Welding Engineering
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Module - 4
Arc Welding Processes
Lecture - 5
PAW & SAW

So, in this presentation we will be talking about the principals and practices of the plasma arc welding process and the submerged arc welding process. We will first see that how the plasma arc welding process is different from the gas tungsten arc welding process, which is very commonly used for welding the reactive metals.

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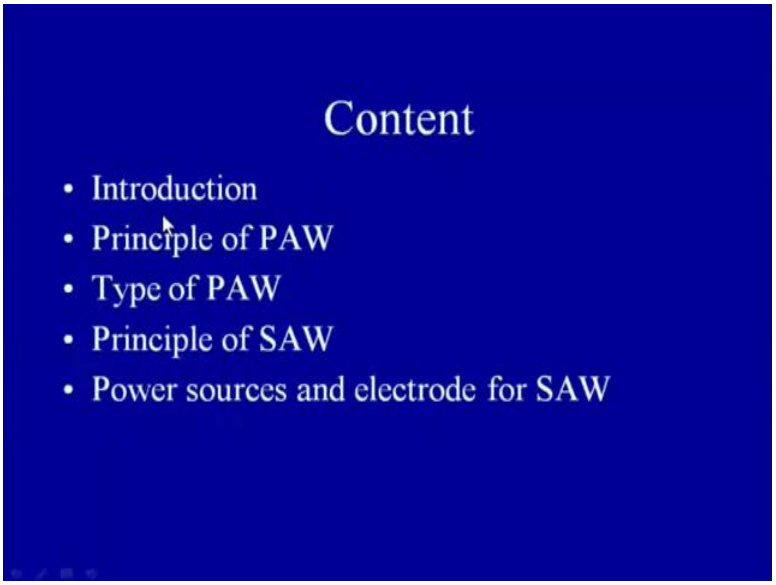

So, as far as content of this presentation is concerned we will be looking into the aspect related to the plasma arc welding process and submerged arc welding process. Then the principal which is used for generating the heat in plasma arc welding process and this heat is then used for melting of the faying surfaces to develop the weld joints. Depending up on the way by which the arc is generated and the plasma is formed for the welding purpose, we can have either transferred plasma or non-transferred plasma.

So, accordingly that the two common types of the plasma arc welding process will be looking into, thereafter we will see that what is the basic principal of the submerged arc

welding process and how heat is generated, which in turn affects the and the way by which it affects the quality of the weld joint, which is formed by the submerged arc welding process. Further, we will see the power sources which are commonly used with the different types of the electrodes in case of the submerged arc welding process and what are the electrodes which are commonly used with the submerged arc welding process. So, starting with the plasma arc welding process, this process is very similar to that of the gas tungsten arc welding process, where arc is established between the non-consumable tungsten electrode and the work piece.

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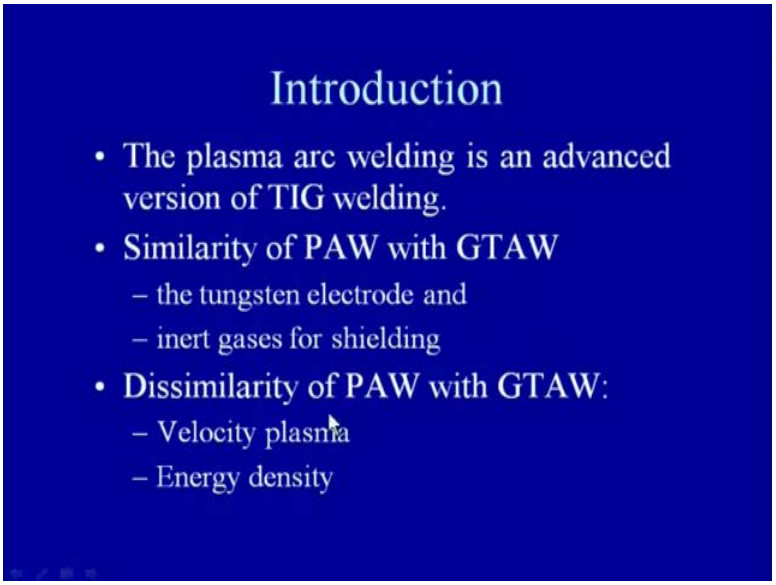

Here the current is very low current is allowed to flow from the electrode to the work piece and so the very high energy density arc is developed in case of the gas tungsten arc welding process. This in turn helps in reducing the net heated input been supply to the base metal during the melting. But the velocity of the plasma which is formed during the gas tungsten arc welding processes found to be low and the temperature is also, somewhat lower than what can be formed in the plasma arc welding process.

So, if we see in the plasma arc welding process is different from the gas tungsten arc welding process in the sense that it forms the plasma of the higher velocity and the temperature is also high. This in turn results in the great difference in there the energy density is associated with the plasma arc welding process has compared to that of the gas tungsten arc welding process. So, the plasma is basically the advance version of the

GTEW process where the tungsten electrode is used for developing the arc between either nozzle, and the electrode or the between electrode and the base material, so that this arc can be used for developing the plasma.

Similarity, similarities which exists between the plasma and the GTAW are the application of the tungsten electrode in both the cases. So, for developing the arc in both the processes the tungsten electrode is used and this arc is for the used in case of the plasma arc welding process for developing the plasma and in the GTAW process the tungsten electrode is used for developing the arc only which develops the low velocity plasma and this is used for developing the heat for melting the faying surfaces of the base material to develop the weld joint.

Similarly, the inert gases are also used for protecting the weld pool from the atmospheric contamination like GTAW process in case of the plasma arc welding. So, the shielding gases like argon and helium are commonly used for protecting the weld pool for preventing the atmospheric, preventing the contamination of the weld pool from that atmospheric gases like oxygen and nitrogen. But there are certain dissimilarities also like the velocity of the plasma and the energy density which is as shared as the plasma as compared to the GTAW.

The velocity of the plasma in case of the PAW processes is found to be significantly higher than that of the GTAW process and high energy density is found with the PAW processes is compared to that of the GTAW process. The main reason is that the high temperature plasma is allowed to force to forced, is allowed to pass through the very fine nozzle. Which in turn constricts the arc and it results in the jet of the plasma coming out from the nozzle at very high velocity which is also at very high temperature. This in turn when strikes to the surface of the base material energy is delivered to the base material for the melting.

So, the energy which is, energy density which is associated with the plasma because of the high temperature as well as high velocity of the plasma being formed in plasma arc welding process. The energy density of the PAW process is found a much greater than the GTAW process.

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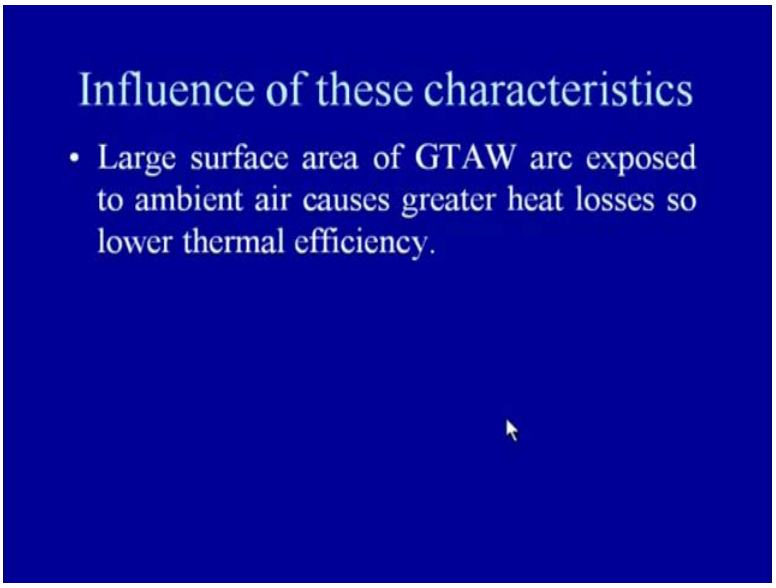

So, to understand that how it will be affecting to the welding characteristics when the PAW or the plasma arc welding process is used as compare to the GTAW process, we need to see that how the plasma is formed. How it is used for melting the faying surfaces. For this purpose, we will be looking in to this schematic diagram to understand that how plasma is formed?

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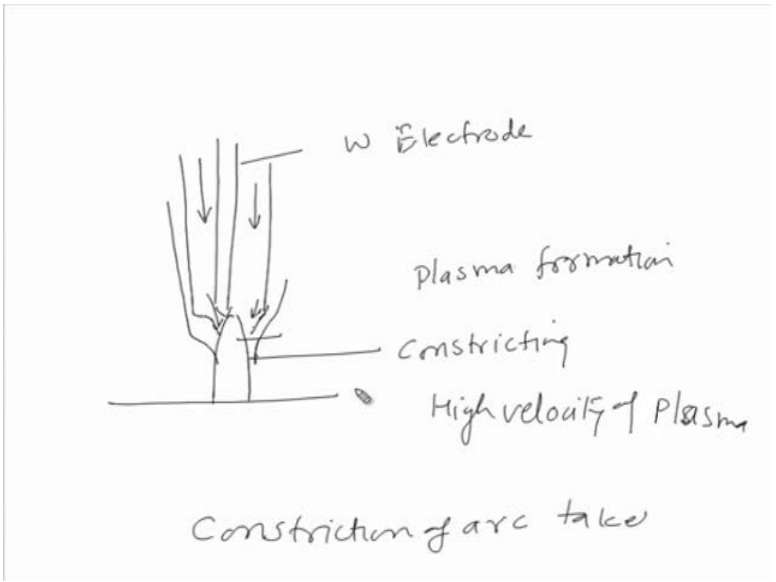

First, we use one tungsten electrode and then this tungsten electrode is used to establish the arc. So, this arc can be established either between the base material and the tungsten

electrode or it can be established between the nozzle itself. So, here so this is the tungsten electrode and then we have supplies of the plasma forming gas. So, plasma forming gas will be feed in through the arc zone, so these plasma forming gas when it is allowed to pass through the arc zone it is decomposed and ionized under the plasma is formed.

The plasma is formed when the plasma forming gas is allowed to pass through the arc, so this plasma which is mainly composed of the charged particles having the electrons and the positively charged ions these, the plasma gases are then allowed to pass through the fine nozzles. So, this nozzle will be constricting this nozzle will be constricting the arc and the plasma and resulting in the high velocity of plasma. So, when the plasma forming gas is coming passing through the arc region, they will be developing the plasma and these plasma gases will be passing through the nozzle.

Because of this constriction of arc takes place and this constriction results in significant increase in high velocity of plasma and it also increases the temperature because of the constriction of the arc. So, high velocity plasma with high temperature coming out of the nozzle, when it is directed on to the base material, it leads to the melting rapidly.

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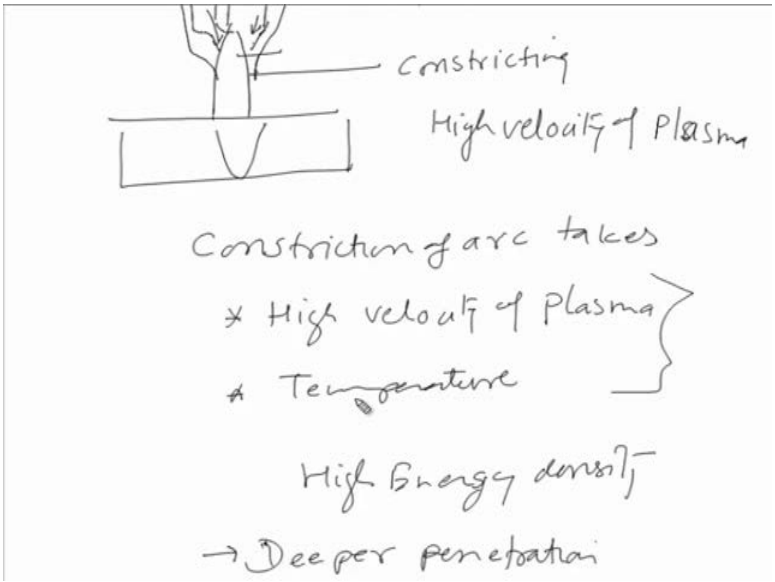

So, combination of these two results in high energy density and this high energy density associated with the high velocity plasma at high temperature results in the deeper penetration into the base material and this deeper penetration helps us in successful

welding of the thick sheets. Since, the melting of the base material because of the high energy density associated with the high velocity plasma and the high temperature results in the rapid melting of the base material even of the thick sheets and this in turn increases the welding speed.

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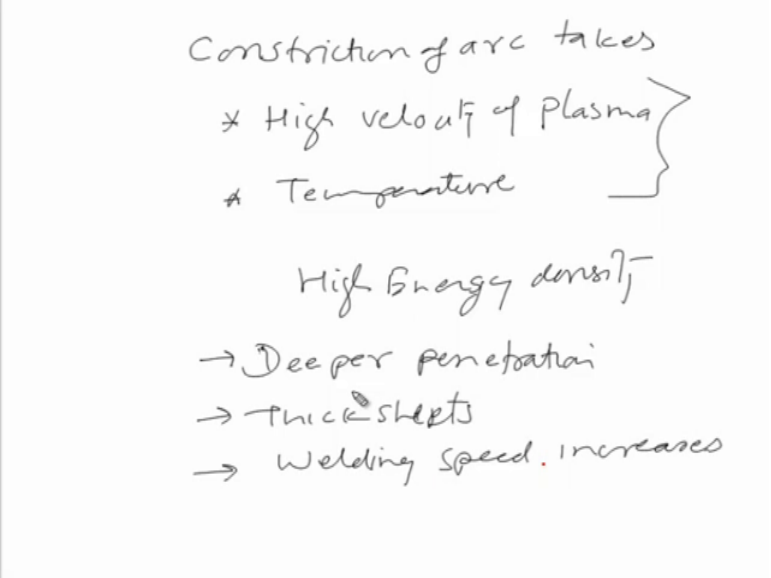

So, welding speed increases when the plasma welding is used, so these are the advantages which are obtained when the high velocity plasma at high temperature is directed on to the base material for melting the faying surfaces of the base material. This in turn causes the deeper penetration into the base material and makes the plasma jet to melt even the thicker sheets and fast melting results in the welding at the higher speed. So, these are, this is how the plasma works as compare to the tungsten inert gas welding process.

Now, we will see, as compare to that of the tungsten inert gas welding process the arc is very defused in case of the GTAW process which is exposed to the atmospheric air and because of this exposure the lot of heat is lost to the ambient air around and this in turn results in the lower thermal efficiency. While in case of the plasma arc welding process, since the arc is constructed and the high velocity plasma is allowed to flow through the very small nozzle and the same is directed towards the base material for melting to take place.

This in turn, results in the smaller surface area, lower surface area of the constructed arc, in case of the PAW process and reduced surface area of the arc associated with the PAW process results in the greater energy density.

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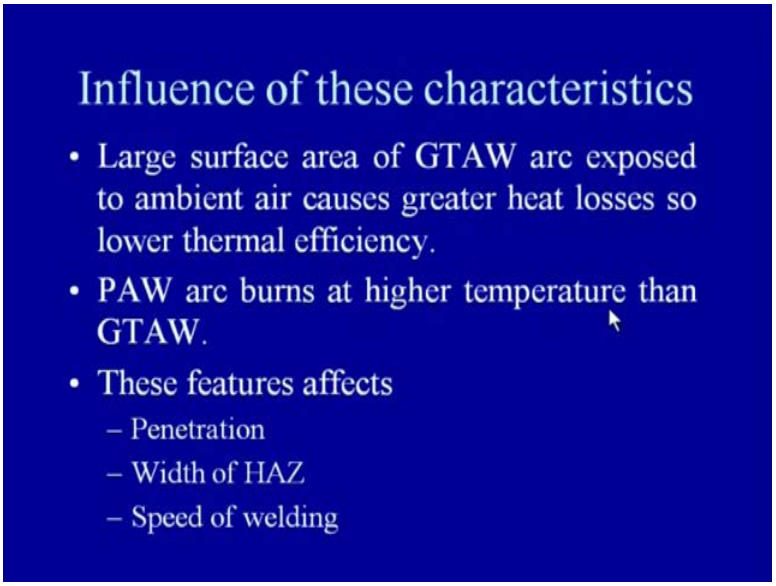

The reduce losses to the ambient gases and which in turn increases the arc efficiency or the efficiency of the PAW process as compare to the GTAW process. So, as I have just explain that arc PAW arc works a burns at much higher temperature than the GTAW process. Because it has a smaller surface area and because of the lower surface area the loses of the heat to the ambient air are reduced and which in turn leads to have the higher temperature in the arc associated to the PAW process as compare to the GTAW process.

These specific characteristics associated with the PAW process, which is the high temperature of the plasma and coming out at high velocity and directed towards the base material for melting to take place. This feature, this two specific feature results in the higher penetration or the deeper penetration into the base material and the higher welding speed because rapid melting takes place. Further, since the energy density associated with the PAW process is high. Therefore, it requires less amount of the heat input for the base material to bring it down to the molten state.

Therefore, heat put requirement for melting the faying surfaces is reduced by the PAW process as compare to the GTAW process and because of the reduced heat input requirements with the PAW process in turn, results in the reduced width of the heat

effected zone. So, we get all the benefits related with the high energy density process in case of the PAW welding plasma arc welding process, that is high penetration and the smaller or the narrow width of the heat affected zone and the higher welding speed. So, these are the features which are affected by the high temperature and the high velocity of the plasma associated with the plasma arc welding process.

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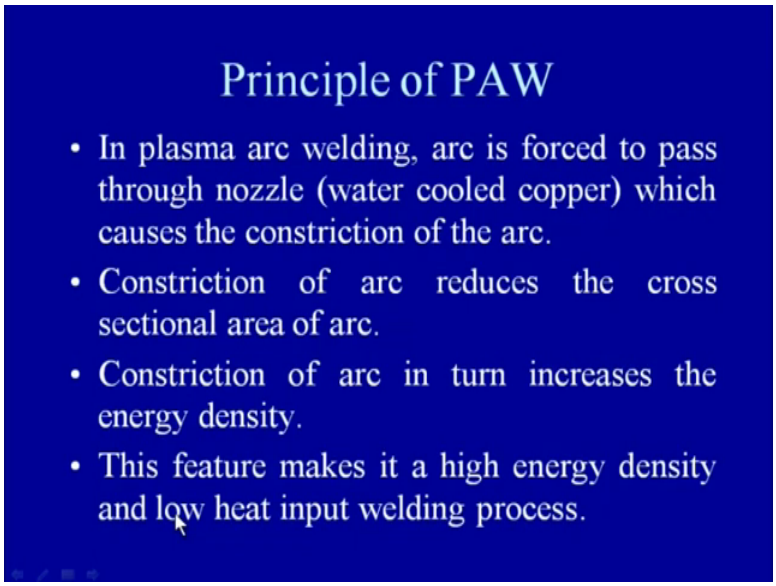

In the plasma arc welding process arc is forced to pass through the nozzle I have just explained and this nozzle is normally water cooled made of copper to, so that the temperature, its temperature can be maintained within the limits, within the safe limits without getting the created much. This forcing of the arc to pass through the nozzle results in the constrictions of the arc this is a this constriction of the arc, means its cross section area is reduced. The arc is allowed to flow through the narrow nozzle through a small size nozzle.

So, the constriction of the arc reduces the cross sectional area of the arc and which in turn increases the energy density associated with the arc in PAW process. In the, this increase in energy density in turn reduces the heat require for melting the faying surfaces of the base material and this makes it the low heat input welding process. Because the higher is the energy density associated with the particular process lower will be the amount of heat required for melting the faying surfaces of the base material to bring the faying surface to the molten state and to develop the weld joint.

So, since the energy density associated with the PAW process significantly higher than the GTAW process SMAW process and the SAW process also therefore, it offers the advantage us to shift to the low heat input welding process. These are mainly the reduced width of the heat zone and the reduced magnitude of the residual stress is associated with. So, the reduced effect of, on the reduced effect on the mechanical properties and cruzin performance of the weld joint further distools and tendencies also reduced when the heat net heat input is reduced to the base material because of the low heat input process if we have to understand.

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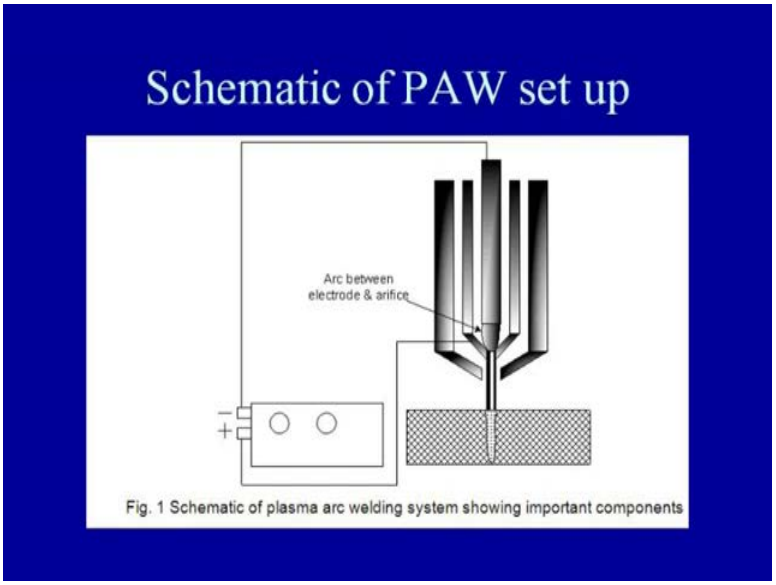

Schematic diagram of the PAW process bit it basically involves the power circuit which power source can deliver the required amount of the welding current which may be in range of 100 to 300 ampere for establishing the arc between the electrode and the base material or the nozzle. So, first the arc is established and then once the arc is established then the plasma forming gas is allowed to flow through the arc zone and then this plasma gases are pass through the nozzle where there constriction takes place.

So, basically there is a power source which is use negative terminal is normally connected to the tungsten electrode and a positive terminal is connected to the base material or sometimes it is connected to another anode, which is their inside the torch. So, and these when these gases come out through the nozzle in form of high velocity plasma after passing through the arc region the high temperature gases coming out high

temperature plasma coming out of the nozzle transfers the heat effectively to the base material for melting to take place.

Basically one typical technique which is used with a PAW process is called key holing technique where first the plasma is allowed to penetrate the material to the full depth. Once the melting takes place, thereafter once the melting takes place through the thickness of the plate to be welded the plasma is moved slowly, so that the weld joint can be made across along the length of the plates to be joined. Now, we have seen that once the plasma gases are formed they are forced to pass through the small nozzle and this in turn causes the constriction of the arc.

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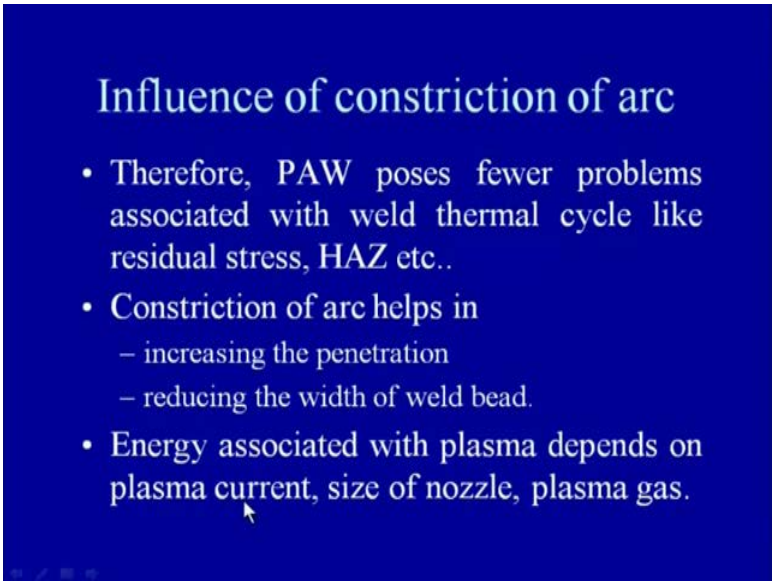

When the constriction of the arc takes place this reduces the heat to be supplied for welding of the plates and the reduced amount of the heat input in turn decreases the problems associated with the weld thermal cycle like residual stress and the heat effected zone. This is the reason, why we say that the PAW process the reduces the problems associated with the weld thermal cycle like residual stress and a heat effected zone. Because if we supply more amount of the heat and the greater portion of the material below the fusion boundary will be subjected to the differential expansion and contraction, which in turn will be causing the great development of the greater residual stress.

Similarly, the base material near the fusion boundary will be affected to the greater

extent with the higher heat input, so if we are able to reduce the heat input by the PAW process this in turn will be helping us in reducing the residual stress and the heat effected zone. So, the construction of the arc which is increase which is helping us in increasing the energy density associated with the plasma and its temperature, this in turn will be increasing the penetration capability of the plasma and it will be reducing the width of the weld bead. Because if the arc is not constricted then it will be defused and it will have wider cross sectional area and in this which in turn will be making the wider width of the weld bead.

So, if the arc is constricted it will increasing the penetration into the base material during the welding and further it will be reducing the width of the weld bead being made. So, the energy density which is being achieved in the plasma arc welding process depends up on that what is a magnitude of the current being used for developing the plasma that is the plasma current. Then the size of the nozzle and the plasma gas which is being used for developing the plasma. So, these are the three factors that affect the, that affect the energy associated with the plasma arc welding process.

Though so, if we go with the higher current for developing the plasma it will result in the higher current inside the in the arc zone and higher current, in the arc zone will be causing the higher temperature of the plasma region. So, the, if we increase the plasma current it will simply increase the energy density associated with the plasma. If we increase the size of the nozzle it will reduce the energy density associated with the plasma because the velocity and the constriction of arc will be reduced. Similarly, the plasma forming gases which on decomposition the gas is which on decomposition for formation of the plasma.

They absorb some energy and thus form the ionized charged particles ionized particles and the free electrons. When they re unite on the reunion they release lot of the gases, so depending up on the gases and the energy associated with the thermal, energy which is associated with the release with the reunion of these gases during the welding also effects the energy associated with the plasma in case of the plasma arc welding process.

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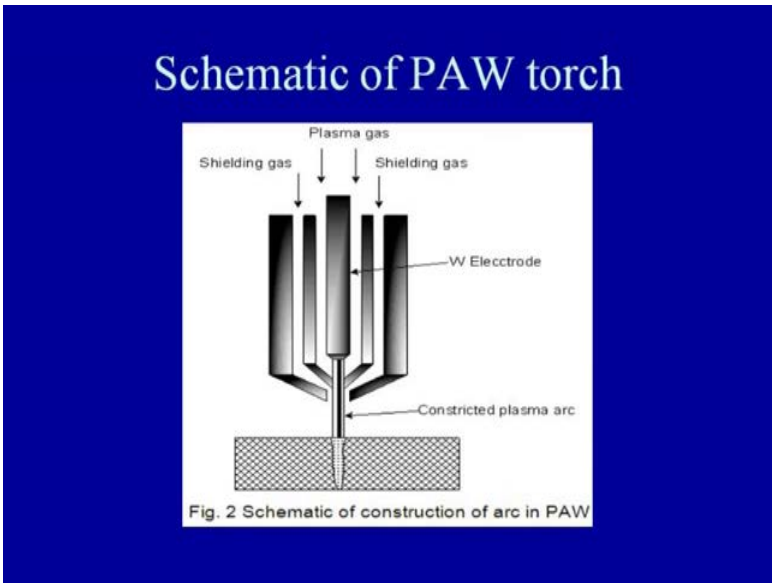

Schematic diagram, if we see that here we have various channels through which the different gases are supplied, so that the plasma is formed and the gas and the weld pool is protected by the suitable shielding gases. Here, if we see in the middle we have the tungsten electrode and the arc is established either by the supplying the current between supplying the current from the power source between the tungsten electrode. The base material or one nozzle one additional anode can be brought in between the electrode and the base material.

So, the in that case arc is striked between the nozzle striked between the plasma form this electrode and the nozzle and the anode. So, once the ark is developed the plasma forming gas is formed is allowed to flow through the arc zone. So, when the plasma forming gas flows through this area, this is the plasma annular space through which plasma forming gases fed in. When it passes through the arc zone the plasma is developed and then this plasma is allowed to pass through this nozzle and around. This means further all around this we supply the shielding gas.

This shielding gas will be helping us in protecting the plasma zone and the weld pool being formed from that atmospheric from the contamination of the atmospheric gases. So, the weld pool contamination due to that atmospheric gases is prevented by supplying the inert gases like argon and helium and there mixture is also sometimes used. So, this constricted plasma arc is developed basically due to the flow of this plasma gases

through this small size nozzle.

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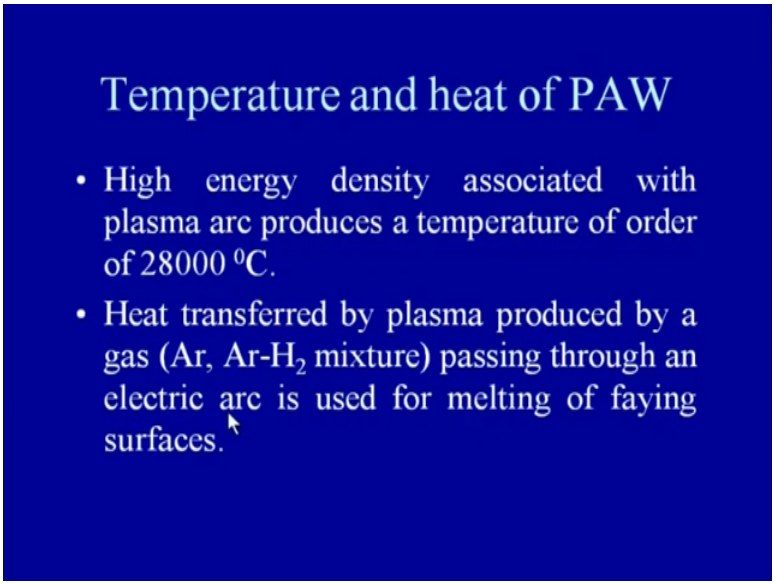

Because of this constriction the high energy density associated with the plasma produces a very high temperature to the tune of 28000 degree centigrade. This high temperature makes possible to melt even the defect difficult to the melt materials and makes welding easier. The heat, further the heat transferred by the plasma produced by the gases like argon or argon helium mixture passing through the electric arc is used for melting the faying surfaces.

So, heat transferred by the plasma is basically used for melting the faying surfaces in case of the plasma arc welding process. So, to protect the weld pool once it is brought to the molten state and it is ready to solidify must be protected from the contamination by the atmospheric gases. Therefore, the inert gases like the argon and the helium are frequently use to protect the molten weld pool from the atmospheric gases. Further, if you see that the plasma forming gas when strike to the surface of the base material heat is transferred and the melting of the material melting of the faying surfaces of the base material takes place.

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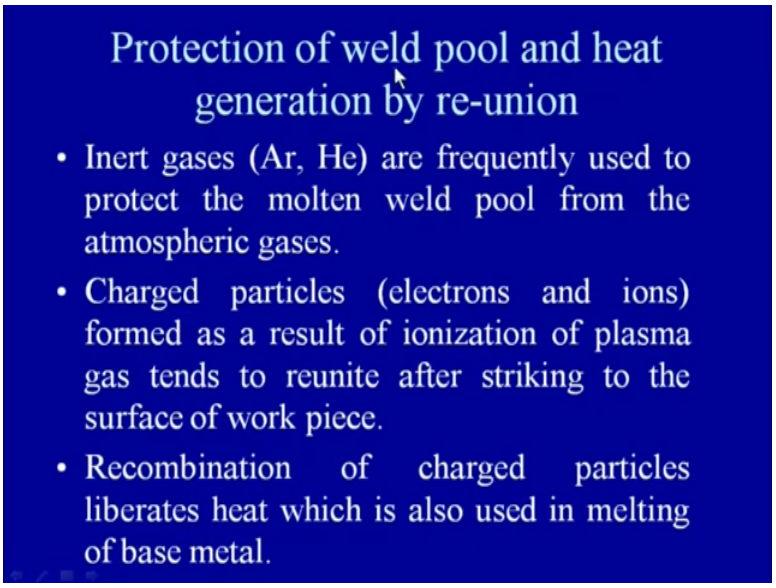

These charged particles which are there in the plasma inform of electrons and ions these tends to re unite and then this reunion or recombination of the charged particles liberates lot of heat and this heat liberated is further use for melting the faying surfaces. So, this is the another way by which the heat generated due to the re union of the charged particles in the plasma forming gas helps in melting of the face base material.

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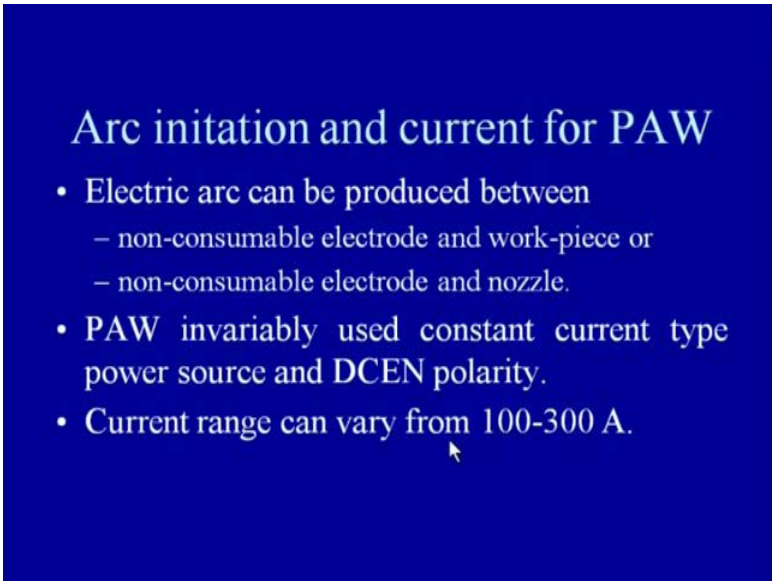

Further the heat and but, the major portion of the heat generated by the plasma is transferred to the base material and the same is used for melting the faying surface. But

some of the heat which is generated by reunion of these charge particles is also used for melting of the faying surfaces for welding to take place. Now, we will see that how the arc is initiated in the PAW process and the how welding is done.

There are two ways basically for initiation of the arc between the electrode and either the base material or with the nozzle. So, we have the non-consumable electrode and the work piece we can strike the arc either between the electrode and the work piece or between the non-consumable electrode and the nozzle. So, when it is done we can have the transferred plasma or the non-transferred plasma arc welding process. So, the way by which arc is striked for developing the plasma. We can have the two variants either the plasma transferred plasma arc or non-transferred plasma arc.

So, these are the two ways through which the arc is established between the electrode and the base material. In case of the PAW process it can striked between either non consumable electrode and work piece or it can be strike between non consumable electrode and the nozzle. PAW process for striking the arc for developing the arc normally uses the constant current type of the power source with the DCEN polarity. So, means the tungsten electrode is connected with the negative terminal of the power supply, so that the electrode can be therefore longer duration.

The less heat is generated in the electrode side and more in the anode side which can be replaced or which can be there in form of the base material. To have constancy in the current supply the constant current type of the power source is used with the PAW process. So, similar to the GTW welding where the constant current type of the power source with the DCEN polarity is commonly used, PAW also uses the similar type of the power source that is constant current type of the power source.

The DCEN polarity and the current range which is normally used with the PAW process varies from the 100 to 300 ampere range. Further, if we see what is there curtain precautions which are required in case of the PAW process and these are mainly associated with the kind of the sound which is created during the PAW process and the radiations which are generated during the welding.

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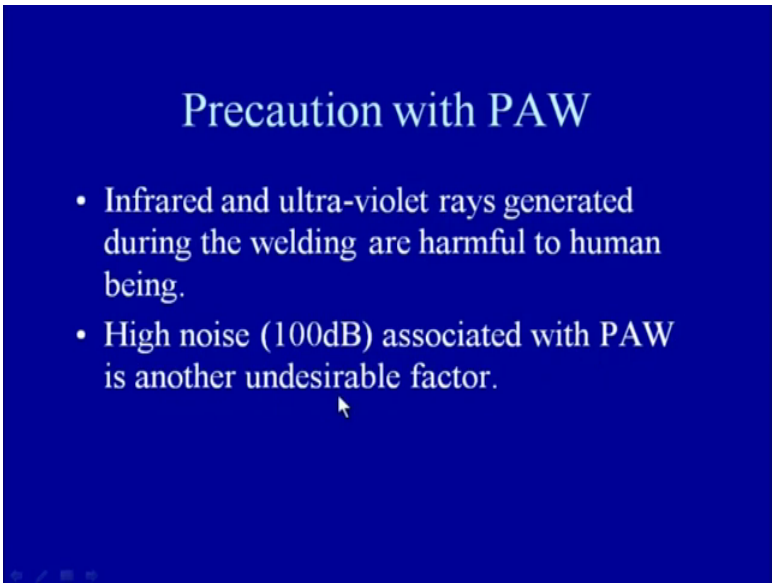

So, during the PAW process infrared and ultra violet rays are generated and these are considered to the harmful to the human being when they are expose for longer duration. So, new care must be taken to avoid the excessive exposure to these ultra violet and infrared rays during the welding when the PAW is used. Suitable protection to the ears should also be made because the noise which is generated during with PAW process is significantly high which is in the order of the 100 decibel. So, to avoid any kind of undesirable adverse effect on the ears and the body of the human being suitable precautions must be taken while PAW process is used.

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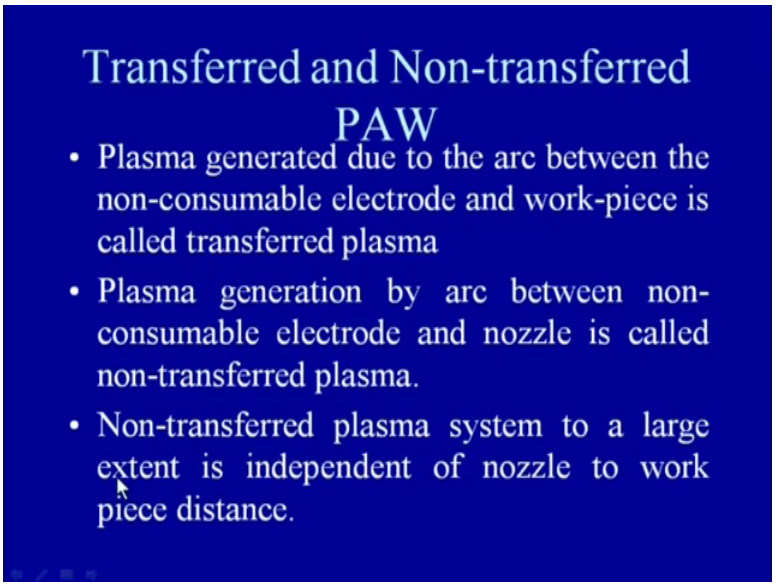

Now, we will see that the two variants of the PAW process as I have described the non-transferred plasma and the transferred plasma welding process. The plasma, we know that the plasma is generated due to the arc between the non-consumable electrode and the work piece. When the, now, we know that for generating the plasma the plasma forming gas is allowed to pass through the arc zone, where it absorbs a required amount of heat and develops the plasma.

This plasma is then further force to pass through the nozzle for the welding purpose. Now this plasma can be generated by the flow of the plasma forming gases when the arc is establish either between the non-consumable electrode and the work piece. The when it is done then we call it as a transferred plasma means in case of the transferred plasma the plasma is generated by the arc which is established between the non-consumable electrode and the work piece.

So, this situation when the work piece is a part of the electric circuit in case of the transferred plasma well the plasma generation by the arc between the non-consumable electrode and the nozzle then we say as a non-transferred plasma. So, in this case the plasma is generated by its flow through the arc which is established between the non-consumable tungsten electrode and the nozzle. In this case the arc is not between the electrode and the base material but, it is established between electrode and the nozzle and the work piece is not a part of electrical circuit for developing the plasma.

This feature in turn helps us in having the variable torch distance so, because the non-transferred plasma system is largely independent of a the work piece and the transferred plasma system to a large extent is independent of the work piece because nozzle arc is established between the tungsten electrode and the nozzle not with the work piece. Therefore, it allows the flexibility in using the varying the nozzle to the work piece distance.

So, the extend of means work piece to the nozzle distance flexibility is found to be there with the non-transferred plasma system as compare to the transferred plasma system where work piece is very much part of the electrical circuit. Now, we will see the submerged arc welding process which is one of the commonly used arc welding process especially for joining the heavy sections of the steels and the other materials. And this process is very extensively used in case of the shift welding and the press a vessel

industry, where heavy sections are required to be joint for developing the variety of the engineering component.

This process is called so because arc in this process is always submerged under the flux which is granular in nature and this flux under the influence of the arc heat melts and covers the weld pool and the arc completely to protect it from the any contamination from the gases of the atmosphere. So, the shielding to the welding pool and to the arc zone is provided by the molten flux in this case and the arc is completely submerged under the molten flux and the granular flux.

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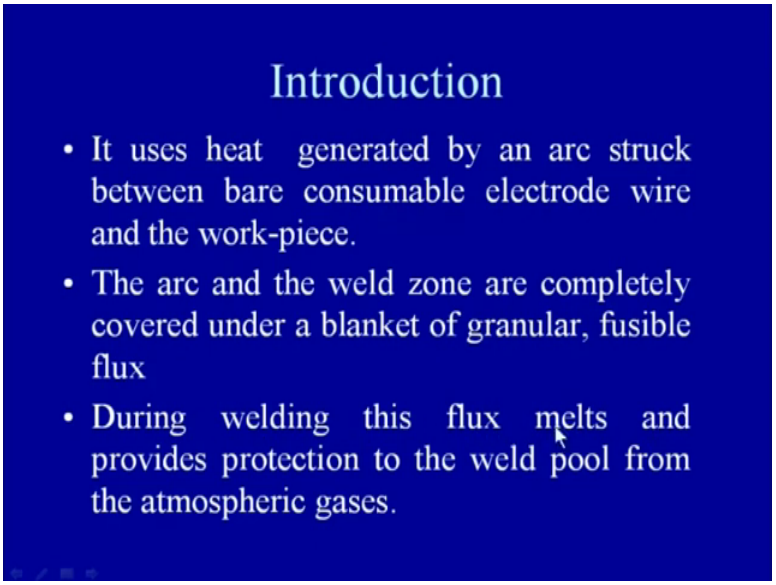

Now, we will see the some important features of the submerged arc welding process and the principal association with the SAW process. We know that it submerged arc welding process uses the heat generated by the arc between the bare electrode and the work piece. So, the basically this process uses one bare consumable electrode wire and the work piece so the arc is stricked between the electrode wire and the work piece and this heat generated is used for melting the faying surfaces of the base material. The arc and the weld zone are completely covered in this case under the blanket of the granular flex and the fusible flux.

So, this the blanket forming, formed by the granular flux is melts continuously by the heat of the arc during the welding and it provides it the required protection from the atmospheric contamination. During the welding this flux which is covering to the arc

completely melts and provides protection to the weld pool from the atmospheric gases. So, basically heat generated by the arc between bare non bare consumable electrode and the base material is basically used for melting the faying surfaces of the base material, so that the weld can be made.

But the protection to the weld pool is provided by melting of this flux which is covering to the arc completely during the welding. Now, we know that the in submerged arc welding process the arc is completely covered by the granular flux. And this granular flux melts continuously during the welding and forms the complete cover around the arc and the weld pool to protect it from the atmospheric from the contamination of the weld pool by the atmospheric gases. So, during the welding this flux melts and provides the protection to the weld pool from the atmospheric gases.

We have to see if the role of the flux is the molten flux flows down continuously during the welding. The fresh flux melts around the arc. And the molten flux performs very important roles during the welding because this flux reacts with the impurities protect the protect with the weld pool and also reduces the heat transfer. So, these are the three important rules which are performed by the molten flux forming cover around the arc and the weld pool.

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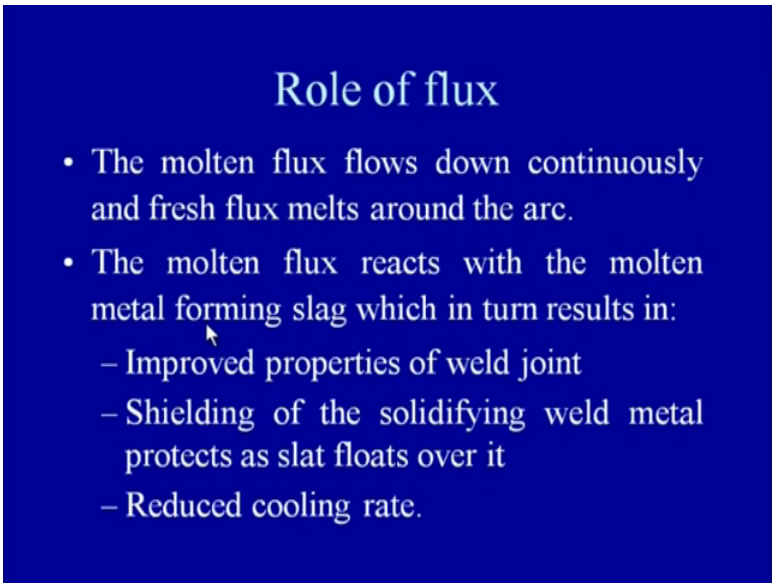

So, because of the reaction of the molten flux with the impurities present in the weld metal, the these impurities are take of at the removed by the flux which in turn helps in

improving the properties of the weld joint. And it provides the shielding of the solidifying weld metal to protect it from the, to protect it from the atmospheric gases.

So, here because the slag being formed becomes the lighter and that then it is starts to float over the surface of the solidifying weld metal and that is provides protection to the weld metal. Now further, the cover of the slag over the solidified base metal further reduces the cooling rate during the welding and this reduced cooling rate in case of the hardenable steels helps introducing the cracking tendency.

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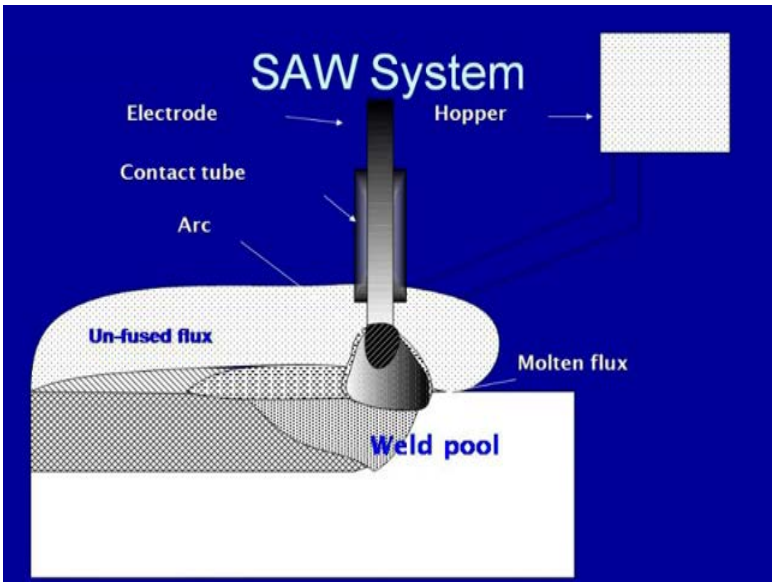

If we are to understand that the, this is the consumable electrode which is in contact with the contact tube and this electrode establishes the arc with the base material. So, the flow of current between the consumable electrode and the base material develops the arc and this arc is completely covered by the granular flux which is there all around. This granular flux melts in by the effect of the heat being generated by the arc and this molten flux which is all around the arc forms a complete cover. And this flux also reacts with the impurities being formed during the welding in the weld metal and these this in turn leads to the formation of the slag.

So, the slag becomes lighter, so it is float over the surface of the molten weld pool and forms a cover around the weld pool which is already being solidified. So, the at the top we have the unfused flux and immediately around the welding arc we have fused flux and below this is the arc region below this we have the weld pool and which is still in the

molten state and this is the weld metal which has been solidified. So, here and we keep on supplying the flux continuously around the arc zone, so that whatever the flux is melting continuously during the welding.

That is compensated continuously by supplying the additional flux from the hopper. So, the hopper from the hopper flux is separate continuously around the arc so that arc is always under the flux and the molten flux forms a complete cover around the arc and the weld pool to protect it from the atmospheric contamination.

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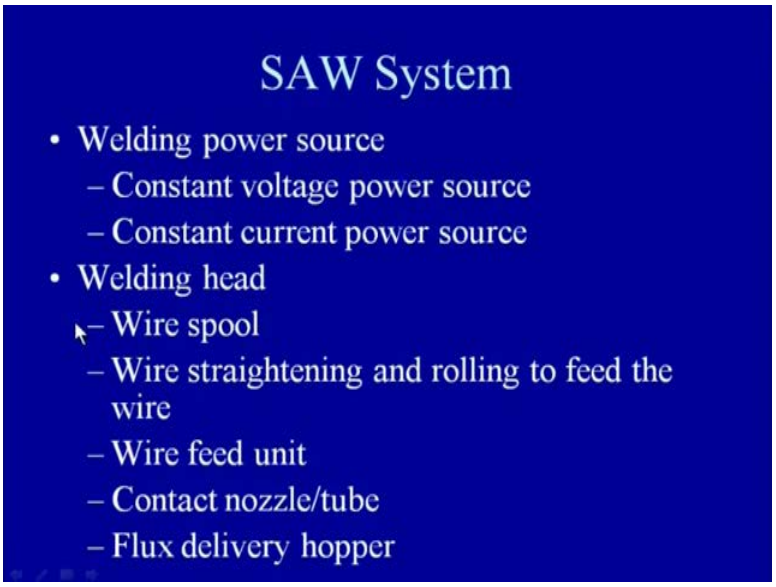

The submerged arc welding system forms is composed of the various important components and these are like welding power source is one which can be the constant voltage type of the power source or the constant current type of the power source. Constant voltage type of powers source is used for taking the benefit of the self-regulating arc especially when the small diameter electrode are used. While with the large diameter electrode have a four mm size normally in constant current type of the power source is used.

Then another important component is the welding head which is which includes the wire spool. The wire spool is nothing it is the electrode which is wrapped around which is wrapped in form of the spool and this is used continuously during the welding. So, wire means consumable electrode for the welding purpose is obtained from the wire spool and then this wire is first straightened and then fed through the rollers to feed in to the arc

zone. So, the rollers means the feed system is there to feed the wire into the arc zone after straightening it.

Then this is a there is wire feed unit wire feed unit will be helping in to feed the electrode at either constant rate or at the varying rate depending up on the kind of the power supply is being used or the approach is being used for controlling the arc length. Then there is a contact nozzle or the contact tube, this contact nozzle or contact tube delivers the required current to the electrode, so that the arc is established between the base material and the electrode. So, basically supply to the electrode is made through the contact tube or the contact nozzle to the electrode. Then there is a flux delivery hopper, so the flux require for covering the arc completely from all around the flux is feed continuously from the hopper so that the arc is always covered by the flux and the weld pool is protected.

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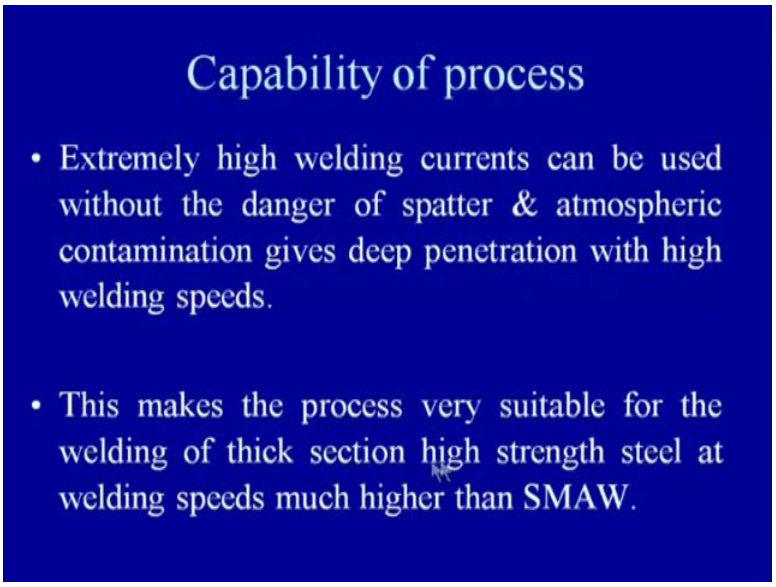

Now, we will see that what are the factors that decide the capability of the submerged arc welding process? We know that the submerged arc welding process is mainly use for the welding the heavy sections where, very high heat input is required and that is made possible by supplying the high heat high welding current. So, to get the advantage of the high heat input associated with the SAW process, extremely high welding current is used with this process.

Because it can have, it can deliver the high amount of heat, large amount of the heat for

melting the electrode and without any danger of the spatter and the atmospheric contamination. And further when the high heat is supplied the deeper penetration is obtained and the deeper penetration the fast melting possible with the high large amount of the heat results in the high welding speed. So, the capability of the process is mainly associated with the, with the ability to work using the high welding current so that the deeper penetration and the high melting rate can be obtained.

Further, the weld pool is also protected by the molten flux and this avoids the any possibility of the spatter also. So, these factors makes this process suitable for welding the thick sections of the high strength steels at much higher welding speed than that is possible with the SMAW process. SMAW process is very low current process compare as compare to that of the SAW process where current we can use from two hundred to two thousand ampere range.

While in case of SMAW process the current range which is normally restricted to the four hundred to five hundred ampere because too high current leads to the excessive electrical resistance heating of the core wire in SMAW process which in turn decomposes the coating around the core wire and adversely affects shielding affect produced by the electrodes during the welding. Thus decreases a means that is reduces the quality of the weld which is being made by the SMAW process.

So, the ability of this SAW process to work with the higher current provides deeper penetration and the higher welding speed free form the spatter weld. The reduced contamination of the weld from the atmospheric contamination makes it very good for welding the heavy sections of the high strength steel. However, the oxygen contained in the SAW process weld is found somewhat greater than the other welding process, because the these fluxes are mostly oxides of the different metals which are used for providing the desired characteristics to the flux.

So, these oxides provide lot of oxygen to the weld pool during the welding and therefore, oxygen content with the oxygen content in the weld joints made by the SAW process is found higher than the other welding process like MIG welding process or the TIG welding process. Another important feature associate with the submerged arc welding is that the composition of the weld metal can be easily controlled as compare to the other approach where we need to supply the electrode of the desired composition.

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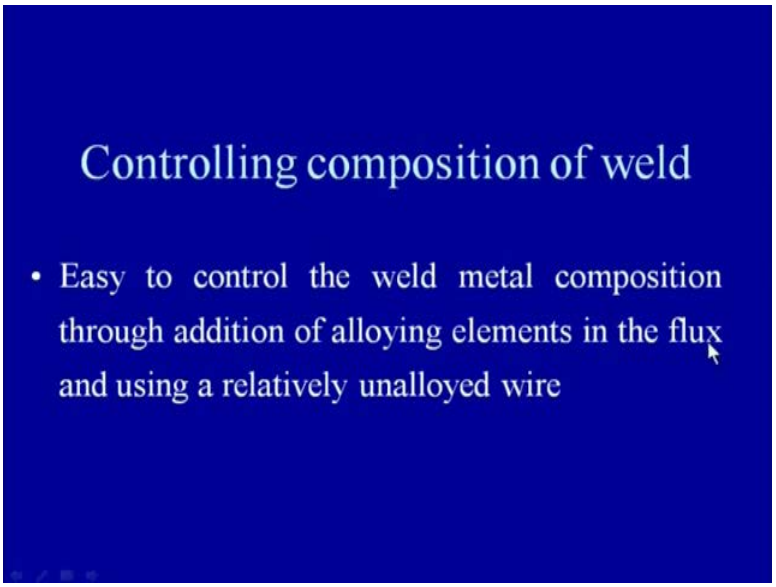

So, here what we do to control the composition of the weld metal is that the required alloying elements which are to be added in the weld material are first added with the flux. So, these alloying elements will be melting with the flux and will be added to the weld metal. So, for easy control of the weld metal composition through the addition of the trough the addition of the alloying elements in the flux using relatively unalloyed the filler wire. So, the electrode we can use of the composition of specific composition which we want or we can add the required amount of the alloying elements by missing them with the flux so that during the welding they bring they can enter in to the weld pool and modify the composition of the weld material as per requirement.

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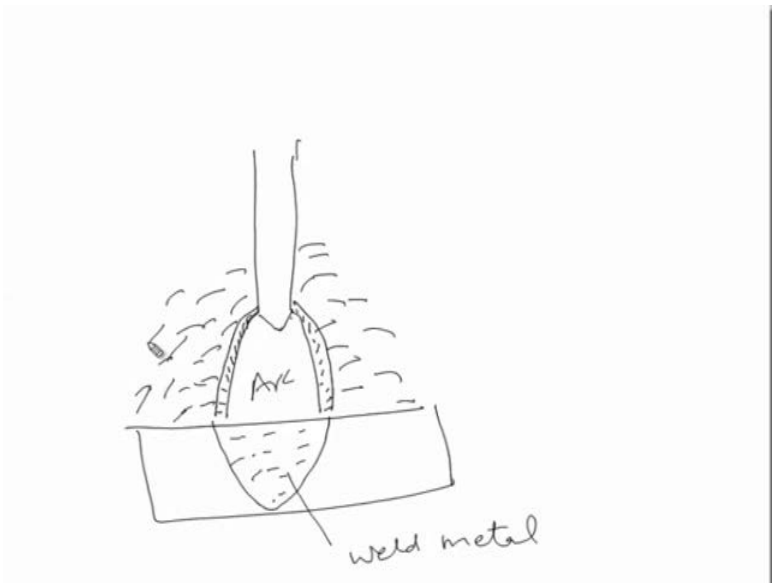

So, this approach is very simple if we have to understand this we will see this schematic diagram where we can see that this is the electrode and this is the welding arc. This welding arc is completely covered by the flux all around and or a thin layer of the flux is brought to the molten state. So, this is molten layer, the layer of the molten flux around the arc and this is the arc zone and here we have the weld pool. So, to change the composition of the weld metal this is weld metal.

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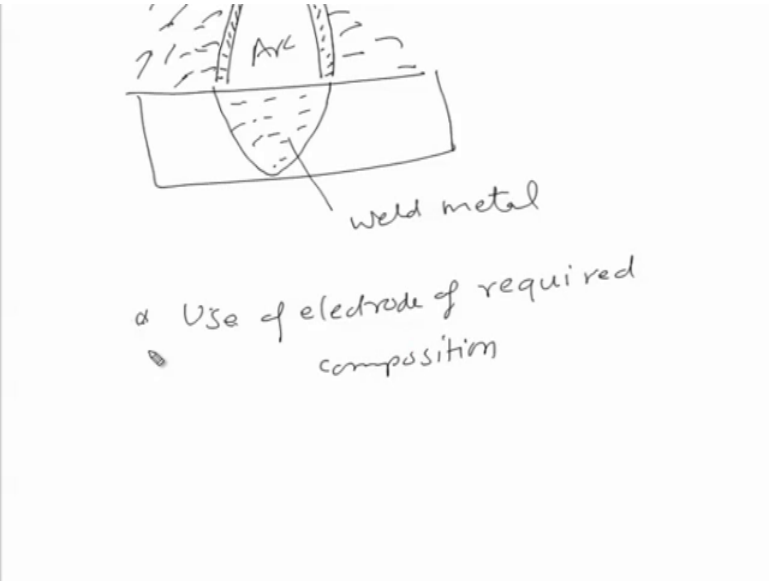

To change the composition of the weld metal there are two possible approaches, one is use of electrode of required composition. This is one, but sometimes it becomes difficult to get the electrode of the required composition. So, under such situations where it is not possible then we can use comparatively unalloyed electrode material and the required elements can be added in that case while putting the elements with the flux.

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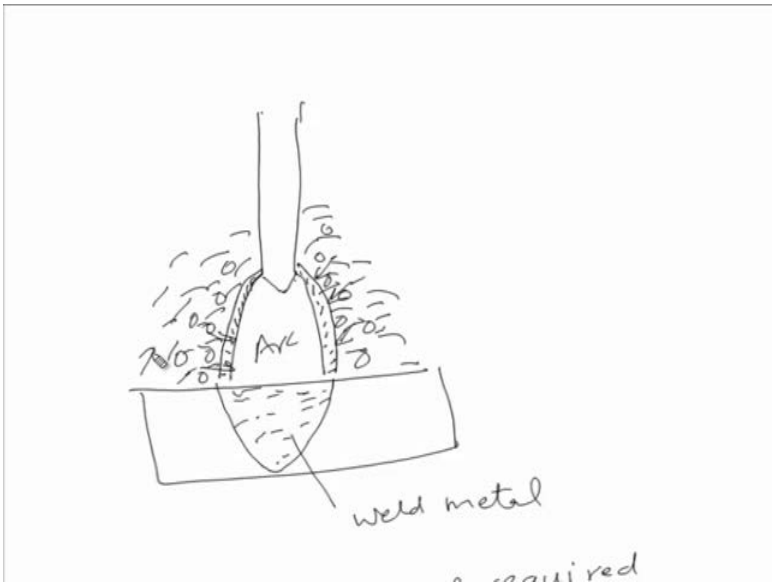

So, these elements are mixed in form of powder with the flux and when this flux melts during the welding these powder particles also melts and they get mix up with the weld material. So, this approach for modifying the composition of the weld material as per requirement is that the mixing of the required elements with the flux itself.

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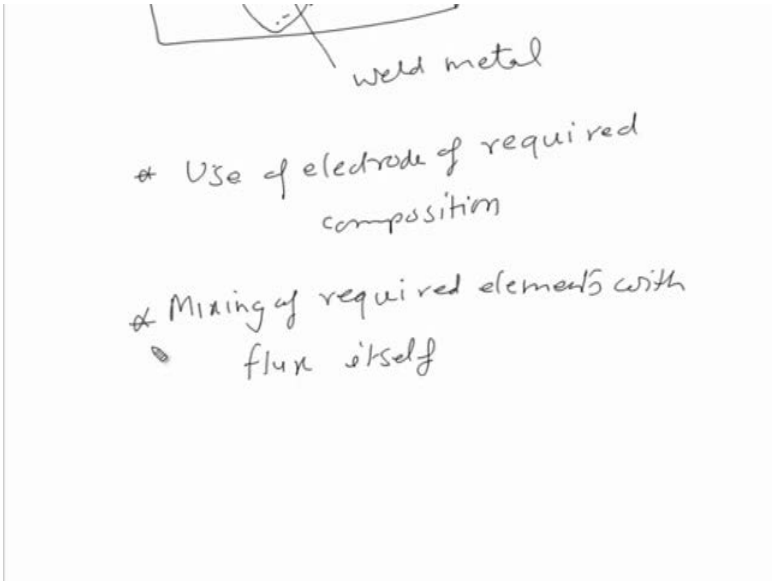

So, when this flux melts during the welding the alloying elements automatically get mix with the weld material and the weld material composition is modified as per the requirement. So, this out it is comparatively it is comparatively easy to control the weld

metal composition in case of the SAW process by adding the alloying elements in the flux and using the relatively unalloyed filler material. Because getting the filler material of the required composition may be difficult. So, if that is difficult and we still want to change the composition weld material as per our requirement, then this kind of modification can be made easily by adding the filler material by adding the alloying elements with the flux itself.

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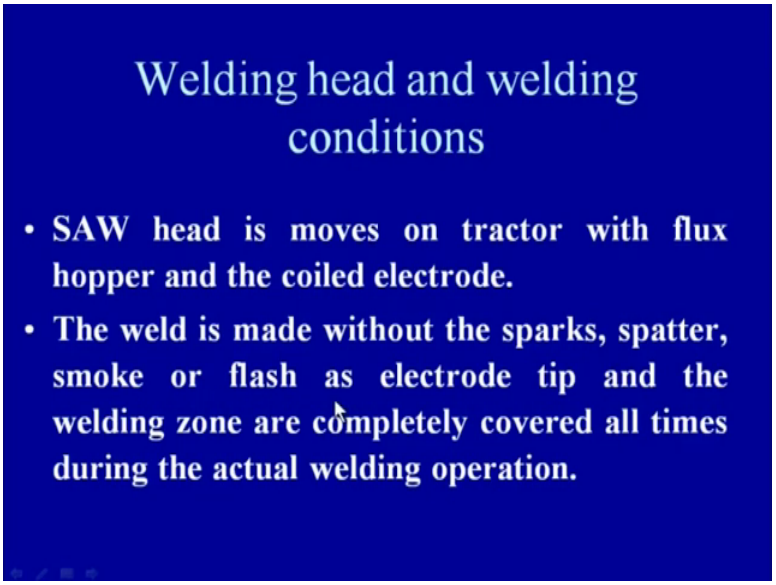

Now, we will see that during the welding we use welding head and this welding head movement is controlled very carefully, so that the heat is generated in the required location and the melting of the base material is obtained to develop the weld joint along the desired line of the weld. So, for this purpose submerged arc welding head is moved on the tractor with the flux and the coiled electrode. So, this entire assembly, which includes the flux hopper, the electrode and the electrode feeder, straightness, contractive etcetera all this is entire assembly is moved along the line of the weld in which the weld joint is to be made. For this purpose one tractor is moved and its welding speed is set according to the requirement.

Now, the weld is made in this case without sparks without spatter and the smoke and no flash is also formed as the electrode and the weld zone are completely covered all the times during the welding by the molten flux. So, because of this advantage since the electrode and the arc and the weld pool is always cover by the molten flux and the

granular flux during the welding. Therefore, we do not get sparks spatters and the flash is during the welding.

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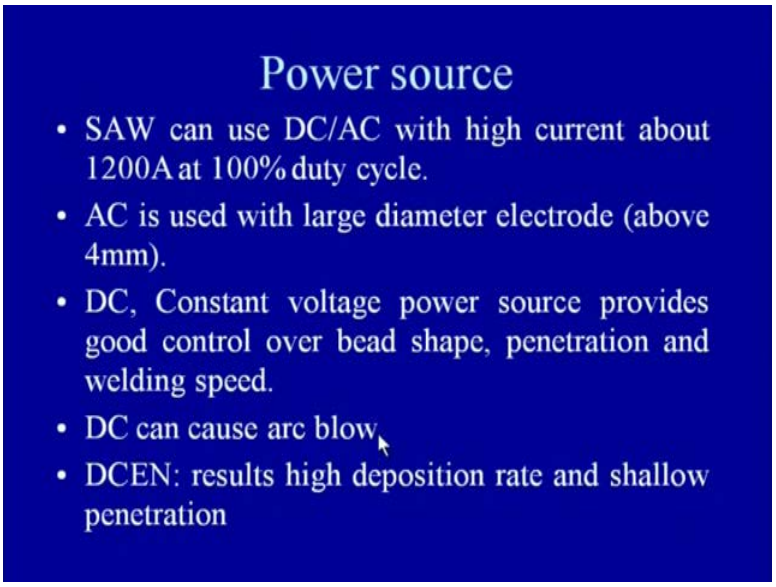

Now, we will see what are the types of the power sources, which are used during the SAW process, and what are the current ranges and what are the other aspects related with the SAW process. The SAW process can use can work with the both AC and DC with the high current above 200 1200 ampere at 100 percent duty cycle. We can go further higher current levels while using the lower duty cycles or depending up on the capability of the power source to deliver the particular range current. But, it, the SAW can work as high as the 2000 ampere range of the current. So, it can work with both AC and DC. AC is used with the large diameter electrode above the 4 mm while the DC constant voltage power source is used to obtained the very good control over the bead shape penetration and the welding speed.

This, the DC constant voltage power source is specifically used when the small diameter electrode is to be used for the welding purpose. And but, there will be possibility of the arc blow when the DC is used because of the interaction between the electromagnetic fields generated around the arc and due to the flow of current through the base material. But, when the DCEN is used it results in the higher deposition rate and the shallow penetration normally the electrode in case of the SAW is connected to the positive terminals of the DC power source.

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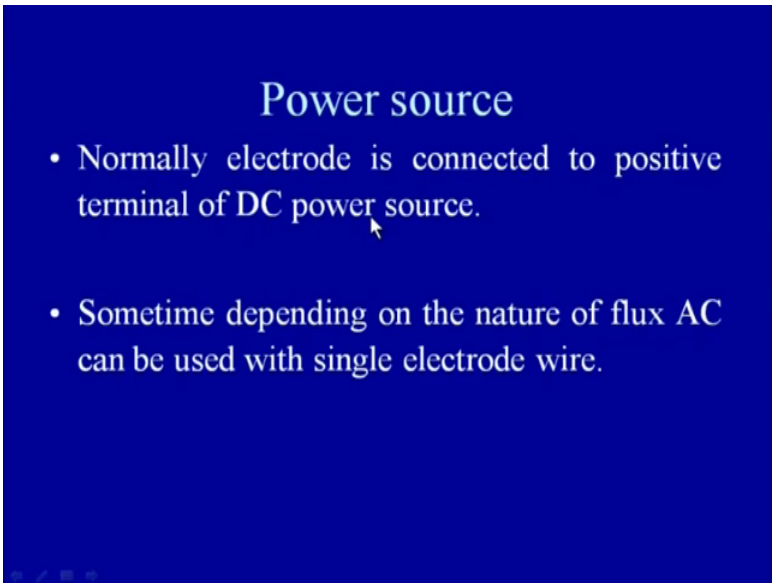

So, that more amount of heat being generated towards the anode that is the positive terminal side of the electrode can be effectively used for fast melting of the electrode and so has to achieve the higher deposition rate. So, the high deposition rate can be obtained while making the DCEP that is the electrode positive polarity. But when DCEN is used it results in the shallow penetration in the weld.

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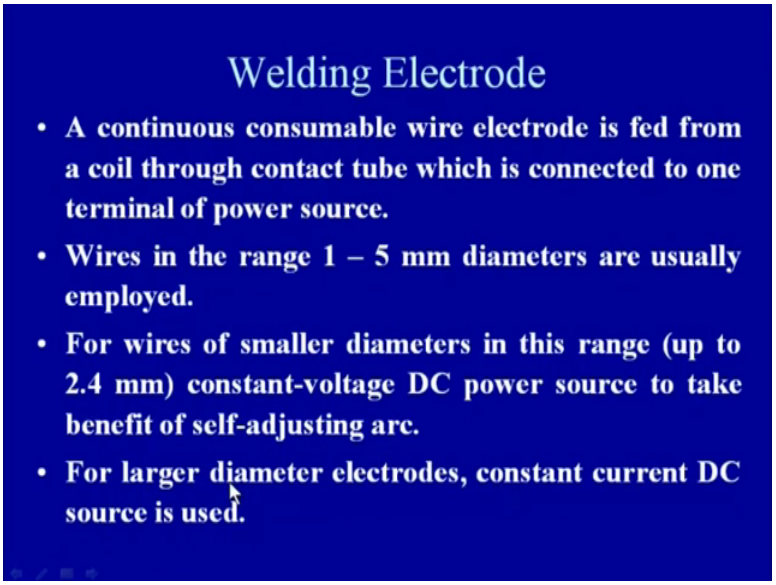

Sometimes depending up on the nature of the flux AC can be used with the single wire electrodes. The welding electrodes which are used, in case of the SAW process are feed

continuously during the welding from the coil which is always in contact of the contact nozzle of the contact tube. So, that the power is delivered to the electrode for establishing and maintaining the arc between electrode and the base material.

So, the electrode which is continuously fed by the electrode feeding device through a coil is always in contact with the contact tube so that the power is delivered to the electrode from the power supply for establishing the arc between the electrode and the base material. The electrode diameter can range from 1 to 5 mm and depending up on the thickness which is to be welded the suitable electrode diameter is selected. Normally, for thicker plates the large diameter electrodes are used, so that the required amount of the heat can be generated for melting the faying surfaces of the base material of the heavier sections.

So, for the wires of the smaller diameter in the range up to the 2.4 mm, the constant voltage DC power supply is used to take the advantage of self-regulating arc. So, that the, with the help of constant voltage power source and the constant speed feed drive system we can take the advantage of self-regulating arc that will be helping us in maintaining the arc length without much fluctuation. While in case of the large diameter electrode the constant current power source is used, because in this case we do not get that advantage of the self regulating arc and which is mainly based on that how rapidly the melting rate is regulated with the change of current?

So, if there is no possibility for rapid change of current the change of the arc length in case of the large diameter electrode the constant current power supply is used. While in case of the small diameter electrode where rapid change in the melting rate is possible with the change of the welding current therefore, the constant voltage DC power source is used. Now, I will conclude this presentation here in this presentation, we have talked about the basic principal of the plasma arc welding process and how can we compare and the bases and the factors on the bases of which we can compare the plasma arc welding process with the GTAW process?

Further, we have seen that the various variants of the PAW process and the important benefits associated with the PAW process. We have also seen that the submerged arc welding process is very effectively used for welding of the heavy sections because of the high heat input associated with this process and that is made possible through the use of

the heavy welding current which can go up to the 2000 ampere. We have also seen the different components which are used and which will be making submerged arc welding system like the power source and the welding electrode and the welding head. In the coming lectures, we will see the, what are the welding parameters associated with the submerged arc welding process and their effect on the melting and the characteristics other characteristics of the welding.

Thank you for your attention.