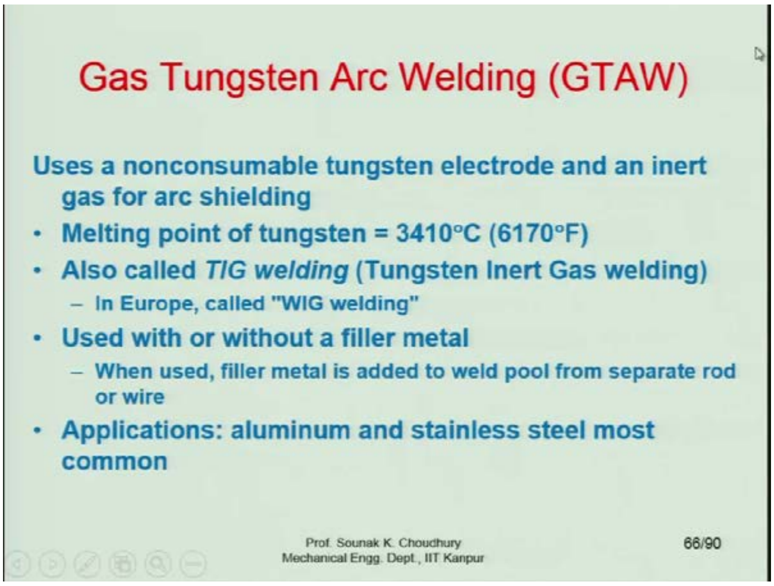
Manufacturing Processes – Casting and Joining
Prof. Sounak Kumar Choudhury
Department of Mechanical Engineering
Indian Institute of Technology Kanpur

Lecture – 20
Gas Welding, Brazing and Soldering, Welding Defects

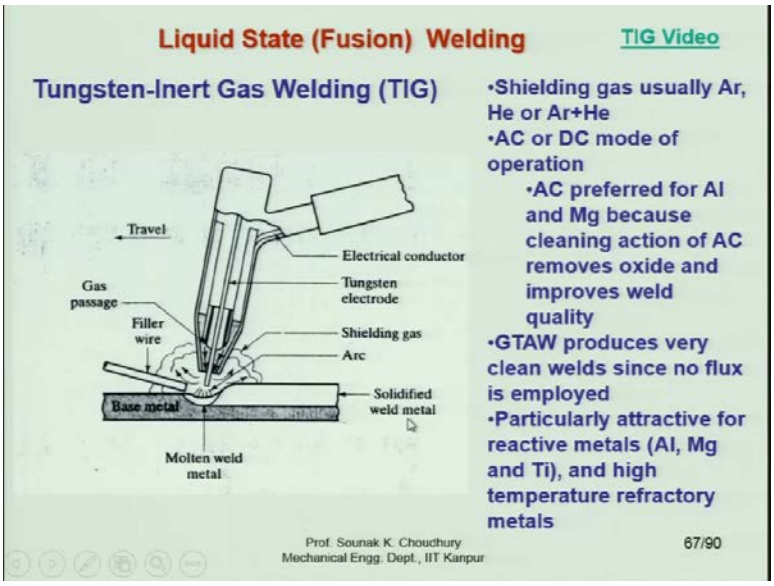
Hello and welcome back to the lecture series on Manufacturing Processes - Casting and Joining. This is going to be the last lecture in this series of Manufacturing Processes - Casting and welding. We have discussed casting processes and we have discussed some of the welding processes. Some more of the welding processes I will discuss in this last lecture.

(Refer Slide Time: 00:49)



I will remind you that in our last session, we started discussing the Gas Tungsten Arc Welding and which is also called the TIG welding or WIG welding. this is used with or without a filler metal as I said and then, the application is for aluminum and stainless steel. These are the most common materials.

(Refer Slide Time: 01:09)



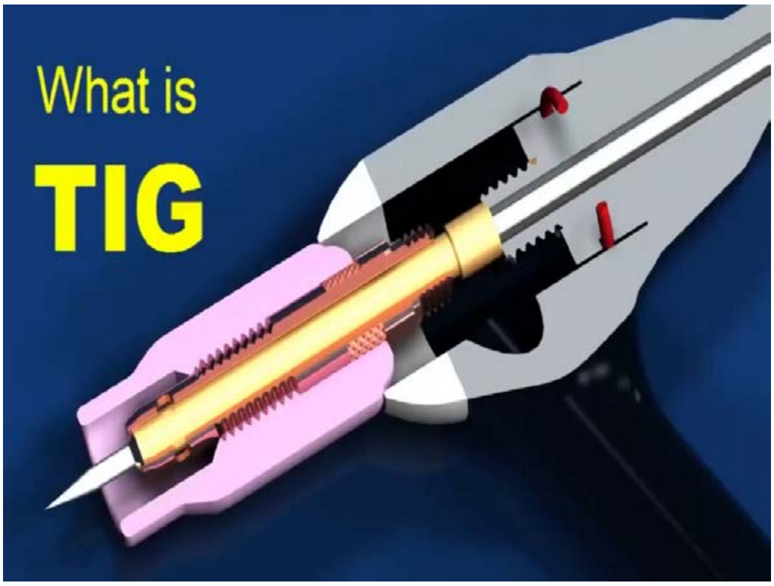
This is the schematic diagram. I will show you a small video as well. The Tungsten-Inert Gas welding: here the shielding gas normally used is argon, helium or together argon and helium. Both AC or DC mode of operation can be used. AC preferred for aluminum and magnesium because as aluminum and magnesium when it is available normally, a layer of oxide is formed on the surface; aluminum oxide or magnesium oxide.

When the welding process take takes place, this oxide level has to be cleaned. AC, alternative current, because of its nature, it pulsates. It removes oxide and improves the weld quality. That is why AC current is particularly used for such metals like aluminum and magnesium, where you have the oxidation problem. Gas tungsten arc welding produces very clean welds, since no flux is employed.

Particularly, attractive for reactive metals; aluminum, magnesium, titanium and the high temperature refractory metals are difficult to weld with any other welding process because of the inaccuracy that is obtained because of these oxide levels.

Also suitable for refractory metals, where the heat is not penetrated. In this process these metals are very easily welded. I will show you a small video of that TIG welding which will clarify further the process characteristics.

(Refer Slide Time: 03:15)



What is TIG welding?

(Refer Slide Time: 03:17)

TIG stands for Tungsten Inert Gas welding.

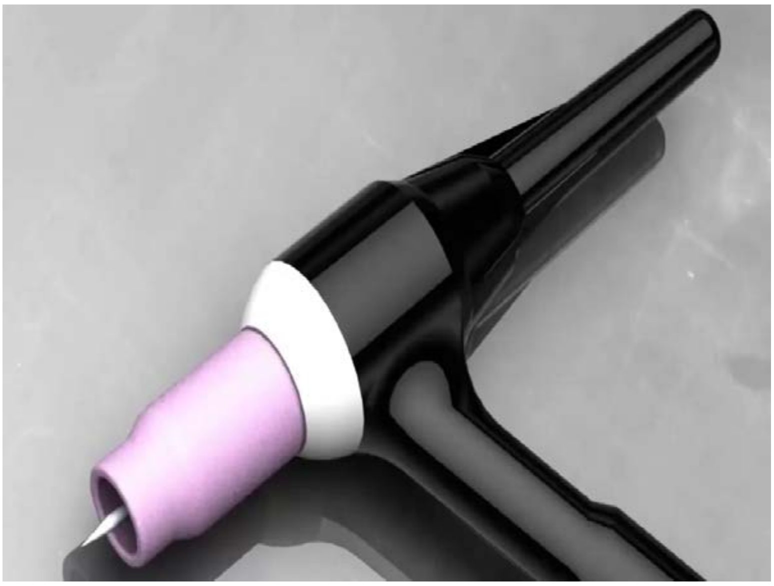
(Refer Slide Time: 03:21)

The American welding society calls this process Gas Tungsten Arc Welding or GTAW.

(Refer Slide Time: 03:39)

You might also hear it called “Heliarc” welding.

(Refer Slide Time: 03:31)



TIG welding uses a tungsten electrode.

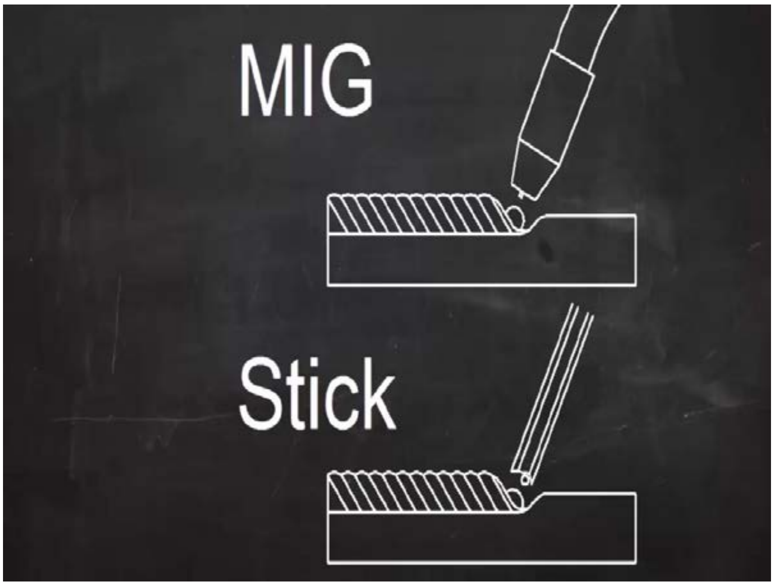
(Refer Slide Time: 03:33)

And tungsten has an extremely high melting point, when you TIG weld, the electrode gets hot; but it does not melt. We say that it is a non-consumable electrode.

(Refer Slide Time: 03:41)

And it does not mean it lasts forever that just means that it does not melt and become part of the weld.

(Refer Slide Time: 03:51)



You see in a lot of other welding processes, the electrode melts and becomes filler metal. Those are consumable electrode processes. So, here is the tungsten electrode being held in a TIG torch, the electrode slips into a collet.

(Refer Slide Time: 04:05)

And the collet tightens up against the collet body.

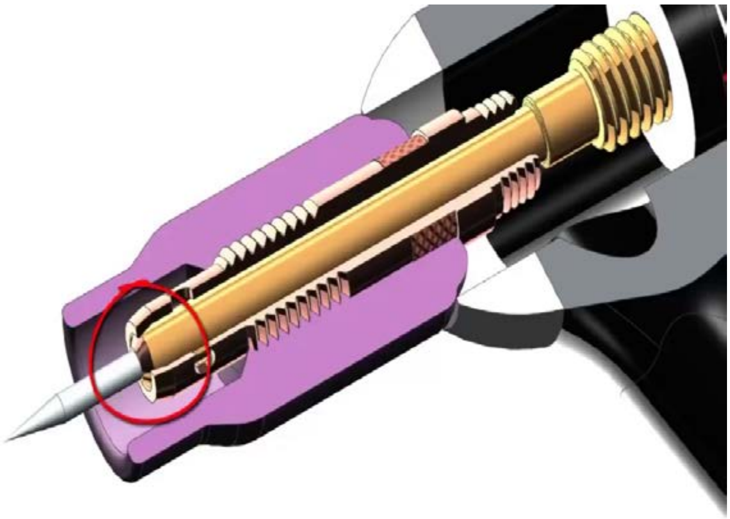
(Refer Slide Time: 04:07)

You can adjust the length that the electrode sticks out of the holder by loosening up the end cap.

(Refer Slide Time: 04:13)

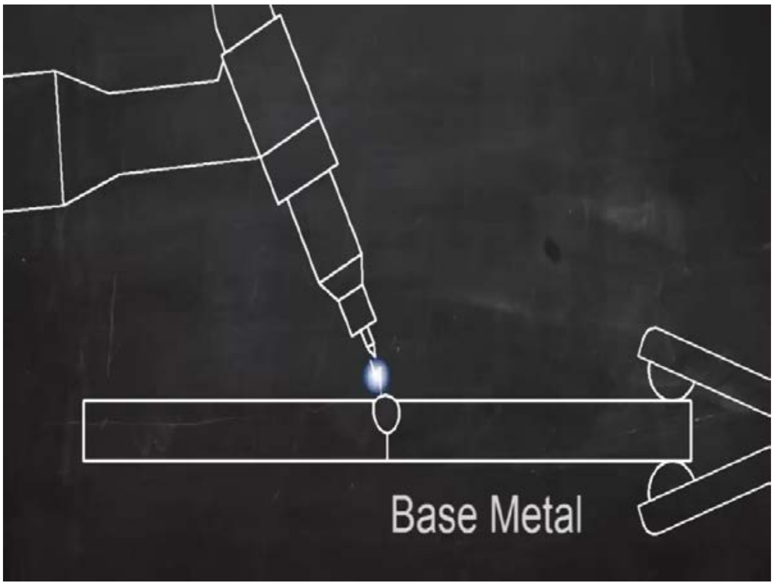
When you tighten the end cap, the collet clamps down on the electrode.

(Refer Slide Time: 04:19)



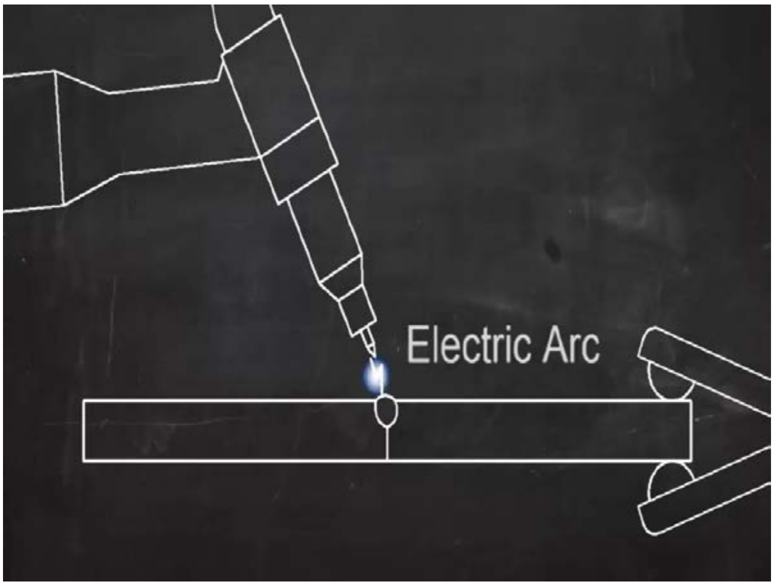
TIG works by melting the base metal.

(Refer Slide Time: 04:23)



That is the metal that makes up the two pieces that are to be joined the heat is generated by an electric arc that forms between the base metal and the tungsten electrode.

(Refer Slide Time: 04:29)

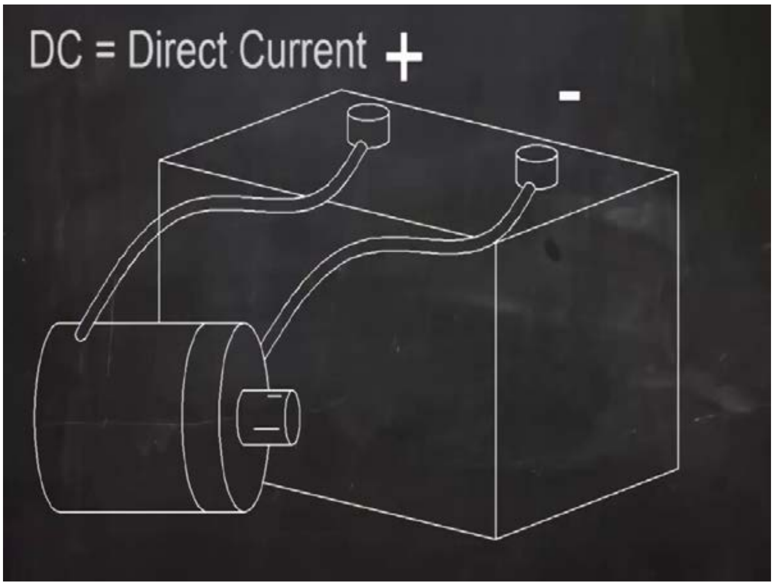


(Refer Slide Time: 04:35)

You can control the amount of heat with a foot pedal or with a thumbwheel on the torch.

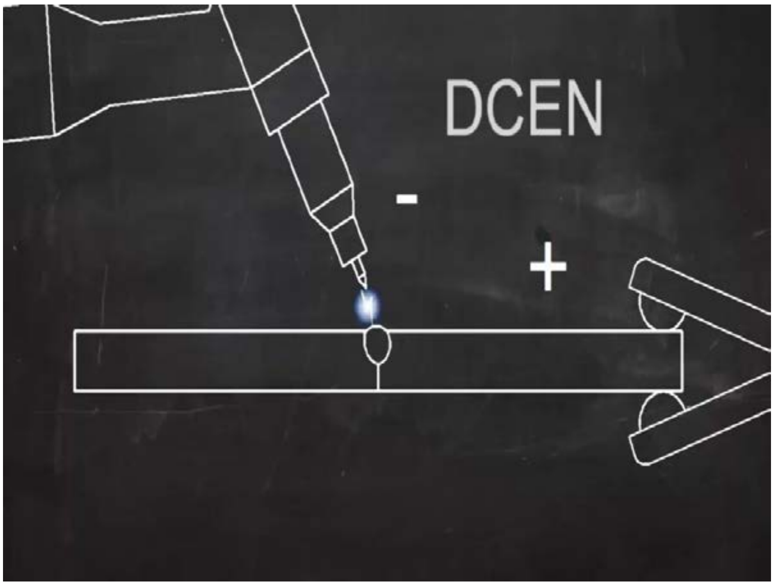
(Refer Slide Time: 04:37)

(Refer Slide Time: 04:41)



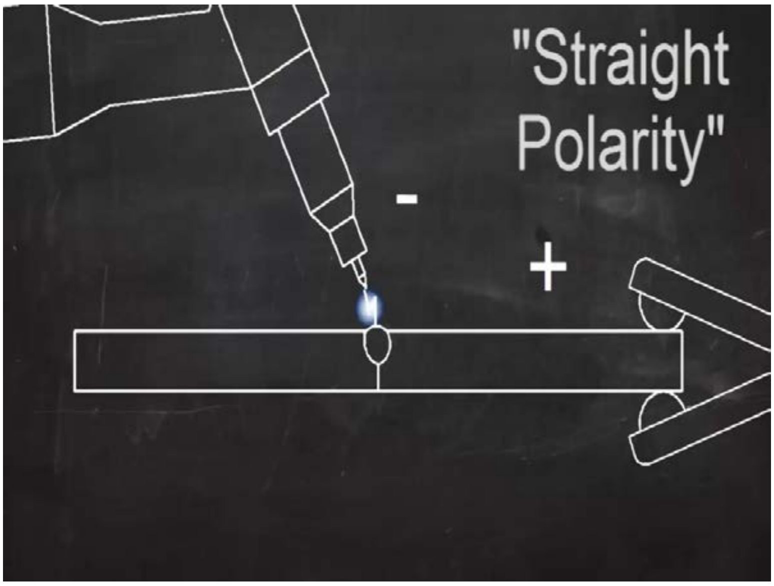
For most metals, the current is direct current or DC. DC is like the current flowing from a car battery; one wire is always the negative and one is always the positive. DC TIG welding, the electrode is usually negative and the workpiece is positive.

(Refer Slide Time: 04:59)



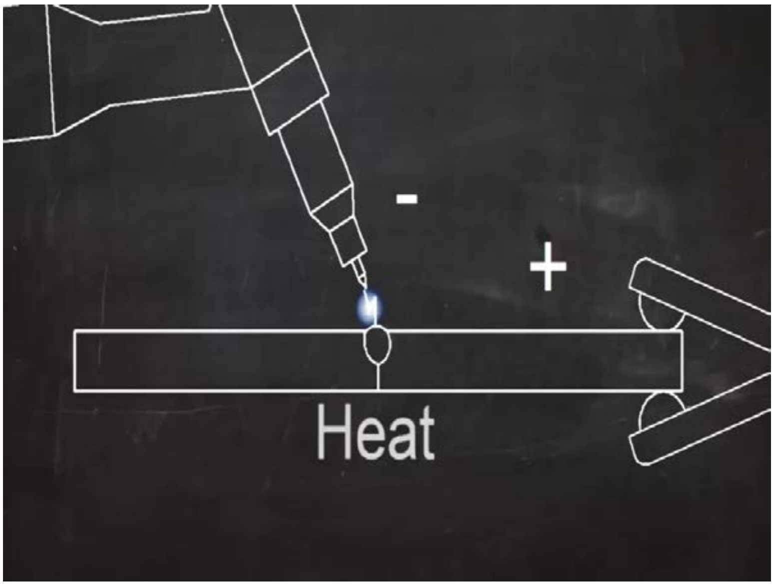
The term DCEN is used for this indicating that the current is DC and the electrode is negative. This is also called “Straight polarity”.

(Refer Slide Time: 05:07)



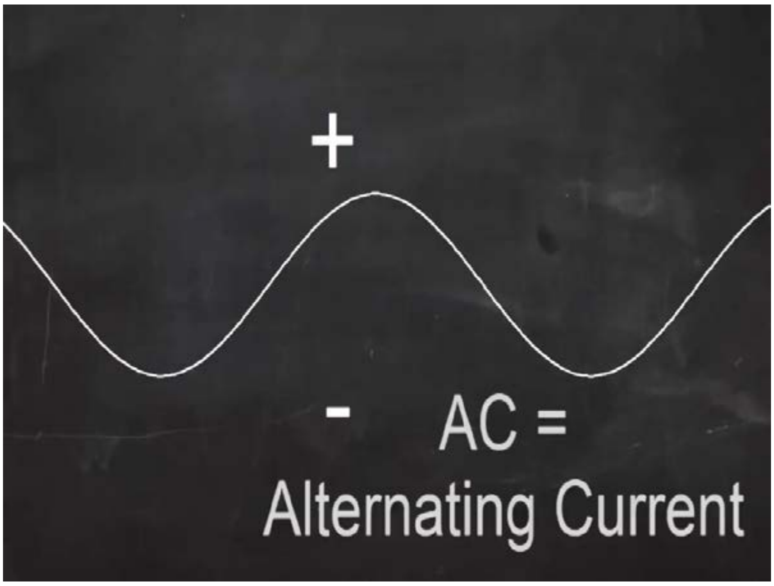
The DCEN is a more descriptive term. DCEN put most of the heat on the work piece.

(Refer Slide Time: 05:13)



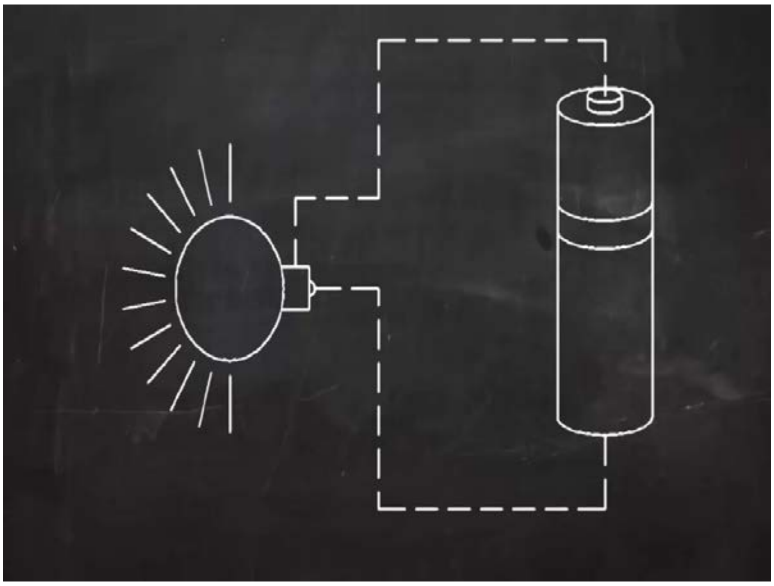
And it is the most common setup.

(Refer Slide Time: 05:19)



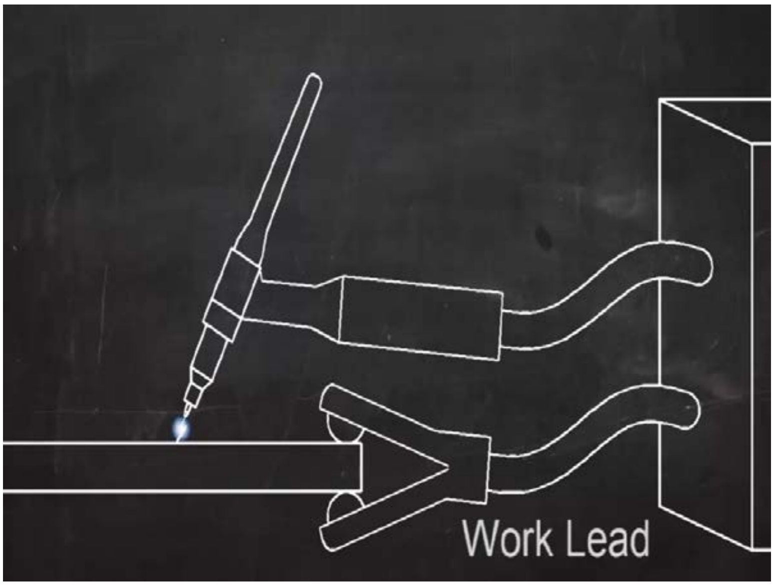
When welding aluminum, however, AC is used. In AC, the positive and negative voltages switch back and forth between the electrode and the workpiece and this puts more heat on the electrode, but it has a cleaning effect on the workpiece. You see aluminum forms oxides that floats to the top of the weld pool and prevent a good weld. AC current helps control these oxides.

(Refer Slide Time: 05:43)



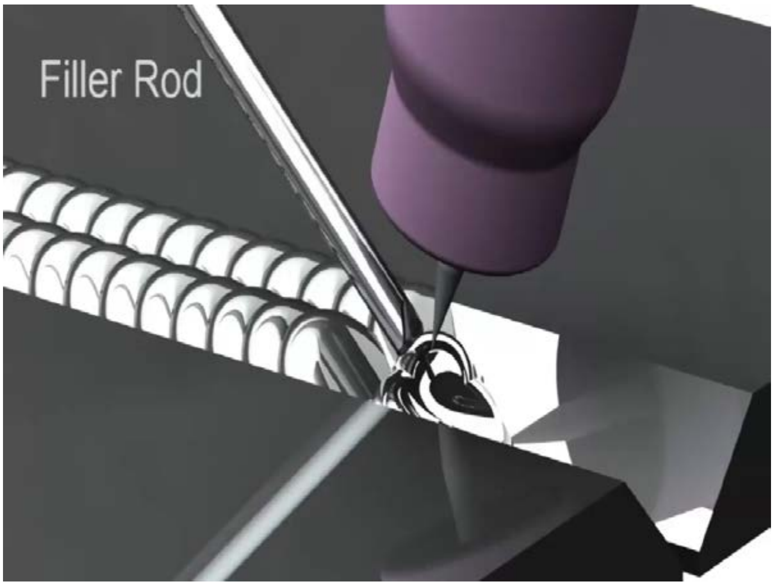
In an electric circuit the current flows in a loop and TIG welding.

(Refer Slide Time: 05:47)



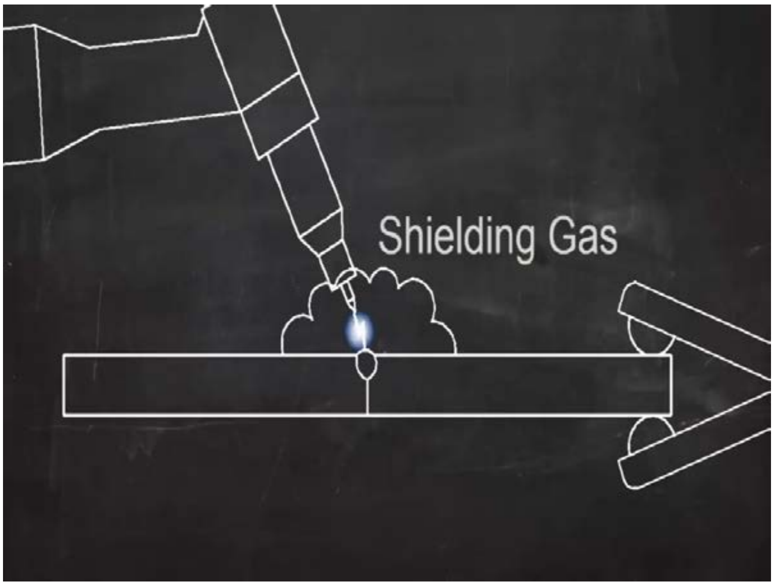
The current has to flow in a complete circle from the machine to the torch into the work and back to the machine. A work lead is clamped to the work to complete the circuit from the work piece back to the machine.

(Refer Slide Time: 05:59)



Now, you can TIG weld with or without filler metal and that is not a choice, you have in a lot of other processes. If you want to add filler metal to a TIG weld, you use a filler rod which is just a rod of metal with a specific Galloway. You want to make sure that the filler metal, you are using is compatible with the base metal and that it has the strength required to do the job.

(Refer Slide Time: 06:21)

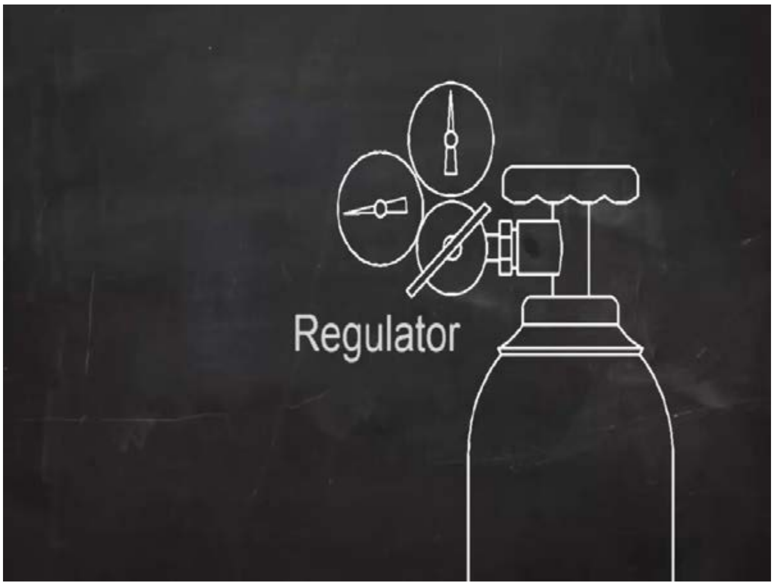


In TIG welding, the molten metal is protected by a shielding gas. This gas usually argon and sometimes helium or other gases, keeps the molten metal from reacting with oxygen water vapor in the atmosphere.

(Refer Slide Time: 06:37)

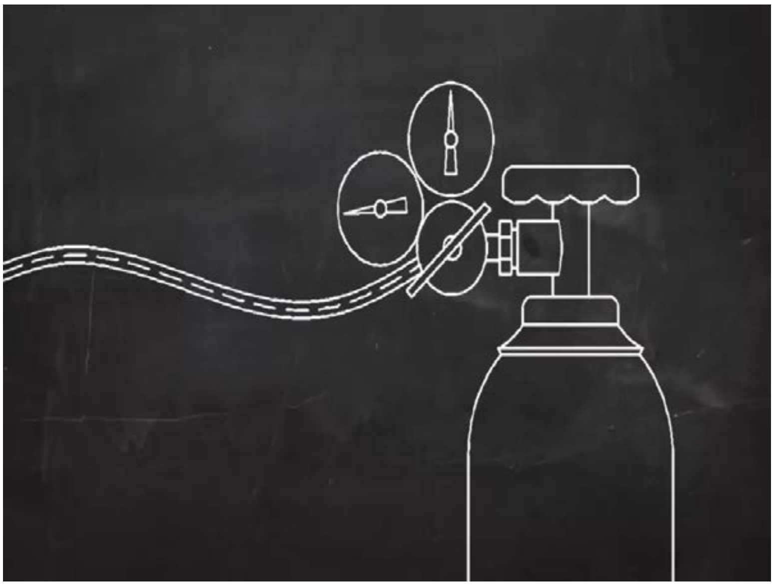
This shielding gas is stored in high pressure cylinders like these.

(Refer Slide Time: 06:39)



The pressure is reduced to a usable level by a device called a Regulator.

(Refer Slide Time: 06:45)

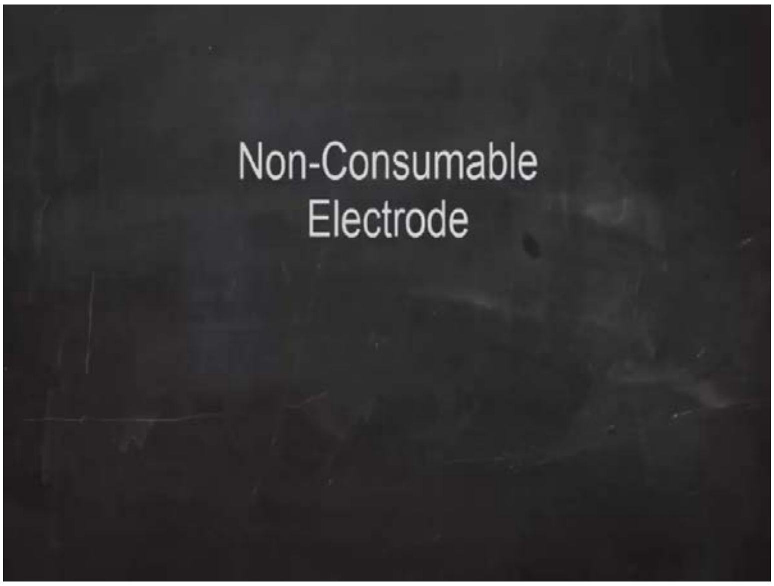


The shielding gas flows through a hose and comes out right at the point of the weld.

(Refer Slide Time: 06:49)

So, in summary, TIG welding is an electric arc welding process, uses a non-consumable tungsten electrode.

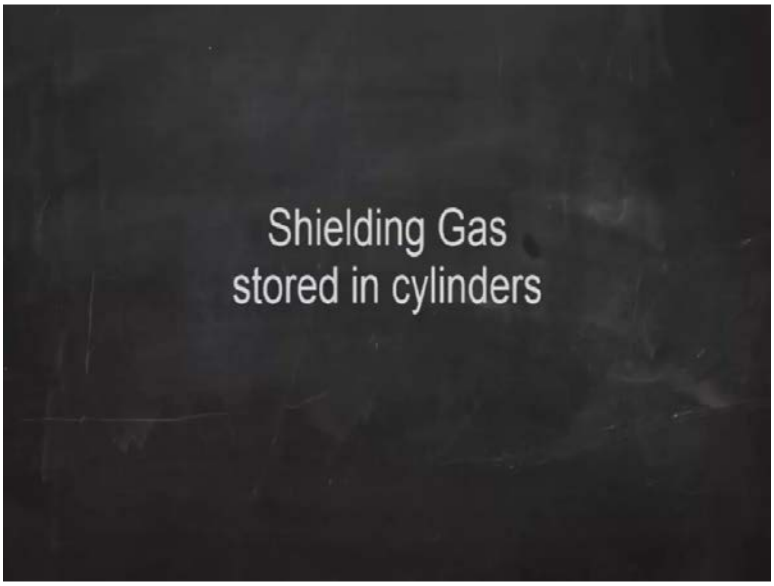
(Refer Slide Time: 06:53)



(Refer Slide Time: 06:55)

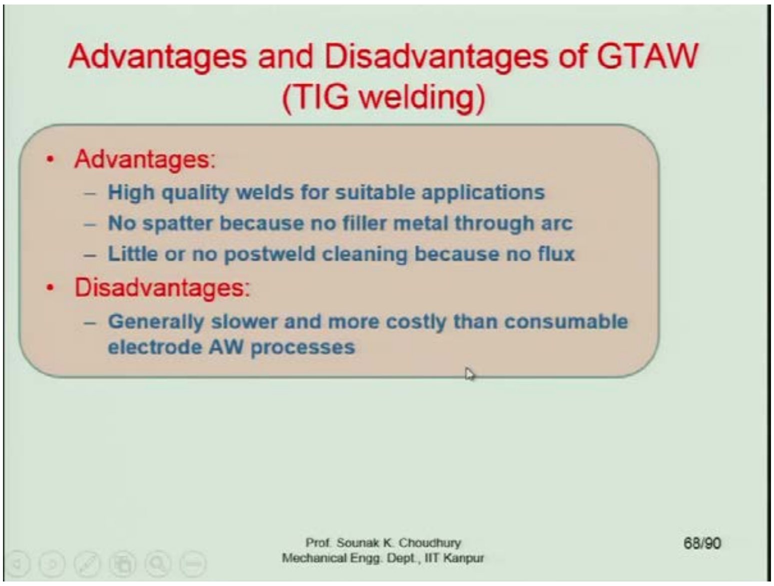
The filler metal is added separately in the form of filler rod.

(Refer Slide Time: 06:59)



And the shielding gas comes from a high-pressure cylinder. I hope you enjoyed the video and some of the process characteristics got clarified. This is similar to the other process, where we have seen that is the MIG weld. Only difference is that here it is the non-consumable electrode, but otherwise the polarity wise or the shielding gas wise, this is a very similar one to the MIG welding that we have seen earlier.

(Refer Slide Time: 07:33)



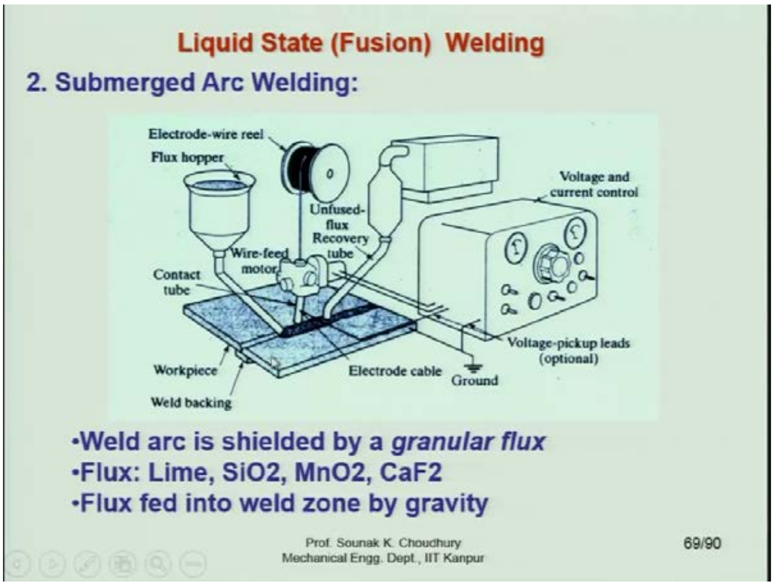
Advantages and disadvantages of the TIG welding are the following. Advantages: these are the high-quality welds for suitable applications. A high-quality weld basically because you do not have the slag on top of that, that is once again I am repeating, there is no slag so there is no further processing required and the surface quality will be better. No spatter because no filler metal through the arc is used.

This is one of the most important advantages also because there is no filler metal. Well, filler metal can be added; but if no filler metal is there, in that case there is no splashing. The little or no post weld cleaning because there is no flux. I already said that the disadvantages are that they are generally slower process and more costly, more expensive than the consumable electrode arc welding processes.

First of all, this is a tungsten rod which is used that itself is expensive. Although, this is not consumable, but still there is a varying action and as you have seen that is in the collet chuck. Collet is similar to one in the mechanical pencil. You must have seen that mechanical pencil, inside that there is a 0.5 or 0.7 mm diameter of the pencil lead.

Just imagine that, the lead is the the tungsten electrode. Tungsten electrode in the long run, wears out and therefore, it has some kind of wear and tear and this is expensive and overall, this entire process becomes expensive. It is of course, slower than the MIG welding.

(Refer Slide Time: 09:27)



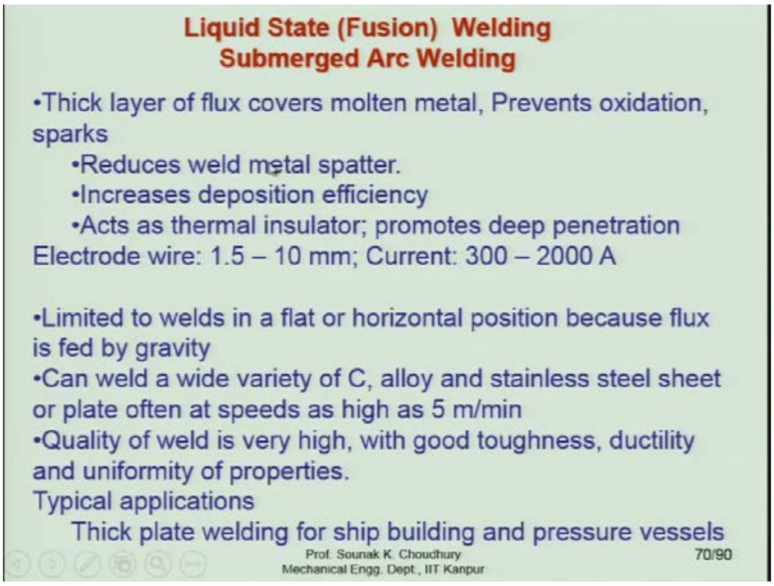
Submerged arc welding: this is the simple process, which is very popularly used, and this is the entire setup. It is shown schematically. There is a flux hopper through which the solid flux material is delivered to the welding zone. This is the wire feed motor which feeds the motor from the spool. This is the wire reel, and this wire is the electrode.

This will be submerged. This will be hidden inside the flux, which is being supplied here. There is a contact tube through which this wire is passed. This is kind of a support; and these are the electric cables going to the voltage and the current control panel and the unfused flux recovery by vacuum will be done through this.

Because there will be a heap of flux here and part of it will be melted, the weld pool will be covered by the molten slag. But much of it, much of the slag will not be consumed. This will be dry one as it is being supplied. This will be sucked to this box by creating vacuum and then, it can be re-circulated. The weld arc is shielded by a granular flux.

Flux normally is consisting of lime, silicon oxide, manganese oxide, calcium fluoride. These are the substances which constitute the flux. Flux is fed into weld zone by gravity. Flux is stored in the hopper and from here it is fed by the gravity in a control mode.

(Refer Slide Time: 11:47)



The characteristics are the following. Thick layer of flux covers the molten metal, prevents oxidation and the sparks, reduces weld metal spatter, increases deposition efficiency; acts as thermal insulator. The heat is not going out, it will be staying inside.

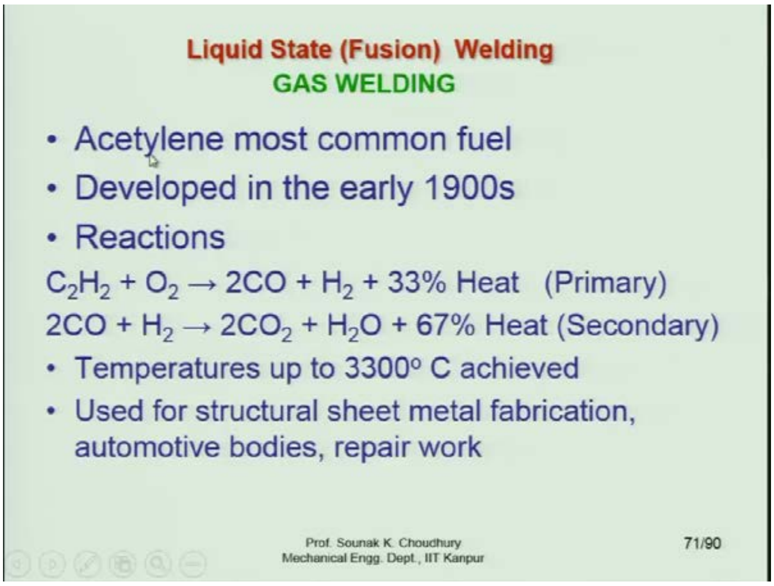
Promotes deep penetration because of that. Penetration will be less if the heat flows out to the atmosphere. Electrode wire of about 1.5 to 10 mm diameter is used; current used is as high as 300 to 2000 Amperes. Limited to welds in a flat or horizontal position because flux is fed by gravity.

So, you cannot do it on the ceilings because the flux cannot be provided there. It has to be on the horizontal and that is one disadvantage of this kind of welding processes.

Can weld a wide variety of carbon alloy and stainless-steel sheet or plate often at speeds as high as 5 meter per minute; 5 meter per minute is considered to be quite high speed.

Quality of weld is very high with good toughness, ductility and uniformity of properties. Typical application is the thick plate welding for the ship building and pressure vessels. These are very important welding processes, when you need to have the very thick sheets in the ship or the pressure vessel they have to be welded and most importantly, that this should not have any leakage. When they are welded, they should not have any kind of leaking.

(Refer Slide Time: 14:07)



The acetylene is most commonly used for the gas welding. This is also a fusion welding or the liquid-state welding as I mentioned earlier. This gas welding was developed in the early 1900s and you will find this welding process in most of the road-side repairing shops, for automobile repairing or scooter repairing, gas welding is very popularly used.

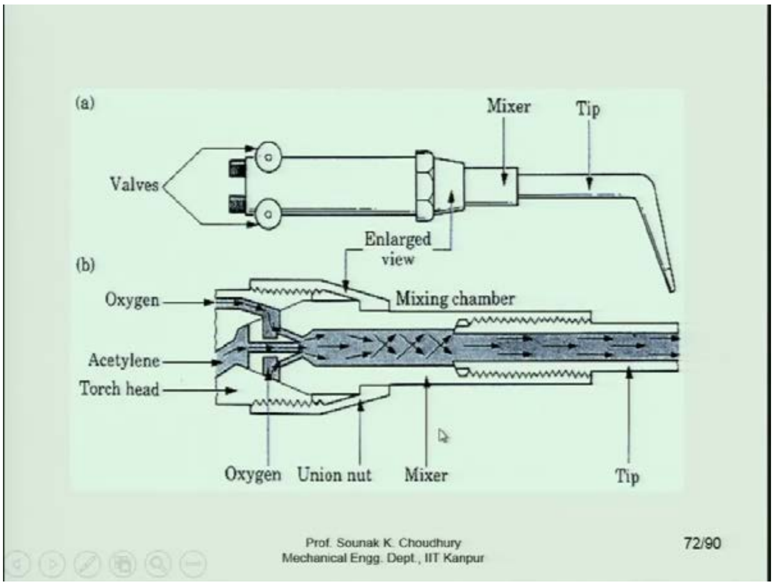
Here the reactions are the following: C_2H_2 is burnt with oxygen and it forms the carbon monoxide and the hydrogen plus 33% of heat. This is the primary heat when it is oxy acetylene. oxygen with the acetylene. There are two cylinders; one having the acetylene and another having the oxygen. Those two gases are mixed and then, they are burnt.

As a result, 33% of the heat required will be produced and hydrogen and carbon monoxide gas will be evolved. It goes to the atmosphere. This carbon monoxide with the hydrogen forms the carbon dioxide before going to the atmosphere and there will be H_2O plus 67% of heat recovered from here, from this reaction.

The primary reaction when the oxygen and acetylene burns, it is only 33 percent. And then, the carbon monoxide and hydrogen gas will be evolved. Those two gases - carbon monoxide and hydrogen will react with each other and they will form carbon dioxide and water and that will also produce 67% of heat in secondary reaction.

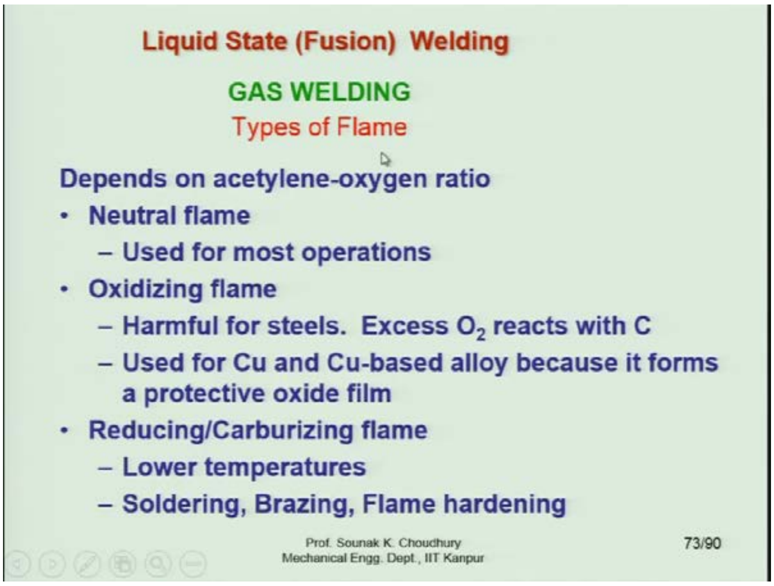
The temperature goes up to 3300^0C. You can see that the flame of that gas is at a very high temperature. It is used for structural sheet metal fabrication, automotive bodies, repair work as I said. These processes you must have seen on the road-side repairing shops.

(Refer Slide Time: 16:37)



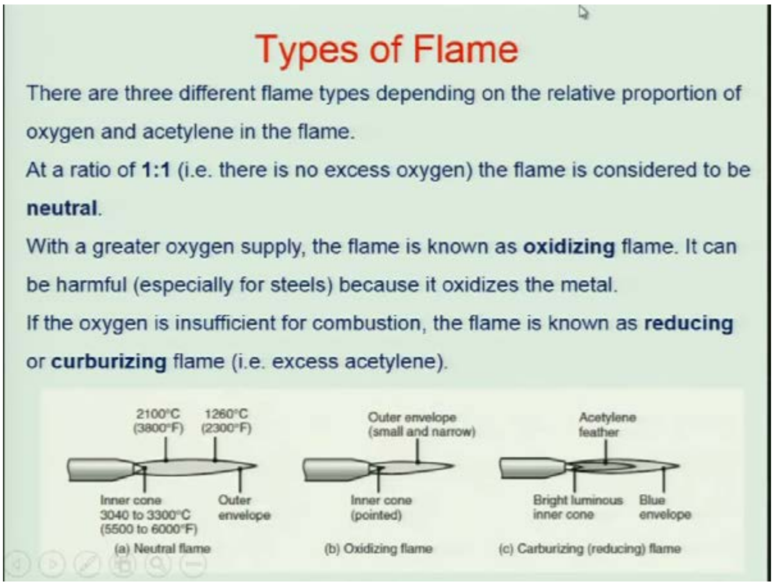
Here is the gun. There are valves to adjust, mixer, this is the tip and then, oxygen and acetylene will be passed through as you can see here in the cross section and here, it will be burned. They are mixed together, and the gas will be burn here. This is the mixer, this the union, this is the union nut so that the flow can be regulated, this is the torch head through which the oxygen and the acetylene gases pass through in the mixing chamber.

(Refer Slide Time: 17:17)



Types of flame: This is very important in the gas welding that depends on the acetylene and oxygen ratio. A neutral flame is used in most operations. Oxidizing flame is harmful for steels because excess oxygen reacts with the carbon. Used for copper and copper-based alloy because it forms a protective oxide film. Reducing or carburizing flame has lower temperature. It is used in the soldering, brazing, flame hardening because there the temperature required is not very high.

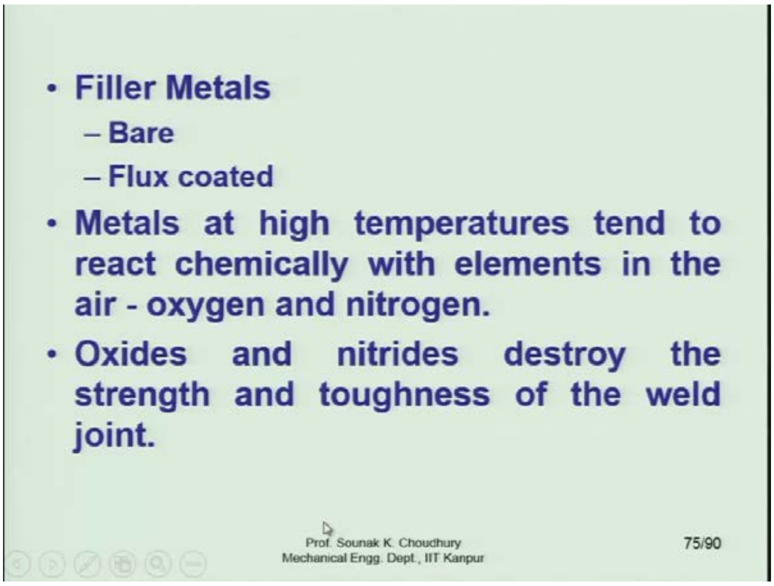
(Refer Slide Time: 17:55)



These are the three types of flames that you have seen; here it is the bright luminous inner cone in the carburizing flame. In the oxidizing flame this inner cone is pointed and here is the outer envelope that is small and narrow. Here, you can see that there is a blue envelope and inside that is called the acetylene feather.

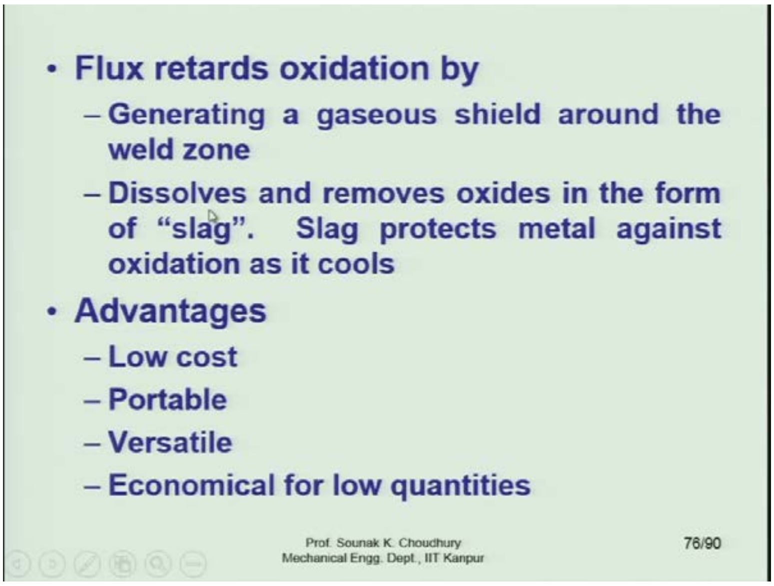
In case of neutral flame, we have different temperatures - at the outer envelope it is 1260^0C ; here the temperature is more, it is about 2100^0C and inner core has the maximum temperature of 3300^0C .

(Refer Slide Time: 18:45)



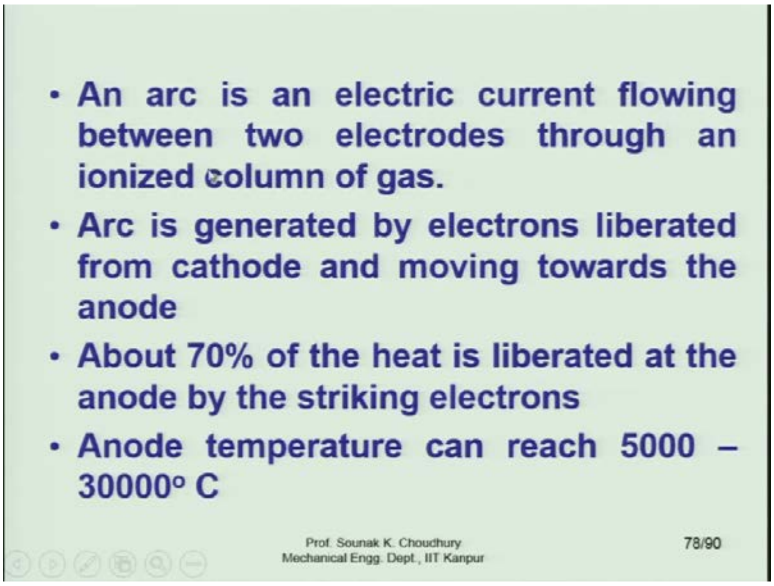
Filler metals: they are either bare or flux coated. Metals at high temperatures tend to react chemically with elements in the air oxygen and the nitrogen. Oxides and nitrides destroy the strength and toughness of the weld joint of course. So, this is the disadvantage.

(Refer Slide Time: 19:09)



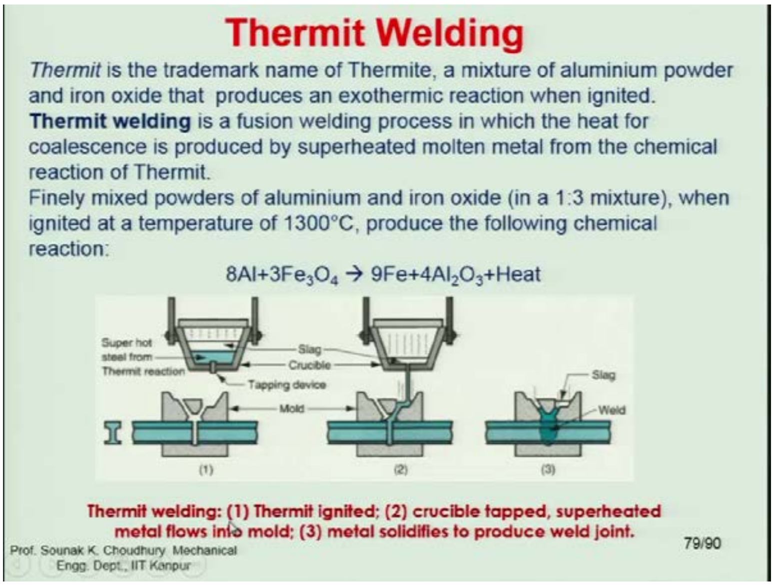
Flux retards oxidation by generating a gaseous shield around the weld zone and this is the "slag"; advantages are that it is low cost; portable, it can be taken to any places; versatile; economical for the low quantities.

(Refer Slide Time: 19:31)



An arc is an electric current flowing between the two electrodes and 70% of the heat is liberated at the anode striking electron and the anode temperature can reach up to 30000^0C.

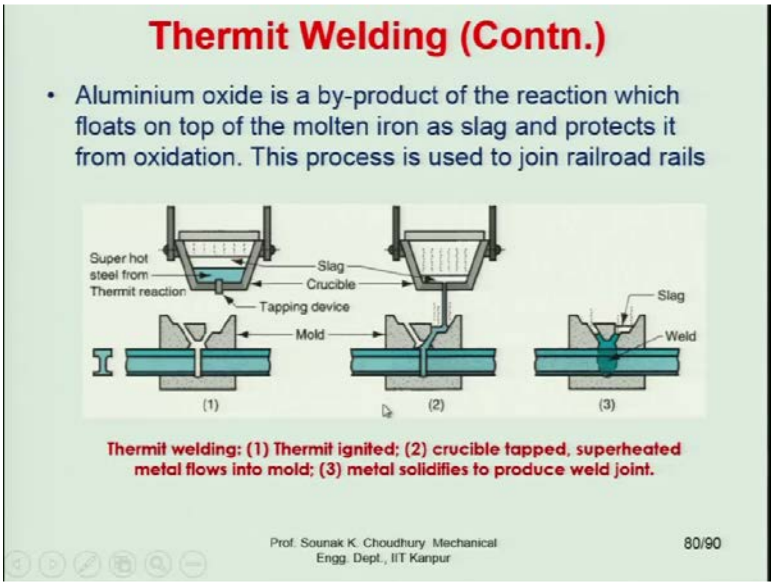
(Refer Slide Time: 19:49)



This is another interesting welding process which is called the Thermit welding. This thermit welding is schematically shown here. This is used popularly for welding of the railway tracks. Wherever there is a defect, it can be carried to that place. This is the mold set and from here, through the tapping device from the cubicle, the super-hot molten steel is poured

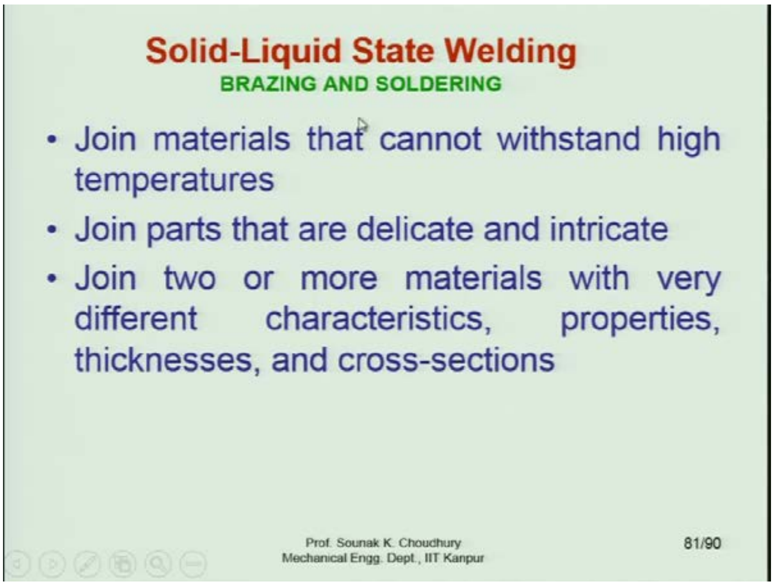
Here, the slag in the form of aluminum oxide will be on the top; The material that is used here is the aluminum, finely mixed powders of aluminum and iron oxide Fe_3O_4 and this is the reaction, ferrous is melt. This ferrous will be coming to the welding zone and the aluminum oxide as a byproduct, will be as a slag. This will protect from the top.

(Refer Slide Time: 20:55)



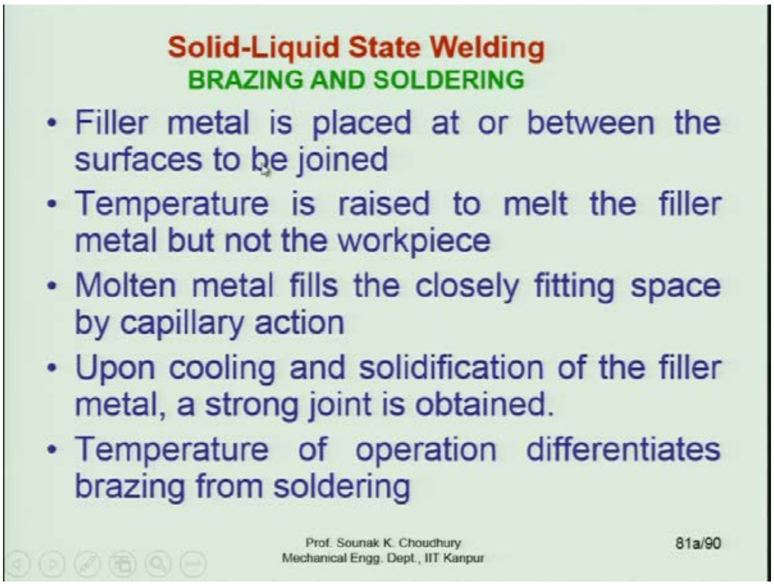
Aluminum oxide is a byproduct of the reaction, which floats on top of the molten iron slag and protects it from oxidation. The process is simple. This is the diagram, and you can see that these are the three stages which are shown here.

(Refer Slide Time: 21:13)



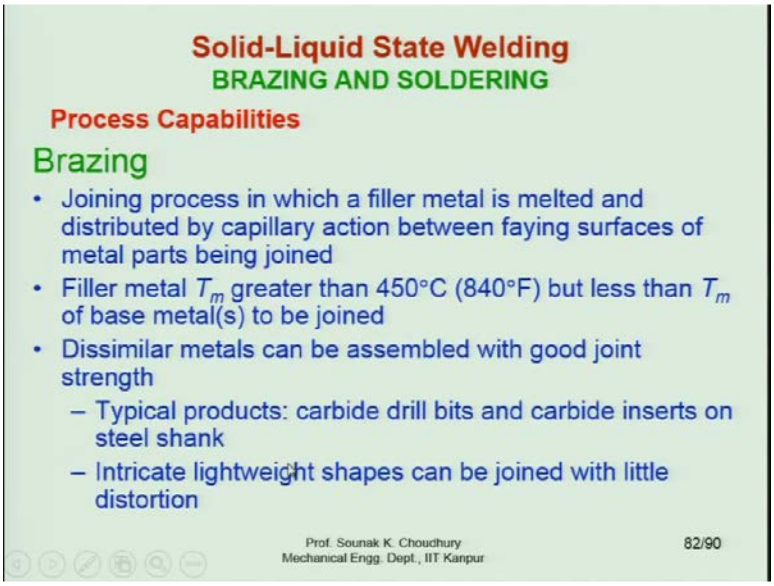
Brazing and soldering, as I said in the beginning, are performed at a lower temperature that join materials that cannot withstand high temperature.

(Refer Slide Time: 21:27)



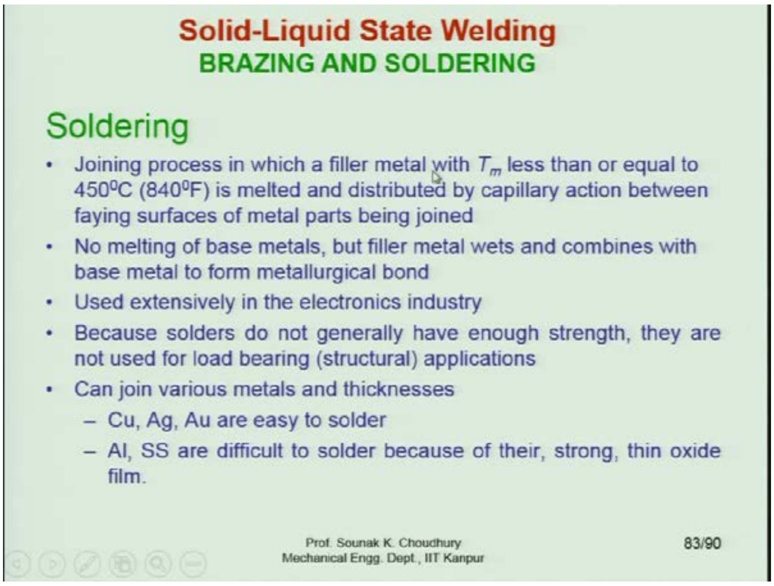
Filler metal is placed at or between the surfaces to be joined. Temperature is raised to melt the filler metal, but not the work piece. This is important here. Molten metal fills the closely fitting space by capillary action.

(Refer Slide Time: 21:45)



In case of brazing, the important thing is that filler metal temperature is greater than 450^0 C; but less than the melting temperature of the base metal. Dissimilar metals can be assembled with good joint. Typical products are carbide drill bits, where you cannot have the high temperature to avoid the thermal distortion.

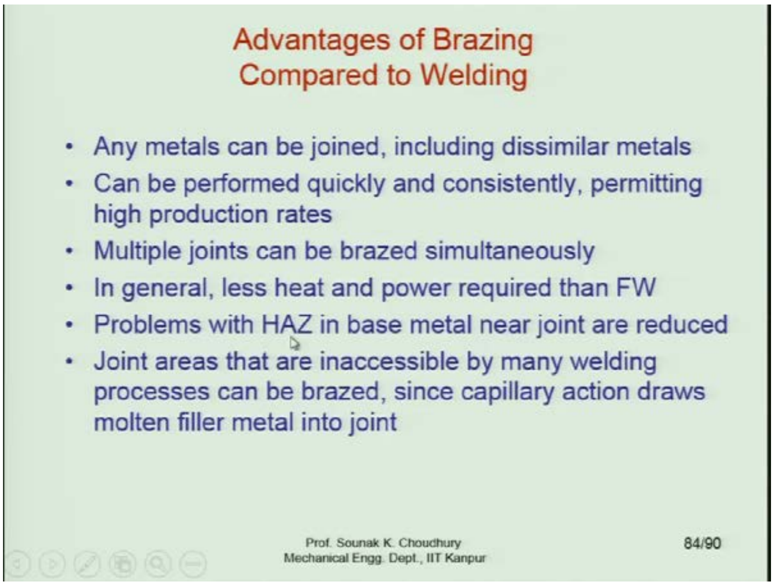
(Refer Slide Time: 22:19)



Soldering is a joining process in which a filler metal is used with the melting temperature less than or equal to the 450^0 C. In case of brazing, it is greater than 450^0 C, but much less than the melting point of the base metal. Here, it is less than or equal to 450^0 C.

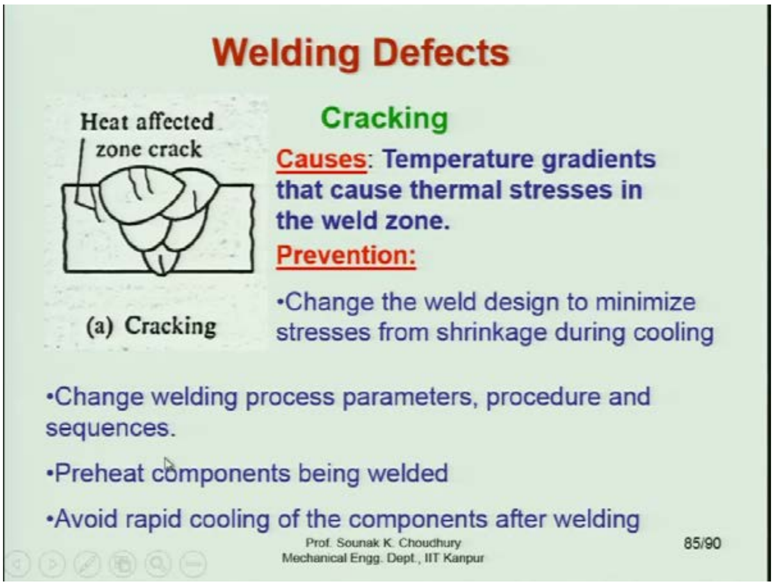
Soldering is done even at a lower temperature than the brazing. You can go through the following slide for more details.

(Refer Slide Time: 22:57)



Problems with the heat affected zone in the base metal near the joint are reduced here in this case. This is one important point here.

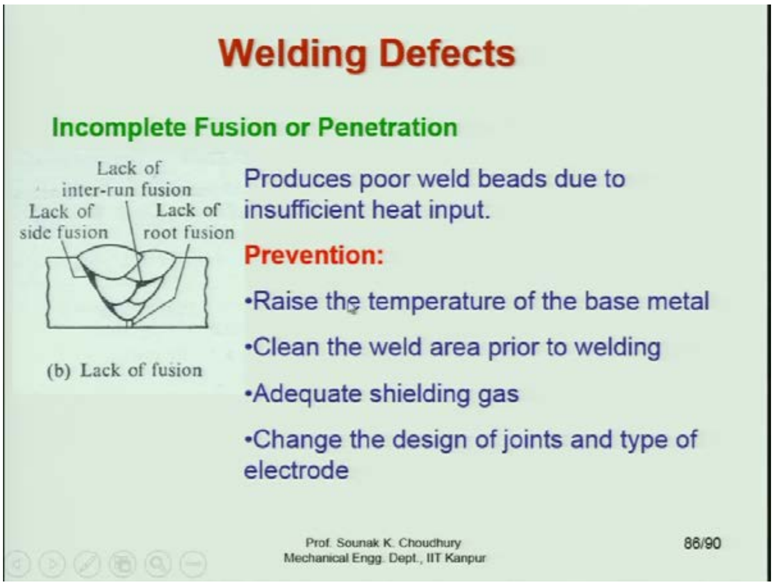
(Refer Slide Time: 23:09)



There are different kind of welding defects you can go through. I have given it here. They are self-explanatory. For example, the cracking like this which causes because of the temperature gradients that cause the thermal stress in the weld zone and it can be prevented by changing the weld design to minimize the stresses from the shrinkage during the cooling process or you change the welding process parameters or preheat the weld zone, or the components.

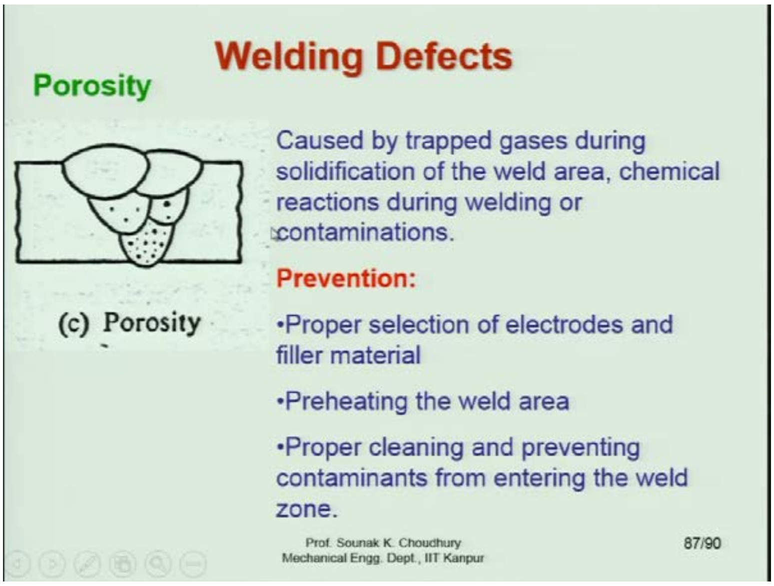
Avoid rapid cooling so that there is no thermal stress and there will be no cracking. Basically, it is because of the thermal gradient, thermal stress or it can be incomplete fusion or penetration.

(Refer Slide Time: 23:57)



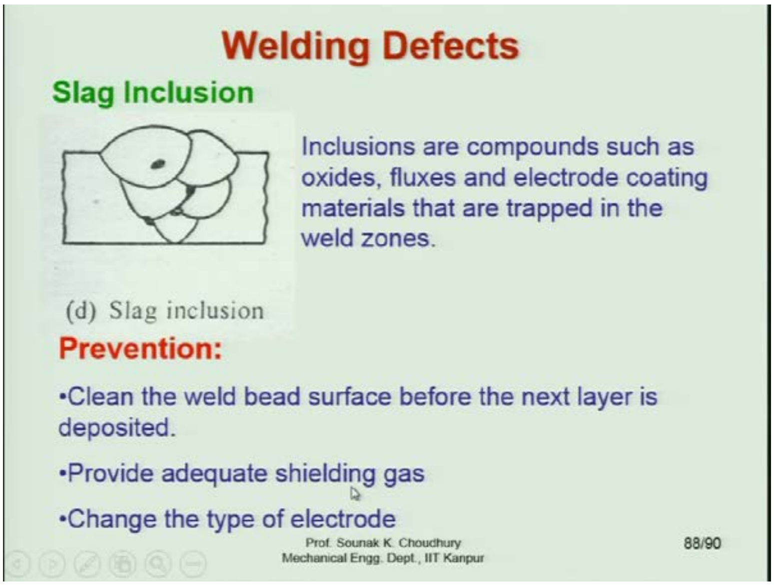
Because of that, there will be a lack of side fusion; there may be lack of inner run, it is called lack of root fusion here, that can be prevented by raising the temperature of the base metal. Cleaning the weld area prior to welding, adequate shielding gas can be supplied or change the design of joints the type of electrode.

(Refer Slide Time: 24:25)



Porosity is another welding defect and in case of casting we have seen that porosity occurs because of the gas which is evolved and here are the three ways how to prevent them; proper selection of the weld of electrodes, preheating the weld area, proper cleaning and preventing the contaminants.

(Refer Slide Time: 24:47)



Or it may be the slag inclusion, where inside there are slags and it can be prevented by cleaning the bead weld bead, providing adequate shielding gas or changing the type of the electrode or it can be even the bad profile like excessive reinforcement undercut.