is applied.
- The joint strength depends on rotational speed and axial force.
- This method eliminates the need for filler metals, fluxes, or shielding gases and is ideal for butt welding round bars or tubes.



Next is the friction welding process. Friction welding, also known as inertia welding, is a solid-state welding process. In this process, two cylindrical parts are brought together, causing high friction.

Due to the high friction, you can also try to rotate them. Two cylindrical parts are brought into contact with friction pressure, causing heating and forming the joint as pressure is applied. You can either apply pressure this way or try to rotate one part. One part remains constant while the other rotates. This also creates friction.

The friction creates heat. That is why it is called the friction welding process. The heat is created, and then pressing occurs. No foreign element is attached or added to it. The joint strength depends on the axial speed and the axial force.

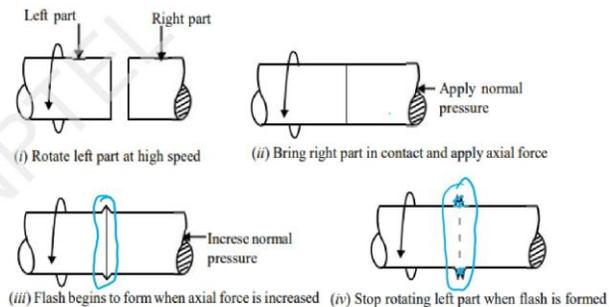
So, you apply force, and you rotate. The combination is very much talked about. You can try to have a solid workpiece to be welded. You can also have tubes to be welded; tube welding of dissimilar materials is possible. The method eliminates the need for a filler metal, flux, or a shielding gas. And it is ideal for butt welding of round bars or tubes.

# Friction Welding



## Principle of Operation

- In friction welding, coalescence is achieved through heat generated by the sliding motion between rubbing surfaces.
- One component is rotated at the desired speed, while the other remains stationary and moves forward to contact the rotating part.
- Pressure and rotation are maintained until the metal reaches a plastic state.
- Braking is applied to stop rotation, and axial force is increased to weld the components together.



<https://tristatefabricators.com/types-of-welding/>

So, the principle is first you have a right part and a left part; the rotation happens in the left part. So, it is brought in contact with the right part, and parallelly you also apply pressure. And then, when the pressure keeps on increasing, there is a flash that is getting formed—this flash. We saw in flash butt welding; this flash is getting formed.

And here, you can see the joining is happening, and the flash projection occurs. So now, later we can trim this portion and then make this dissimilar joining. So, the entire process, whatever I discussed here, is given in detail: rotation. Then you try to press it; then pressing will increase, then there is a flash happening, joining happens—friction.

# Friction Welding

## Advantages:

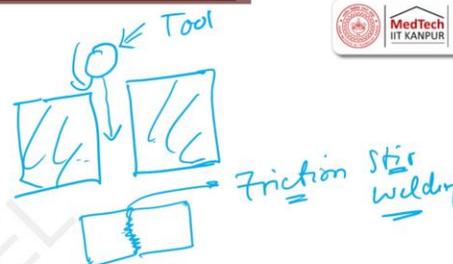
- High quality welds.
- Very little loss of material through exclusions.
- Annealing of weld zone is not necessary.
- The heating zone being very thin, therefore dissimilar metals easily joined.

## Disadvantages:

- The parts to be welded must be essentially round and must be able to withstand the high torque developed during welding.
- The method is limited to smaller components.

## Applications:

HSS twist drills, gas turbine shafts, refrigerator tubes (dissimilar metals), sintered products, string columns, aero-engine drive shafts, and valves.



So, twist drill bits, gas turbine shafts, refrigerator tubes, sintered products, string column, aero engine drive shafts, and valves. All these things are joined by the friction welding process. If you have ceramic-to-metal joining, the friction welding process can be considered. If there is a twist drill, HSS material, or this is a tungsten high-strength material, high wear-resistance material. The shank, where we hold it in the sleeve, is made to be a soft material. So, these two can be joined by the friction welding process. Gas turbine shafts, yes, and then refrigerator tubes are also made by the friction welding process.

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## Forge Welding



- Forge welding is the oldest method of welding in the category of solid state welding.
- Surfaces to be joined are heated till they are red hot and then forced together by hammering.
- Prior to forge welding, the parts are cleaned in order to prevent entrapment of oxides in the joint.
- It is a crude method of welding and quality depends upon the skill of the welder.

### Principle of Operation:

- The process is carried out by heating the components to be joined to a plastic state in a blacksmith's forge with upsetting edges.
- The hot work pieces are withdrawn in appropriate time and joined by repeated hammer blows.
- Borax in combination with ammoniac is the most commonly used flux in forge welding of steel.



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Forge welding process, and here, interestingly, in friction welding, you can also have two plates here, right? And then you can have a tool. I am drawing the plan view; this is the workpiece. This is the workpiece; it can be similar or dissimilar. Here is a tool; I am drawing the plan view. So, the tool rotates and then is moved inside the two metals.

Now, this rotating tool creates friction between these two plates, and then you try to have a joining here. This is also friction. This is called the friction stir welding process. So, wherein the steering action happens by the tool, and friction is introduced by the tool. When it comes in contact with the workpiece, that helps to soften the material, and then you try to join them. So, this is also part of the friction welding process.

Now moving to the forge welding process. The forge welding process is one of the oldest welding methods in solid-state welding. The surfaces are joined or heated until red hot and then forced together by hammering. So you keep a base plate, heat it, then forge it. So you can keep a die and do it, or you can keep a hammer and do it.

So this is how it is done. If you see the olden-day wooden carts, you have a wooden wheel. And then on top of it, there is a shrink-fit metal ring to reduce wear. A wooden wheel on top of it will have a metal ring. So there also, what they do is a forge welding process.

It is a shrink-fit, but they do a forge welding process for joining at the edges. The process is carried out by heating the component to be joined to a plastic state in a blacksmith forge with the upset edge. The hot workpieces are withdrawn at the appropriate time, and the joining is done repeatedly. Borax in combination with ammonia is the most commonly used flux in the forging process.

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## *Forge Welding*



### **Advantages:**

- Good quality weld may be obtained
- Parts of intricate shape may be welded
- No filler material is required.

### **Disadvantages:**

- Welding is restricted to wrought iron and mild steel Slow welding process.
- High level of the operator's skill is required.
- Weld may be contaminated by the coke used in heating furnace.

### **Applications:**

Railroad and general repair shops, manufacturing pipes from rolled plates, metal art pieces, and welded tubes.



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Railroads, general repair shops, manufacturing pipes from rolled plates, metal art pieces. And welded tubes are all part of the forged welding process.

# Thermochemical Welding



## Thermit Welding:

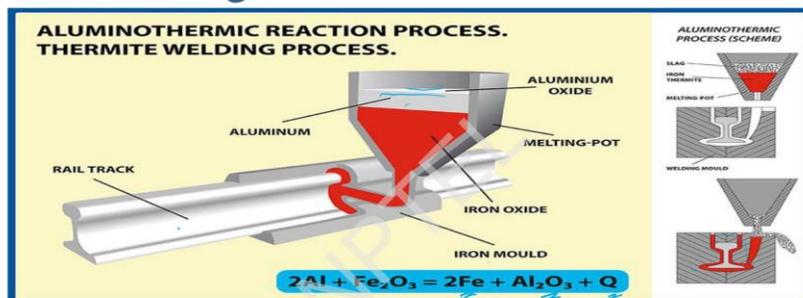
- Thermit welding is the method of uniting iron or steel parts by surrounding the joint with steel at sufficient high temperature to fuse the adjacent surface of the parts together.
- In this process the coalescence is produced by heating with superheated liquid metal and slag resulting from chemical reaction between a metal oxide and aluminium with or without the application of pressure.

## Principle of Operation

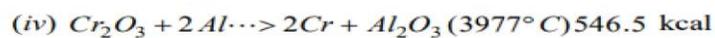
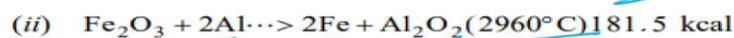
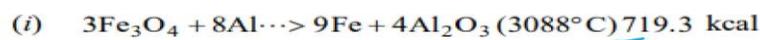
- Thermit welding is based on casting and foundry practice and consists essentially of providing, by means of a chemical reaction, a volume of molten weld metal which is poured into the joint to be welded.
- The chemical or thermit reaction takes place between a metal oxide and a metal reducing agent. The chemical affinity of aluminum for oxygen is the basis for the thermit process. Thermit reaction is an exothermic one.



# Thermit Welding



A few typical thermit reactions are



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The thermochemical welding process, so here it is thermochemical—there is heat, and there is a chemical flux phenomenon happening. Thermit welding is a method of uniting iron or steel parts by surrounding the joint with steel at a sufficiently high temperature to fuse the adjacent surfaces of the parts together. Here, the chemical components are mixed, and you bring the two metals together. There is a reaction, and this reaction forms the joint. Thermit welding is based on casting and forging practices.

It consists essentially of providing, by means of a chemical reaction, a volume of molten weld metal, which is poured into the joint during welding. You try to take a container outside, do the chemical heating to create a reaction, a liquid is formed, and you pour it like casting. The chemical or thermit reaction takes place between the metal oxide and a metal-reducing reagent. The chemical affinity of aluminum for oxygen is the basis for the thermit process.

Thermite reactions are exothermic in nature. So, what we do is we have a hopper filled with aluminum, and then we have aluminum oxide. So, here, there is a reaction happening. So, the aluminum—whatever is there—you have iron oxide. So, let me explain.

So, it is an aluminothermic reaction process shown here. You have a railway track. Then we have aluminium, which is there. The aluminium melts, and aluminium will always have an oxide on the top. So, this is a pot in which the melt has happened, and then you have iron oxide and an iron mould is also used. So, the mould is to make sure that it tries to guide; it is like a gating system, it tries to guide the material to the portion.

So, if you see here, the aluminum is on the top—aluminum-aluminum oxide—and iron thermite is here. So, it melts and pours down, and then it tries to fill the entire region. The aluminum, whatever is there, once the filling happens, whatever is the aluminum and aluminum oxide where the reaction happened, that will try to be oozed out and gone.

So,  $2\text{Al} + \text{Fe}_2\text{O}_3 \rightarrow 2\text{FeAl}_2\text{O}_3 + \text{Q}$ . So, this is the reaction. You can try to see there are similar other reactions also possible. You can try to have  $\text{Fe}_3\text{O}_4 + 8\text{Al} \rightarrow 9\text{Fe} + 4\text{Al}_2\text{O}_3$ . So much heat is released. So, the  $\text{Fe}_2\text{O}_3 + 2\text{Al} \rightarrow 2\text{FeAl}_2\text{O}_3$ , and it forms this compound. If these corrections have to be done, be very careful.

## Thermit Welding

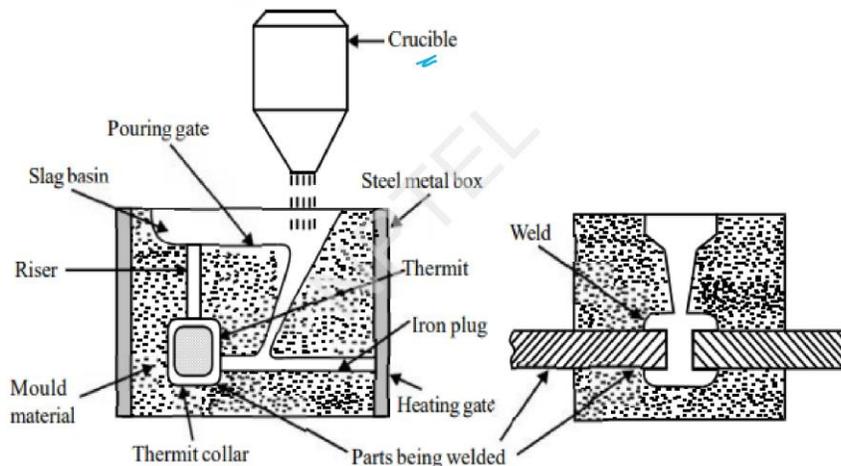
The desired size and shape of the wax pattern are prepared around the joint.

- The pattern is encased in a sheet iron box, with sand packed and rammed around it.
- After curing, heating gates and risers are prepared, and the wax is melted and drained by flame heating, raising the parts temperature.
- Thermit mixture (aluminum and iron oxide) in a crucible is ignited, producing superheated (3000°C) molten iron and aluminum oxide slag.
- The molten iron flows into the mold, fusing with the parts and forming a thermit collar.



<https://makeagif.com/gif/thermitnaya-svarka-relov-thermite-welding-of-the-rails-ntuivb>

## Thermit Welding



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So, this is how it is done, and here is a video that shows that. So, we have a railway track on top and bottom, and then at the front side, and then this is the railway track. So, we try to react the reaction, and the liquid is poured at the joints.

So, you try to get it and then keep moving. A pattern is encased in a sheet of iron oxide with sand packed and rammed around. After curing, the heating gates and the riser are prepared, and the wax is melted and drained by flame heating. The raising of the part temperature, the thermit mixture in a crucible is ignited, producing a lot of heat. And then, the molten iron and the iron oxide slags are formed.

The molten iron flows into the mold, flushing the part and forming the thermit welding process. So, whatever we have said is clearly put in this figure or clearly placed in the figure.

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## Thermit Welding

### Advantages:

- The heat necessary for welding is obtained from a chemical reaction and thus no costly power supply is required.
- Can be used anywhere.
- Most suitable for welding of thick sections
- Not a highly skilled operation

### Disadvantages

- Thermit welding is applicable only to ferrous metal parts of heavy sections i.e., mill housings and heavy rail sections.
- High set-up and cycle time.
- The process is uneconomical if used to weld cheap metals or light parts.



So, advantages and disadvantages: here, the biggest advantage I see is that you do not need a power supply. And depending upon the thickness, whatever it is, you can try to pour material accordingly. The disadvantages: it is applicable only for ferrous parts. It has a high setup and cycle time. The process is uneconomical if used to weld cheap metals or lightweight materials.

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## Thermit Welding

### Applications:

Thermit welding is used chiefly in the repair or assembly of large components i.e.,

- (i) For repairing fractured rails (railway tracks)
- (ii) For butt welding pipes end to end



So, this is the application of thermit welding. A hopper is there, and the clamps are there; they do it.

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## Radiant Energy Welding

### Laser Beam Welding (LBW)

LASER

- The laser (light amplification by stimulated emission of radiation) beam welding process is the focusing of monochromatic light into extremely concentrated beams.
- It employs a carefully focused beam of light that concentrates a tremendous amount of energy on a small area to produce fusion.

### Equipment

The laser welding process comprises the following equipment

- (i) Electrical storage unit
- (ii) Capacitor bank
- (iii) Triggering device
- (iv) Flash tube that is wrapped with a wire
- (v) Lasing material
- (vi) Focusing lens mechanism
- (vii) Work table

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So, the radiant energy welding process. Laser beam welding: a laser, light amplification by stimulated emission of radiation, LASER. We will see the lasing effect later when we go through the machining part. The beam welding process is the focusing of

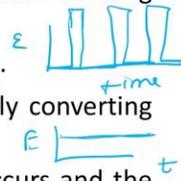
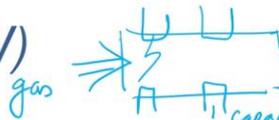
monochromatic light into an extremely concentrated beam. So, there is a huge heat flux that comes and hits, and then melting occurs. It employs a carefully focused beam of light that concentrates a tremendous amount of energy on a small area to produce fusion.

So, the laser beam process comprises the following: an electric storage unit, a capacitor bank, and a triggering device. A flash tube is there, then a focusing lens and a work table. So, all these things are equipment which are part of a laser.

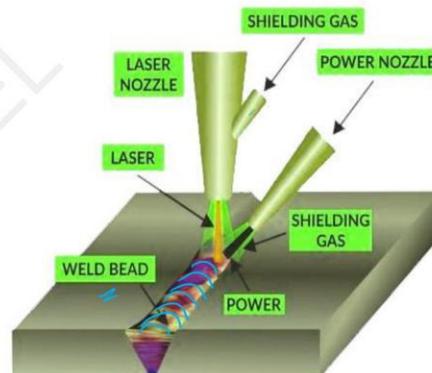
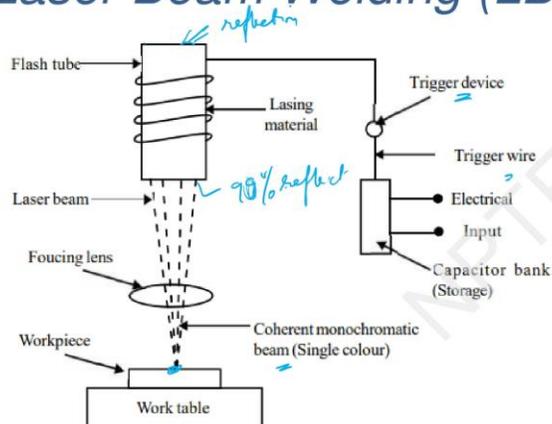
## Laser Beam Welding (LBW)

### Principle of Operation:

- When the capacitor bank is triggered, energy is injected into the wire surrounding the flash tube, creating imbalances in the material inside.
- Thick Xenon is often used to produce high power levels for brief periods.
- The flash tubes operate at thousands of flashes per second, efficiently converting electrical energy into light, which pumps the laser.
- The laser beam is then focused onto the work piece, where fusion occurs and the weld is made.
- Both the Nd : YAG (neodymium-doped yttrium aluminum garnet;  $\text{Nd:Y}_3\text{Al}_5\text{O}_{12}$ ) and  $\text{CO}_2$  lasers may be used for welding
- Since Nd : YAG laser is pulsed, it is used for producing spot and seam welds.
- $\text{CO}_2$  laser can produce deeper weld at higher rates of speed than possible with Nd : YAG laser.



## Laser Beam Welding (LBW)



So, when the capacitor bank is triggered, the energy is injected into a wire surrounding a flash tube, creating an imbalance in the material inside. So, here we are talking about a tube. There is a capacitor bank. So you have a capacitor. In this capacitor, high energy is stored, and there is a discharge. So there is a gas that is passing through. This is gas; this is a capacitor.

When a capacitor branch is triggered, the energy is injected into the wire surrounding a flash tube, creating an imbalance in the material inside. So a gas—I have written it as gas—so you can also have a wire. So there is a discharge; there is an imbalance. Xenon is often used to produce a high power level for a brief period. So during the discharge, the energy level goes very high.

A flash tube operates at thousands of flashes per second, efficiently converting electrical energy into light, which pumps the laser. So now the gas which is there is excited, and then it tries to have excited electrons. The laser beam is then focused on the workpiece where fusion occurs. Both Nd-YAG lasers and CO2 lasers may be used for welding. CO2 laser is gaseous welding; solid-state welding is Nd-YAG laser.

Since Nd-YAG is pulsed, it is used to produce spot and seamless. CO2 is continuous. So, why are they talking about pulse and continuous? Pulse lasers have very high energy density because pulsed means you are pulsing it. So, this is the energy; this is the time.

So, it goes flat, you have a peak, then it comes down, then it goes for a peak. So, these are pulsed ones. When you talk about continuous, the energy is constant with respect to time, E. So, here you have peak powers which are very high. So, that is why they are used for spot and seam welding.

CO2 lasers, the majority of the time or 99 percent, have a continuous laser with constant energy. The energy efficiency of CO2 is less than the Nd-YAG laser. So, this is the flash tube which we were discussing: flash tube, then we have a laser. Trigger device, wire is there, a trigger device is there. So here, what we do is the flash tube is surrounded by a coil.

So that coil creates the excitement inside the lasing material. Now the lasing material is excited and here we have partial. So this is 100% reflecting surface. Here we have partial reflecting surface, 99% reflecting surface or 90% reflecting surface. So moment there is a critical energy there, so then it gets released and this forms the laser beam.

The laser beam is broad, so you put a focusing lens to focus it on a smaller spot. So whatever comes out of this is a coherent monochromatic beam. So this tries to hit at the workpiece and the table is joining there. So if you want to see the picture wise this is what it is. So you have a laser nozzle.

So then you have a laser. So a shield gas is given so that the oxidation and other things are not formed. So if you want to add a powder you can add it or without adding a powder if you want to join you can join. Like in welding you have a weld beads are formed and then these weld beads they try to dictate the microstructure and the quality of the joining. So this is laser beam welding. More details about laser we will see during machining process.

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## Laser Beam Welding (LBW)



### Advantages:

- Dissimilar metals with varying physical properties can be welded.
- High precision welds can be made.
- Laser welding minimizes thermal distortion and shrinkage.
- Welding can be done in air or with shielding gas.

### Disadvantages:

- High energy loss and slow speed.
- Requires skilled operation and precise joint preparation.
- Limited to materials  $\leq 0.3$  mm thickness.

### Applications:

Used for cutting and welding metals like copper, nickel, and titanium.



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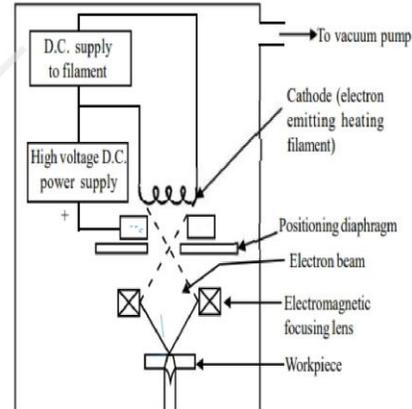
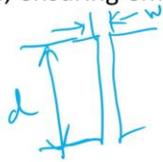
So again advantages and disadvantages are given. Used for cutting and welding metals like copper, highly conducting materials can be easily done. So this is how the machine at its focus looks like. So you have two work pieces. So laser comes and then there is a lasing action. So heat is applied at the joining portion.

## Electron Beam Welding (LBW)

- Electron beam welding uses a focused, high-velocity stream of electrons for deep fusion welds with minimal width, allowing the weld depth to exceed the width by up to 15 times.

### Principle of Operation:

- Electron beam welding fuses base metals by directing a dense stream of high-velocity electrons onto the workpieces.
- The process takes place inside a vacuum chamber to prevent electron velocity loss due to atmospheric particles, ensuring efficient melting of the metals.



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So the laser has larger diameter as compared to that of electron beam. So electron beam is also a similar process. Instead of light, here electron jet is generated.

This electron jet is focused by electrical lenses. So there it is optical, here it is electrical lenses. So this will try to focus the beam and try to hit it on the workpiece. So it hits on the workpiece, it has to be a conducting workpiece. Or we try to give a coating on top of it and make it conducting a thin layer and then the joining happens.

Electron beam welding uses a focused, high-velocity stream of electrons for deep fusion welding with minimal width. This allows the weld depth to exceed the width—depth to width. So, this is depth. And this is width. So, very high aspect ratio joining has to happen.

We use electron beam. The principles of operation: electron beam welding fuses base metal by directing a dense stream of high-velocity electrons onto the workpiece. The process takes place inside a vacuum because electrons can be scattered. They heat air particles or molecules. So, we want to focus it.

Thus, the entire operation is done inside a vacuum. So, you have a DC supply; a filament is there. The filament is excited by a very high current. This, in turn, emits thermions; there will be filters. Only electrons are extracted and pushed down further.

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## Electron Beam Welding (EBW)



### Advantages:

- Low thermal input, high purity, and sound welds with deep penetration.
- Suitable for welding high conductivity metals.
- High energy conversion efficiency (~65%).

### Disadvantages:

- High joint preparation, tool costs, and expensive equipment.
- Limited penetration, stand-off distance, and work size due to chamber limitations.
- X-ray shielding required for safety.

### Applications:

Welding of automobile, airplane, aerospace, form and other types of equipment including ball bearing over 100 mm.



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The welding of automobiles, airplanes, and aerospace forms. And other types of equipment, including ball bearings over 100 millimeters thick, use electron beam welding. Well, friends, these are the references we have used in preparing the slides. We have seen a spectrum of welding processes that will try to give you a feel for what process to choose and how to choose it.

Thank you very much.