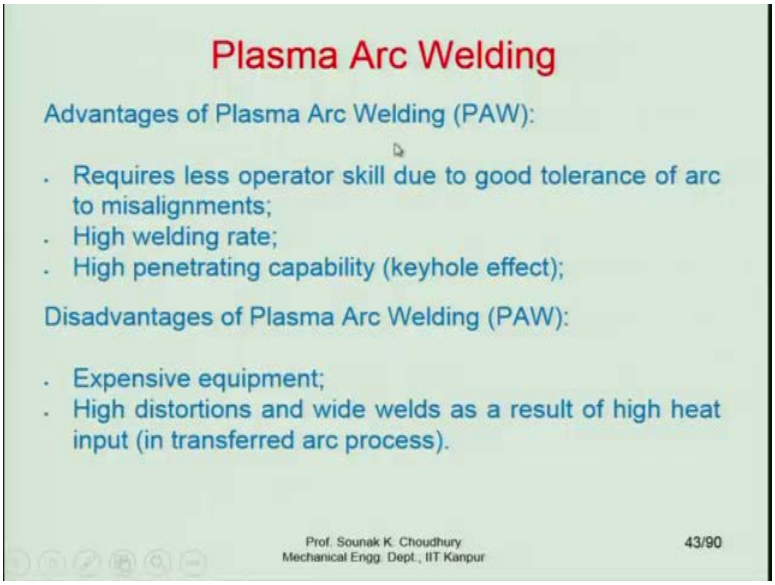
Manufacturing Processes – Casting and Joining
Prof. Sounak Kumar Choudhury
Department of Mechanical Engineering
Indian Institute of Technology Kanpur

Lecture – 18
Characteristics Features of Arc Welding

Hello and welcome to the course on Manufacturing Processes - Casting and Joining. Let me remind you that in our last discussion session, we started discussing the plasma arc welding. It was said that very high temperature can be generated by the plasma arc which can be generated between the constricted tungsten rod or the tungsten electrode and the work piece.

The process is simple, the high energy density of the plasma arc can create very high temperature that will cut or weld any material of any hardness. That is what we said.

(Refer Slide Time: 01:15)



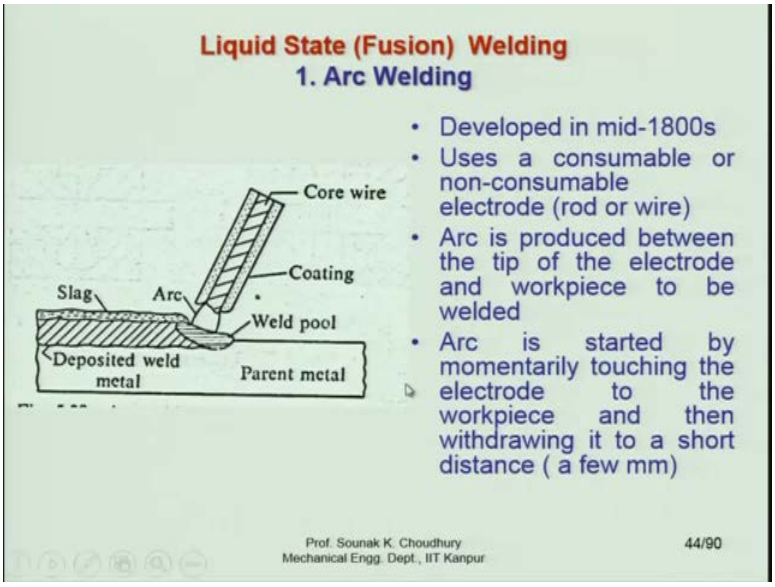
The advantages of plasma arc welding are the following. Requires less operator skill due to good tolerance of arc to misalignment; meaning that it is so controlled that the interference from the working personnel is not really required and his skill is immaterial. Because this arc itself is not misaligned.

It is highly aligned arcs. High welding rate is another advantage along with high penetrating capability; this in technology is called the keyhole effect. The high

penetrating capability; that means, it can have very high thickness of the material melted; it can cut or melt very high thickness material. This is also because of the high concentration of the energy; like we said about the ion beam or electron beam processes.

Disadvantage however is that the equipment is expensive the high distortions and wide welds as a result of high heat input. It is while in transferred arc processor. So, processes are different, like in case of in transferred arc process particularly, because of the high input the distortions are more, that is another disadvantage.

(Refer Slide Time: 03:14)



The fusion welding processes - the liquid state: it is the arc welding which is one of the most popular one and most diversely used or most popularly used welding processes. This is called the arc welding process. Arc welding is a very old process developed somewhere in the mid-1800s. As you can see that this is one of the oldest welding processes.

In the diagram as shown in the slide, this is the parent metal which is to be welded. there is a core wire through which the arc is generated because there is a circuit between the core wire and the parent metal and the electricity is passed between them. Here the circuit is not shown, I will show it to you. This core wire is coated and that coating has certain purpose and advantages that we will describe later.

The electric current when it is passed through the wire and the parent metal will create the arc. This coating will generate the slag while it is being melted because of that heat generated.

Because of the heat generated due to that arc, there will be weld pool, that is, the parent metal will be melted and it will help in welding the parts. Since this is the molten metal, it will have the tendency to get oxidized from the air.

That will be protected by the slag which will be created because of the coating which is around the core wire. This is the entire process which is simple and not very difficult process; however, as I said earlier that this requires experience. The technician who is performing this process should be highly skilled to get the good quality welding.

This process uses a consumable or non-consumable electrode rod or wire it can be consumable or it can be non-consumable, we will see in the process. Arc is produced between the tip of the electrode and the workpiece to be welded here in between. Arc is started by momentarily touching the electrode to the workpiece and then withdrawing it to a short distance a few millimeters.

Many of you might have performed the welding process in your first year of undergraduate studies and you must have seen that initially you have to make the short circuit by touching the electrode with the base metal. Many times what happened initially, if you remember, the electrode gets stuck in the parent metal because of the short circuit, because of the melting.

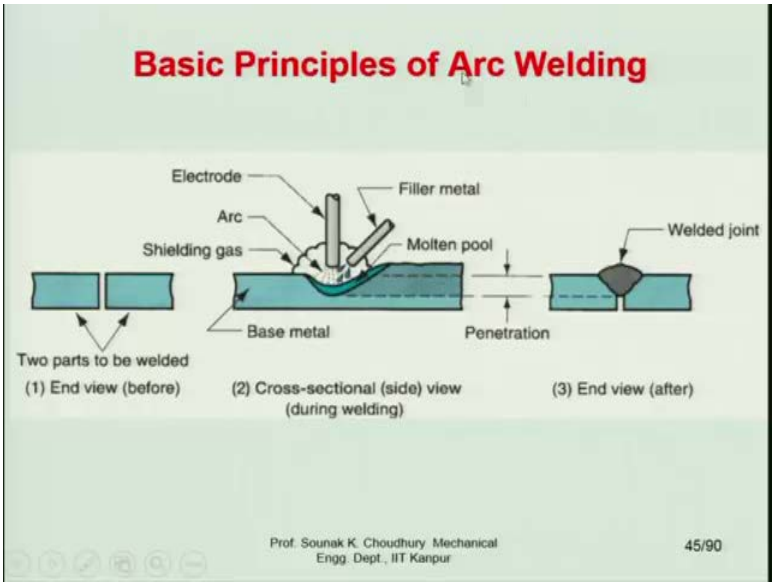
It has to be withdrawn momentarily and then it has to be kept at a certain distance. If you momentarily withdraw at a higher distance again, the arc will bediscontinued and you have to repeat the process of creating the arc again.

So, the arc will be generated as you are touching the parent metal with the wire because of the short circuit and then you have to withdraw to maintain the arc at a certain distance. If the distance is more than a particular value, the arc will disappear and again you have to generate the arc by touching that the base metal. That is the arc welding process.

When I said that you need high skill and experience to make a high-quality welding, this is the experience I am talking about. A skilled welder knows how to make that arc, how to maintain that arc, how to maintain that distance and on.

Even how to move the welding rod because it has to be uniformly moved. If you are not moving uniformly then the weld pool will not be uniform as you understand. In some places if you are holding, the pool will be more. If some places you are going rapidly, the pool will be less than required and so on.

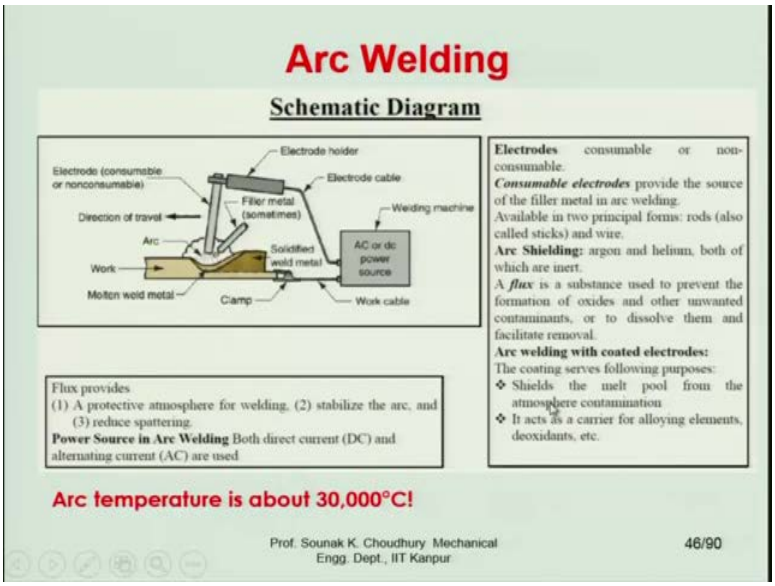
(Refer Slide Time: 07:57)



These are the basic principles shown here in the diagram; these are the two parts to be welded, this is the base metal, here is the filler metal. This is the electrode, and this is the filler metal which will cause the shielding gas and this is the molten metal because of the current passing through the electrode and the base metal.

This much is penetration and this is molten pool, and here this is the welded joint after the molten pool is solidified. This is the end view, this is during the welding, and this is the end view after the welding process.

(Refer Slide Time: 08:46)



This is the schematic diagram in more details. Here is the circuit; this is the electrode cable from AC or DC power source, this is the welding machine. And here it is connected to the part, which is to be welded, when the electricity is passed, the arc will be generated; there is a filler metal.

Filler metal is not used all the time. It is used depending upon the kind of material, what kind of material you are joining, what kind of accuracy that you need and so on; there are many other points that we will discuss.

Now, the arc is generated and there is a shielding gasso that the oxidation does not take place in the metal. Here electrodes can be consumable or non-consumable, consumable electrodes provide the source of the filler metal in the arc welding, available in two principal forms - rods these are also called the welding sticks and the wire. It can be a wire also. Arc shielding through argon or helium - both of which are inert.

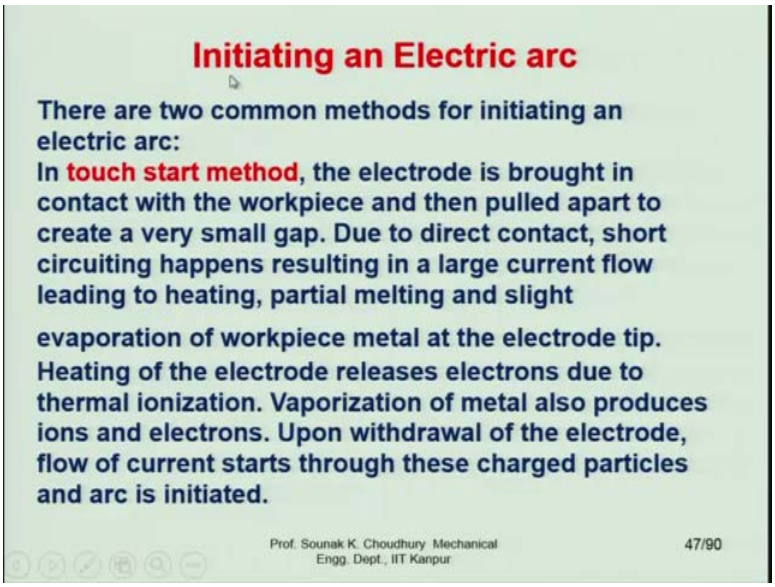
This is the shielding gas which is passed through the external source. A flux is a substance used to prevent the formation of oxides and other unwanted contaminants or to dissolve them in the molten metal and facilitate the removal. In arc welding with coated electrodes, the coating serves the following purposes, shields the melt pool from the atmosphere contamination this is already said and it acts as a carrier for alloying elements, oxidants etcetera.

As you can see, this is the coating. This coating melts and it covers the molten pool, that is one purpose. Another purpose is that it can also provide the alloying material to the weld pool to make it stronger.

This is another carrier of alloying element; it is another purpose of the coating. Flux provides a protective atmosphere for welding, stabilizes the arc, and reduces the splattering.

So, this is the purpose of using the flux and this is very important. Flux is very often used in the case of the arc welding, I will show you in a video clip as well. Power source in arc welding: both direct current or the alternative AC current can be used and the temperature of the arc can be as high as 30,000 degree centigrade. Mind it its very high temperature and at that temperature of course, the metal will be melted.

(Refer Slide Time: 12:13)



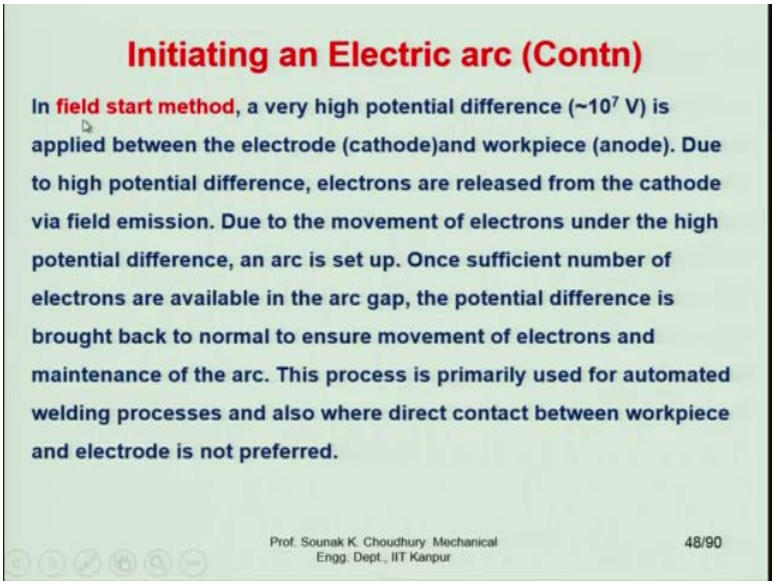
Initiating an electric arc is the method which is described here. There are two common methods; one is called the touch start method where the electrode is brought in contact with the workpiece and then pulled apart to create a very small gap as I just described. Due to direct contact, short circuiting happens resulting in a large current flow leading to heating partial melting and the slight evaporation of the workpiece metal at the electrode tip.

As soon as it is touched, there is a very high very high current passing because of the short circuit and that creates very high temperature. Heating of the electrode releases electrons due to thermal ionization. Vaporization of metal also produces ions and electrons.

Upon withdrawal of the electrode, flow of current starts through these charged particles. So, why that arc is stable, because of this reason this is what is explained here. Flow of current still goes through these charged particles which is in the gap between the two electrodes, meaning between the workpiece and the electrode an arc is initiated.

If we are maintaining that gap, the arc will be stable and that arc then can travel throughout the surface you want to weld.

(Refer Slide Time: 14:01)



Another process is called the field start method. That was the touch start method and this is the field start method. This is a very high potential difference of 10^7 volt is applied between the electrode and the workpiece.

Anode and cathode: anode is the workpiece electrode is the negative one which is the cathode. Due to high potential difference, electrons are released from the cathode via the field emission. This is another process where you put the very high potential difference. Due to the movement of electrons under the high potential difference an arc is set up.

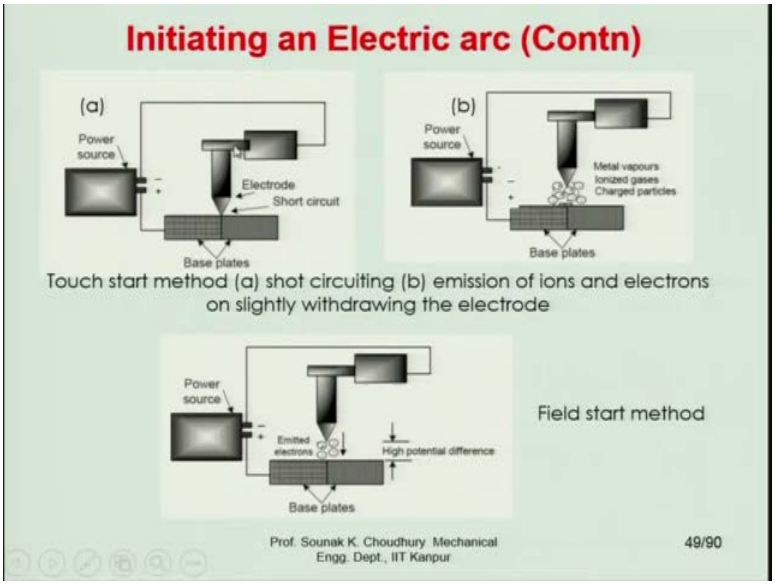
You are not making contact between them, but there is a very high potential created. Once sufficient number of electrons are available in the arc gap, the potential difference is brought back to normal to ensure movement of electrons and maintenance of the arc. This process is primarily used for automated welding processes where it is automatic because the human being is not maintaining that gap or performing the job and also where direct contact between workpiece and electrode is not preferred.

Because in the touch start method you are 'start touching' that and creating the short circuit; not always it is preferable, particularly in case where it is automated, where the welding process is automated and I also mentioned it in the beginning that many of the welding processes are automatically performed so that the precision can be maintained and faster welding can be made.

These days there are robot manipulators used for making the welding process, particularly in enclosed areas. Like for example, making the welding in an automobile chassis whether it is enclosed or inside a well.

That will be enclosed and the fumes which are coming because of the burning of the coating and the gases evolving that will harm the human being. So, there are different kind of manipulator robots which are used for making the welding process. Those are automatic welding processes.

(Refer Slide Time: 16:41)



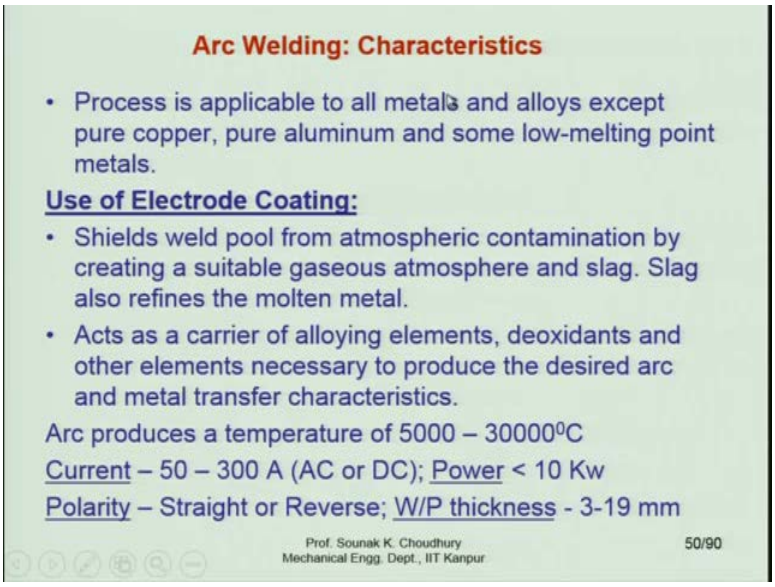
Schematically the process is shown here. This is the electrode and the short circuit is made, these are the base plates. This is the power source - the workpiece is made anode and the cathode is the electrode.

When this is touching the short circuit is created and very high temperature is created and it is welding the two plates to be joined. Metal vapors, ionized gases charged particles are remaining here. When you are creating a gap between them, the electricity or the electrons are passing through the charged particles.

As I mentioned that here flow of current starts through these charged particles. So, that is what happens after it is taken out and a particular gap is created. This is the touch start method - short circuiting and then emission of ions and electrons on slightly withdrawing the electrode. Here it is shown also in an exaggerated way; the same diagram here.

This is the field start method; diagram is the same, but here what is shown is that it is not touching but a very high potential difference is created. As I said that it is about 10^7 volt. In that case, the two electrodes are not in touch with each other and when the process is automated, these kind of field start methods will be convenient.

(Refer Slide Time: 18:41)



The arc welding characteristics are given in this slide; the process is applicable to all metals and alloys except pure copper, pure aluminum and some low melting point metals because it will create the oxide layer at the top. Electrode coating shields the weld pool

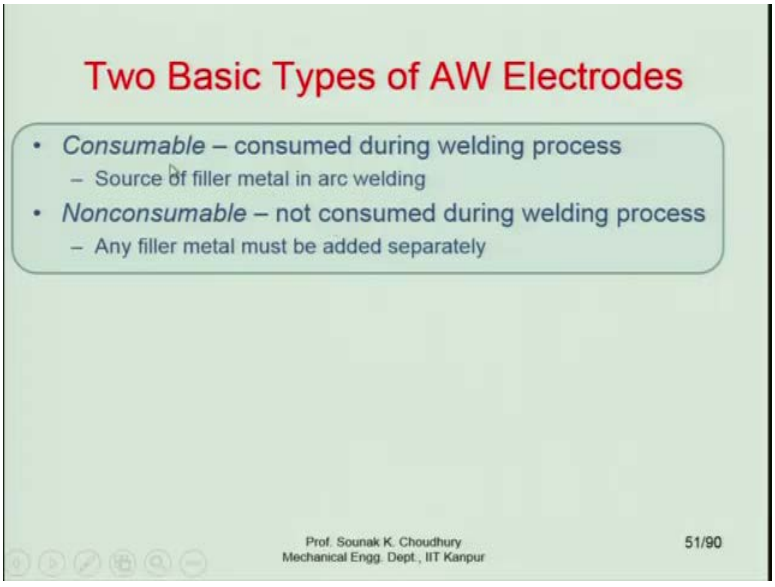
from the atmospheric contamination, this is the electrode coating I am repeating, I have already told about that coating - what the coating does.

First of all it shields the weld pool from atmospheric contamination so that it does not get oxidized from the oxygen of the air by creating a suitable gaseous atmosphere and a slag which will cover the molten metal. I will show it in a small video clip. Slag also refines the molten metal I said to you that it can provide the alloying elements to the molten metal to make it stronger, acts as a carrier of alloying elements.

Deoxidants and other elements necessary to produce the desired arc and metal transfer characteristics. The arc produces a temperature of up to $30,000^0$C as I said, the current normally used is either AC or DC which starts from 50 to 300 ampere.

As you understand that depends on the resistance, that is the thickness and the type of the welding that you are creating and power is less than 10 kilowatts. The polarity, straight or reverse both can be used; workpiece thickness is not more than 19 millimeters. It starts from 3 mm to 19 mm. Within that range the workpiece thickness can be used.

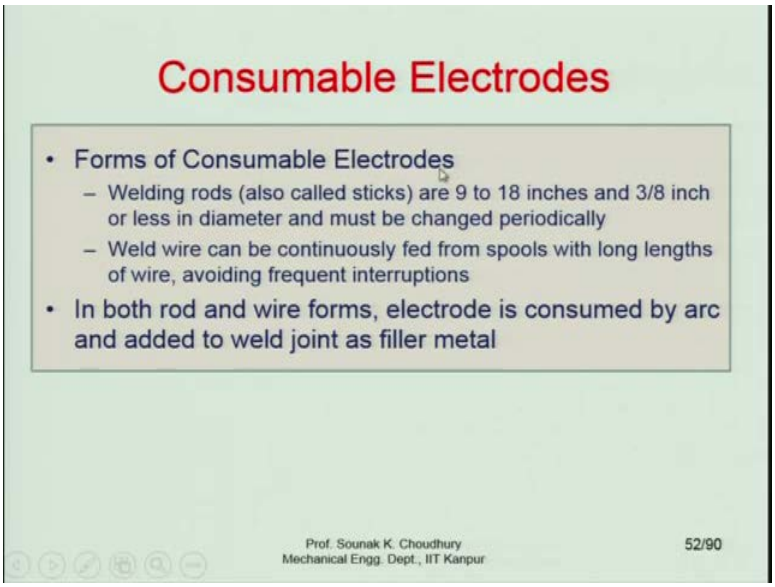
(Refer Slide Time: 20:52)



Two basic types of arc welding electrodes are used, that is consumable and non-consumable. Consumable, which is consumed during the welding process that is expended. Source of filler metal in arc welding is non-consumable. it is not consumed during the welding process. Any filler metal must be added separately therefore.

You understand what does it mean that, when the electrode is non-consumable, we have to use some kind of a filler metal separately, but in case of consumable this itself is a filler metal that is what it is said in the arc welding.

(Refer Slide Time: 21:46)

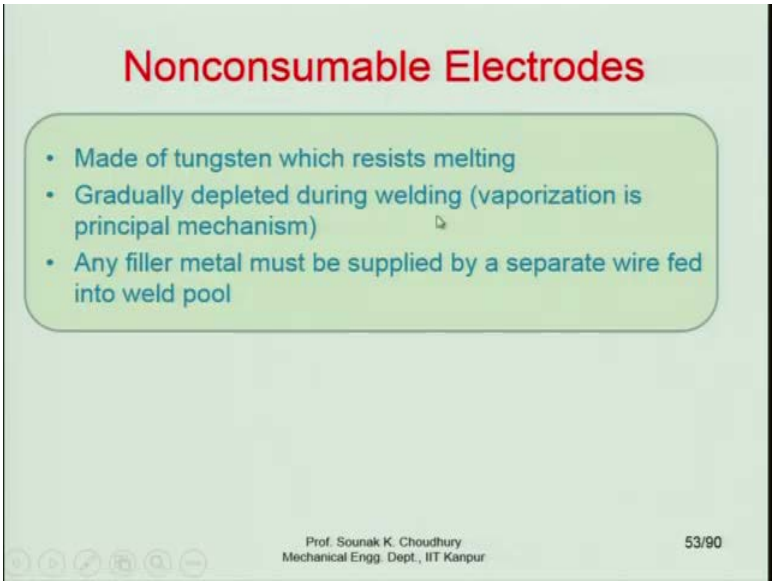


Forms of consumable electrodes: welding rod, also called the welding sticks, are 9 to 8 inches and 3 by 8 inch or less in diameter - these are all standardized. They must be changed periodically; because it is consumed and the coating layer is being exhausted.

Because it is consumable weld, wire can be continuously fed from spools with long lengths of wire avoiding the frequent interruptions. When the consumable rods are used, they get exhausted requiring frequent replacement.

It gets shorter in length because it is getting exhausted. So, it has to be replaced and while replacing, you have to stop the process. So, the process is interrupted; instead of that spool of wires can be used also as the electrode, in both rod and the wire forms, electrode is consumed by arc and added to weld joint as the filler metal. I already told you that when the electrode is consumable, this also acts as a filler metal.

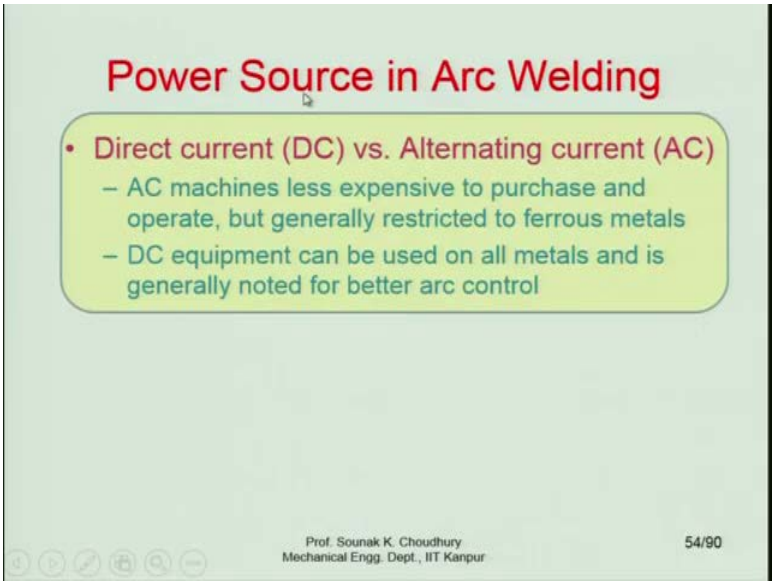
(Refer Slide Time: 23:07)



Non-consumable electrodes are made of tungsten which resist melting, gradually depleted during the welding and vaporization is principal mechanism. We say that this is non-consumable, but in the long run it has to be replaced, a little bit of it vaporized in each welding process and in the long run it has to be replaced.

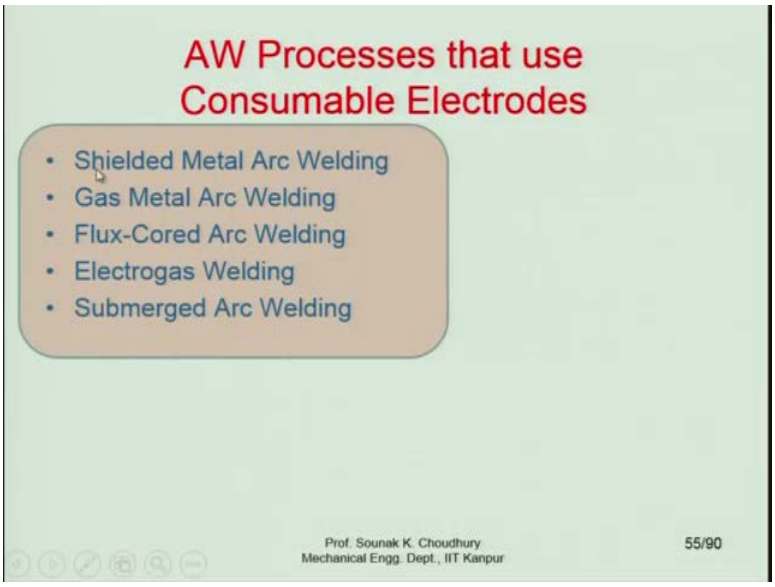
Any filler metal must be supplied by a separate wire fed into the weld pool because the electrode is non-consumable and we are not feeding the extra material. So, the extra material has to be fed by separate wire feed.

(Refer Slide Time: 23:53)



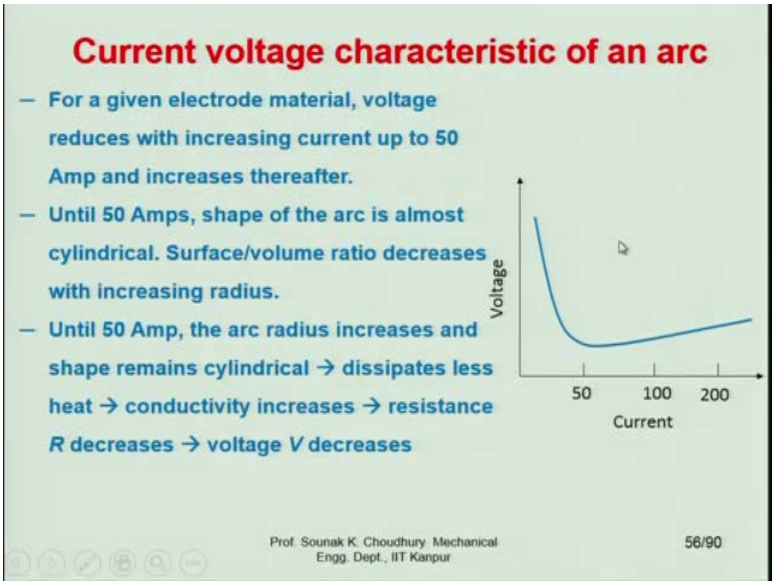
The power source in arc welding: as we said that it can be direct current or the alternating current. AC machines are less expensive of course, alternative current machines are less expensive to purchase and operate, but generally restricted to ferrous metals only and the Direct Current equipment can be used on all metals and is generally noted for better arc control although they are more expensive, but they are used for better arc control. In AC the arc control is difficult.

(Refer Slide Time: 24:31)



Arc welding processes that use the consumable electrodes are shielded metal arc welding, gas metal arc welding, flux cored arc welding, electro gas welding and the submerged arc welding. In all of them, the electrode is consumable, which is used to create the arc as well as to feed the alloying material and to protect the molten metalso that the welding zone is not oxidized and not distorted because of that.

(Refer Slide Time: 25:16)

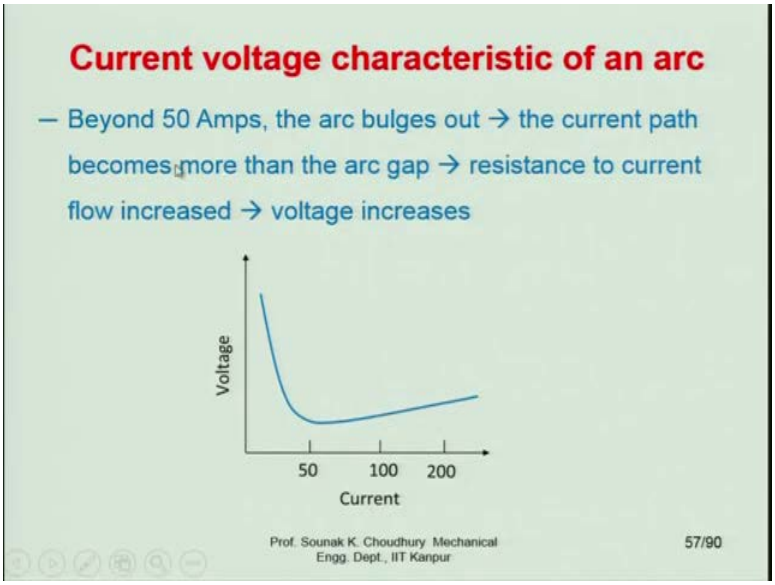


Current-voltage characteristic of an arc: this is very important to knowt how the voltage is changing; for a given electrode material voltage reduces with increasing current up to 50 amperes.

After 50 ampere of current, the voltage is coming down, voltage reduces and thereafter, it increases. Until 50 amperes shape of the arc is almost cylindrical; surface by volume ratio decreases with increasing the radius.

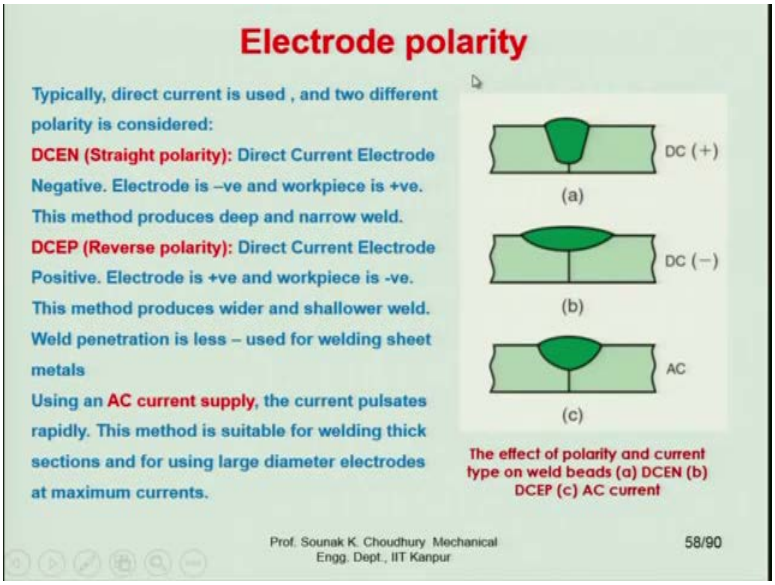
Until 50 amperes, the arc radius increases and the shape remains cylindrical, dissipates less heat; conductivity increases, resistance decreases, and voltage decreases therefore. This is the reason why the curve goes like that as the current goes up to 50 amperes.

(Refer Slide Time: 26:23)



Beyond 50 ampere what happens? The arc bulges out, the current path becomes more than the arc gap, resistance to current flow increases, therefore and the voltage starts increasing. Once again, beyond this point the arc bulges out and the current path becomes more than the arc gap. Therefore, the resistance to the current flow increases and the voltage goes up. Electrode polarity:

(Refer Slide Time: 27:02)



We discussed that the polarity can be reversed as well; that means, normally workpiece is taken as an anode, as a plus. Typically, direct current is used and two different polarity is considered - one is the straight polarity which is called the Direct Current Electrode Negative DCEN.

DCEN stands for Direct Current Electrode Negative. Electrode is negative and workpiece is positive; which we kept telling in all the processes so far. I have shown it to you that this method produces deep and narrow weld.

The reverse polarity can also be used. This is also called the straight polarity DCEN. Reverse polarity can also be used and which is called the direct current electrode positive in both these cases of course, we are talking about the direct current. The direct current electrode positive and workpiece is negative in that case this method produces wider and shallower weld.

For welding the sheet metal, weld penetration used is less. Sheet metal thickness is very less. So, you do not need to have the large penetration and we should use the reverse polarity in that case. Using an AC current supply. In those two cases that we have so far discussed, that is, the state polarity and the reverse polarity, in both cases we said that the DC current is applied.

Using an alternative current supply, the current pulsates rapidly because its AC current, this method is suitable for welding thick sections and for using large diameter electrodes at maximum currents. This is the advantage of the AC current supply; because it can be suitable for the welding thick sections; there the direct current may not be useful because it will not penetrate .

In Fig. (a) here what is shown is that this is the DC, workpiece positive producing deep and narrow weld. In Fig (b) it is shallow weld because this is the reverse polarity and in Fig. (c) it is AC current used; where the thickness will be more. The effect of polarity and current type on weld beads you can see from these figures that in AC current this is wider and this is thick section for the thick section. The rest of the welding processes and the other techniques in welding we will discuss in my next discussion session.

Thank you for your attention.