Manufacturing Process - I
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Module - 3
Lecture - 11
Tungsten Inert Gas Welding Part – 1

Welcome students, this is the eighth lecture of welding series and this lecture is based on the tungsten inert gas welding process. During the second world war, when it was required to join the aluminum plates and the magnesium plates, there was lot of difficulty experienced in joining the reactive metals of aluminum and magnesium alloys and that is why, the technologies were forced to develop new process. And because at that time gas welding and shielded metal arc welding processes were available, but both these processes were unable to join the aluminum alloys and magnesium alloys successfully, and this has led to the development of the tungsten inert gas welding process.

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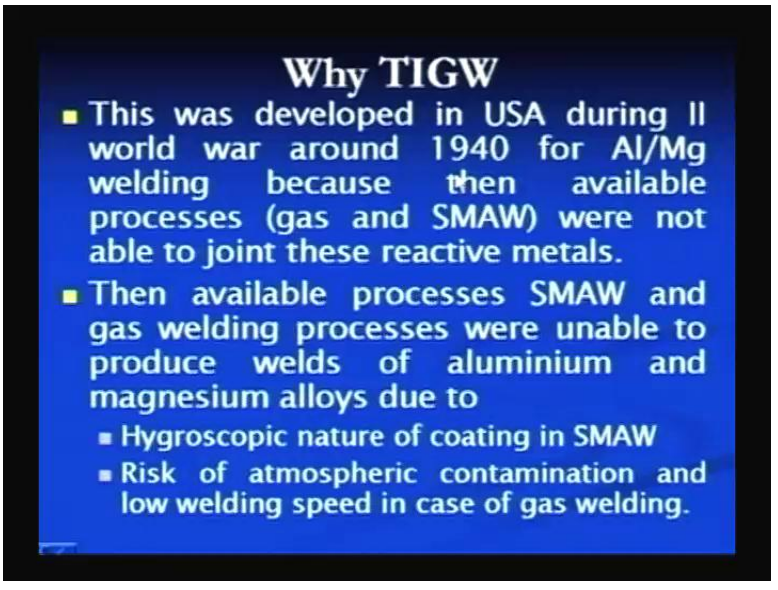

This process was developed in USA somewhere in 1940 and for the welding of aluminum and magnesium alloys, particularly because then available processes, gas and shielded metal arc welding processes, were unable to join these reactive metals successfully. And that is why, this TIG process, TIG welding process was developed at that time.

The difficulty in welding of the aluminum alloys and magnesium alloys by the shielded metal arc welding and the gas welding process was experienced due to the two main reasons. One was, that the hygroscopic nature of the coatings. The shielded metal arc welding process, you know, that it uses the coated electrodes and the coating materials are hygroscopic in nature, which absorbs the moisture from the atmosphere. And when moisture goes into the coating during the welding, this moisture is released in form of water vapor, water vapors.

And water vapors decomposed into the hydrogen and oxygen in arc environment and this hydrogen is absorbed by the aluminum and magnesium metals, molten metal in in the weld pool. And which increases the tendency to form porosity. And that is, only whatever welds of these alloys were produced by shielded metal arc welding process, were having lot of porosity, that is why, difficulty was experienced in joining the aluminum and magnesium alloys by shielded metal arc welding process.

And the same difficulty was also experienced in case of the gas welding also. Gas welding had two disadvantages, one was related to the atmospheric contamination because there was nothing like shielding of the molten weld pool of the aluminum or magnesium alloys that led to the atmospheric contamination due to the oxidation of the molten metal at high temperature.

And another reason was the low welding speed, which is offered by the gas welding system, particularly in welding of the aluminum because whatever heat is supplied, that is transferred rapidly from the weld, from the base metal to the comparatively, from the faying surfaces to the base metal and that is why melting of the faying surfaces by gas welding of aluminum plates becomes difficult. This, these factors force the technologies to develop the tungsten inert gas welding process. Tungsten electrodes are used, inert gas is used as a shielding gas and that is why, entire process is known as tungsten inert gas welding.

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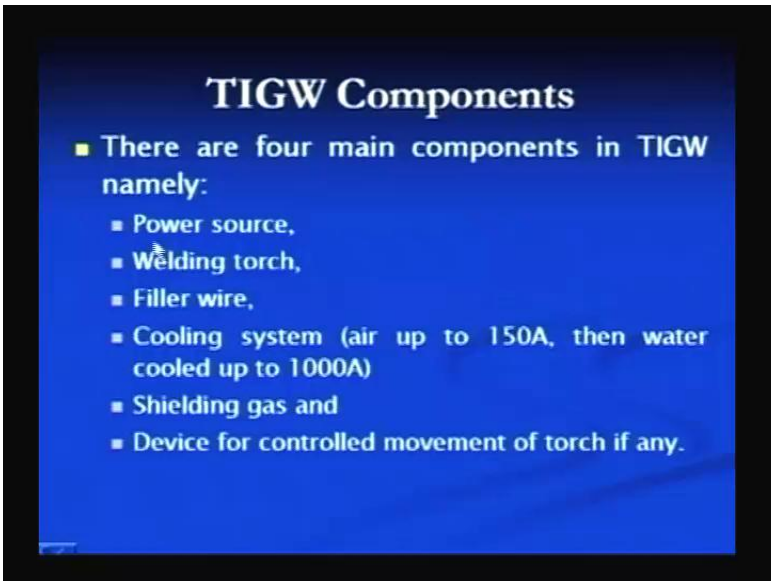

And this welding system, the tungsten inert gas welding system consists number of major components, which plays significant role in successful welding by this process. One is the power source. Power source is required to lever high current at low voltage of the desired type, may be constant voltage or constant current type. Normally, constant current type of the power sources are used in tungsten inert gas welding process and the desired type of current, means either AC or DC current is required for the welding of the specific kind of metal, like aluminum welding needs AC and for other metals even DC with electrode negative polarity the welding power sources are used.

The welding torch, which accommodates electrodes and nozzle and collates to hold the electrode are provided in the welding torch. Filler metals sometimes used in case of somewhat thicker sheets welding, otherwise if, if the thin sheets are to be welded, then no filler metals are used. And selection of the filler metals also plays a significant role in successful welding of the metals, like aluminum and magnesium stainless steel, wherever high quality weld joints are to be produced.

Cooling system is also very important, in gas, in tungsten inert gas welding process where the cooling systems can be of air cool type or water cool type. Normally, for the low current range welding torches, like up to two, 150 ampere air cooled, air cooling is used. And for higher current range welding torches water cooling systems, systems are used, so that the torch, welding torch can be maintained within the specified safe limits.

Shielding gas helps to protect the weld pool and the tungsten electrode from the atmospheric contamination. So, effective shielding plays a significant role in producing the successful high quality weldments and some device may also be required to move the torch at a constant speed or at desired speed. So, for automatic or semiautomatic welding processes additional devices may also be used which will help to produce the weldment of the good quality.

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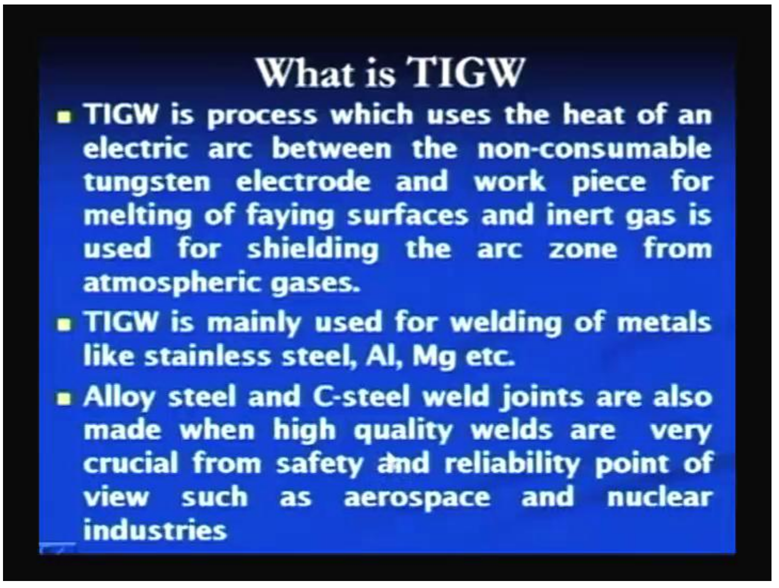

If we have to understand the things related to the tungsten inert gas welding process, we have to see what it is and how does it work. It is a process in which heat generated by an arc, which is struck between the non-consumable tungsten electrode and the work piece. So, heat generated by the arc between the tungsten electrode and work piece, is utilized for melting of the faying surfaces of the base metal and the filler metal. And at the same time, inert gas is used to provide shielding of the arc zone and the weld pool, so that the electrode and the weld pool can be protected from the atmospheric contamination.

A TIG is mainly used process for welding of the metal, like stainless steel, aluminum and magnesium. These metals tend to form the refractory oxides, which impose difficulty in, in producing the sound joint in conventional welding processes, like shielded metal arc welding or gas, gas welding. That is why, the formation of those oxides of these metals is avoided by providing the shielding of the inert gas.

And the alloy steels and cast steels can also be joined successfully by the tungsten inert gas welding process. But these will be used only when very high quality joints are to be produced for safety and reliability reasons, such as in case of the aerospace, another in the nuclear industries.

So, if the high quality welds are to be produced, then cost will not be a consideration and even if steels, alloy steels and carbon steels can be welded by the tungsten inert gas welding process, that will help to produce high quality weld, weld joints, which will offer high safety and the reliability.

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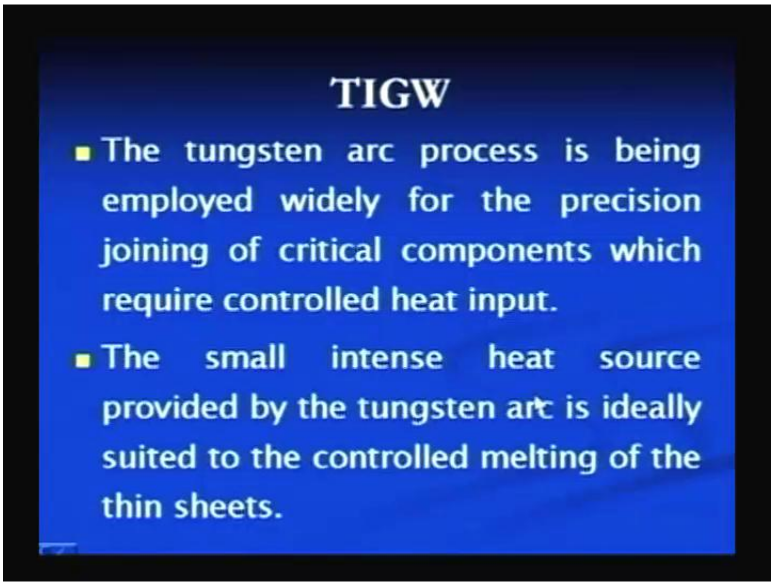

Some other points related to the tungsten inert gas welding processes are like, that this process is mainly used for joining the very thin components and very critical components where very controlled heat input is required. Like, joining of the thin weld pipes is possible mainly by the tungsten inert gas welding process or very thin components are to be welded, then very closed control over the heat input is required and under those conditions TIG can be used successfully. And because, very increase, very high intensity heat source is provided by this process and which helps to have better control over the melting of the thin sheets and that is why, this process is normally used for producing the high quality weld joints of the thin sheets and wherever precision is required.

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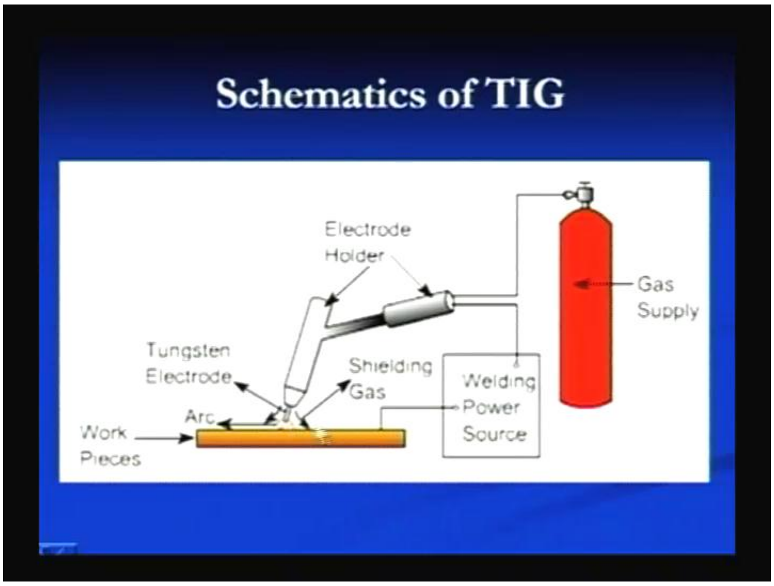

We can see, that the schematic diagram of the tungsten inert gas welding process where this is the work piece and this is the tungsten electrode. Arc is struck between the work piece and the electrode and heat generated by the arc is used for melting of the faying surfaces of the work piece. And as per needs filler metal can be added, either manually or automatically, in the arc region for filling the groove or the faying surfaces, the gap between the faying surfaces.

And around the arc a jet of shielding gas is supplied, so that a blanket or cover of the shielding gas can be made available around the weld pool and around the arc, so that they can be protected from the arc environment. And here the shielding gas is supplied in form of the helium or argon, which is supplied from a cylinder and that passes through this nozzle, another welding torch.

And here these, these also indicate power supply line connections. Here, one terminal of the power source is connected to the electrode through the contact tubes or through collates and here, another terminal of the power source is connected to the work piece, so that welding circuit can be completed. Here, we can see, mainly power source welding torch work piece and the shielding gas cylinder here. But there are many other components are also used in tungsten inert gas welding process. So, those details of those elements can been seen in the next slide.

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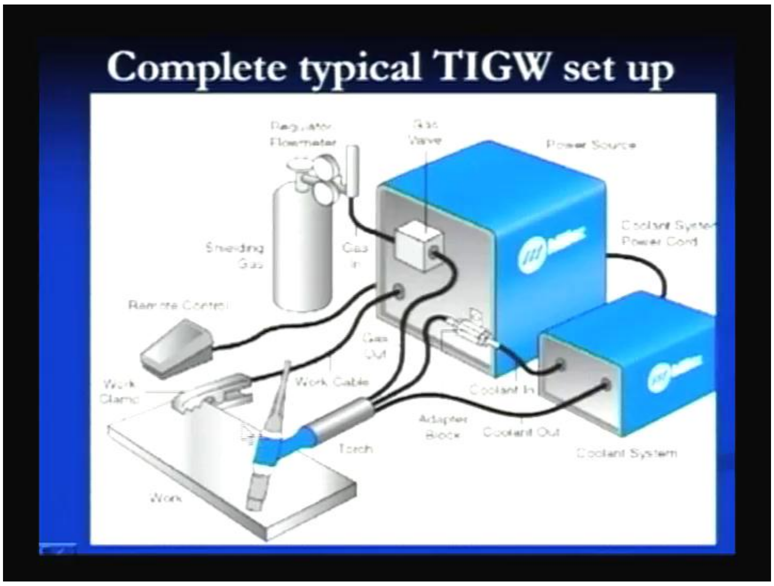

Here, complete typical TIG welding setup can be seen here. This is the welding torch, this is work piece here, the ground connection or connection of the power source, one terminal of the power source to the work piece. This is the remote control to start and stop and the, and the power source and here, the gas supply unit. This is the power source and here, this you can say coolant, cooling system, which is used to maintain the temperature of the welding torch within the safe limits. So, here all these elements are, I mean, important elements of the tungsten inert gas welding process along with the connections can be seen here from this diagram.

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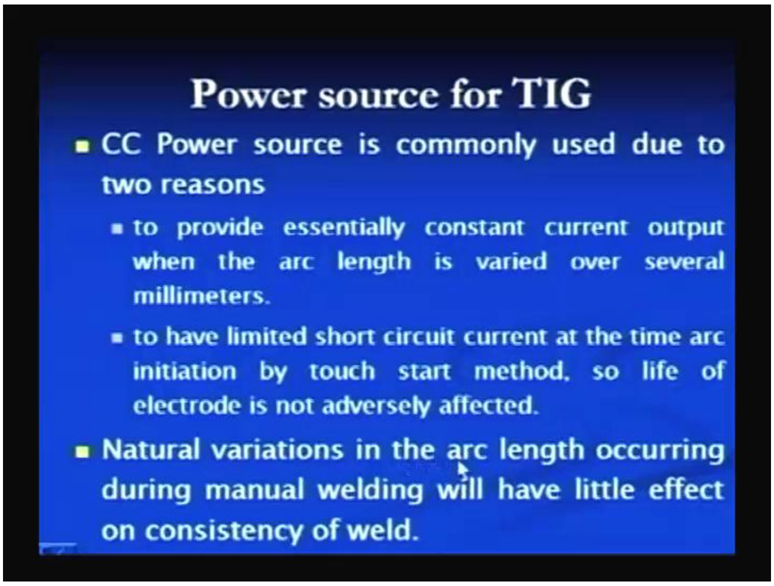

Power source is most important component. Here, we, we have seen, that whenever we talk about the tungsten inert gas components, the power source will be talked about first because it delivers the power, which is required for producing the sound weld joint or producing the heat required for melting the faying surfaces of the base metal to be joined.

The power source, which is used for tungsten inert gas welding process is mainly of the constant current type here and this constant current type of the power source is mainly used due to the two reasons. One is, it is essentially, it essentially provides the constant current, which helps to produce the heat uniformly during the welding, so that uniform penetration melting can be obtained. And that is required for producing the consistent and uniform weld. So, the ability to supply the constant current is important even when there is minor fluctuation in arc length.

And another reason is, that during the welding, the short circuiting between the electrode and work piece can take place during the starting or during the operation itself. So, when short circuiting takes place, the constant current power sources are able to supply the constant power. Sources supply very limited short circuiting current under that helps to protect the power source cables from any kind of damage. Because the constant voltage power sources and the short circuit condition supplies, theoretically infinite value of the current, that can damage to the power source and to the welding cable.

So, ability to supply the short circuiting current in limited manner, the time when short circuiting has taken place, improves the life of the electrode, otherwise life is adversely effected. Because during the actual welding this, there is always some fluctuation in arc length if it is controlled manually. And under those conditions, constant voltage power source will be able to supply the constant current magnitude even when there is minor fluctuation in arc voltage or minor fluctuation in arc length. That will not affect the soundness of the weldment even when there is fluctuation in arc length because the constant voltage, constant current power sources are able to supply the constant current even when there is minor fluctuation in arc length.

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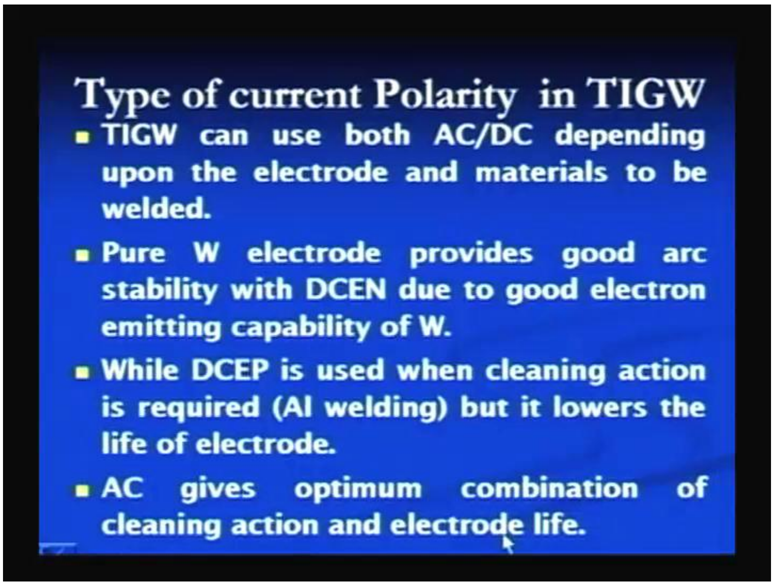

With constant current, power sources can be of AC or DC type. Normally, constant current power sources of the DC type is normally used for ferrous metals welding. The AC type of the constant current power sources are used in welding of the metals like aluminum and magnesium. So, TIG can use both AC and DC type of the power sources of constant current type, but it depends on the type of the electrode and materials to be used.

Pure electrodes provides good arc stability with DCEN due to good electron emitting capability. But the pure electrodes, pure tungsten electrodes are also known to offer the poor life when other polarities are used like DCEP or the AC current is used. While DCEP is used when cleaning action is required in welding of aluminum, but it lowers the life of electrode.

Both these points are need to be understood. One is, when DCEP is used, two-third of heat is generated in the electrode side and that leads to the excessive erosion of the tungsten electrode, which in turn, adversely affects its life. But when DCEP is used, work piece acts as, as electrode or as work piece becomes the negative one, so that electrons are, are expected to be produced by the work piece. And when DCEP is used, the mobile cathode spots are formed in the base metal side and those mobile cathode spots help to loosen the refractory oxide film, which is formed on their surfaces, that helps to clean, provide the cleaning action, loosening of the oxide film; leads to the better cleaning action of the oxide film from the surface.

So, if the advantage of the cleaning action is to be taken DCEP is used, but it adversely affects the electrode life. Therefore, to have an optimum combination of the cleaning action and the electrode life, AC is used for welding of the aluminum or other reactive metals like magnesium. So, AC gives an optimum combination of the cleaning action and the electrode life.

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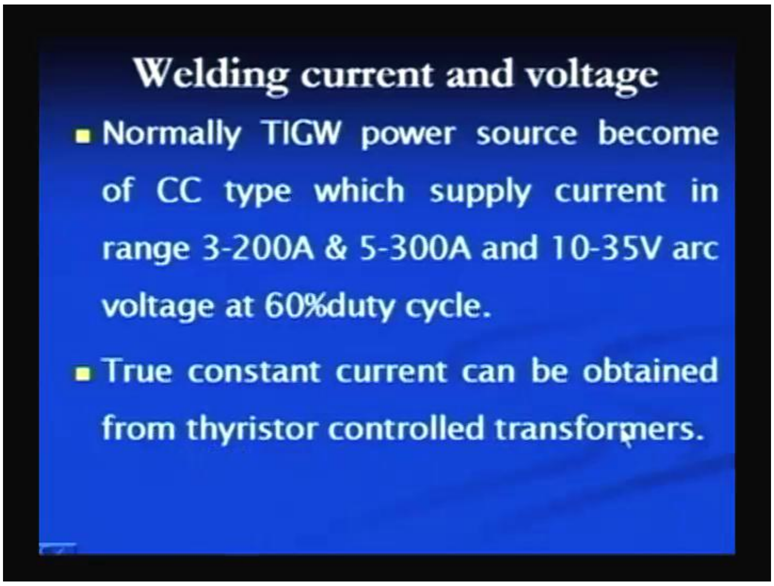

Normally, the welding current and the voltage are very important for successful welding because the kind of penetration and the deposition rate, which will be obtained, largely depends on the welding current and the voltage. If current and voltage is not set properly, we may lead to have either erratic arcs or arcs, which are having poor stability. Even arc ignition may also become difficult. So, normally tungsten inert gas welding process, welding power source become of constant current type, which supply the current in range of the 3 to 200 amperes or 5 to 300 amperes and the arc voltage in range of 10 to 35 volts at 60 percent duty cycle.

The true constant power can be obtained from the thyristor controlled transformers. Actually, there is always some change in, in the current value whenever there is fluctuation in arc length. Although that change is significant, but exact constant value of the current can be obtained when, where there is, even when there are fluctuations in, in the arc length with the thyristor controlled transformers. So, if the true constant current is to be obtained, it is better to use thyristor controlled transformers.

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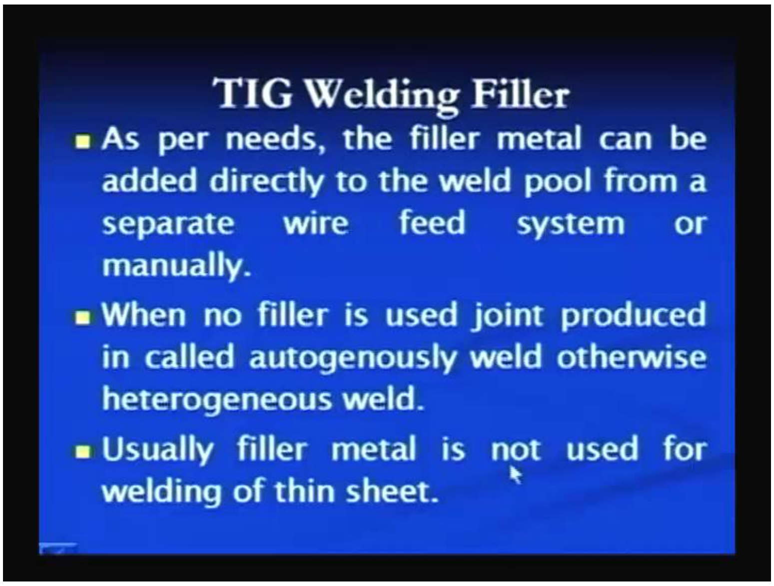

And filler metals are used only when somewhat thicker sheets are to be used. Filler metals will be provided either manually or automatically. It depends upon how much volume of the materials is to be deposited through the filler metal. As per needs, filler metal can be added directly into the weld pool from a separate wire feed system or it can be done manually.

Normally, for welding of the thin sheets no filler metal is used. Like, 1 mm, 2 mm, 3 mm thickness sheets can be welded directly without using any filler metal. And when no filler metal is used, we call that joint as autogenous joint or autogenous weld, otherwise when filler metal is used it is termed as heterogeneous weld. Usually, filler metal is not used in welding of the thin sheets.

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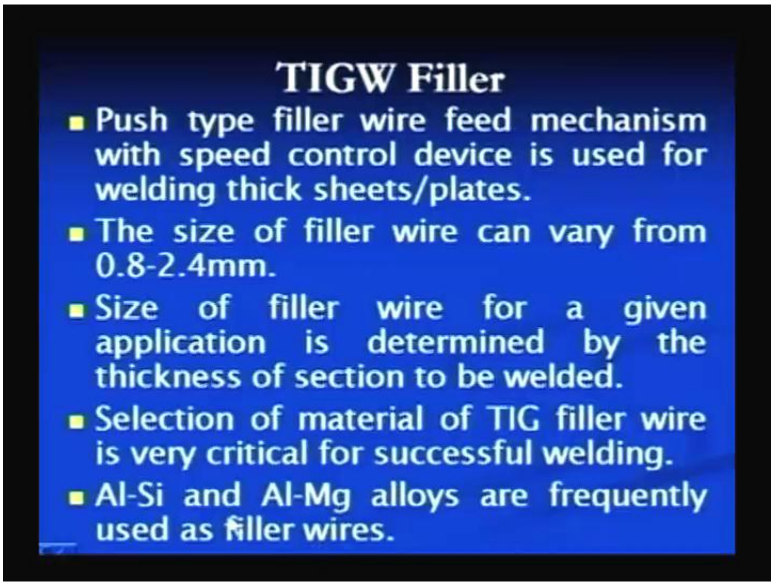

And for automatic feeding of the filler metal in welding of the thick sheets automatic feeders can be used, which will help to feed the filler wire at a constant speed. And normally, since the diameter of the filler wire is small, push type of the filler wire feeding mechanisms is used, which may be having better control over the speed to feed the filler wire as per needs and this is particularly used when thick sheets or plates are to be welded.

So, electrodes size, sorry, filler wire size is normally small and it can vary in a range of 0.8 to 2.4 mm. So, if the aluminum filler wires are to be used they will show tendency to get damaged if the pool type of filler wire feed mechanisms is used. Normally, that is why, for feeding a small diameter aluminum fillers, the push type of filler wire feed mechanisms is used.

The size of filler wire for a given application is determined by the thickness of the section to be welded. This will help to determine, that how many passes will be used to fill the gap. If the very thick plates are to be welded using small diameter filler wire, we may need large number of passes. So, depending upon the volume of the metal, which is to be deposited for filling the gap or for filling the joint, the size of the filler wire is determined in such a way, that it will require reduced number of the passes for producing the joint and the selection of the filler wire depends upon the kind of material, which is to be deposited.

If improper selection of the filler wire is made, it may lead to very defective welds, the weld joint with number of cracks and very reduced mechanical or metallurgical properties, particularly improper selection can lead to the cracking and poor corrosion resistance. So, the selection of the material for TIG filler wire is very critical for successful welding. And normally, aluminum-silicon and aluminum-magnesium based filler wires are used for joining the aluminum sheets.

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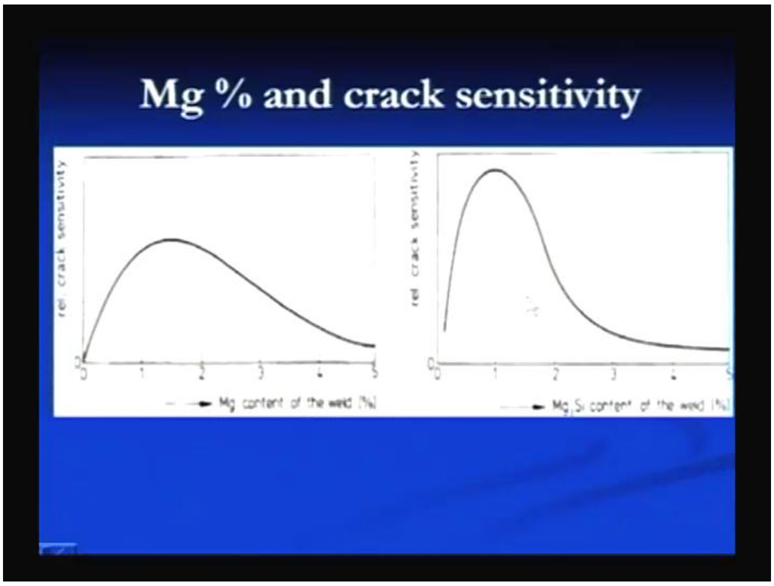

If the aluminum filler wires are not selected properly, it can lead to the cracking of the weld, weld joint immediately after the welding. Like this diagram, these two diagrams shows the cracking sensitivity of the weldment as a function of the magnesium content, as a function of Mg 2 Si content in the weldment. Here, you can see, related, relative crack sensitivity increases with the increase in magnesium content up to same 2.2 percent and then it, it starts to decrease.

So, if the cracking is to be avoided, it is desired, that in the weldment magnesium percentage is more than 5 percent, so that crack sensitivity of the weld joint can be reduced. And the same is applicable here also, that the joint composition is designed in such a way or weld composition is designed in such a way, that the Mg 2 Si percentage is above this 5 percent, so that the crack sensitivity of the joint can be reduced. And this is particularly important in case of aluminum-magnesium-silicon or aluminum-silicon-magnesium weld joints.

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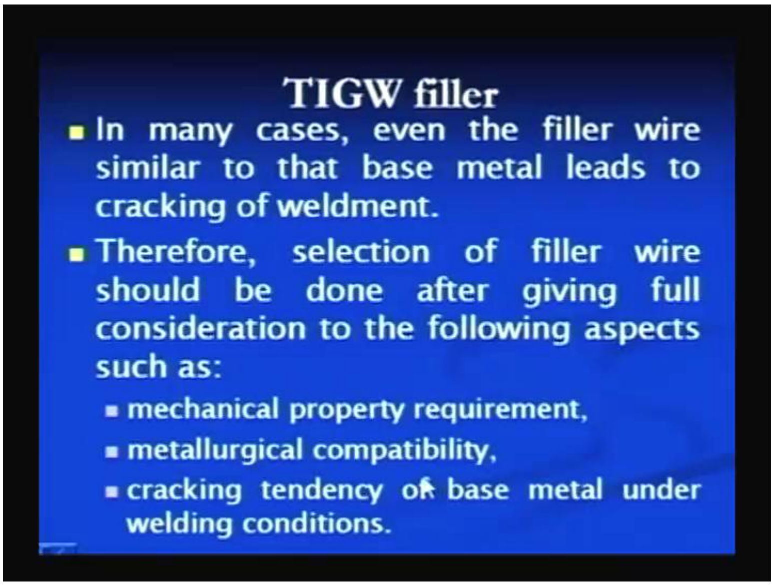

Here, we will see, some other aspects related to the selection of the tungsten filler wires. In many cases, if the filler wire is of the same, is that of base metal, even when, then it causes the cracking problem. Cracking in the weldment mainly takes place due to the development of the residual stresses and if the strength of the metal at high temperature ((Refer Time: 26:28)) can lead to the cracking of the weldment when it is very hot.

So, that is known as hot cracking or hot shortness or solidification cracking. So, the even similar base filler metal same as that of base metal can also lead to the cracking of the weldment. Therefore, proper selection of the filler metal is important for successful welding.

Some of the points are to be considered, when, while selecting the filler wire for tungsten inert gas welding process for joining of given material and these points are mechanical property requirement where to see, that what weld joint will be produced after the welding and what will be its mechanical strength or the other mechanical characteristics. The joint produced must provide the strength or the other mechanical properties required to perform the desired function by the weld joint. So, the filler metal must be able to provide the weld metal, which can take the desired load or which can perform the intended function.

The metallurgical compatibility is also important because sometimes dilution changes the composition of the weld metal and that leads to the some of the problems, like solidification, cracking or mismatch in, in, in, in the thermal expansion coefficient between the different metals or between the base metal and the weld metal, can also lead to the problems in, in after producing the joint.

The cracking tendency of the base metal also should be seen under the welding conditions. Many times, HZ shows the sensitivity for cracking and that should be taken into account while selecting the filler metal, like aluminum-copper and aluminum-zinc-magnesium alloys shows the tendency for partial melting zone or the liquation cracking in the heat effected zone.

So, those aspects should be kept in mind while selecting the filler metal and filler metal should be selected in such a way, that it offers the desired, the joint is able to offer the desired mechanical properties and it is compatible with the base metal, and it does not create the, creates the problem related to the cracking of the base metal under the welding conditions. And so, alternatively for third point we can say, it should not develop much residual stresses, which can lead to the otherwise cracking of the heat affected zone or the weld joint itself.

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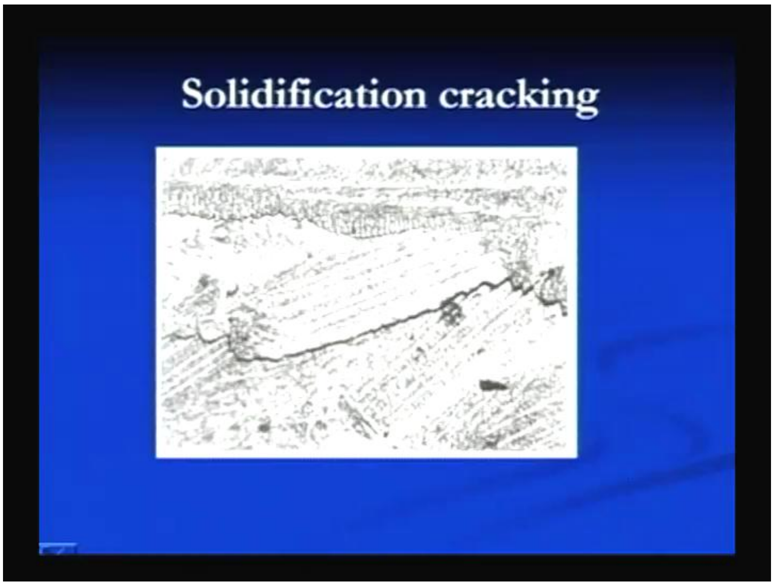

So, as I have said, that improper selection of the filler metal can lead to the cracking or even poor corrosion resistance of the weld joint. Here, typical trigger will show the solidification cracking of the weld joint.

Here, at the center of the weldment, we can see long crack is running along the weld center line indicating the occurring of the solidification cracking due to the development of residual stresses and poor strength of the weld joint, weld filler metal, particularly at high temperature.

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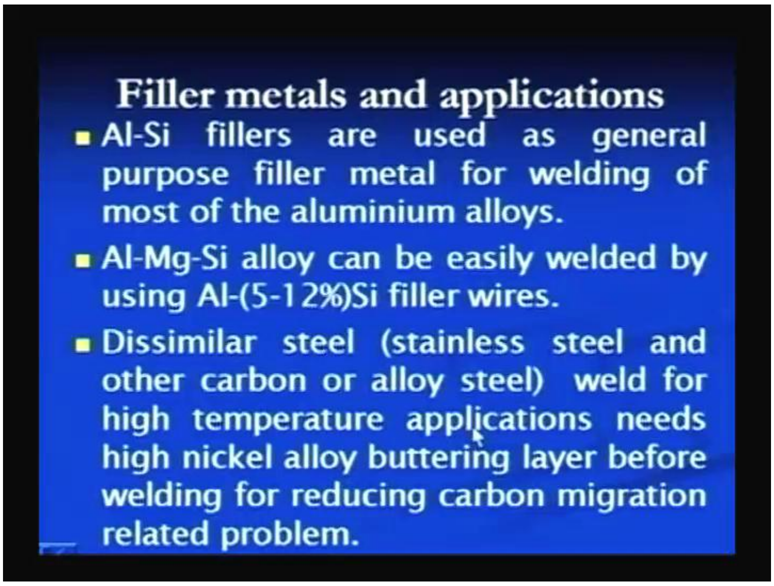

The specific material wise the filler metal, we can see here aluminum-silicon fillers are used as a general purpose filler metals for welding of the aluminum alloys. And aluminum-magnesium-silicon alloys can be easily welded if, if we use aluminum, 5 to 12 percent silicon filler wires. Aluminum-silicon filler wires offers low melting point and very good fluidity and quite good strength and that in turn, helps to produce the weld joint easily.

And while in case of steels, the filler metal is to be selected very carefully, like in welding of the dissimilar steel, the stainless steel and carbon or alloy steels welds. If the welds are to be used for the high temperature purpose, for high temperature applications, then it requires some sort of buttering layer at the faying surfaces before using the final filler metal to fill up the gap between the plates to be welded because this is a, this helps to, this buttering layer of the nickel helps to check the diffusion of the carbon from the base metal of one type to the another type, like the diffusion of the carbon take place from the carbon or alloy steels towards the stainless steel through the weld metal after a long exposure at high temperature.

So, to check that diffusion, it is required to butter the faying surfaces, first by using nickel alloy. And then, go for filling gap between the plates to be welded using this suitable filler metal.

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Now, we will see the TIG torch, which is used for producing the desired heat. And melting the faying surfaces is also another important component in the TIG welding system. And the TIG torch includes the number of components, like the nozzle, electrode and collets and combination of these three components form the TIG torch.

It is rated in terms of the current carrying capacity because the torches are, if the welding torch is able to handle higher level of current it will produce a deeper penetration, it will be able to produce deeper penetration and higher welding speeds. And if the welding current ability of the torch to handle the high current is not there, then it will not be possible to get the high welding speed and the high production rate and the desired penetration.

And that is why, TIG torch is rated in terms of its current carrying capacity. Higher the current carrying capacity of the TIG torch, greater will be the current it will able, it will be able to handle for welding of the thick sheets. So, that is why, the TIG torches are rated in terms of the current carrying capacity.

The welding torch can be of air cooled type for the lower current range and the water cool type for the higher current ranges, say 0 to 150 ampere, up to 0 to 150 ampere welding torches are normally air cooled because whatever heat is generated due to the flow of current up to this range, that is dissipated under the normal cooling provided by the ambient air. But if the welding torch is to be used to handle for the higher current, like 150 to 1000 ampere, in, in range of 150 to 1000 amperes, then water cooling system is used to maintain the temperature of the torch within the safe limits.

So, the air cool torches can be air cooled or water cooled type depending upon the current carrying capacity of the welding torch. Welding torch mainly consists electrode, collet and the nozzle each element or each component of the torch has to perform a specific function.

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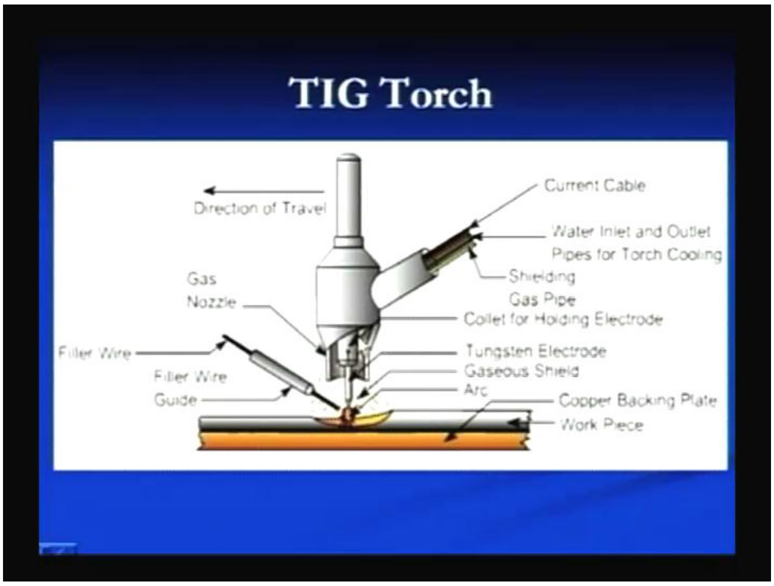

Before going into the functions we can see the details of TIG torch. Here, this is the filler wire being supplied in arc region, this portion indicates the electrode and electrode of the tungsten and here, this is the collet portion, which is used to hold the electrode and this is the nozzle, nozzle. So, here we can see, first of all we have electrode, around the electrode there is a collet and around the collet there is a nozzle. Nozzle, nozzle helps to form a jet of the shielding gas around the arc to provide the desired protection from the atmospheric contamination.

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The function of the parts of TIG torch can be seen here in slightly detail. The collets are mainly used to accommodate the electrodes of the varying diameter. We may have to use the collets of the different types or the sizes, so that the electrodes can be held firmly with the firm electrical contact, so that desired power can be supplied to the electrode for striking the arc. Nozzle helps to form a jet of the shielding gas around the electrode and the weld pool, and the weld pool, for its production from the atmospheric contamination.

So, the size of the nozzle and its material is very important for proper functioning and production of the sound weld joint. The electrode here, third component, electrode supplies the desired current required for developing the arc and melting of faying surfaces of the base metal to be welded because an arc is struck between the tungsten electrode and the base metal. So, the electrode must get power and it should supply the required power for developing the arc.

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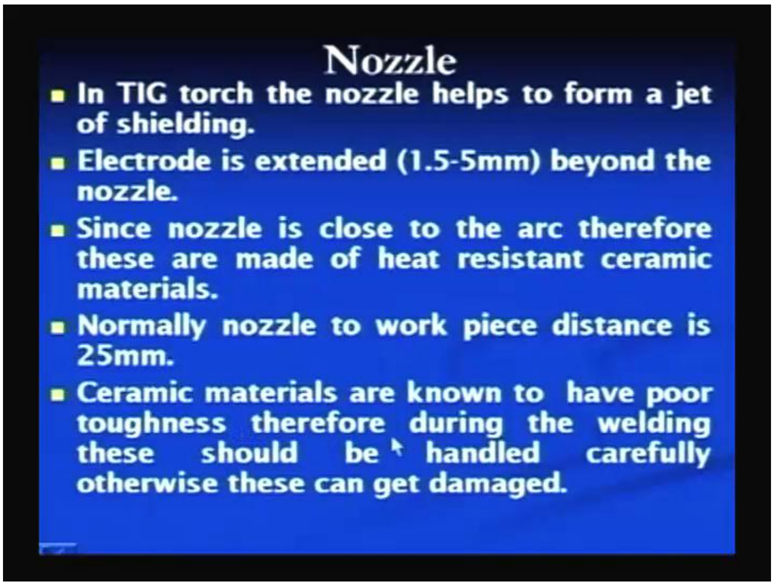

Here we can see the things in detail about the nozzle. The nozzle helps to form the jet of the shielding gas and normally electrode is projected beyond the nozzle, so that arc can be struck between the electrode and the work piece. And this projection of the electrode from the nozzle can be in range of 1.5 to 5 mm. Normally, for joining the corners and the fillet welds, smaller nozzle and smaller projections from the nozzle are used while conventionally it is in range of 4 to 5 mm.

Since nozzle is very close to the arc, so it always get heated from the heat of the arc and that is why, chances are there to get damaged. And to increase that resistance to the heat from the arc, these nozzles are made of the ceramic materials, but the ceramic materials are known to have the poor mechanical properties, that is why these need to be handled carefully.

And during the welding, nozzle to the work piece distance is kept in about 25 mm. If the distance is small between the work piece and the nozzle, it can cause the back burn to the nozzle and that is why, an optimum distance has to be maintained between the nozzle and the work piece.

Ceramic materials, of which nozzles, a nozzle is made, have the poor mechanical properties, particularly the toughness. And that is why, there is need to avoid any kind of shock to the nozzle because due to the poor toughness it can fracture just like a very brittle material. And therefore, during the welding it should be handled carefully to avoid any kind of damage to the nozzle.

Gradually, in practice, the nozzle is damaged gracefully by chipping of small pieces and also these are damaged gradually from the heat of the arc. And the grace weld damage leads to the reduction in size and change in shape of the nozzle, which adversely effects its ability to form a firm jet around the weld pool and around the arc. And that is why, it is frequently required also to change the nozzle at regular intervals.

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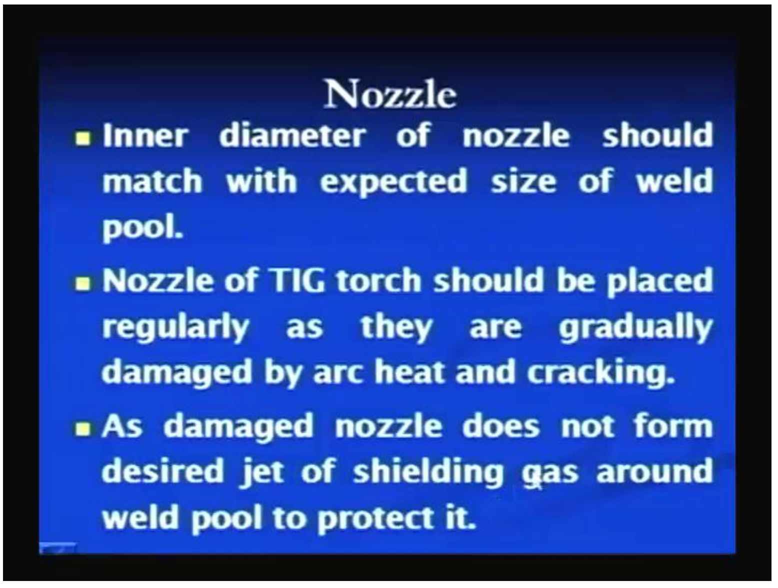

The inner diameter of the nozzle is selected in such a way, that it matches with the size of the weld pool, which is expected. If this point is not kept in mind, then weld pool may be left uncovered by the shielding gases and that may lead to the atmospheric contamination. That is why, inner diameter of the selected, in such a way, that it at least matches with the size of the weld pool or bigger than the size of the weld pool.

And the nozzle of the TIG torch should be replaced regularly because gradual damage to the nozzle leads to the change in size and shape of the nozzle, which causes the reduction in ability to form a firm jet of the shielding gases around the arc and around the weld pool. And that is why, it should be replaced regularly for proper shielding of the weld pool because here, we can see the same thing as damaged nozzle does not form desired jet of the shielding gas around the weld pool to protect it from the atmospheric contamination.

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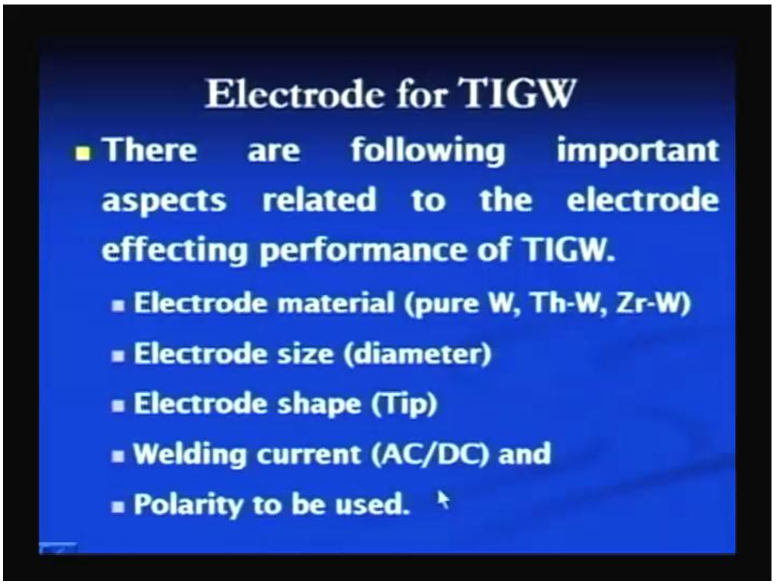

We can see the things now in, in the welding torch nozzle plays a significant role in, in forming a perfect shielding around the weld pool and another component electrode of the welding torch supplies the desired current to a, struck an arc between the electrode and work piece.

The electrode plays a major role in successful welding by the TIG process and these, there are certain important aspects related to the electrode, which affects the performance of tungsten inert gas welding. And these are, that what is the material of the electrode. Electrode can be the pure tungsten or it can be coated with the thorium or zirconium. The performance of all these three types of the electrodes is different. So, as per needs, as per the application, either pure or thoriated tungsten electrode or zirconium coated tungsten electrode is used.

The size of the electrode also plays the significant role in deciding the kind of the big geometry, which will be formed and the depth of penetration, which will be obtained. And the electrode size is mainly specified in terms of its diameter. Although length is also there, but these are considered as a non-consumable electrodes. Gradually, there will be reduction in the length of the electrode and when these are gradually worn out one by one, after long period of time we require to replace even these tungsten electrodes. But normally the size of that tungsten electrodes is specified by its diameter.

Shape of the electrode, what kind of the electrode tip has been shaped, is it a ball shaped or a square ended or the ((Refer time: 44:00)) one, that affects the weld bead cross-section and the depth of penetration, which is produced by the arc in the weldment. So, the cross-section of the weldment and its penetration is governed by the shape of the electrode tip.

And the type of the current, which is to be used, the different electrodes will be able to give different performance in terms of the arc stability and in terms of the life of the electrode and the cleaning action. So, as per the type of the electrode material the suitable current, AC or DC type of, DC type is selected. And the selection of the type of welding current also will be governed by the type of material, which is to be welded.

And the same way, if the DC is to be used, which polarity is to be used, that will also affect the performance of the electrode because all these, life of all these electrodes is different when DCEN is used compare to the when DCEP is used because there is a significant difference in the amount of heat, which is generated in the electrode side with the change of polarity. And that is why, to have the proper utilization of the electrode, to produce the desired weld joint, it is necessary to look into in, in greater detail about all these factors related to the electrode.

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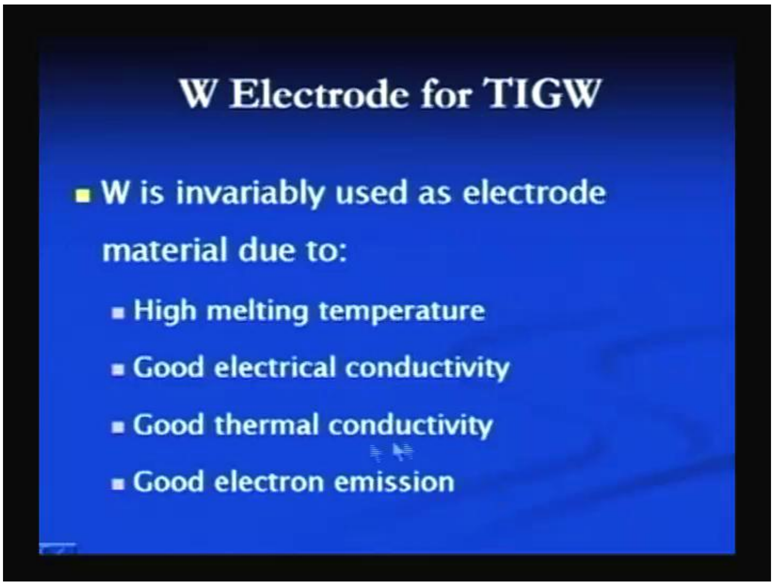

Pure tungsten electrode is invariably used in the tungsten inert gas welding process and main reason for its use as an electrode are, like this ability to withstand up to the high temperature. It, its melting point is quiet high and that is around 3410, 3410 degree centigrade and because of this ability, it, it can withstand easily under the arc conditions or the arc, which is produced.

And the good electrical conductivity for striking the arc it is necessary, that electrode material has the ability to supply the desired current with, with less electrical resistance heating effect. And because of good electrical conductivity, electrical resistance heating is very less and that is why, it is not heated much because of the electrical resistance heating when even when the high current is passed.

Although tungsten electrode will have also its current carrying capacity, which can be increased by coating some other materials, thermal conductivity is also important because heat generated at the electrode tip has to be transferred effectively to maintain its temperature and reduce its degradation.

So, the good thermal conductivity, good electrical conductivity and high melting point are the important points because of which it is selected. And one more important point of tungsten material, as a selection of the tungsten material as electrode is, that its good electron emission ability, good electron emissivity. Means, for striking the arc and for arc maintenance it is necessary to have the electrons in, in the arc zone. And if the electrode is able to produce the large number of electrons easily, the arc, striking of the arc and its maintenance becomes easy. And that is why, if the tungsten is used as an electrode, it offers the advantage of the good electron emissivity and that helps to strike and maintain the arc easily in addition to the other factors.

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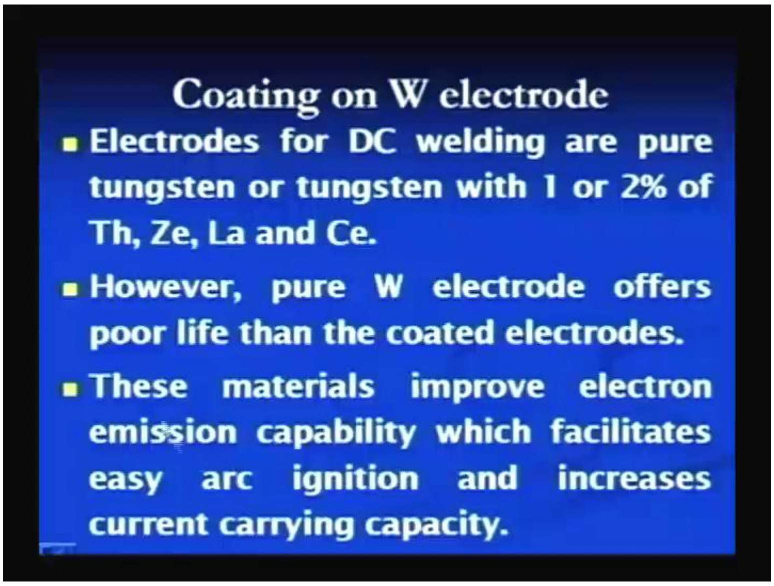

Sometimes special coatings on the tungsten electrodes are used to increase its performance, like the current carrying capacity of the pure tungsten is limited and because of that it offers also poor life and inability to handle the heavy currents. And that is why, special coating materials are used to increase its current carrying capacity, like electrodes for DC welding can be normally, can be of the pure tungsten or tungsten with the 1 or 2 percent of thorium, zirconium, lanthanum and cecesium.

Here, addition of these metal oxides help to increase the current carrying capacity of tungsten electrode and because the pure tungsten electrodes offer the poor life compared to the coated electrodes, the electrodes, which are coated with thorium zirconium lanthanum and cecesium. And these materials, coating of these materials helps to improve the further electron emissivity of the electrode, tungsten electrode, when these are coated with these materials and which helps to facilitate the easy arc ignition and also increases the current carrying capacity.

So, coating of the pure tungsten electrode with the thorium and zirconium particularly, is very helpful in improving the electron emissivity and increasing the current carrying capacity. That is why, for the AC welding and at higher current, normally the thorium and zirconium coated electrodes are used because pure tungsten electrodes offer somewhat poor life compared to the coated electrode.

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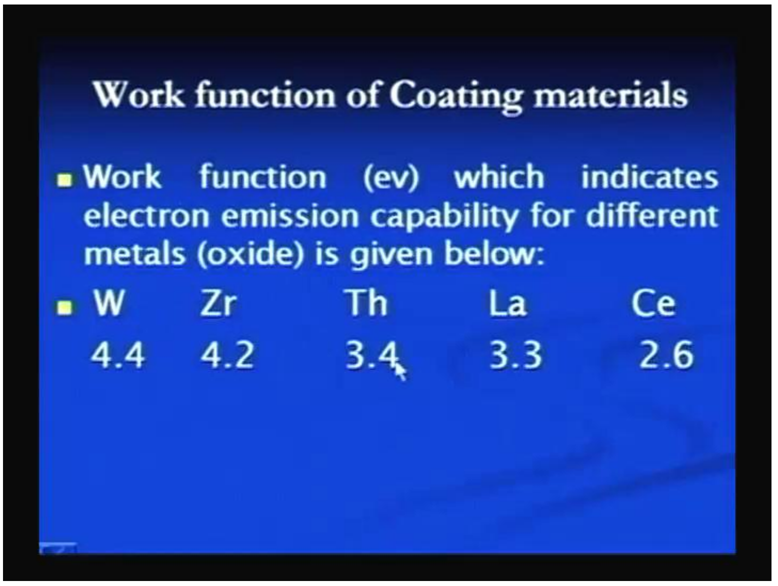

And the reason behind the better performance of the coated electrodes is, that work function, which indicates the electron emission capability of different material is different and the work function of the tungsten material and other coating materials is also different.

Work function indicates the amount of energy it will take to, energy it will take to release the electrons. Greater is energy requirement for releasing the electrons, greater, poorer the electron emissivity. Here, for tungsten, work function is 4.4; for zirconium, it is 4.2; for thorium, it is 3.4; for lanthanum 3.3 and cecesium 2.6.

So, here application of these two material oxides as a coating material significantly helps to increase the electron emissivity of the coated tungsten electrodes and increase their current carrying capacity. The reason is the work function of these coating materials is poor. These needs less energy to release the electrons and that is why, their electron emissivity is better compared to the pure tungsten. So, when these low potential elements, means, the elements of the lower work function when coated over the tungsten, then these coatings helps to increase the electrons emissivity of the coated electrodes and also increase their current carrying capacity.

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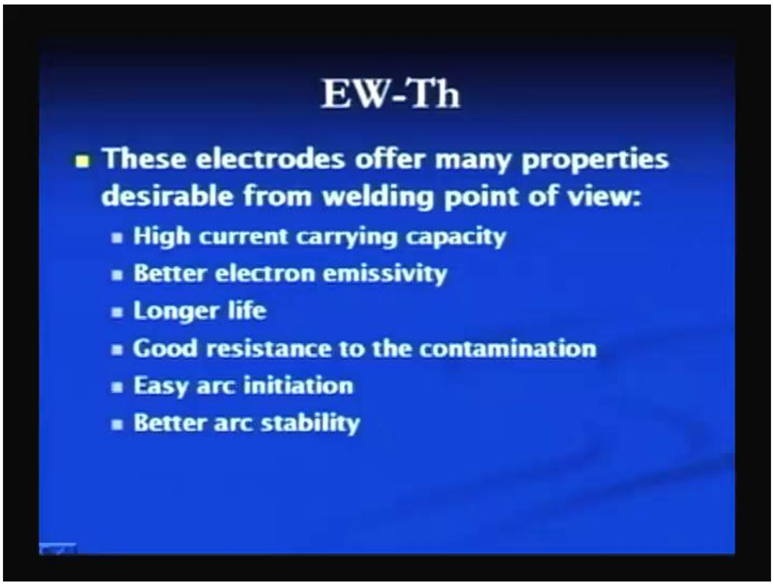

You can see here, thorium coated tungsten electrodes offers many advantages over the pure tungsten electrode, like high current carrying capacity, better electron emissivity, longer life, longer life of the thorium coated electrode, good resistance to the contamination and easy arc ignition.

Thorium coated electrodes also offer the advantage of the better arc stability because these electrodes are able to release the electrons easily. And when the large number of the electrons are available in the arc region, the arc is maintained easily and which in turn, helps to increase the arc stability.

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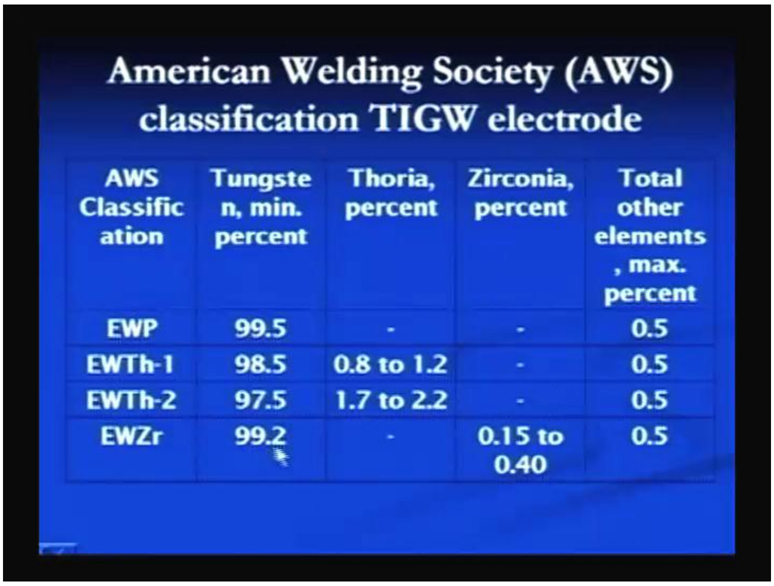
American Welding Society (AWS) classification TIGW electrode

AWS Classification	Tungsten, min. percent	Thoria, percent	Zirconia, percent	Total other elements, max. percent
EWP	99.5	-	-	0.5
EWTh-1	98.5	0.8 to 1.2	-	0.5
EWTh-2	97.5	1.7 to 2.2	-	0.5
EWZr	99.2	-	0.15 to 0.40	0.5

Here, as per the American welding society, the different composition of the tungsten electrodes have been given. And EWP indicates the pure tungsten electrodes and it is the percentage, minimum percentage of tungsten in this electrode is 99.5 percent, nil thorium, nil zirconium. And here, the total other elements can be maximum 2.5 percent and thorium-1 coated tungsten electrode can have 98.5, and 0.8, point, 98.5 and the thorium, it can be varying range of 0.8 to 1.2 percent and the maximum other elements can be 2.5 mm.

Thorium-2, tungsten coated electrode, EWTh-2 can have, maximum, minimum percentage of the tungsten 97.5 and the thorium percentage is in range of 1.7 to 2.2 and the maximum percentage of other elements is 0.5, and the zirconium coated tungsten electrodes, minimum percentage of tungsten 99.2 and the zirconium 0.15 to 0.4 and the maximum percentage of other elements is 0.5.

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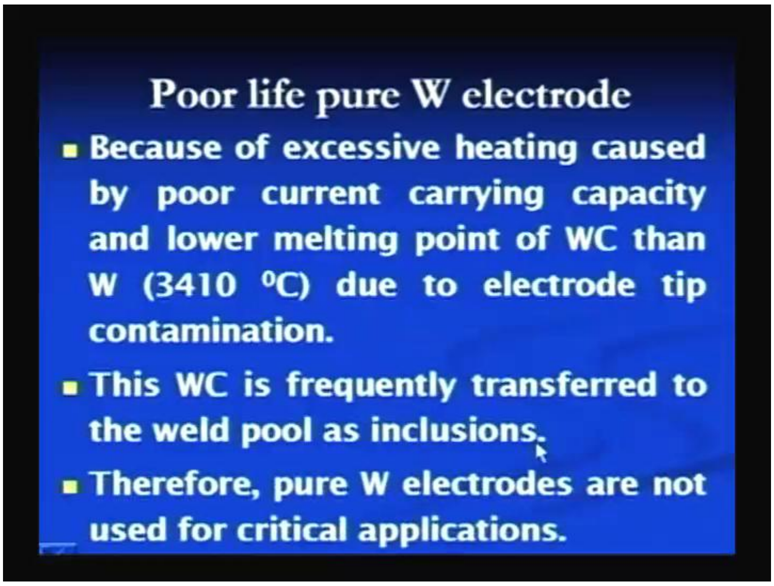

The poor life of the tungsten, pure tungsten electrode is, is attributed to the excessive heating caused by the its poor current, current carrying capacity and the lower melting point, lower melting point of the tungsten carbide, which is formed due to the contamination during the welding.

Here, as I have said, that pure tungsten electrodes have the poor, poor current carrying capacity. So, the flow of the current through the tungsten causes the electrical resistance heating, which in turn degrades life of the electrode. At the same time, whenever the contact between the electrode and the work piece takes place, if it picks up the impurities at the tip of the electrode, the impurities in form of the carbon forms the tungsten carbide, which has the lower melting point than the pure tungsten and that also leads to the degradation of the tungsten electrode.

And this tungsten carbide if transferred to the weld pool, then it will be present as a tungsten carbide inclusion, which can adversely affect the performance of, mechanical performance of the weld joint because the inclusions of the tungsten carbide particles acts as site of, ((Refer Time: 56:02)) site of the cracks or acts as if weak areas. That is why, pure tungsten electrodes are normally not used for the critical applications because there will be tendency for transfer of tungsten carbide particles as inclusion in the weldment, which will degrade mechanical properties of the weld joint and decrease the reliability and safety of the joint particularly in the critical applications.

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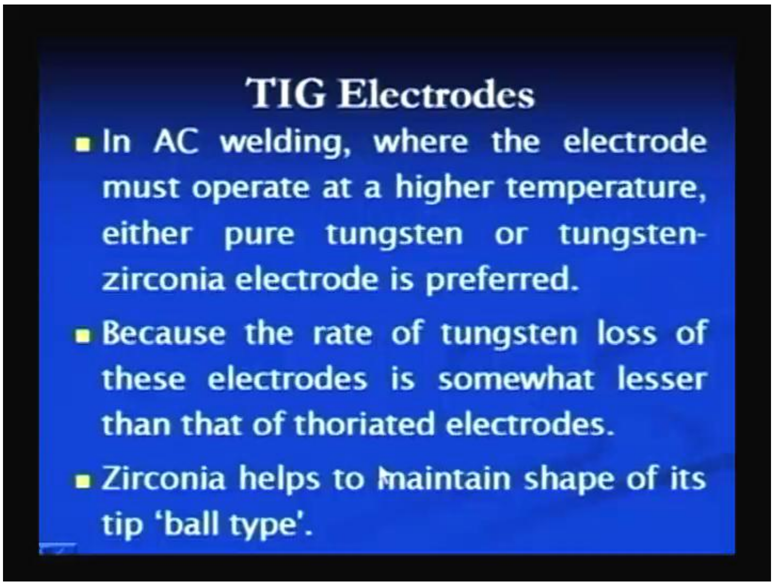

The TIG electrodes can be, can work with the AC or with the DC, but the AC electrodes are the tungsten electrodes for AC welding, should have good electron emissivity. If the electron emissivity of the tungsten electrode is poor, arc stability and its maintenance will be a major problem. That is why, for AC welding, where tungsten electrode must operate at high temperature, either zirconium coated tungsten electrode or pure tungsten electrode is preferred because the rate of tungsten, loss of this electrode is less compared to the thorium coated electrode.

Thorium coated electrode are subjected to the rapid degradation under the AC welding conditions compared to that of the pure tungsten and the zirconium coated tungsten electrodes. Zirconium coated electrodes helps to maintain its shape of the ball type, which is desired for producing the desired weldment cross section during the welding.

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And the size of the electrode, which are commonly used in industrial application is found in range of 0.5 to 6.4 mm in diameter and the length of electrode can vary from 150 to 200 mm. And the current carrying capacity of the electrode depends on the polarity being used, with DC welding current carrying capacity of an electrode, with DCEP is found lower than the DCEN.

Here, this is an important point because in, in, in case of DCEP more heat is generated in the electrode side and which causes rapid degradation of the electrode compared to the case when DCEN is used. Because when DCEN is used, is used, only one-third of the heat of the arc is generated in the electrode side and that is why, life of the electrode is not very adversely effected. AC is used only when the welding of the aluminum or magnesium and their alloys to be carried out because AC welding offers the advantage of the cleaning action during the welding of the aluminum and magnesium alloys.

So, now I will summarize this lecture. In this lecture we have seen, that need of the development of tungsten inert gas welding process and the different components related to the tungsten inert gas welding process, like the power source, the filler metal, which is used in and the, in this process and the tungsten weld tip welding torch and some of the details related to the electrode, which are electrodes, which are used in TIG welding process.

Some other aspects related to the tungsten electrodes and the shielding gas, which is used in this process and some important variants of the tungsten electrode gas welding process and the application of this process we will see in the next lecture. This lecture will continue in the second part of, and this lecture based on the tungsten inert gas welding process.

Thank you.