Basics of Mechanical Engineering-2

Prof. J. Ramkumar

Prof. Amandeep Singh Oberoi

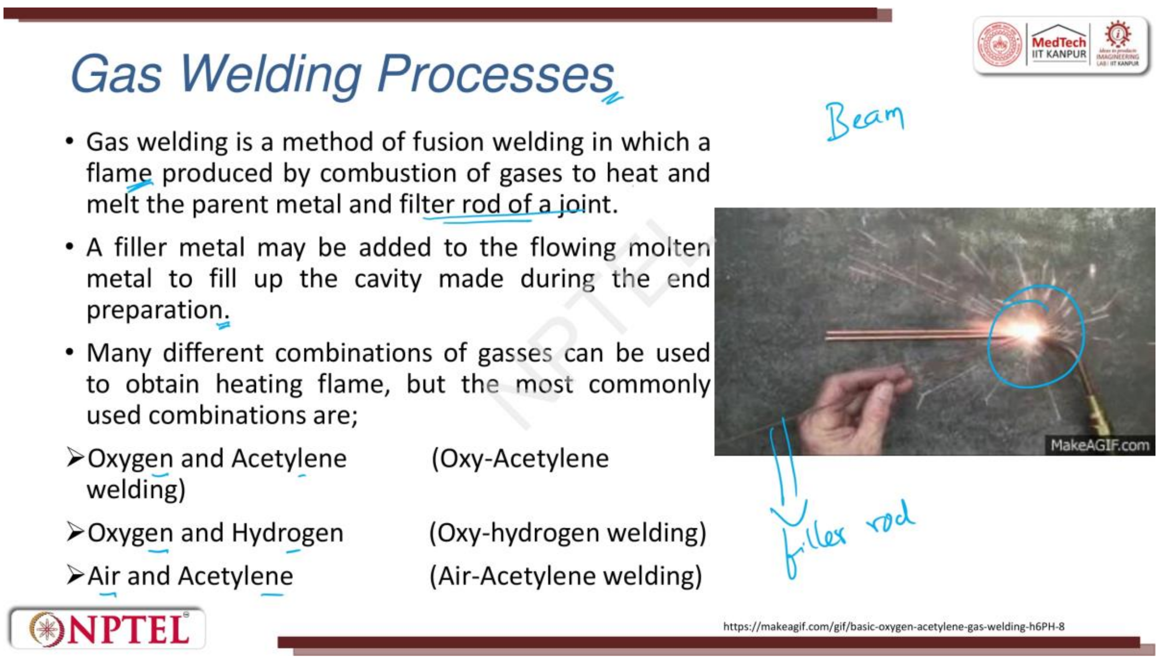
Department of Mechanical Engineering

Indian Institute of Technology, Kanpur

Week 08

Lecture 30

Basics of Welding (Part 7 of 7)



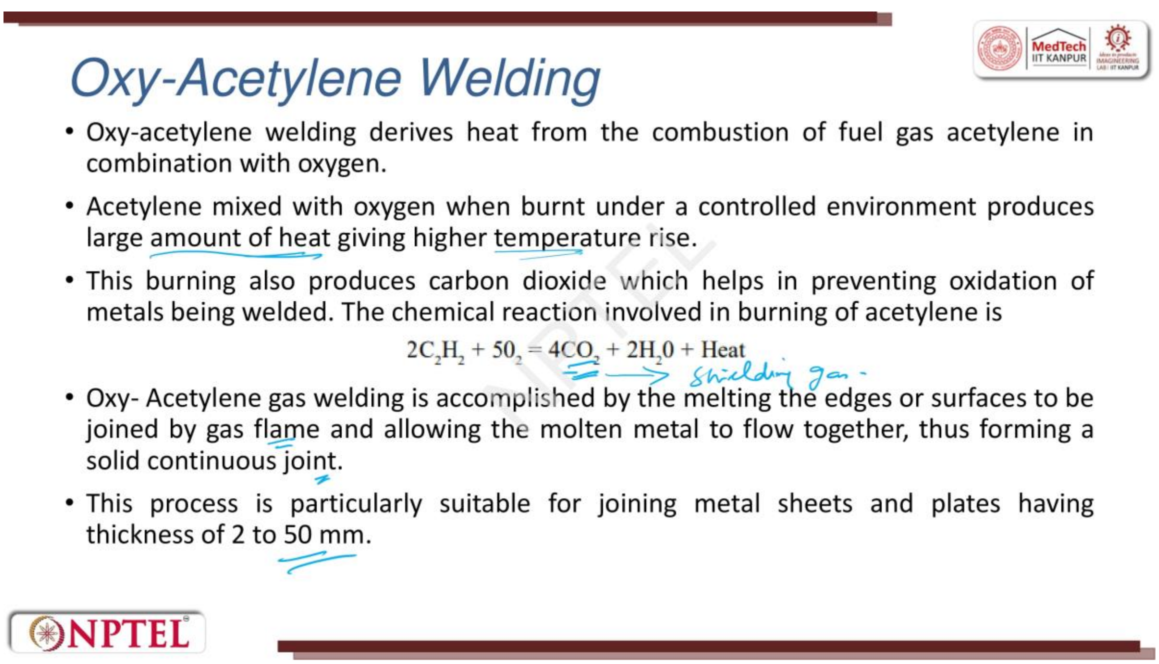
The other classification of welding processes is gas welding. Gas welding is a method of fusion welding in which a flame is used. Earlier, we saw a beam is used. Now we are saying a flame is used. If you have a flame or want to generate a flame, there has to be a gas medium.

It can be through plasma forming or a set of gases mixing, initiating the heat there. Gas welding is a method of fusion welding in which a flame is produced by combustion of gases. It heats and melts the parent material and filler rod of a joint. So we try to melt and add material. Copper-to-copper joining has to happen.

We do this by the gas welding process. A filler metal may be added to the flowing molten metal. It fills the cavity made during the edge preparation. Many different combinations of gases can be used to create the flame. It can be oxygen and acetylene.

It can be oxygen and hydrogen. It can be air and acetylene. So it is called as oxyacetylene flame, oxyhydrogen flame, air acetylene flame. So you will have two cylinders. Both the cylinders will be gushing the air.

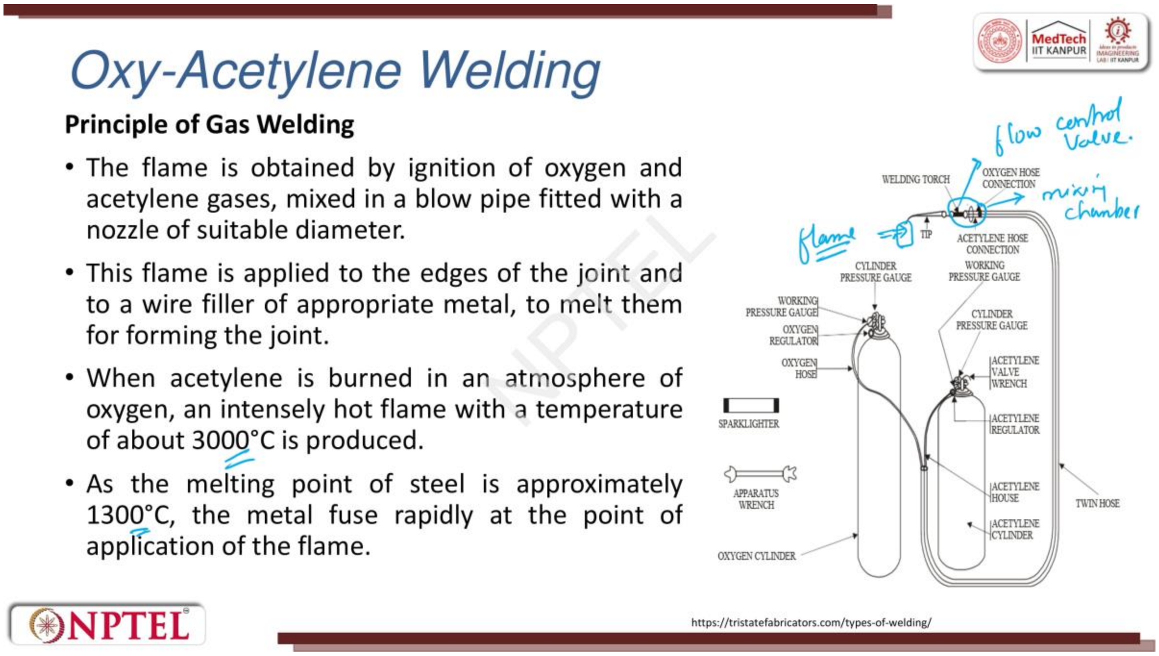
So it comes through a nozzle. At the nozzle what we do is we try to initiate a spark. So then the flame starts. Moment the flame starts, then you try to heat the parental material, start filling the filler. So, you can see in the hand what he has is a filler rod. Bracing is done by this, gas welding bracing we do and many other processes we do.



Oxi-acetylene welding derives heat from the combustion of a fuel gas acetylene in combination with oxygen. The acetylene mixed with oxygen when burned under controlled atmosphere produces a large amount of heat giving high temperature rise. This burning also produces CO2 which helps in preventing oxidation of the metal during welding. So, ethylene plus oxygen giving you carbon dioxide plus water plus heat.

So, this now becomes a protective shielding layer, a shielding gas. Oxyacetylene gas welding is accomplished by melting the edge or surface to be joined with a gas flame.

And allowing the molten metal to flow through, thus forming a continuous joint. You can join materials as thick as up to 50 millimeters using this oxyacetylene welding process.



So, you will have one cylinder, and then you will have another cylinder. So, these two cylinders—we try to take this cylinder. So here, before the welding torch, you will have a mixing chamber. Wherein individually, the flow of oxygen and the flow of acetylene can be controlled. Once you control it under pressure, here you can also try to do it. Then, after the mixing chamber, you will have a gas flow rate controller.

Through that, you can control the flow such that at the tip exit, I will create a flame. So here is a flame. So here, you will also have a flow control valve. A flame is obtained by igniting oxygen and acetylene gas mixed in a blowpipe fitted with a nozzle of suitable diameter. The flame is applied to the edge of the joint and the wire filler of appropriate metal to join them, forming a part.

The oxyacetylene flame can go up to 3000 degrees Celsius. As the melting point of the steel is approximately 1300 degrees Celsius. The metal fuses rapidly at the point, and the application of the joint happens.

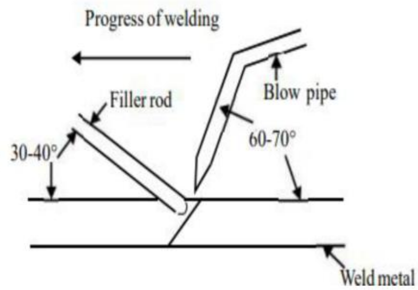
Welding Techniques

Depending upon the ways in which welding rod and the welding torch can be used, there are two usual techniques used in gas welding;

(i) Leftward or Forward welding (ii) Rightward or Backward welding

(ii) Leftward or Forward or Forehand Technique: (Pre heat)

- Welding starts at the right end and moves left,
- directing the flame towards the unwelded joint.
- Torch angle: 60°–70°; filler rod angle: 30°–40°,
- progressively fed into the flame. Preheats base
- metal for proper fusion; suitable for metals under
- 5 mm thick.
- Prevent contamination when restarting the weld



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

So, there are different techniques: one is called the forward technique, and the other is called the backward technique. So, this is the forward technique. So, in the forward technique, the weld starts at the right end and moves toward the left. Directing the flame toward the unwelded joint. So, the flame is directed toward the unwelded joint. So, right end and moves left, right. The progressively fed into the flame preheats the base metal for preheating.

Proper fusion is suitable for metal under a thickness of 5 millimeters. So, the torch angle is 60 to 70 degrees. The filler rod angle is around 30 to 40 degrees. So, the filler rod angle is given. This angle is also given. So this is joint.

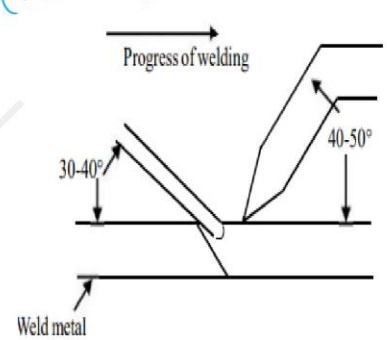
Welding Techniques

(ii) Rightward or Backward or Backhand Technique (Post heat)

Welding starts at the left end and moves right, with the torch flame directed at the completed weld.

Filler rod is positioned between the flame and completed weld, annealing the weld to relieve residual stress.

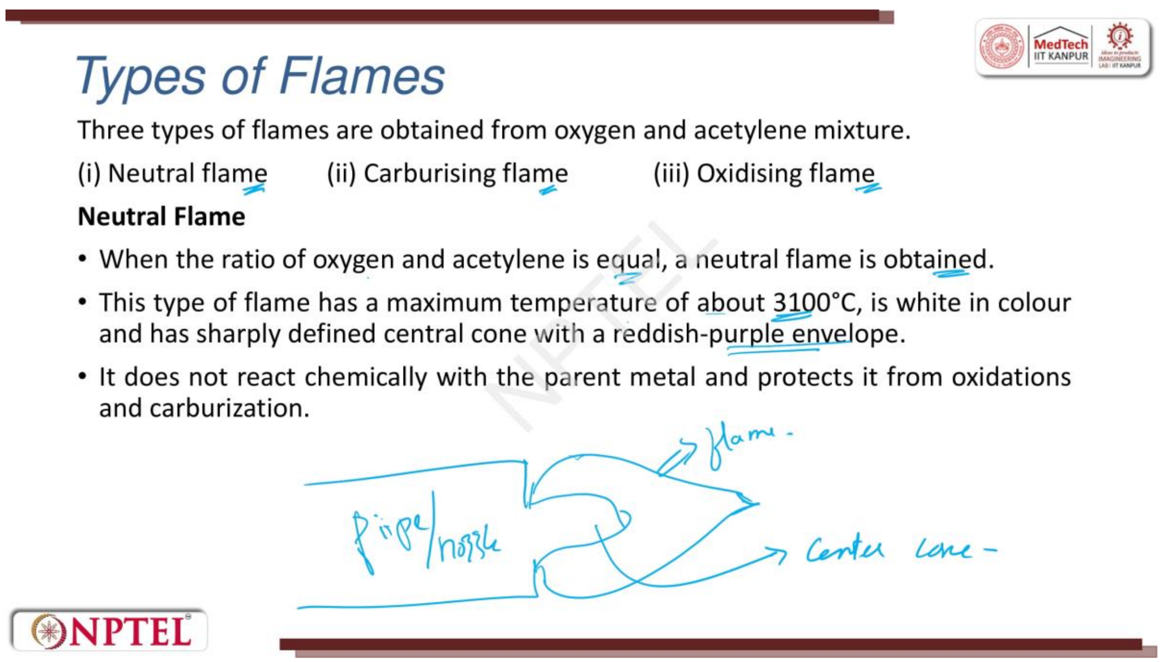
Smaller metal volume reduces shrinkage, distortion, and filler rod usage, lowering welding costs.



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

From rightward or backward, the weld starts from the left and move towards the right. The torch flame directs at the completed weld. So, the first one is something like a preheat. So, we can write it here.

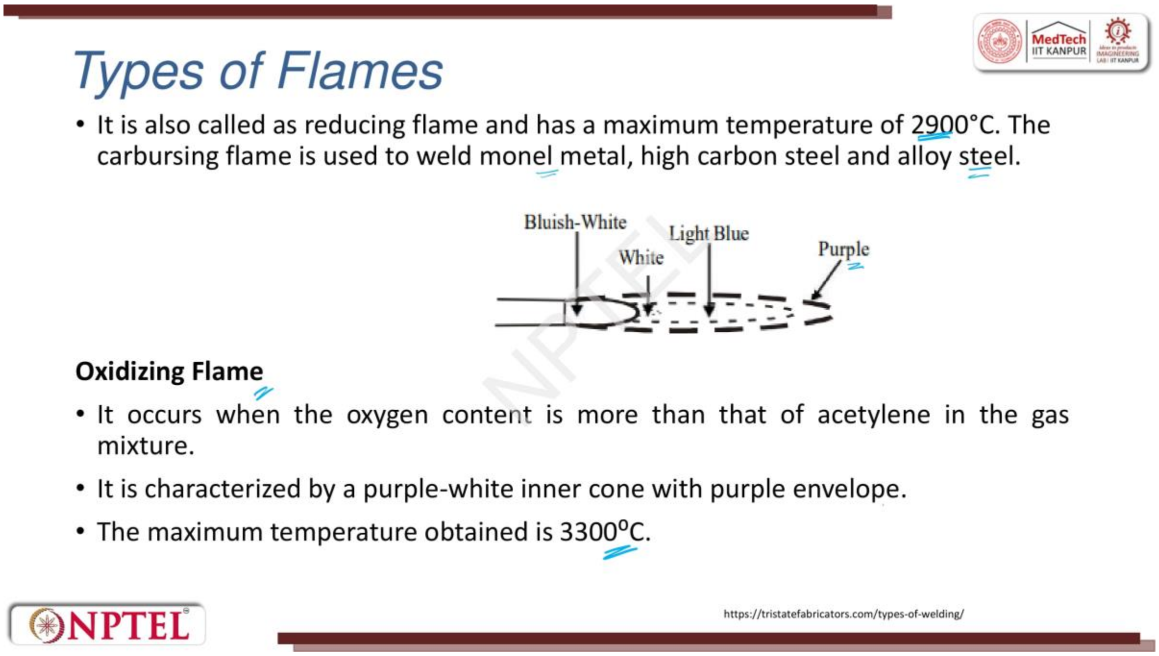
This is a preheat of the previous one and this is something like a post heat. Why is that post heat? Some defects or oxides or something has to be removed. It can be removed when we do it in the backward direction.



So there are three types of flames. One is called as neutral flame, carburizing flame and oxidizing flame. Why are these things important? Because all these things have its heat which is getting generated very important. So, and how do you make this neutral carburizing and oxidizing? Based upon the compositional difference between the two gases which is filled.

Neutral flame, when the ratio of oxygen and acetylene is equal, the neutral flame is obtained. This type of flame has a maximum temperature of about 3100 degrees Celsius. It is white in color and has a sharply defined central cone with a reddish-purple envelope. So, what we are trying to talk about is something like this. You have an envelope, then you have a cone inside, and this will be the flame.

So, this is the pipe or the hose or the nozzle; this is the flame. This is the central cone. And here we talk about the envelope. So, this is the envelope. It does not react chemically with the parent metal and protects it from oxidation—neutral.

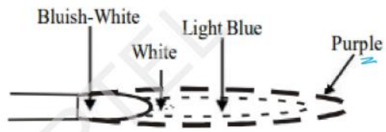


This is the cone, and this is the complete flame envelope. So here we say purple, here we say light blue, here we say bluish-white. The neutral flame is used to weld mild steel, stainless steel, cast iron, copper, and aluminum. When we talk about a carburizing flame, an excess of acetylene is created for a carburizing flame. It consists of three zones: the luminescent zone, the feather zone, and the outer envelope.

So you have seen the outer envelope. So you have three zones. So now basically what we do is we try to change the three zones such that you try to get the maximum temperature.

Types of Flames

- It is also called as reducing flame and has a maximum temperature of 2900°C. The carbursing flame is used to weld monel metal, high carbon steel and alloy steel.



Oxidizing Flame

- It occurs when the oxygen content is more than that of acetylene in the gas mixture.
- It is characterized by a purple-white inner cone with purple envelope.
- The maximum temperature obtained is 3300^{o}C.

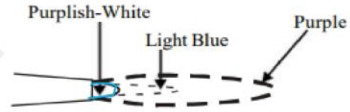
https://tristatefabricators.com/types-of-welding/

It is also called as reducing flame. Carburizing flame is also called as reducing flame and has a maximum temperature somewhere close to 2900 degree Celsius.

The carburizing flame is used to weld molyne metal, then it is also used for high carbon steel and alloy. So here carbon, this carbon should not get diffused. So once the carbon get diffused, it forms a highly brittle material. Oxidation flame, it occurs when the oxygen concentration is more than the acetylene. It is characterized by a purple white inner core with a purple envelope. The maximum temperature is 3000 degree Celsius. So this is what it is.

Types of Flames

- It is used to weld nonferrous metals and alloys such as copper, brass, bronze and zinc alloys etc. This flame is harmful for steels, because it oxidizes the steels.



Gas Welding Equipment For gas welding following equipments are used.

- Gas cylinders
- Pressure regulators
- Pressure gauges
- Welding torch
- Hoses and the Hose fitting
- Safety device etc.

NPTEL

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

So you can see how small is the whitish flame. So you see the white flame, how it is broad, it is elongated, it is thin. Then you see the light blue flame occupying a larger area.

Here it is thinner and then here it is much thinner. So the purple environment you see here in the oxidizing flame. The purple is projecting for a long distance. And here you can see purple is very small, the light blue is dominating. And in this it is just touching with each other.

So now you know the temperatures, you know the flame characteristics. Now you accordingly place your filler to get the melting whatever you want.

Gas Welding Equipment

Oxygen Cylinders

- Oxygen cylinders are painted black and the valve outlets are screwed right handed.
- The usual size of oxygen cylinders are 3400, 5200 and 6800 lit .
- For safety purposes oxygen cylinders are fitted at a pressure 12500 to 14000 KN/m^2.

Acetylene Cylinder

- An acetylene cylinder is painted maroon and the valves are screwed left handed.
- The usual size of acetylene cylinders are 2800 and 5600 lit.
- The cylinder is usually fitted to pressure of 1600 to 2100KN/m^2.

So the equipments when we see we have cylinders. The cylinders are attached with a regulator. These regulators are attached with a pressure gauge.

Because we have to know what is the cylinder pressure and regulate such that the gauge. We know what is it there. Then a weld torch, a hose pipe to fit the gas to the weld torch and the safety device goggles. So oxygen cylinder, oxygen cylinders are painted black and the valve outlet are screwed right handed. This is very important because there are cylinders when you do oxygen flame gas sealed welding.

So, you will see cylinders, and you have to identify which cylinder is what. So, oxygen is painted black, and it has a right-handed screw. The size of the oxygen cylinder is 3400, but it should be taller: 5200 liters, 6800 liters. The pressures are fitted with values of 12500 to 14000 kilo Newtons per meter square. Acetylene cylinders are painted maroon, and their valves are left-handed.

So, we are talking about only oxygen and acetylene, and here we saw three things: neutral, oxidation, carburizing. So, depending upon the composition, they are usually of a smaller height, the height is small, and they are up to 5600 liters. The cylinder pressures are lower compared to oxygen; they are lower.

Gas Welding Equipment

Pressure Regulators

- The cylinders are provided with pressure regulators to control the working pressure of oxygen and acetylene to the welding torch.
- Value of supply pressure depends upon inside diameter of outlet nozzle, supply flow rate of gas.

Pressure Gauges

- Pressure gauge measures the pressure with respect to the atmospheric pressure.
- Two pressure gauges are mounted on each of the cylinders.
- One for knowing pressure of gas inside the cylinder which is the measure of gas content inside the cylinder.
- Second gauge is used to know the supply pressure of the gas to below pipe.
- Former gauge is called cylinder pressure gauge and later one is called outlet pressure gauge.

Pressure regulators play an important role. So, you regulate the pressure such that at the torch exit, you get the flame. The pressure gauges are used to monitor the pressure. So, you have two pressure gauges mounted on each cylinder. One for knowing the pressure of the gas inside the cylinder, which is measured as the gas content inside the cylinder. The second gauge is used to know the supply pressure which comes out. So two gauges are there.

Gas Welding Equipment

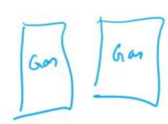
Welding torch or blowpipe

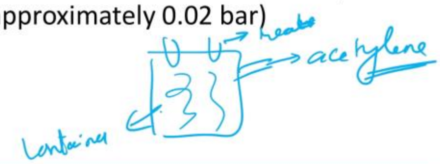
- It is used for moving oxygen and acetylene in the required volume and igniting it at the mouth of its tip.
- There are two types of welding torches available.

(i) High pressure (or equal pressure) type.

(ii) Low pressure (Injector) type

- **High-pressure** blow pipes or torches are used with (dissolved) acetylene stored in cylinders at a pressure of 8 bar.
- **Low-pressure** blow pipes are used with acetylene obtained from an acetylene generator at a pressure of 200 mm head of water (approximately 0.02 bar)

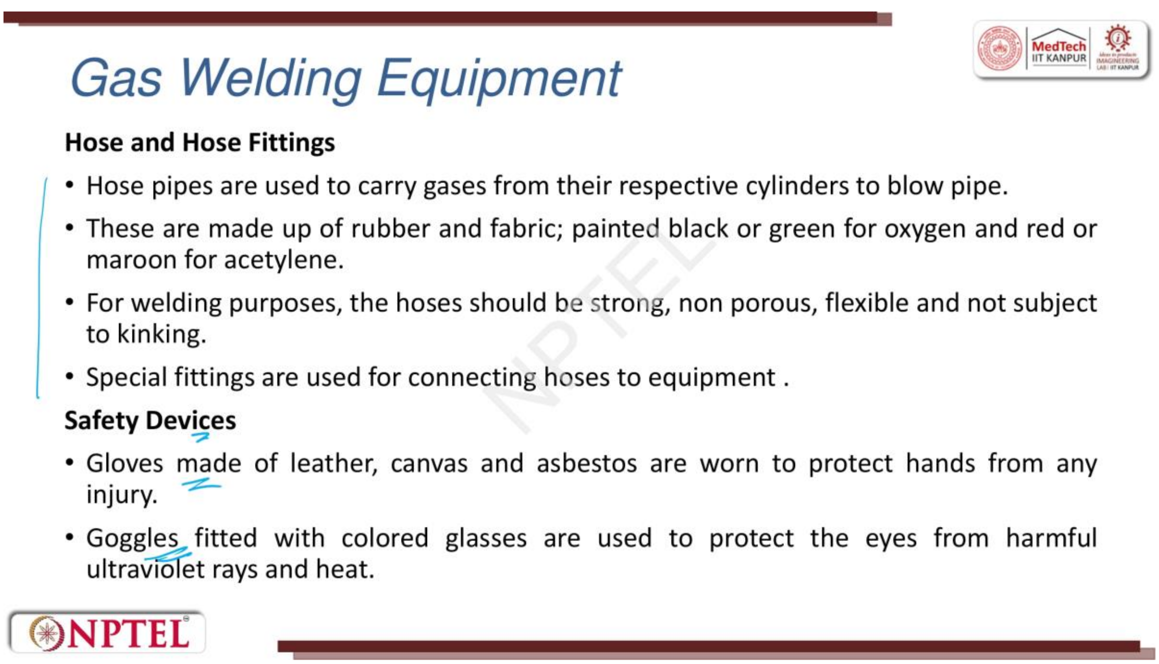




Torch, we have seen there are two types of torch, high pressure torch and low pressure torch. High pressure torch where blowpipe or torch are used with acetylene stored in the cylinder at a pressure of 8 bar. Low pressure, the blow pipes are used with acetylene obtained from an acetylene generator at a pressure of 200 mm head of water. So you can have, interestingly today, what we are talking about is these are gas cylinders we are having.

Now what we are trying to say is, we are trying to say let us generate. Maybe you fill it with water, you fill it with some liquid and then you have a heat source. From here, you generate acetylene. From this, you generate acetylene. That acetylene is used for adjoining.

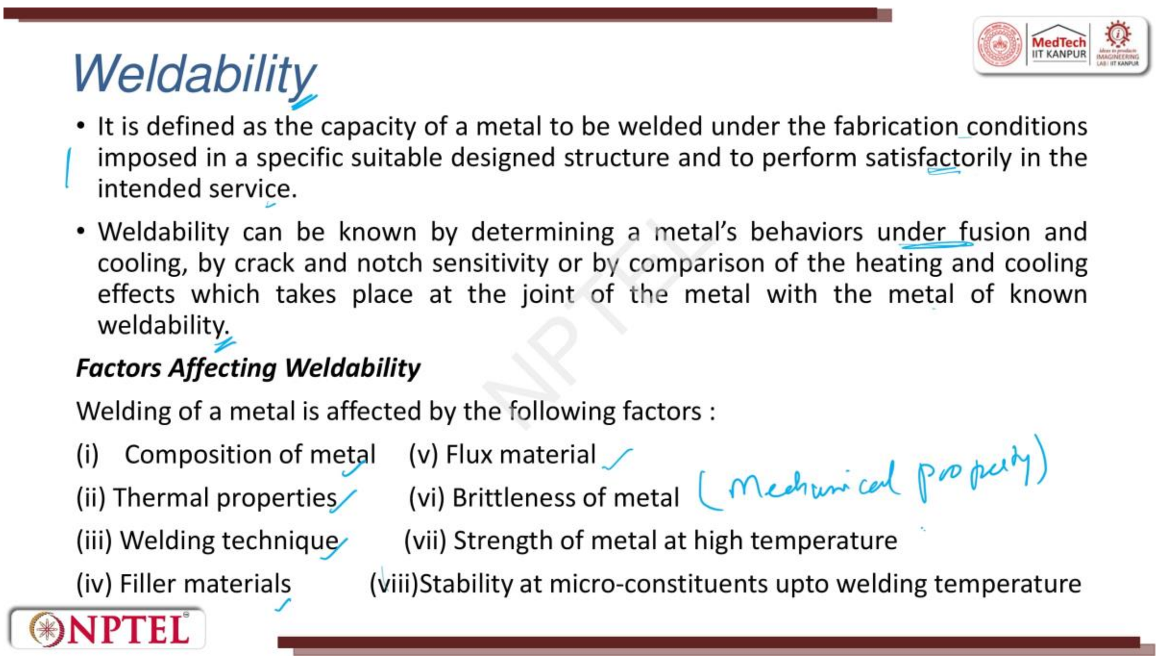
So, high pressure blow pipes are used with acetylene obtained from an acetylene generator. So, this is now a generator. These are heat sources or electrodes. So, this is a container. Acetylene is generated. So you can use from a gas cylinder or from a generator.



Hose pipe, these are all diameter fixed depending upon your requirements. And in welding, we have already seen the welding shield will be used when we do arc welding.

Here we have to use goggles because there will be spatter and that can hit your hands or eyes. So you have to use the safety goggles.

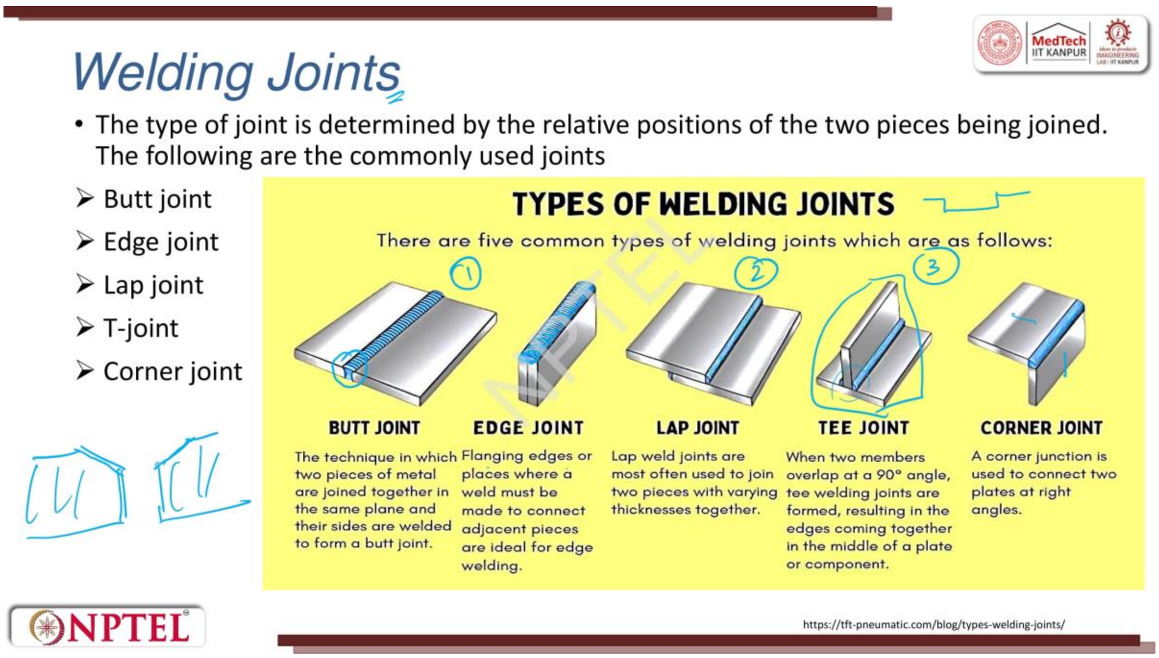
So we use goggles for protecting our eyes. We use gloves for protecting our hand. Advantages, disadvantages are discussed in plenty, so I leave it to you for studying.



So now the important terminology which comes is weldability. Can this material be machined, machinability? Can this material be cast, castability? Can this material be forged, forgeability? So can this material be weld, weldability? It is defined as the capacity of a metal to be weld under the fabrication condition imposed in a specific suitable design structure. And to perform satisfactorily the intended service is called as weldability.

Weldability can also be determined by analyzing a metal's behavior under fusion and cooling through crack and notch sensitivity. Or by comparing the heating and cooling effects that occur at the joint of the metal with another metal known for weldability. So, the factors affecting weldability are the composition of the base metal, the thermal properties of the metal, and the welding technique used. The filler material used, the flux, and the mechanical properties of the material must also be considered. Other factors include heat leading to brittleness, strength at high temperatures, and the stability of microconstituents.

So, all these factors influence weldability. Weldability essentially means the weld can perform well under service conditions in a stable position.



There are different types of joints available. It is helpful to have some understanding of them. This is called a butt joint. In solid-state welding, we often discuss different types of butt joints, such as flash joints. These are all butt joints. This is a butt. So, face to face. This is called an edge joint.

So flanging edges or placing where a weld must be made to connect the adjacent piece are ideal at the edges. So this is an edge. Something like a book, right? But here you cannot open. The two metal pieces are there.

On the top we do. This is an edge. This is a butt. This is an edge. Lap, one sitting on the other, is called a lap.

You decide which one you want. The larger the lap, the larger the surface, the higher will be the welding joint. But you cannot keep on lapping it because then you have a restriction. So we try to have as minimal as possible but to have a sink. So next is a T-joint.

This was also discussed in the arc welding process; this is what I showed—a T joint. So, in a T joint, you will have a perpendicular joint—a plate joining another plate perpendicularly—and this is the weld bead. Then, you can also have a corner joint—like an open book—so this portion is joined. So, these are the commonly used joints in welding. Depending on the requirements, we try to do them.

Again, here, if we look closely, there will be a surface like this. We do edge preparation. So here, this is where the welding will happen. So, this portion we call the root, and here, we do it by edge preparation. This is metal; this is metal.

So, this is how it will be. In the same way, here, you will also try to have a trench like this. So again, this is called the root because the weld has to flow between the two metal pieces. So, these are the different types of joints, and the most commonly used ones are here. This is a butt joint. Lap joints and T-joints are very common.

Welding Joints

Butt Joint:

- Plates are joined edge-to-edge.
- No bevel for thickness below 5 mm; V or U groove beveling needed for 5 mm to 12.5 mm.
- Plates above 12.5 mm need V or U grooves on both sides.

Edge Joint:

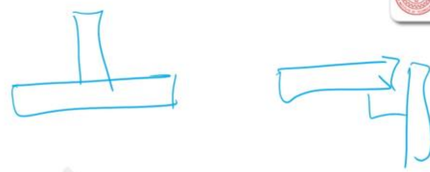
- Two parallel plates joined.
- Economical for plates with thickness less than 6 mm.

Lap Joint:

- Plates are overlapped and edges welded.
- Types: single traverse, double traverse, parallel lap joints.
- Suitable for plates with thickness less than 3 mm.

So, plates joined edge to edge are called butt joints. Two parallel plates joined on top are called edge joints. Lap joints are when one overlaps the other.

Welding Joints



T-Joint:

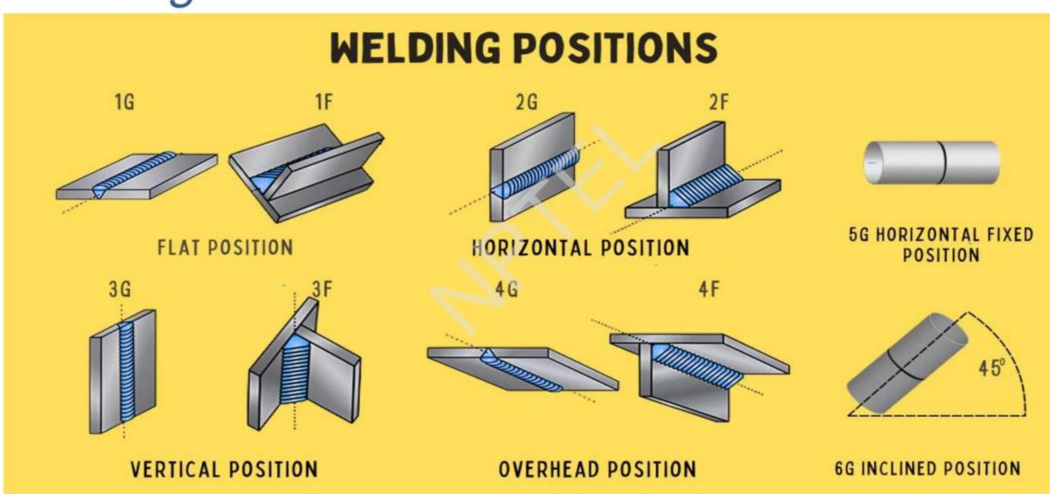
- Plates joined at right angles.
- Suitable for plates up to 3 mm thick.
- Widely used for welding stiffeners in aircraft and thin-walled structures.

Corner Joint:

- Plates are joined at a 90° angle.
- Can be welded without filler metal by melting the edges of the parent metal.
- Used for both light and heavy gauge sheet metal.

T-joints are at a right angle. Corner joints are at 90 degrees. So, it is a perpendicular plate. This is a 90-degree plate.

Welding Joints



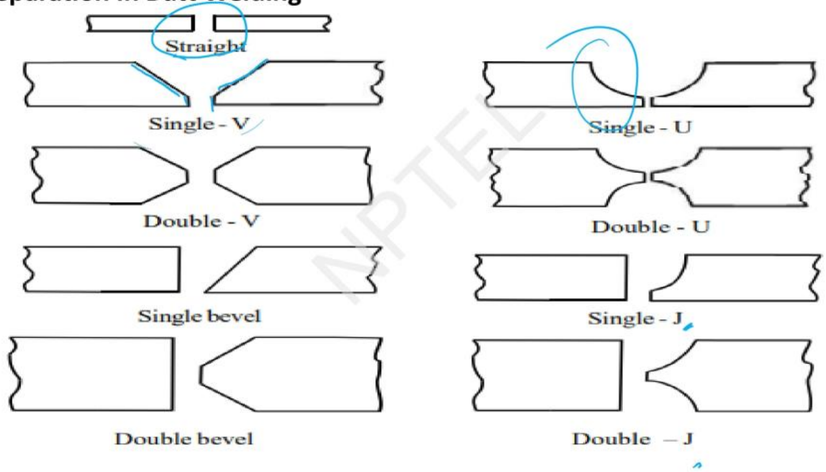
https://tft-pneumatic.com/blog/types-welding-positions/

So the positions can be flat; you can have a flat position. You can have a horizontal position; these are also horizontal fixed positions.

You can have a vertical position. So, you should understand welding is not done like this; welding is done like this, welding is done like this. So, flat positions, horizontal positions—all are possible. And then you can have vertical positions and overhead positions. And then inclined positions. So, all these things are welding positions. So, you have to be very careful when we do welding operations.

Welding Joints

Edge Preparation in Butt Welding



https://tft-pneumatic.com/blog/edge-preparation butt welding/

Preparation of Welding

Edge Preparation in Butt Welding

Square/straight butt joints: For plate thickness 3-5 mm, edges are kept straight with no bevel.

Single V-butt joints: For plate thickness 8-16 mm, bevel angle ranges between 70°-90°.

Double V-butt joints: For plate thickness above 16 mm, welding is performed on both sides.

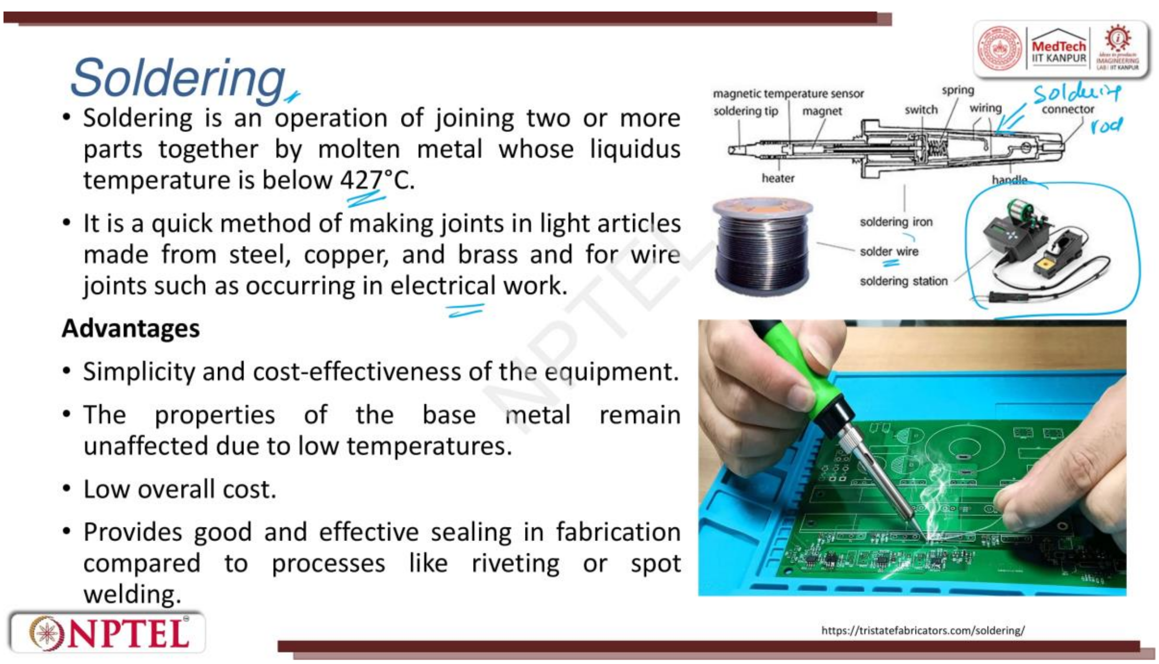
Single and double U-butt joints: For plate thickness above 20 mm, double U-joint is welded on both sides.

Edge preparation: Essential for a sound joint, involves bevelling the edges and cleaning faces before welding.

This is what is the edge preparation I have been time and again telling you. So, we have a V0 and then we have a flat portion. So, if you have a metal like this between join to join you will never have perfect joining.

So, we always do edge preparation. So, this is called as V preparation, this is called as U, you can also have something like double V. Then W U, then you can have one flat and one bivoult. So you can have one flat and one U, then you can have one flat and double wedged. You can have one flat and double U. So it is called as double J.

Single J, double J. So, all these things are done in the edges. You have a flat plate. So, what we do is we do edge preparation and then we try to get this surface. Edge preparation is very important. So, what you see here is only joints, but between the plates you have to do this edge preparation. So, you can try to have square edge, single V, double V, single and double U, and edge preparation is possible.



So, the next important thing, which is commonly used in the electronic industry, is soldering. Soldering is an operation of joining. Two or more parts together by molten metal whose liquidus temperature is below 427 degrees Celsius. So, you have a gun or a soldering rod.

So, at the tip, this is a non-consumable electrode. You pass current, and this portion gets heated. Now, you use a wire, and then that wire is touched—the filler wire is touched by the gun soldering rod. And that tries to melt the material you exactly place at the location where you want. It is a quick method of making joints in light articles made of steel, copper, brass, or any other joints, such as those occurring in electric work.

So, soldering—this is how the entire setup looks like. So, you have a soldering rod or a soldering gun—a soldering rod. So, inside a soldering rod, you have all these things; today, it is also battery-operated. So, this is a solder wire, which is made out of lead. So, when this touches this, the solder melts and establishes an electrical connectivity.

Soldering

Disadvantages

- The soldered joints are not suitable for high temperature because of low melting.
- The joint has poor mechanical strength

Applications

- Connection in wireless set, T.V. sets etc.
- Drain water gutters and pipes.
- Radiator brass tubes for motor car.
- It is sometimes used to repair utensils.
- Wiring joints in electrical connections, battery and other terminals

https://depositphotos.com/photo/circuit-board-soldering

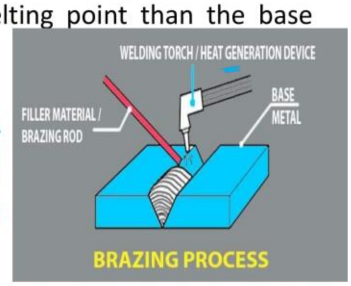
So, connecting wireless TV sets, drain water gutters, pipes, and radiation brass tubes for motor cars. And it is also used for repairing utensils. The solder joints are not suitable for very high temperatures. Because it melts, and the mechanical strength is also poor. So, in electronics, we do not do tensile tests. So, it is all connected together and placed there.

Brazing

- Brazing is a soldering method using brass (copper-zinc alloy) as the joining medium.
- Brazing joins metals using a filler metal with a liquidius temperature above 450°C but below the base metal's solidus, without melting the base metal.
- It can join dissimilar metals, except aluminum and magnesium.
- It is considered hard soldering because the joint is stronger than standard soldering.
- Brass used in brazing, called "spelter," has a lower melting point than the base material for compatibility.

Three brazing alloys are

1. Copper = 70%, Zinc = 30%, Melting point = 960°C
2. Copper = 60%, Zinc = 40%, Melting point = 910°C
3. Copper = 50%, Zinc = 50%, Melting point = 870°C



https://tristatefabricators.com/Brazing/

So, soldering is at a lower temperature, and brazing is at a higher temperature. Brazing is a soldering method using brass as a joining medium. Here, the temperature is above 450 degrees Celsius. Dissimilar metals can be joined.

It is considered a hard solder because the joint is stronger than the normal material. The brass used in brazing, called spelter, has a lower melting point than the base material for compatibility. So that is why this brazing process uses brass, leading to brazing. So, the alloy composition can have copper at 70 percent, 60 percent, or 50 percent. Accordingly, zinc changes, and you see a variation in the melting point.

So, so much of heat has to be applied. So, in bracing process we use a flame, generally we use a flame. But in soldering process we use a soldering rod where in which the current is passed. And it is not a very high current, it is only heating it and then this melts.

Brazing

Advantages

- Cast, wrought, and dissimilar metals can be joined with minimal disturbance to base properties.
- Complex assemblies and varying thickness materials can be brazed efficiently.
- Brazed joints require little finishing, and operations are easily mechanized.

Limitations

- High degree of skill required
- Limited size of parts, Brazing is not suitable for high-temperature applications due to the low melting point of the filler metal.
- Machining of the joint edges forgetting the desired fit is costly
- Joint design is somewhat limited if strength is a factor.

Applications : bicycle frames, pipe joints, exhaust pipes, band saws, and tipped tools.

So, the bicycle frames are done by bracing, pipe joints, exhaust pipes, band saws and tipped tools are all braced. For example, in cutting tool tungsten is braced on top of a holder.

Comparison

https://www.cruxweld.com/blog/the-difference-between-soldering-brazing-welding//

Comparison

	Soldering	Brazing	Braze welding
1. Mechanism	Adhesion	Adhesion	Adhesion
2. Max temperature of join	T < 427°C max	T > 427 max	T > 427 max
3. Filler material	Lead + tin	Cu + Zn brass	Cu + tin bronzes
4. Joint proprietor	Not	Required	Required
5. Flow of filler material	Capillary	Capillary	Gravity
6. Application	To join electric and electrical	To repair cracks or to join this chest	To join thile state difference national

https://www.cruxweld.com/blog/the-difference-between-soldering-brazing-welding//

So, this is soldering, this is bracing and this is welding. So, I am trying to compare. So, this is used in electronics. This is used in inserts and this is used in rest.

So this is the difference between soldering, brazing and welding. So mechanism it is all the three are adhesion. The temperature you can see what is the difference. So filler material it will be lead and tin. It will be copper and zinc.

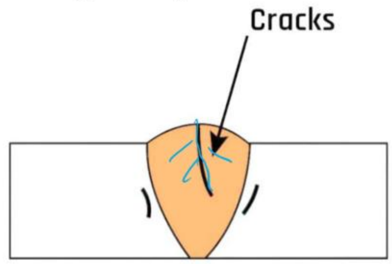
It will be copper brass welding, copper tin bronze you can use. The joint properties are given here. All the soldering is, the majority of the time, by capillary action. Brazing is also by capillary action. Capillary means there is a thin wall.

So there is a negative pressure; the metal flows and sucks inside. Capillary action and you do it. So, they are all used for different types of electronic applications.

Defects in Welding

Weld Crack

- Cracks are major welding failures that occur as planar fractures in the weld or base metal, caused by localized rupture from pressures, cooling, contraction, and grain development in the heat-affected zone (HAZ) during solidification.
- These cracks create stress concentrations near the crack tip, making the weldment more prone to fracture.
- They can vary in size, shape, and type, including;
  - ➢Longitudinal
  - ➢Transverse
  - ➢Crater
  - ➢Radiating
  - ➢Branching



https//16 Common Types of Welding Defects, Causes and Remedies.html

Now, moving to the last part of welding: defects which occur in welding. So, there are many defects because there is heat and cooling. There is a residual stress component involved. So, there are many defects which are generally possible in welding. Welding cracks are the major welding failures that occur as planar fractures. You can see here the cracks. Planar fracture in the weld or base metal caused by localized rupture from pressures, cooling, contraction, and grain development in the heat-affected zone.

These cracks are stress-concentrated cracks near the crack tip, making the weldment prone to failure. They are of various sizes, shapes, and types. The cracks can be longitudinal, transverse, crater, radiating, or branching. So these are branching cracks. So there are different types of cracks that are possible.

Defects in Welding

Depending on the temperature they occur, cracks can be:

Hot Cracks

- *Solidification cracks* occur due to high impurity or carbon content or disrupted heat flow during solidification.
- *Liquefaction cracks* occur from high heating temperatures causing the liquefaction of low melting point constituents

Cold Cracks

- Cold cracks are delayed defects that form after solidification, often days later, and typically lie parallel to the fusion boundary.
- These cracks are caused by factors such as lack of preheating, high stresses, low temperature, high hydrogen content, and material susceptibility.

And depending upon the temperature, there can be a hot crack or a cold crack. What is a hot crack? The solidification crack occurs due to high impurity or carbon content or disrupted heat flow during solidification and is called hot cracking. The liquefaction crack occurs from high heating temperature, causing the liquefaction of a low melting point constituent. So, this is called a liquefaction crack.

Solidification, flowing—it does not—there are impurities, then solidification happens. Cold cracking are delayed defects that form after solidification. This is during solidification—hot; after solidification—cold. So these cracks are caused by factors like lack of preheating, high stress, low temperature, high carbon content, and material susceptibility.

Defects in Welding

Causes Of Weld Crack

- Poor ductility or contamination of given base metals.
- Combining high welding speed with low current.
- High residual stress solidification from shrinkage.
- Lack of preheating before starting welding.
- The high content of sulfur and carbon in base metals.
- Using hydrogen as shielding gas for welding ferrous metals.
- Excessive joint restraint, limiting movement during cooling.
- Improper depth-to-width ratio of weld beads.
- Incorrect consumable selection (wrong filler metal, incorrect electrode size).

So, these are all the possibilities for the defects to happen. Causes for weld cracks include poor ductility, combining higher welding speeds with low current, and high residual stress during solidification. Lack of preheating before solidification, high sulfur content, using hydrogen as shielding gas, and excessive joint restraint. Improper depth-to-height ratio, incorrect selection of combustible filler or flame. So all these things are causes for various types of weld cracks. Weld cracks, as you know, can happen in the longitudinal direction or the transverse direction.

Longitudinal is this, along this direction. In the transverse direction, it can be a radiating crack or a branching crack. So it is a combination of the process, choice of material, and filler.

Defects in Welding

Preventing Weld Crack

- Use compatible filler materials and welding processes, ensuring clean base and filler metal surfaces.
- Use the right welding speed and current.
- Preheat the base metal and reduce the cooling speed joint.
- Use the appropriate sulfur and carbon mixture.
- Reduce the gap between weld joints.
- Maintain the correct weld bead depth-to-width ratio.
- Avoid hydrogen as a shielding gas for ferrous metals.

To prevent these weld cracks, you have to use a proper compatible filler. Because the filler you use, if it solidifies faster than it attaches to the base material,

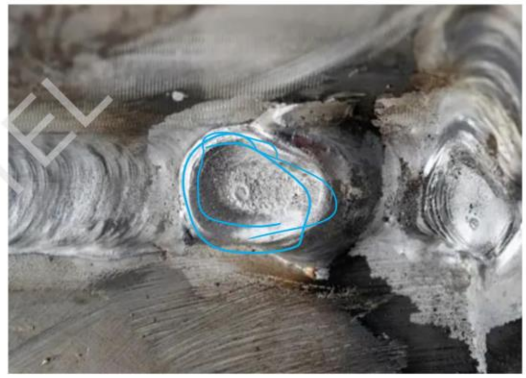
then improper welding occurs, and there will be a crack. So we have to find compatibility where the viscosity of the liquid that flows comes into contact. When it contracts, it also tries to take the base material along with it. It will not shrink so much but take them along. So, use compatible filler material and weld process while ensuring a clean base.

Then use right welding speed and current. Then preheat the base because you are playing with the wettability, cooling speed. Then use of sulphur content has to be reduced in the base. Gaps which are used in welding, arc length, that has to be maintained. Depth to weight ratio is important. Avoid hydrogen as a shielding gas for stainless steels.

Defects in Welding

Crater

- Craters are crater-like cracks that usually follow the arc ending near the end of a weld bead, usually occurring after the welding process but before the weld joint is entirely formed.
- It often occurs due to improper filling of the crater before breaking the arc.
- This leads to faster cooling of the outer edges than the crater.
- Insufficient volume of the weld may prevent it from overcoming metal shrinkage.
- As a result, a crater crack defect in the welding process is formed.



https//16 Common Types of Welding Defects, Causes and Remedies.html

So these are called as crater cracks. Craters are crater-like cracks that usually follow the arc ending near the end of the weld bead. Usually occurred after the welding process, but before the welding joint is entirely formed, this crater are formed. It is often occurred due to improper filling of the crater before the breaking of the arc.

So at the end it happens before, basically why does it happen? There is a solidification phenomena happening. When the solidification phenomena happen, the liquid tries to move. Once it tries to move, then there has to be enough of material to fill up. So if there is not much of enough of material, then it creates a crater.

This leads to faster cooling at the outer edge of the than the crater. So insufficient volume of the weld may prevent this to occur resulting in a crater crack formation.

Defects in Welding

Causes of Crater

- Improper filling of the crater.
- Incorrect torch angle.
- Wrong choice of welding technique.
- Abrupt termination of welding process, inadequate reinforcement.

Preventing Crater

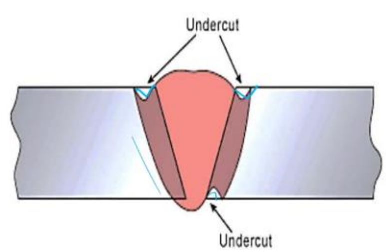
- Ensure proper crater filling and use appropriate angles: 10-15° for wire welding and 20-30° for stick welding.
- Use a small electrode and maintain a 45° angle for fillet welds.
- Gradually reduce welding current and choose the correct welding technique.

So the ensure filling proper then you should also try to have a welding angle of the stick angle and other things. Use of small electrodes maintaining 45 degree is important. Gradually reduce weld current and also occur the welding technique.

Defects in Welding

Undercut

- Undercut defects are irregular grooves formed in the shape of notches on the base metal.
- They occur due to the melting of the base of metal away from the weld zone and are characterized based on their length, depth, and sharpness.
- Undercut defects in welding run parallel to the weldment, causing a loss in thickness.
- As a result, the weld joint becomes more susceptible to fatigue.



The types of undercuts are:

- Continuous undercut
- Inter-run undercut
- Intermediate undercut

https//16 Common Types of Welding Defects, Causes and Remedies.html

Undercut is also one another major defect. Defect are irregular grooves formed in the shape of notch on the base material. They occur due to melting of the base of the metal away from the weld zone and are characterized based on the length, depth and sharpness. So, this is undercurrent.

So there can be three types, continuous undercurrent, inter-run undercurrent and intermediate undercurrent. So this is undercut current range. So there are three types of undercuts, continuous undercut, inter-run undercut, intermediate undercut.

Defects in Welding

Causes of Undercut

- High voltage or fast weld speed can cause melting at the top edge.
- Wrong electrode angle, large electrode, or incorrect filler metal degrade weld quality. Wrong shielding gas compromises weld integrity and protection.

Preventing Undercut

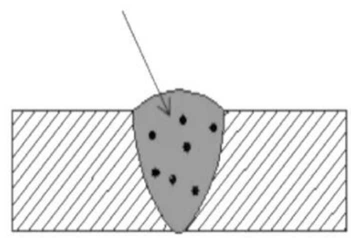
- Reduce travel speed and power input.
- Keep arc voltage between 15-30V and arc length within electrode core diameter.
- Maintain electrode angle between 30-45° and use correct gas mixture and filler metal.
- Weld in flat positions.

So these are the causes, high voltage, fast speed leading to undercut, wrong electrode angle is also one of the major thing.

Defects in Welding

Porosity

- Also known as wormhole welds, porosity defects occur when there is an entrapment of air or gas bubbles in the weld.
- The welding process often generates gases like hydrogen, carbon dioxide, and steam.
- A cross-section of porous weld beads often resembles a sponge with an accumulation of trapped air bubbles.
- The entrapped gases may be localized in a specific location or uniformly distributed in the weld.
- These gas bubbles can weaken the joint of the weld metal, predisposing them to fatigue and damage.



https//16 Common Types of Welding Defects, Causes and Remedies.html

Defects in Welding

Depending on their formation, these orbital welding errors can occur as:

- **Gas Porosity** This is a small, spherical-shaped cavity generated from trapped gases. The various forms include surface pores, elongated cavities, linear porosity, etc.
- **Worm Holes** These are elongated or tubular cavities formed during the solidification of trapped gases. You can see them as single holes or a group of holes throughout the weld surface.
- **Surface Porosity** This is a kind of porosity that breaks the surface of the weld metal.

Then porosities it is the same like what we had in casting also known as warm hole weld porosity defects occur. When there are entrapments of air and other gas bubbles in the weld zone. So, during the welding process, hydrogen, carbon dioxide, and steam are generated, which have to be avoided. So, the cross-section of the porous bead often resembles a sponge with an accumulation of trapped air bubbles. So, there can be gas porous wormholes, and there are surface porosity gas porosities, which are small spherical. And they are generated from trapped gases, including surface pores and elongated cavities.

And linear porosity when we talk about wormholes. They are elongated and tubular cavities. Gas is spherical. Worm is tubular. Surfaces—everything comes to the surface. That breaks the surface of the weld is surface porosity.

Defects in Welding

Causes of Porosity

- Inadequate coating of electrode or use of corroded electrode.
- Presence of grease, oil, water, rust, or hydrocarbon on the weld surface.
- Using incorrect shielding gas.
- Too high arc voltage or gas flow. The voltage should typically be between 15 to 30 volts.
- Poor surface treatment of base metal.

Preventing Porosity

- Choose the suitable electrode and filler material.
- Ensure proper cleaning of the base metal and prevent pollutants from entering the welding area.

Again, the prevention can be suitable electrode filler and cleaning.

Defects in Welding

Spatter

- Spatters consist of metal particles expelled from the welding arc, commonly found in ARC, GAS, and tack welding processes.
- They can also appear, though less frequently, in MIG welding.
- These particles typically adhere along the weld bead or within joint designs, marking a distinct type of welding defect.
- Spatters that accumulate in the nozzle may detach and damage the weld bead.
- They can also cause accidents for handlers if the spatter projections are sharp.

https//16 Common Types of Welding Defects, Causes and Remedies.html

Defects in Welding

Causes of Spatter

- Too low voltage and too high amperage current settings.
- Wrong choice of shielding gas.
- Rigid electrode working angle.
- Using a wet electrode and a larger arc length.
- Contamination of metal surface.

Preventing Spatter

- Use the right polarity and adjust the weld current.
- Use the proper shield gas.
- Increase electrode angle and decrease arc length.
- Clean the metal surface before welding.

These are spatters. Spatters are metal getting expelled and exploded from the place. Spatter consists of metal particles expelled from the weld arc, commonly formed in arc, gas, and track welding processes.

It is very common in MIG welding. Along the weld bead and the welding joint. So, right polarity, proper shielding, increase in electrode angle and cleaning the metal surface are important.

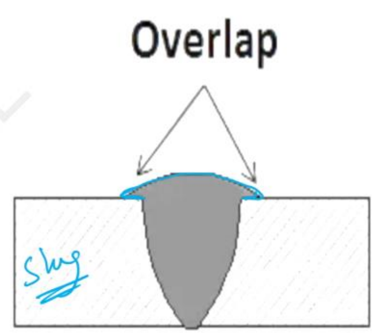
Defects in Welding

Over-roll / Overlap

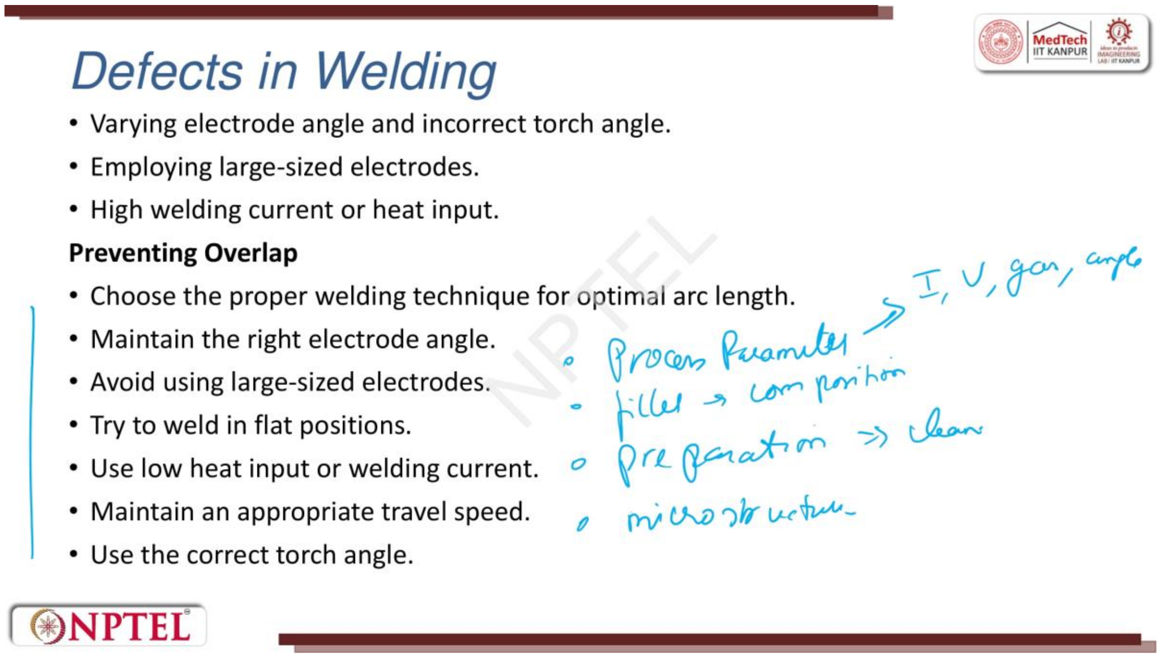
- A weld overlap is a defect where the filler material at the weld's toe covers the meta without bonding.
- In this case, the weld pool flows excessively and extends beyond the toe.
- The weld metal forms an angle below 90 degrees when this condition happens.

Causes of Overlap

- Using the wrong welding technique.
- Slow travel speed.



https//16 Common Types of Welding Defects, Causes and Remedies.html



So, the other defect is overlap. A weld overlap is a defect where the filler metal at the weld toe covers the metal without bonding. So, it just covers, overlaps. There is no bonding. So, it can be removed very fast. So, in this case the weld pool flows excessively and extend beyond the tow. So, many a times because it overlaps it can be removed like a lug, it can be removed like a slug.

So, this portion itself can come out. So, this is overlap. So, these are the preventive actions which we have to take. Again there can be a process parameter related matter. Filler related or there can be any preparation of the metals which are to be joined.

And then it can be the microstructure. So, if you try to do all these things when we talk about this process parameter. It can be current, it can be voltage, it can be gas, it can be angle—all these things can be there, and filler, it most probably goes for composition. Preparation is basically cleaning. So, it is very common for all the defects. If you do this properly, it can be done.

Defects in Welding

Lamellar tearing

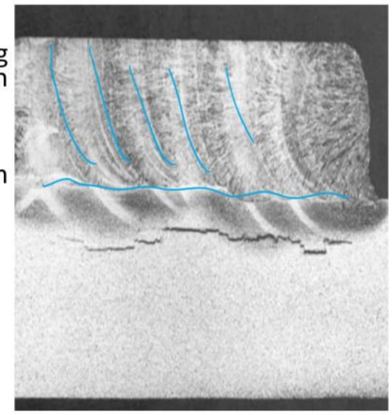
- Lamellar tearing occurs in welded steel plates, causing terraced cracks due to thermal contraction, often parallel to the weld fusion boundary.

Causes of Lamellar Tearing

- Weld metal deposits on surfaces with optimum cohesion.
- Improper material selection and welding orientation.

Preventing Lamellar Tearing

- Ensure welding is done at the end of the fabrication.
- Select the best quality materials and use the right welding orientation.



https//16 Common Types of Welding Defects, Causes and Remedies.html

So, there is lamellar tearing. So, these are lamellar tearing. So, lamellar tearing occurs in welded steel plates, causing terraced cracks due to thermal contraction, often parallel to the weld fusion boundary. Lamellar cracks occur in welded steel plates, causing terraced cracks due to thermal conductivity, often parallel to the fused weld boundaries.

So, this can be prevented by ensuring welding is done at the end of the fabrication. You should try to do it because thermal contraction plays a very important role.

Defects in Welding

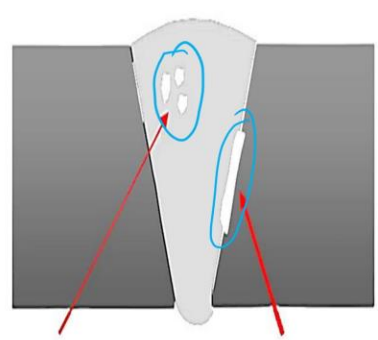
Slag Inclusion

Slag Formation: Slags form when flux melts during welding, creating byproducts on the weld surface or within the weld.

Weld Defects: Slag inclusions and porosity weaken the weld, compromising its integrity.

Impact on Weldability: Slag can obstruct smooth welding and complicate cleaning, making strong welds harder to achieve.

Mechanical Properties: Slags introduce impurities, reducing weld strength and toughness, and weakening structural performance.



https//16 Common Types of Welding Defects, Causes and Remedies.html

Defects in Welding

Causes of Slag Inclusions

- Incorrect electrode angle.
- Using very small welding current density.
- Allowing the weld to cool too fast.
- Improper cleaning of previous weld layers.
- Insufficient space for puddles of molten welds.
- Too fast welding speed

Defects in Welding

Preventing Slag Inclusions

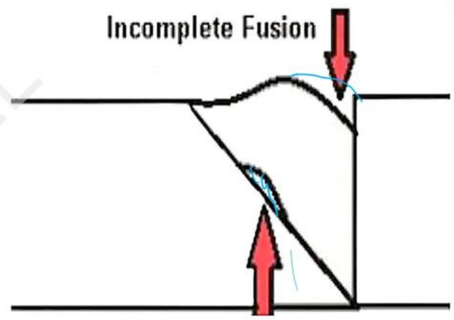
- Adjust the electrode angle and travel rate.
- Increase the current density to the appropriate value.
- Prevent rapid cooling.
- Clean weld bed surfaces before depositing the next layer.
- Redesign joints to ensure there is sufficient space for the proper use of a puddle of molten welds.
- Ensure optimal welding speed.

These are slags which happen; these slags can happen because of oxidation formation or other impurities that are there. The slags form when the flux melts during welding, creating byproducts on the weld surface or within the weld. So, these are the causes for the slags. I am not going in depth, so I would request you to go through it by reading. So the prevention of slag inclusions is also discussed.

Defects in Welding

Incomplete Fusion

- Also known as lack of fusion, this weld defect occurs due to inaccurate welding that results in unfilled gaps.
- It may be a result of the following:
- Lack of fusion between the parent metal and the weld metal at the weld's root.
- Lack of sidewall fusion between parent metal and weld metal at the sidewall weld.
- Lack of inter-run fusion between adjacent layers of weld metals during multi-run welding.



https//16 Common Types of Welding Defects, Causes and Remedies.html

Defects in Welding

Causes of Incomplete Fusion

- Low heat input.
- Contamination of the metal surface.
- Using incorrect electrode diameters for the specific material thickness.
- Too fast travel speed.
- Large weld pools moving ahead of the arc.

Preventing Incomplete Fusion

- Use proper heat input.
- Clean the welding area and metal surface before welding.
- Choose the right electrode diameter that fits the material thickness.
- Optimize the travel speed.
- Use an adequate weld pool that does not flood the arc.
- Ensure proper joint geometry.

So there can be incomplete fusion. So the weld edge preparation is done, the welding is done, but the weld material is not completely filled. So, also known as lack of fusion, this weld defect occurs due to inaccurate welding that results in unfilled gaps.

So weld roots have to be created such that proper fusion can be achieved. So again, what are the causes for incomplete fusion and the prevention of incomplete fusion?

Defects in Welding

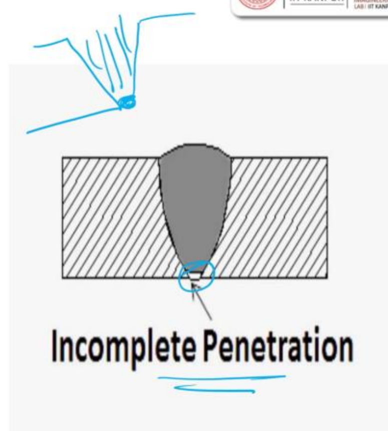
10. Incomplete Penetration

In welding, penetration is the distance from the upper surface of the base metal to the maximum weld extent.

Incomplete penetration occurs when the metal groove is too narrow and is not filled.

As a result, the weld metal does not entirely spread through or get to the bottom of the weld joint.

This reduces the strength of the weld joint and causes weld failure.



https//16 Common Types of Welding Defects, Causes and Remedies.html

Defects in Welding

Causes of Incomplete Penetration

- Improper joint alignment.
- Having too much space between the weld.
- Moving the welding bead too fast, results in little disposition of metal.
- Using too low amperage setting, preventing adequate melting of metal.
- Incorrect positioning of the electrode.

Preventing Incomplete Penetration

- Use the correct joint geometry and proper alignment.
- Ensure enough weld metal deposition.
- Use proper amperage setting.

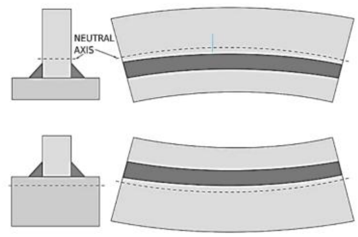
So there can also be a possibility of incomplete penetration. So when we do edge preparation, if the gap is too small, the air gets locked in it. So this air tries to prevent the weld metal from flowing.

That is called incomplete penetration. In welding, penetration is the distance from the upper surface to the base to the maximum weld extent. Incomplete penetration occurs when the metal groove is too narrow and is not filled. As a result, the weld metal does not entirely spread in the joining region. So that is incomplete penetration. So, what are the causes? How do you prevent it?

Defects in Welding

Distortion

- Distortion, or warpage, arises from the excessive heat applied during welding, leading to changes in the position and dimensions of metal plates.
- Distortion is classified into four types: angular, longitudinal, fillet, and neutral axis.
- This defect is more pronounced in thinner plates, as their limited surface area hampers effective heat dissipation.



https//16 Common Types of Welding Defects, Causes and Remedies.html

Defects in Welding

Causes of Distortion

- Varying temperature gradients during welding.
- Using an incorrect welding order.
- Slow arc travel speed.
- Too many welds pass with small diameter electrodes.
- High residual stress in the metal plate to be welded.

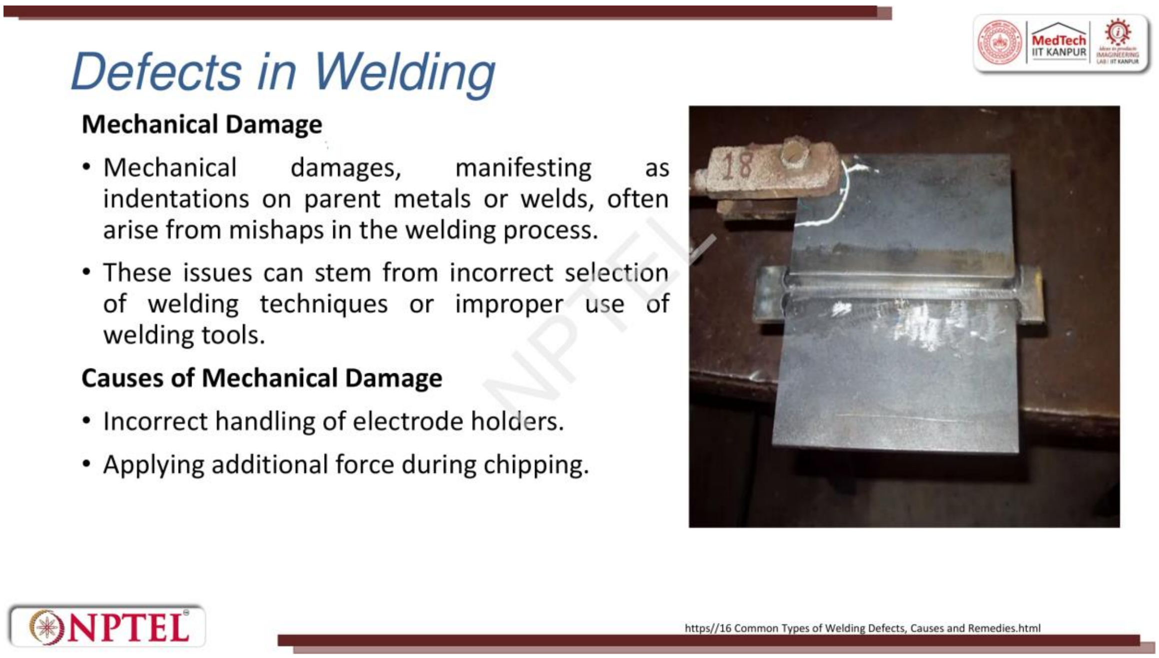
Preventing Distortion

- Stick to an appropriate temperature gradient for welding.
- Use correct welding orders.
- Use the right amount of weld metal to decrease contraction forces.

Because of heat, there can be distortion. Distortion or warping arises from the excessive heat applied during welding, leading to changes in the position and dimensions of the metal. So, how do you avoid it?

You try to have a proper combination and apply process parameters properly. There can be four types of distortion: angular, longitudinal, fillet, and neutral axis. So, these are burn-through. In the application of excessive heat during welding, the process may change. Blowholes—many blowholes through the center of the metal—can happen because of excessive heat.

So, there can be vaporization, and the metal viscosity is very low. So, it spreads very fast. The process may blow holes through the center of the weld. This type of weld can be called burn-through. Again, the cause and the prevention. So friends, I am not going deeper into it because these are all self-learning I would request you to go through.



So the mechanical damage is because of the clamping, whatever you do, there can be an indentation or damage. So that is called as mechanical damage. So you make sure that when you put a clip where the circuit is complete, the force is less. So incorrect holding and other things are there.

Welding Inspection

Non-Destructive Weld Testing (NDT)

- Non-destructive testing(NDT) evaluates welds for flaws without causing damage.
- It ensures the strength, durability, and performance of welded structures
- NDT is essential for verifying weld integrity, especially under severe loading conditions.
- It prevents the need for destructive testing, which requires replacing or discarding test pieces.
- NDT detects internal flaws in welds, helping avoid potential weld failures.
- NDT ensures weld quality by detecting flaws without damaging the weld or test piece.

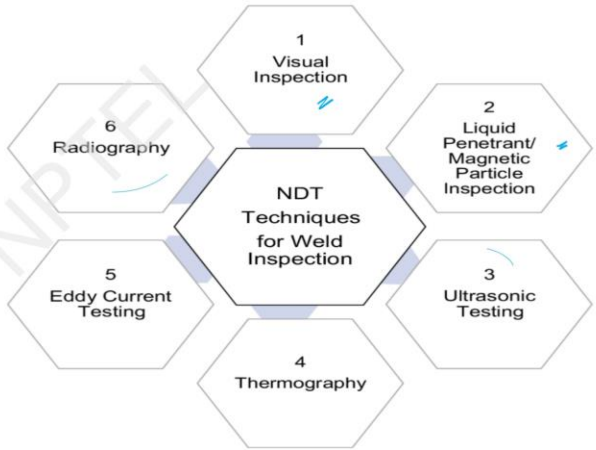
So looking into all these defects, so now there are also non-destructive testing methods which can be used in forging process as well as in casting process. Several of the non-destructive testing techniques are available today to find out the defects, the flaws which are there. Why are we doing non-destructive? Because we wanted to evaluate the strength, the durability and the performance of the weld strength. By looking into the response from the non-destructive testing.

So, NDT is essentially used to weld integrity especially under severe load conditions. So, there are need for destructive testing, replacement or discarding these pieces will happen. So, the internal flaw is weld. So, helps to avoid a failure. So, destructive is you join, you destruct it and see, but that is costly. So, now we are trying to do lot of non-destructive testing ways of inspecting the surface.

Welding Inspection

Types of Non-destructive testing of welds

- Visual inspection
- Magnetic particle inspection
- Dye penetrant inspection
- Radiography testing
- Ultrasonic testing
- Eddy Current Testing

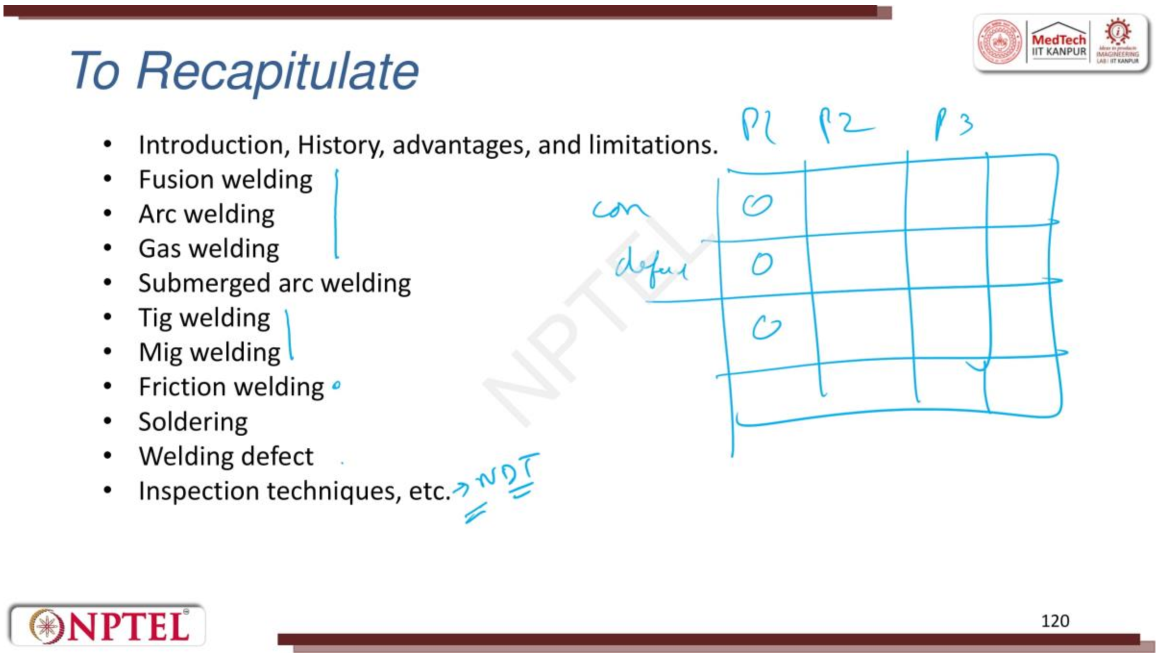


M.P. Groover, *Fundamental of modern manufacturing Materials, Processes and systems*, 4ed

So, these are some of the non-destructive techniques which are used. Visual inspection can be thought of. Liquid penetration is you pour a liquid and then you pour one more liquid. So, wherever there is a develop, so you have a liquid which is smeared on top of a surface.

You have a developer which is at wherever there is overflow of liquid. So, there you can see very prominently the development will not happen, rest of the places it will happen. The ultrasonic which we use for welding, we use an ultrasonic piezo actuator to generate a signal pass through the weld joint and collect the signal back. So, we try to evaluate. Thermography is also one of the most popular non-destructive testing way.

Radiography is x-ray taking like human we do and eddy current testing is we pass current. And we try to see what is the response and where is the crack which are getting formed. I am here with giving you all the non-destructive methods which are exhaustively used in welding or in any manufacturing process. So that we try to evaluate the joining, the metal manufacturing process without damaging it. So, friends, in the complete welding process,



In this lecture series, we have seen the introduction, history, advantages, and limitations. Then we saw various welding processes like fusion welding, arc welding, gas welding, submerged arc welding, TIG welding, and MIG welding. Then friction welding, soldering, welding defects, and inspection techniques in non-destructive testing. So, these are some of the topics we covered. I am sure the welding lecture would have been very exhaustive.

You will try to capture more details, the advantages, disadvantages, applications, and prevention methods. These things I have left for you to do as self-reading. So that you can try to understand when you prepare for the examination. You have to form a table, and with this table, you will try to write down the parameters. You can try to read like this: these are the different processes, P1, P2.

And then you can try to have conditions, then you can try to have defects, whatever they are. So, by this way, you will try to compare in a single table what all the different processes are, and which one is used for what.

References

1. Radhakrishnan, V.M., 2005. Welding technology and design. New Age International.
2. Davim, J.P. ed., 2021. Welding technology. Cham, Switzerland: Springer International Publishing.
3. Cary, H.B., 2004. Modern Welding Technology 5/e. Industrial Robot: An International Journal, 31(4), pp.376-376.
4. Schmid, S.R. and Kalpakjian, S., 2006. Manufacturing engineering and technology. Pearson Prentice Hall.
5. Groover, M.P., 2010. Fundamentals of modern manufacturing: materials, processes, and systems. John Wiley & Sons.
6. Rao, P.N., Manufacturing Technology Foundry, Forming and Welding, 2008.

These are the references which are exhaustively used. With that, I would like to thank you all for your patient listening.

Thank you.