Basics of Mechanical Engineering-2

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Week 07

Lecture 26

Basics of Welding (Part 3 of 7)

Welcome to the second lecture on the basics of the welding process. As we know, welding is an additive process wherein material is added wherever it is required. It is a heat-generated process, which means we use heat to join. So heat is present. The moment there is heat, there is a heat-affected zone.

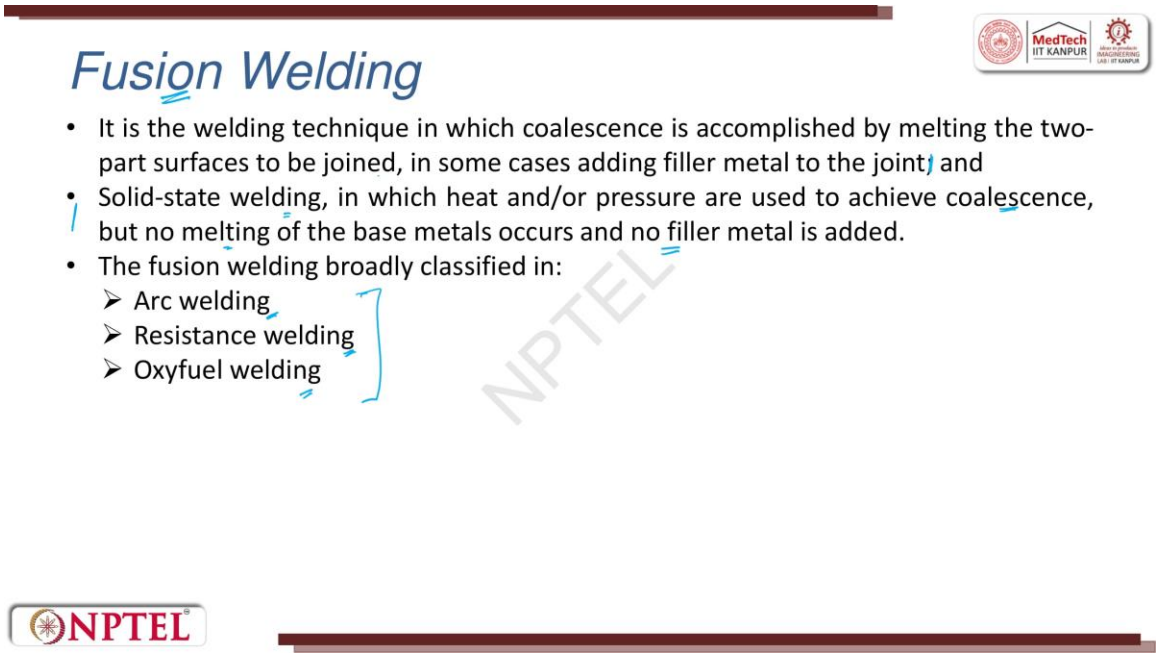
This heat-affected zone affects the microstructure, which in turn affects the mechanical properties of the given material. Because we are trying to join. From that understanding, we will now try to examine three different processes that fall under welding.

Contents

- Fusion welding
- Solid state welding
- Gas welding

The content of this lecture will be: we will study the fusion welding process, then the solid-state welding process, and the gas welding process. Where is this reference?

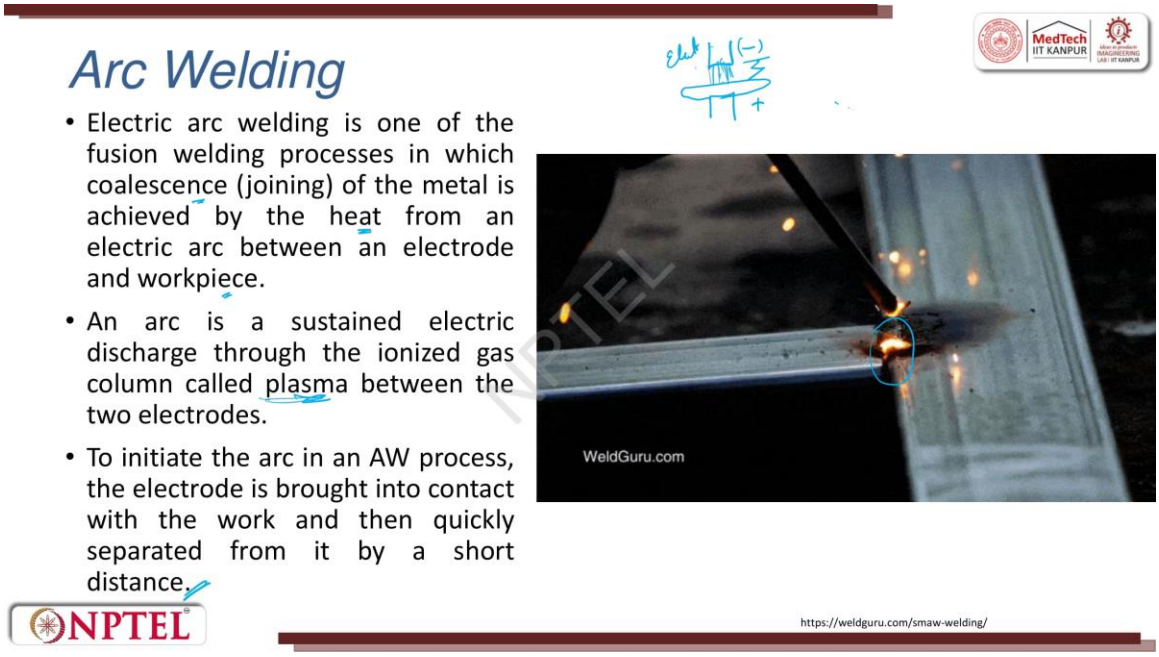
If you refer to the previous lecture, we discussed the classification of various welding processes. There, we clearly mentioned fusion welding, solid-state welding, and gaseous welding.



First, let us try to understand Fusion welding. So, fusion means joining. It is the welding technique in which coalescence is accomplished by melting the two part surfaces to be joined.

In some cases we add filler material to the joint. So this is important. We studied about autogenous, homogeneous and heterogeneous welding process. So there we studied in depth joining between two parts without adding filler and with adding filler. When we talk about solid state welding process, it is heat and pressure are only used to achieve this coalescence.

There is no melting of the base material occurs and no filler material is added. So, that is fusion welding process. I am just showing the difference that is solid state welding process. I am telling you the difference between fusion welding and solid state welding. In the fusion welding process, they are again classified broadly into arc, resistance and oxy fuel welding process.



Let us try to understand the Arc Welding process. Electric arc welding process is one of the fusion welding process. In which the coalescence of the metal is achieved by heating from an electric arc between two electrode and the workpiece. So you have positive electrode, you have a negative electrode. So this is negative, this is positive.

So you try to keep the workpiece attached to it, and here is the electrode. So from where the material comes and droops. So when it droops, it is done by an arc. The arc tries to melt the electrode material and deposit it. An arc is a sustained electric discharge through the ionized gas column called plasma.

So this, whatever is happening here, is basically a plasma phenomenon occurring. An arc is a sustained electric discharge through the ionized gas column called plasma between the two electrodes. When you try to bring two different electrodes very close together, what happens? The electrons jump from the negative side toward the positive side. It jumps.

The electrons are small. They are more in number. They start moving toward the positive electrode. When they are moving, there is a small gap between them. So when they move, they try to hit atoms and electrons.

While they are traveling and while this phenomena leads to ionization between the two electrodes. Once there is an ionized phenomena there, there is a plasma there. This

plasma will further, the electrons continue to move, that leads to an arc. That is what we are trying to say. An arc is a sustained electric discharge.

What is the discharge? The electrons are moving from the negative towards positive. Ions are moving from the positive towards negative. So there is a ionization phenomena happening. So that phenomena is plasma.

Once there is a plasma, then that leads to an arc. To initiate the arc in arc welding process, the electrode is brought into contact with the workpiece. First they touch it and then they slowly pull it up. The touching it is short circuiting and then they slowly pull it up. They try to pull it up to such a distance such that the arc is continuous.

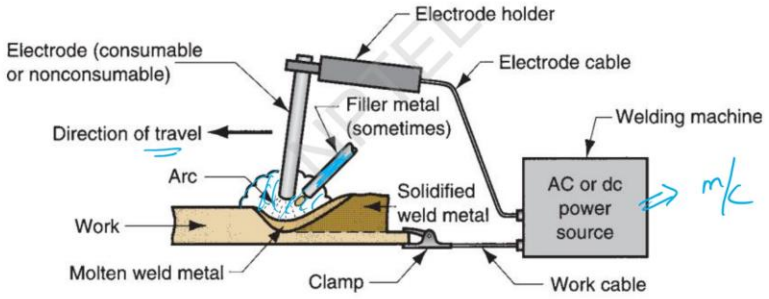
To initiate the arc, first to start, you touch and then pull. In an arc welding process, the electrode is brought into contact with the work. And then quickly separated from it by a short distance. Such that the plasma phenomena can happen. Very important.

If we do not do that, then we are not following the process. For example, you see here, first they touch and then they pull. So now this, in turn now you will understand. In the previous lecture we were trying to talk about short arc, long arc. So what you want to deposit, how do you want to deposit, depends upon the arc length, okay.

You can try to do. You want to have a deeper penetration, you have a short arc. If you want to have a wide spread of material, a farther away.

Arc Welding

- The electric energy from the arc thus formed produces temperatures of 5500°C (10,000°F) or higher, sufficiently hot to melt any metal.
- This creates a molten metal pool of workpiece and filler metal in the welding zone.



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The electric energy from the arc thus formed produces temperature of around about 5000 degree Celsius, 5500 degree Celsius. The arc is very, very high.

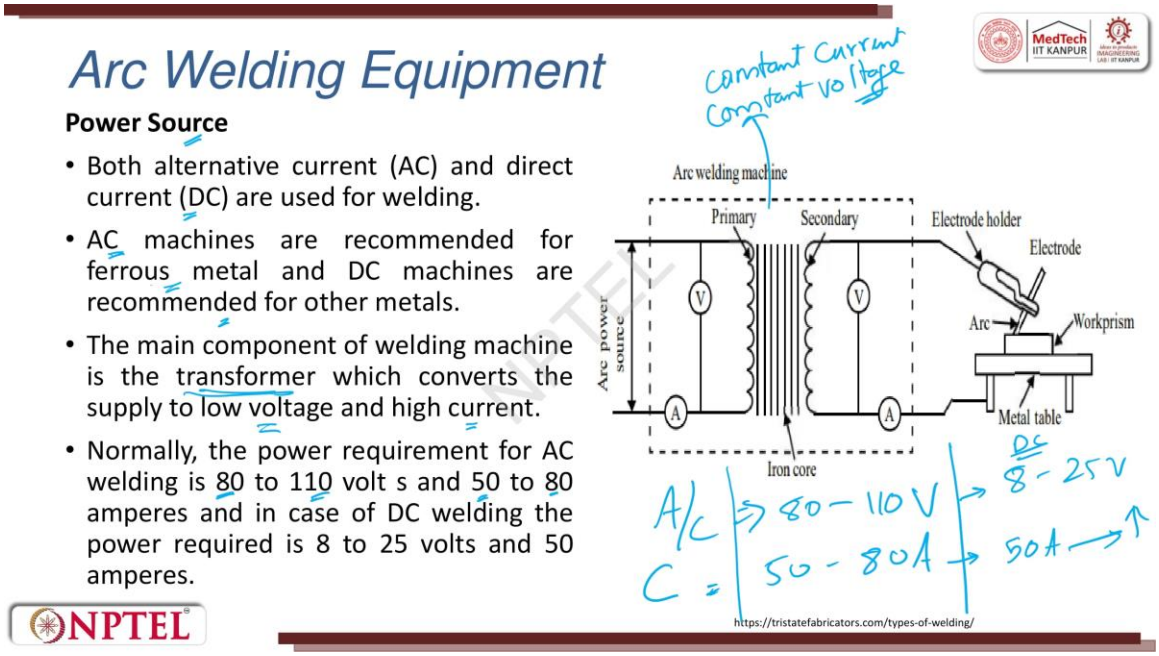
The arc temperature is very high. So with this temperature, whatever the material, you can melt it. This creates a molten metal pool of the workpiece and filler material in the welding zone. So, a molten pool comes into existence. This molten pool—please go back and take an analogy from casting.

You melt by arc. And then you have a liquid pool there—that is the molten pool of the work and the filler metal in the melt zone. So, you can try to have only the melting of the workpiece possible. In the vicinity, you also keep a filler material. This filler material also melts.

Now, one type of material is melting from this side. In the close vicinity, and then the base material also melts. So now, this and this get mixed, and for this mixing to happen, you have to have a flux, and then you have to protect this from the rest of the atmosphere. You have a shield.

So the molten material is this portion is completely molten material. So you can see the electrode holder. This is the negative side. This is the positive side, right. So you are clamping it to the workpiece.

And as and when the electrode moves on top of the workpiece, melt phenomena is happening. This melt phenomena will allow over a period of time to settle down. Molten metal will settle down and it will get deposited. So the direction of travel is given here. This portion is called as the arc portion and this is the work and this is the molten metal, okay.



So now let us get into the power source. You can have, as I said, AC power source or DC power source. So AC stands for alternating current and direct current stands for DC. It would be preferred to have a DC, but this DC has lot of losses. AC-DC conversion, again it is lost.

So now people are trying to work on why don't we start using direct AC and try to do the welding process. So AC machines are recommended for ferrous metals and DC machines are recommended for other processes. So here this is a transformer which is there inside the arc welding machine. So this is the machine. Machines are portable today.

You can have a robust machine and you can also have portable machines. These portable machines are used for on-site operation. So inside this machine, what is there is this transformer. So in a transformer, you have a primary side and you have a secondary side. The output of the secondary side is attached to the circuit or it is attached to the electrode and the workpiece.

So, this complete setup is there. So, you have a current which is passing by, a voltage which is applied. And then this is a secondary where in which we have this ion cores, the secondary EMF is created. So, you have voltage and current. So, it helps in winding.

So, the main components of the welding machine are a transformer. So, you have a step-up transformer or a step-down transformer, depending upon your requirements you can

choose. So here, we can try to set two things. One is a constant current mode setup is possible. You can also have a constant voltage mode.

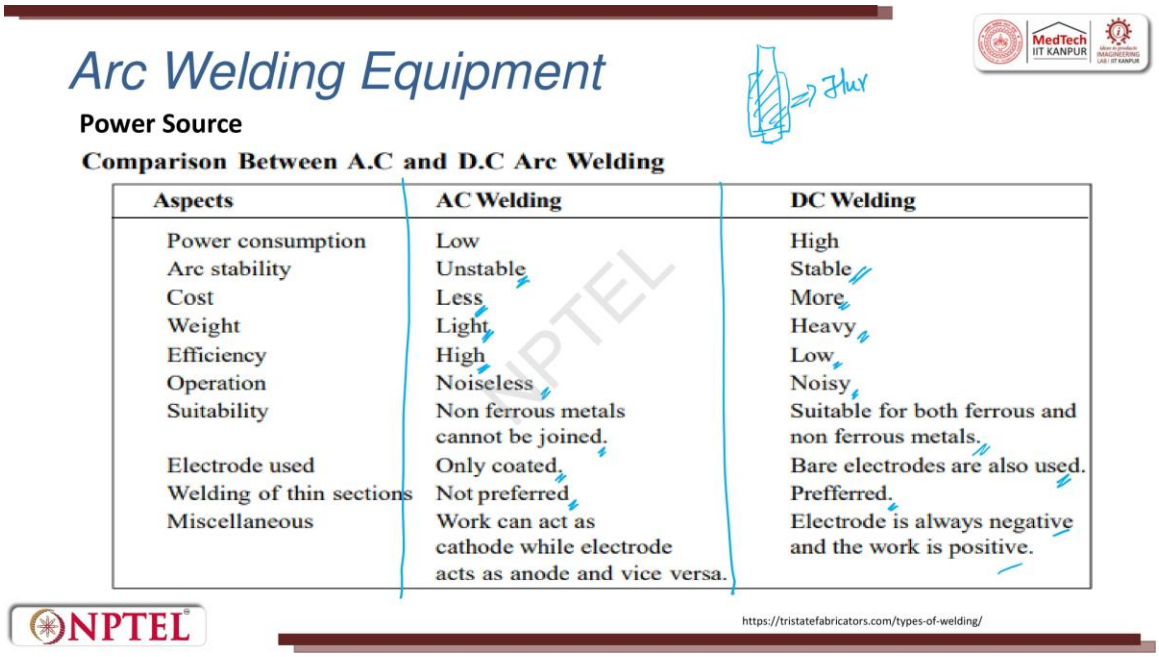
Both you can try. So that means to say, I keep a constant current which is there, and I keep fluctuating the voltage, possible. Or I set a constant voltage, I keep the current fluctuating, possible. Because if you see, these two things are in turn linked with the arc length. So, the main components of a welding machine are a transformer which converts a supply of low voltage and high current.

So normally, we use 80 to 100 volts and we start with 50 amperes to 80 amperes current. In some cases, we can go even up to 300 amperes. So this is in AC; in AC, we try to talk about 80 to 110 volts. Current, we try to talk about 50 to 80 amps, right. Whereas in DC, the voltage goes low; we talk about 8 to 25 volts in DC.

And then the current, we try to talk about 50 amps or more. Depending upon your requirement, you can adjust it based on the rod thickness. Depending upon the thickness of the plate, the current varies. Why does the current vary? Current is nothing but the flow of electrons.

The more current flows, the more melting occurs. And you cannot have infinite current because the entire system has to accommodate so much. So if you have a very high current, the transformer becomes very heavy. The moment the transformer becomes very heavy, a lot of heat is generated. That is why, if you walk through some power substations, you will see large transformers.

The biggest challenge will be: how do I cool it? More current means a bigger transformer and a bigger cooling system. So in welding, we also have a similar situation. The transformer is smaller or larger. When you have a large current, you need large cooling.



So this is just to get a feel for some of the aspects that are present in the welding machine. The power consumption in AC welding is lower compared to that of DC welding. The arc stability in AC is often unstable. But since direct current has fixed positive and negative poles, you get more stability. That is why it is preferred for many other non-ferrous materials we use.

AC, since there is no conversion from AC to DC, the cost is lower. In DC, you add that component. The weight in AC is very light, while in DC it is very heavy because the transformer currents are heavy. So the machine also becomes heavy. So predominantly, we are trying to say DC machines will have to be stationed somewhere.

Efficiency, since there are no conversion losses, is very high compared to this, which is low. And in operation, AC is noiseless compared to DC. Where does the noise come from? The spatter, the arc, and the spatter present create the noise. So non-ferrous metals cannot be joined using arc welding.

DC, we can try to use. Now, there is a question for you. Why is ferrous used in AC and not in DC? So, this question is here. I leave it with you as an assignment.

In the next lecture, I will try to give you the answer for it. So, the electrodes used are only coated. So here, bare electrodes can be used. What is this 'only coated'? So, 'only coated' means you have an electrode.

Then, you try to have flux on top of it. What is the function of this flux? We saw last time. So, it will try to create homogeneity in the pool, whatever it is. It can also try to react with the melt and create a gaseous shield, possibly.

It will try to move the oxides or other impurities to the top. All these things are done by flux. So, this is flux. So, that flux is coated. So, in DC, what you can do is pour it from outside.

So, that is what it said. You have a bare electrode only used. So, welding of thin sections is not preferred. Here, it is preferred. You play with the current.

So, the workpiece can act as a cathode while the electrode can act as an anode and vice versa. In AC, it is possible. But here, the electrode is always negative, and the work is always positive. DC, since there is no transition, there is no swing; cycle change is not there. So, it will have negative and positive.

Here, you can do vice versa. So now, let us try to have a little more understanding about the welding equipment. So, we talk about the welding electrode. So, as I told you earlier, this is the electrode. Bore end for gripping of the electrode holder.

So this is there, and on top of it, you have a solid extruded cover which is the flux. And then, at the striking end, you will have your rod, a small projection there, or sometimes it is on the face. So what we do is first, we try to touch the tip and break the flux a little. And then you give a small exposure of the electrode, and then you can start doing it. So if you look at it, this is the core wire which is there.

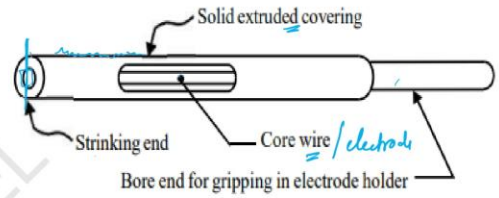
We have said wire, or it can be an electrode. Electrode means it is a single piece. It can be there. So striking end, core wire, solid extruded, gripping part for that electrode holder.

Arc Welding Equipment

Welding Electrodes

Key Considerations:

- Current availability.
- Base metal composition and thickness.
- Welding position (flat, horizontal, vertical).
- Desired penetration depth.
- Coated electrodes must be kept dry to prevent moisture-induced porosity.



Types: (i) Consumable Electrodes:
(ii) Non-Consumable Electrode

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So the key considerations are current available because the current has to pass through the electrode. If the electrode is too thin, very high current, it will melt. So, current availability in turn dictates the electrode dimensions. Base metal composition and thickness is also very important. Because that in turn if the base thickness is very high. So then you will have a solid electrode, thicker electrode.

So, that is also very important. So, the welding position can be three types. It can be vertical, it can be horizontal or it can be flat. So the desired depth is very important corresponding to that you try to dictate the number of passes or the thickness is chosen. Coated electrodes must be kept dry to prevent moisture oxide induced porosity.

So many a times in this coated if you do not keep it or if you do not keep it in a closed environment. Or if you keep it in open environment. There is a possibility of water humidity getting settled down this water humidity. While heat is there when it is deposited will create moisture this moisture will create porosity. So, this porosity will be on the top.

So, it is better to keep all these electrodes in a desiccator controlled environment. So the type of electrodes, there can be two types of electrodes. One is called as consumable electrode. The other one is called as non-consumable electrode. What are consumable electrodes?

The metal, suppose you have metal 1 and metal 2. It is metal 1 and it is metal 2 you have. So in between, you are trying to fill a filler, right. So now what happens? The electrode is consumed and it is filled there.

So this is called as consumable electrode. So you can have a wire type, wire is continuous or you can have an electrode stick type. If you have non-consumable, let us go and see what is that non-consumable. So if you look into it, so the electrode is used only to produce the arc. So and then it is stable.

Nothing happens there; no melting happens there. But you will have a filler rod wherein this material has to come inside. That material alone melts. So then it is called a non-consumable electrode. You can have a soldering rod.

You can just heat it, and the soldering rod melts, and the solder just melts there, and you can do it. You can also do brazing. So, wherein there is a filler which comes, there is heat which is generated. The filler melts and it falls down here on the base metal. There is no change in heat, only this portion.

There will be flowing of this weld portion, and you try to get it. So, consumable electrode and non-consumable electrode are two basic categories. And I would also like to add one more thing. So, if you have a continuous wire, then the flux becomes a problem. Because here you have a flux coating on top of the electrode.

So sometimes what happens is you will have the electrode like a pipe or tube between the tube. There can be flux material coming; that is also possible. One possibility is you coat; the other possibility is you push it through this part. And then you can get that; that is also possible. All combinations are there; creativity can be done, and it is left to you to do it.

And in some places, what people do is they try to have an electrode and then they have a flux. In this flux, they also have powders of metal or something. This is also used to create the arc.

Arc Welding Equipment

Consumable Electrodes:

- Thin rods or wires (bare or flux-coated) melt to form part of the weld metal.
- Coated electrodes (mild steel core with flux) prevent oxidation, provide alloying elements, and form slag to remove impurities.

Examples: Shielded Metal Arc Welding (SMAW), Submerged Arc Welding (SAW).

Non-Consumable Electrodes:

- Do not melt or form part of the weld deposit.
- Typically carbon or tungsten electrodes with slow depletion rates.

Examples: Gas Tungsten Arc Welding (GTAW), Plasma Arc Welding (PAW).

So, consumable electrodes: thin rod or wire is for continuous, bare or flux-coated. As I already discussed with you, they melt to form a part of the weld.

The coated electrode—mild steel rod with flux—prevents oxidation, provides alloying elements, and forms slag to remove impurities. Examples of shielded metal arc welding process (SMAW). So, there are two processes: shielded metal arc welding process, or it is submerged arc welding process (SAW). Two different processes are there. So, here it is consumed when they build a ship; it is consumed submerged arc welding process.

The electrode is consumed when they do the heavy hoppers; it is consumed. In automobiles, many times the electrode is not consumed. Only the filler material is consumed. So, there are two processes or examples for consumable and non-consumable electrodes. They do not melt or form part of the weld deposit.

Typically, carbon or tungsten electrodes with low depletion rates are used. Why tungsten? So, tungsten will be brought like a rod. So, tungsten has a very high melting point. So, this will not melt.

But the filler, which comes and has a lower melting point, This is a filler rod, which has a lower melting point, will melt faster and get deposited. This fellow will only create an arc. Examples are gas tungsten arc welding and the plasma arc welding process. Here, there is no consumption of electrodes.

Arc Welding Equipment

Electrode Holder

- The electrode holder holds the electrode with its jaws. The jaws of holder are made of metal with high conductivity and heat resistant.
- Electrode holder needs proper insulation as electric current flows into the welding zone through it.
- In the cases, when the jaws are subjected to very high temperatures, provision for cooling is made.

Work Table

- The parts to be welded are placed on the work table.
- It is connected with the power source to give a particular polarity to the workpiece.
- An electric circuit forms when an electrode is brought in contact with the workpiece through the work table and electrode holder.

https://rathasochenda.com/diy-fixture-welding-table-workbench/
https://www.amazon.in/Welding-Electrode-Cuwiny-Holding-American/dp/B082TNJYYF

The electrode holder is very important. So, the electrode holder must pass very high current through this. So, you have to be careful. The electrode holder holds the electrode with its jaw. So, this is called a jaw.

So, what happens is you try to put something like a cigar for a person to hold. So, what happens is you try to press this handle on the top. Then this opens, and you fix an electrode. And here, it will have very high current and voltage coming. So that it comes in contact.

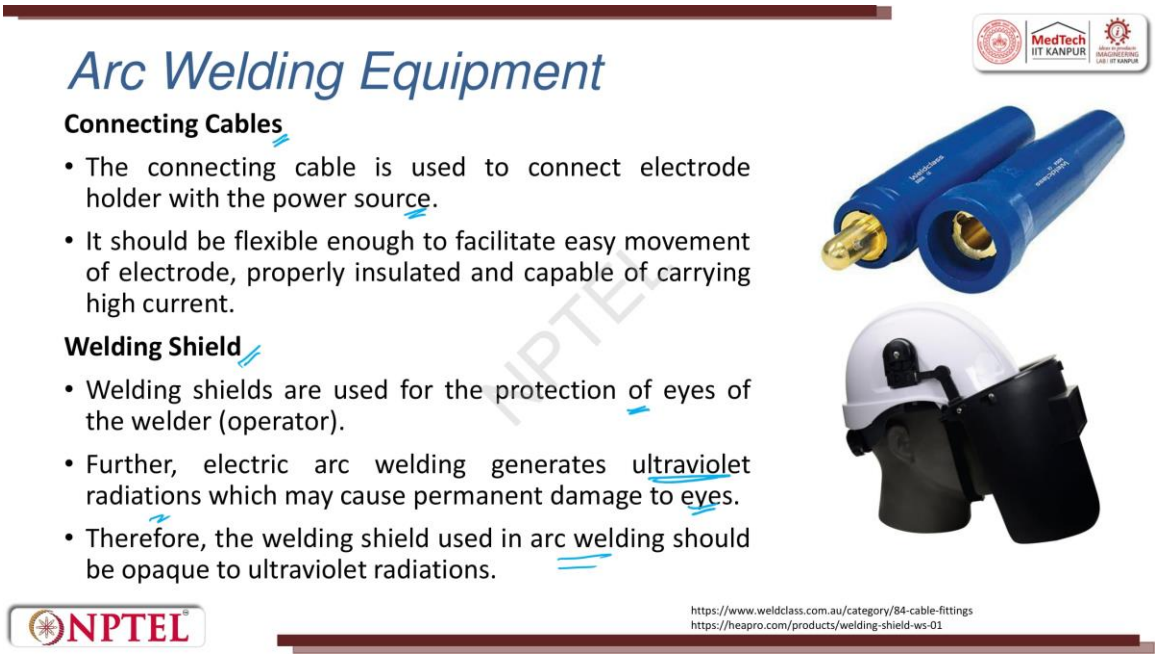
The jaw of the holder is made of metal, highly conductive, and heat-resistant. Because there is current flowing through it. The electrode holder needs proper insulation as electric current flows into the weld zone through it. So, this is insulation. You hold it by hand.

In the case when the jaws are subjected to very high temperatures, provision for cooling is also made. So many times what happens? In manual holding, we do not have this provision. When it is automated, we also have it. So why?

High current, so cooling has to be done. Otherwise, this part will melt. So the other thing is the work table. This is the work table. So generally when you do lab classes, you will have a setup like this.

So that will be a work table. The table will have the negative. This is if you take this as the negative electrode, that will have the positive electrode. So the parts to be welded are placed on the work table, which is flat. And here it is in the lab scale, flat-flat can be kept.

In situations it can be hemisphere, spherical, it can be double convex shape, that can be there. It is connected with the power source to give a particular polarity to the workpiece and electric circuit forms. When an electrode is brought in contact with the workpiece through the work table and the electrode holder. So this completes the circuit, that is what we are trying to say.

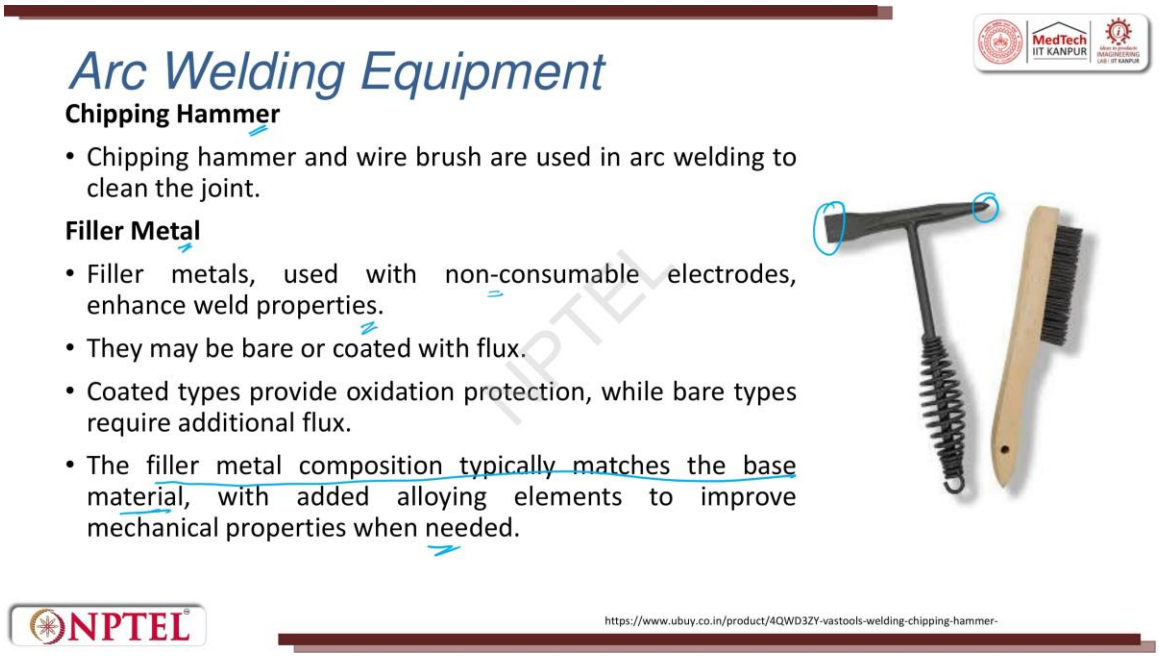


So there are connecting cables which are also used. So the connecting cables are used to connect the electrode holder with the power supply. So this is in turn attached with this. This will have a connecting cable. And this will be attached to a socket where in the power supply machine you try to have it. So, it should be flexible through a facility, easy mount of electrode, properly insulated and capable of carrying high current.

This is very important in welding. We always ask people or the welder always uses a shield. Why is that shield? Because if you go back and look into the process here, you see there is lot of radiation which is coming. In this radiation, there is also UV radiation also coming.

So that has to be protected from your eyes. Otherwise, you will have eye irritation. So this is why there is an important thing called shielding here, which we generally do not use in forging or casting. In machining also, we just try to put it to protect ourselves. But here it is a compulsion that you have to shield your eyes.

So weld shields are used to protect the welder's eyes. The electric arc welding generates ultraviolet radiation, which may cause permanent damage to the eyes. Friends, whenever I do experiments in my lab and when I do welding by myself for developing some setups, the shield, if I do not use it properly, irritates and I do not get proper sleep. So, the UV radiation affects your eyes. Therefore, the weld shields used for arc welding should be opaque to ultraviolet.



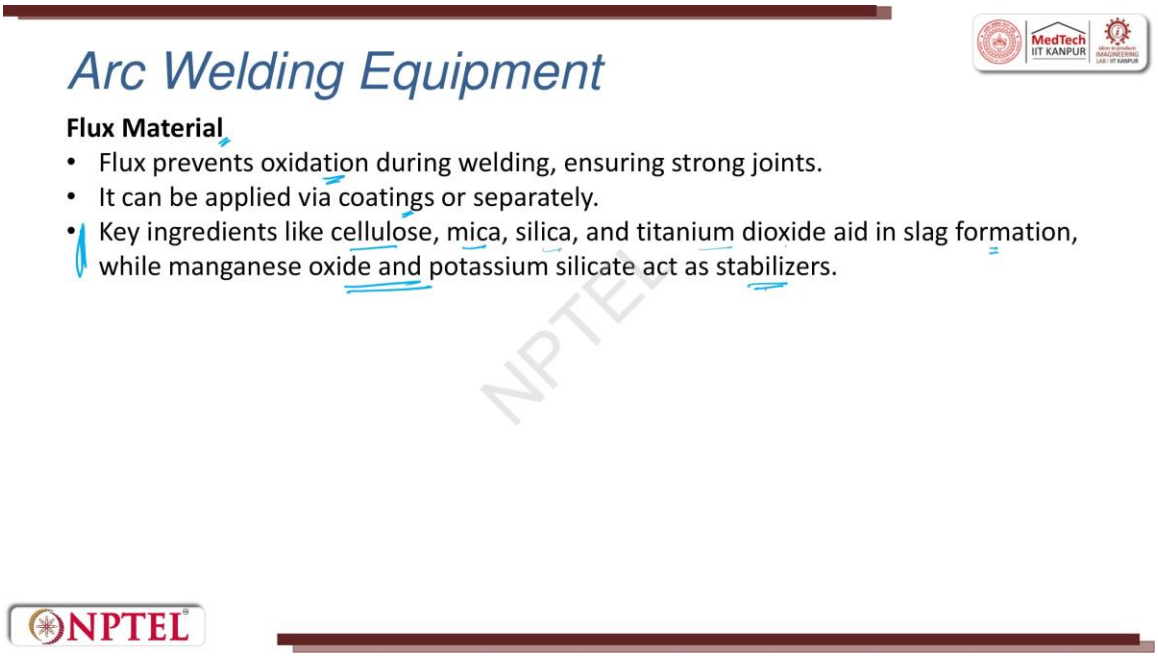
This is a chipping hammer. Why is that chipping hammer very important? As we have discussed till now, when you add a flux, there is a possibility that it creates an oxide, and then this oxide is moved to the top.

Oxides are unwanted metals, so you have to chisel them off. So you use this chipping hammer. You heat it. The other way around is when we are trying to use shielded gas arc welding. Or when we are not using shielded gas arc.

But if you are continuously welding, oxides will form on the surface. So that has to be avoided. So we use a sharp edge. This is a flat one. This is a pointed one, which you try to give an impact load.

That is why it is called a hammer. So it is done, and then you try to do it. Then it is filler metal. Filler metal used with a non-consumable electrode enhances welding properties. In non-consumable electrodes, where we use tungsten to create the arc, filler material is used.

They may be bare or coated flux. The coated type provides oxidation protection, which we have already seen. The filler material composition—typically, this is very important—matches the base material. Such that whatever alloy is added, it is done to improve the properties.



Flux material, as we have discussed, avoids oxidation. Coating is done inclusively or exclusively. The most important—this point is very important—ingredients are cellulose, mica, silica, and titanium dioxide added in the slag formation. While magnesium oxide and potassium silicate are used as stabilizers. So, we use flux for stabilizing, for oxidation, or for slag formation, which is on the top.

Thank you very much.