Joining Technologies of Commercial Importance
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Lecture - 13
Submerged Arc Welding

Hello, I welcome you all in this 11th presentation, related to the subject joining technologies for the metals. And this presentation I will start with the submerged arc welding and thereafter I will try to take up the Electro-slag welding process also.

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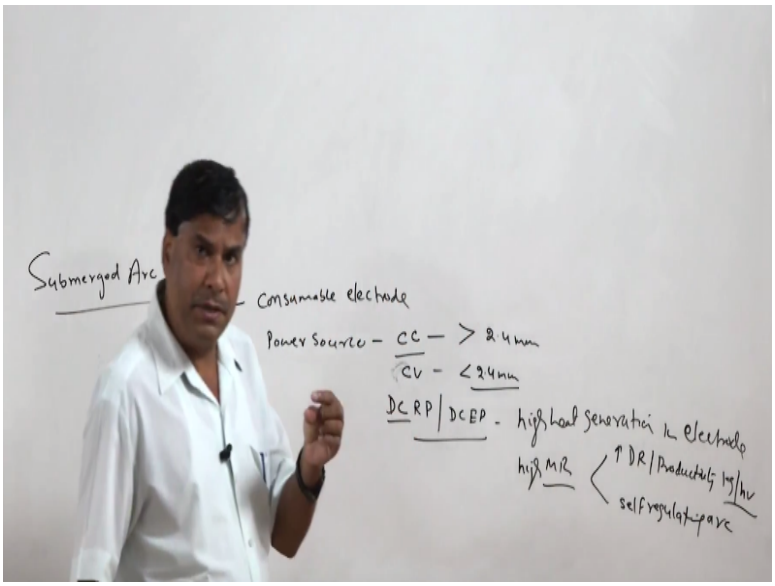

So submerged arc welding process is very unique in the sense the important features like it uses the consumable electrode and the power source used in this process is like say, it can be constant current type or it can be constant voltage type for the small diameter electrodes less than 2.4 mm size constant voltage power sources are normally used and for the large diameter electrodes greater than 2.4 mm size the constant current type of the power sources are used.

When we work with mostly the DC constant current type of the power source with the reverse polarity or DCEP electrode positive polarity is invariably used to take the advantage of the high heat generation in the electrode side, so that we can have very high melting rate of the electrode. So, this is intentionally done to achieve the high melting rate. So high melting rate facilitates in two ways.

It helps in increasing the deposition rate or the productivity in terms of the KG of the weld metal deposited per hour or it also helps in increasing the high melting rate, it helps in realizing the self-regulating arc. Because when the melting rate of the electrode with the small diameter electrodes is high, it responds very rapidly with the change for the change in current.

And that helps to maintain the self-regulating arc that helps to maintain the arc length through the self-regulating arc principle. So, these are the benefits of using the DCEP polarity in case of the submerged arc welding.

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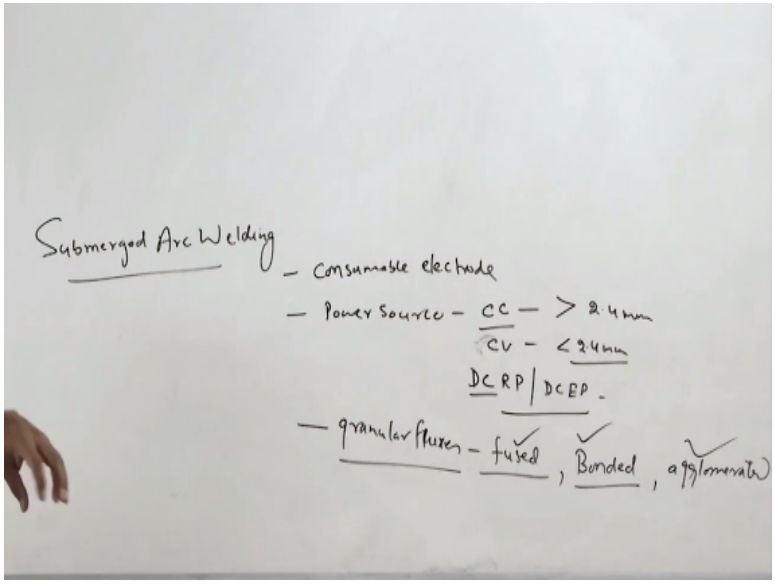

In addition to this, it uses the unique kind of the way to protect the weld pool from the atmospheric condemnation that is the granular fluxes are used. So, these fluxes basically covered around the pool or around the welding arc. So, we will talk in detail about that. Granular fluxes, these fluxes are of the different types like fused fluxes which are homogeneous in composition even if the segregation of the fine and coarse particles takes place.

It does not affect the performance of the fluxes; it does not affect their characteristics. Another is the bonded fluxes. Bonded fluxes are the ceramic base fluxes which are similar to the fuse fluxes, in case of fuse fluxes all the constituents are fused and then they are crushed, powered, gridded and then they used but here the bonded fluxes, they are ceramic based.

And here we will see the agglomerated fluxes and mechanical fluxes, mechanical mixtures, mix fluxes. Mechanical, mix, fluxes and agglomerated fluxes these are the four types of the fluxes which are commonly used. In case of the mechanical types of the fluxes definitely flux constituents are brought together and mixed in the ratio whatever we want did allows us to have a lot of variety with respect to the fluxes.

But there is a lot of segregation tendency in the mechanical mix fluxes where some of the constituents tend to gets segregate which will be leading to the varying performance changing the characteristics of the fluxes like, if there is a bag full of the mechanical fluxes the top layers will be offering one kind of the ingredients in larger quantity than others which will be used in from the, which will be used at the end from the bottom of the bag.

So, mechanical fluxes will have the tendency to show, will have the tendency for segregation and so, the variation in the characteristics of the fluxes which will be available. Electrodes normally this continues the electrode is wrapped in this spool of the electrode and is fed continuously. So the different feeding mechanisms are there for the electrodes.

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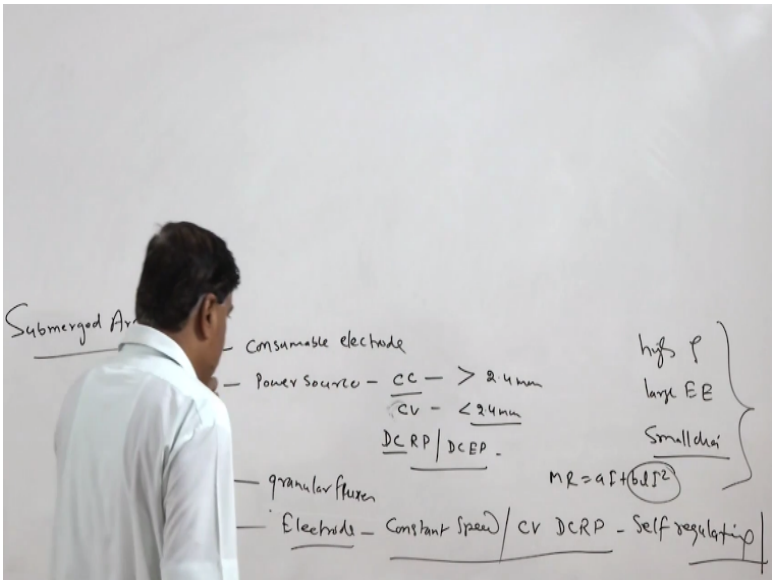

These can be fed at a constantly speed especially when we are using the constant voltage power source with the DC reverse polarity. This is the kind of combination which offers us the self-regulating arc which helps to maintain the arc length by adjusting the welding current, so that melting rate is adjusted under the conditions of the constant feeding of the electrode.

So and this is particularly suitable for the small dia-electrodes, large electrode extension and high electrical resistivity materials. This is the kind of combination where the constant speed, constant voltage, constant feeding arrangement with the constant voltage power sources, DC reverse polarity is used to operate the self-regulating arc especially when the electrical resistivity of the electrode metal is high electrode large electrode extension is used and the small diameter electrode is used.

So, this kind of situation response extremely well for the melting rate as I have explained in the earlier lectures, like the second component dominates in the situation and the melting rate is responds significantly to the melting rate with the change in welding current and which happens in case of the constant voltage power source with the minor change in the welding arc length, significant change in the welding current takes place.

And which in turn helps to maintain the, which in turn changes the welding current significantly and thereby it helps to maintain the arc length.

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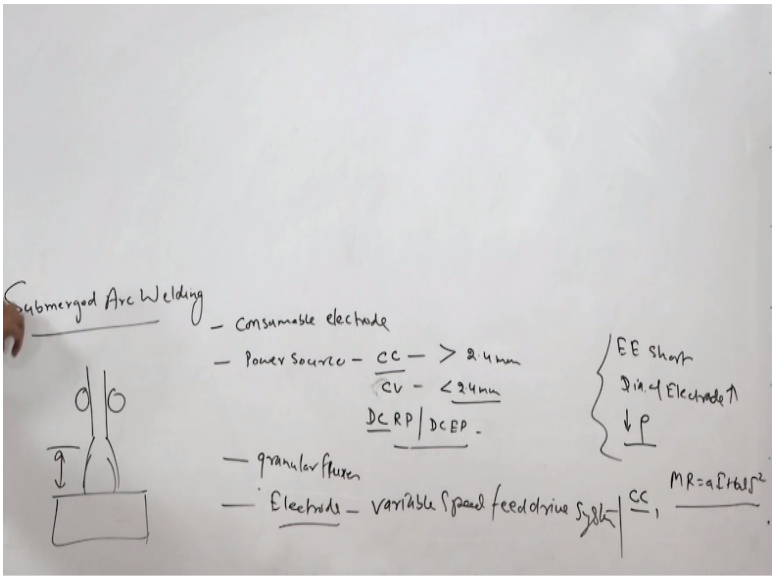

So, this is one type of the electrode feeding kind of system, another one is the variable speed feed drive system where electrode is faded the varying speed as per the requirement. This is particularly done for achieving the electrode constant electrode arc length and so in this case what is done basically this is used to find the constant current type of the power source is used and here you can see the electrode extension is short, the diameter of the electrode is large and the electrical resistivity is less, the raw electrical resistivity is less.

So, these are the conditions which do not respond to the melting rates significantly with the change in welding current. So, to have the control over the arc length in this situation normally the feed rate of the electrode is adjusted like, see this is the feed rollers and this is work piece, here we have the arc. Due to any reason if arc length changes so the arc voltage is sensed and the sensed arc voltage is used for changing the input to the motor which is operating theses rollers.

If the gap increases, so increase in arc voltage will take place, increase in arc voltage will increase the input power to the motor of the variable speed feed drive system. So, it will increase the speed at which electrode was being fed and in that case your electrode will advance towards the work piece for maintaining the arc length. So, this is what is done in case of the large diameter electrode especially for maintaining the arc length, okay.

So now, we will talk in detail how the, what is the role of the fluxes in the submerged arc welding and how does this process work in and what are the unique features related with this process. This process is known to be of the high current, high deposition rate process.

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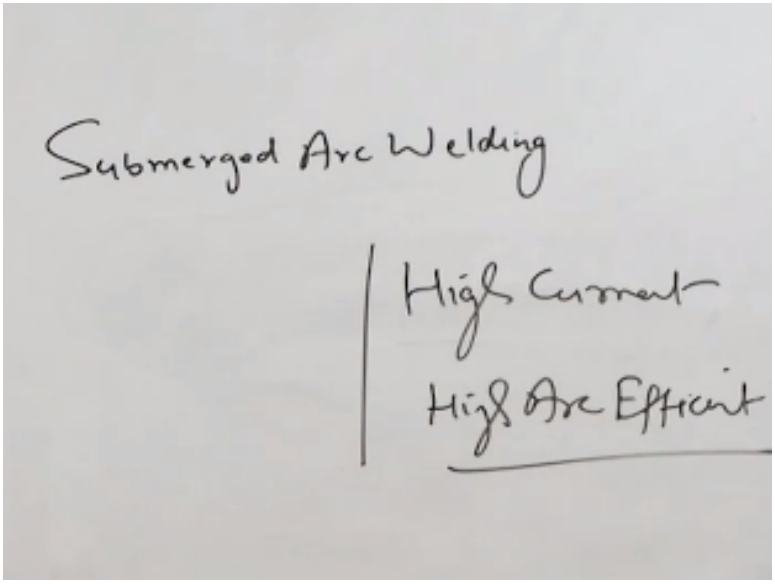

So, high current and high deposition rate process. Because of these two features, this is very popular in industry, in fabrication industry because it offers the high productivity. So this, where from this high productivity comes in that is related primarily with the capability to handle the high current and the high arc efficiency it offers.

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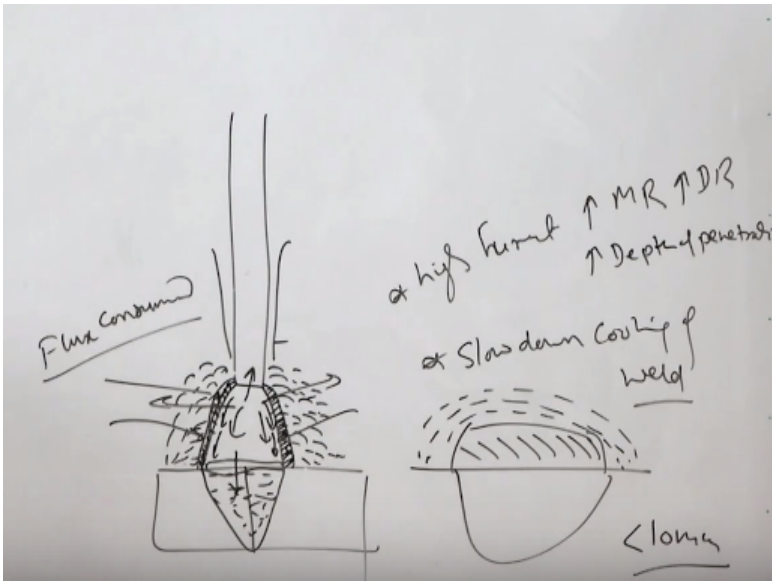

So, whatever the power is fed that is very efficiently and effectively used. So why it is so, in this case the electrode is fed through the rollers using say, then here is arc this is our work piece say, the plates to be welded and here the contact tube will be feeding the current to the electrode and here see all around this one will be a pool of the flux is mount or piling up of the flex is done. So, whole of the arc is actually submerged under the flex.

So that is why this process is called submerged arc welding since this granular flex melts in course of the welding due to the heat of the, so heat of the arc will be melting a thin layer next to the arc and this molten flux will be covering to the arc and protecting to the weld from the atmospheric gases. This molten flux will continuously be flowing down.

So in this process the flux melts and mixes up with the molten metal in the weld where in it reacts with the impurities to form slag. This slag, it starts floating over the surface of the molten metal. So in this process the flux is consumed and here the entire the molten flux layer covers the arc as well as the molten metal there by it protects it from the atmospheric gases. Since most of these fluxes are oxide waste therefore it imports lot of oxygen to the weld.

And therefore submerged arc welded joints normally of or much higher concentration of the oxygen like 0.12, 0.15% of the oxygen, while at present content is not appreciably does not increase appreciably in case of the SAW process. So this is one thing and another one since the weld pool is not exposed in this case to the atmosphere and weld pool is completely covered by the slag, say this is the pool it will be covered by the slags already fed, slag.

And then granular flux which did not melting course of the welding. So these 2 aspects slow down cooling of weld. This is one thing. Another one since the use of current is high, high current is used in this process which increases one melting rate. So it increases deposition rate and it also increases the depth of penetration. So these 3 capabilities make this process very efficient for the welding of thick plates.

And therefore this process is normally not used for the plates less than 10 mm diameter, it is invariably used for welding of thick plates. So here you will see why arc efficiency as I have said it offers and why only thick plates can be, are generally welded using the submerged arc welding process. So to understand the higher arc efficiency what we need to see is that we are supplying the energy inform of the VI.

Voltage means the heat being delivered to the welding arc is VI, V is the arc voltage and I is the current and how much portion of this VI means heat of the arc and the power of arc is being used to see that the part of the heat will be used for melting of the electrode and part of the heat will be used for the melting of the base and whatever heat is there in the heat of the welding arc is there it is very much conserved by this molten layer of the flux.

So heat losses to the atmosphere is very limited and because of this most of the heat being generated in the welding arc is used either for the melting of the electrode or from melting of the base metal, it losses to the atmosphere is very limited and that is why this process of offers the efficiency in the range of 90 to 95 or even higher than the 95%. So this is one reason why it offers very good arc efficiency.

And since the process works with the very high current rating and that is why it offers the higher melting rate, high deposition rate, deeper penetration makes its suitable for welding of the thick plates.

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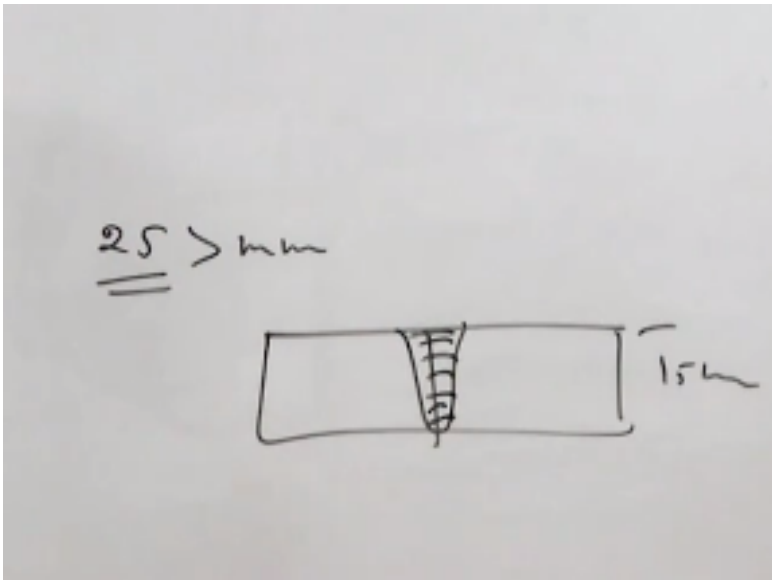

So normally it is applied when the plates of greater than 25 mm thickness to be welded. The plates up to like say the 15 mm thickness can be welded directly in single pause without ash preparation using the square group. So direct in one go the things can be brought to the molten state through thickness penetration can be achieved for the welding purpose.

And if you work with the smaller thickness plates, means thinner plates then it may cause melt and lot of excessive thermal damage related things. So thermal aspects, thermal damage related aspects now I will talk as far as this process is concerned and its limitations also.

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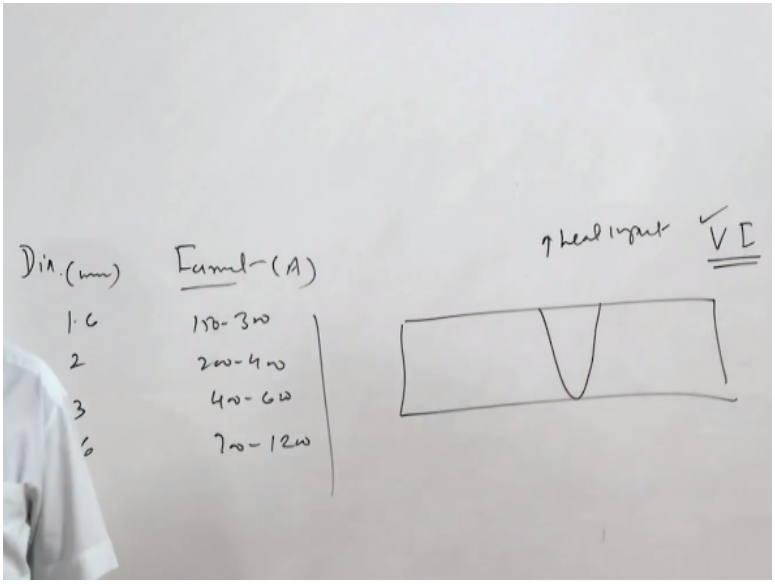

So here we see some direct data about the kind of current which is used in this process like say, diameter of the electrode and the current which is used, the welding current which is normally used in ampere and dia in mm. The diameter of the electrodes for say W process

and for the GMAW process are normally coated in case of the ferrous electrodes, when we say electrodes still they are normally coated with the copper so that the corrosion resistance of the electrode can be improved.

It will not corrode and improve the electrical current carrying capacity of the electrodes. So, see here for the 1.6 mm diameter electrode, the current rating use this 152, 300 for 2 mm, die electrode is 200 to 400 ampere and for say it is a 3 mm electrode it is a 400 to 600 ampere for 6 mm electrode it is 700 to 1200 ampere means with the large diameter, increase in diameter of the electrode is required if the heavier and thicker plates are to be welded.

I will give you very simple example here. If the thick plates are to be welded, thick plates will require much more amount of the heat for the fusion through the thickness or through thickness penetration as well as large amount of the weld material is also to be deposited. So for that for increasing the heat input what we need, we need to generate lot of heat. So heat is not actually generated by increasing the voltage but arc voltage.

But it is simply by increasing the current and to increase the current we have to select the larger diameter electrodes. The large diameter electrodes can handle the heavier current otherwise excessive I square RT heating can damage to the electrode which will soften them and will their loss of their, its stiffness and rigidity can create lot of problems related with the uncontrolled metal transfer and the placement of the metal where it is not desired sector.

So this as far as the welding current is concerned these are the things. In this processes the arc is below the flux so we cannot see where actually the metal is being deposited during the welding. And if that is the case, so it creates the problem sometimes that weld joint is not successfully made and the weld metal is deposited somewhere.

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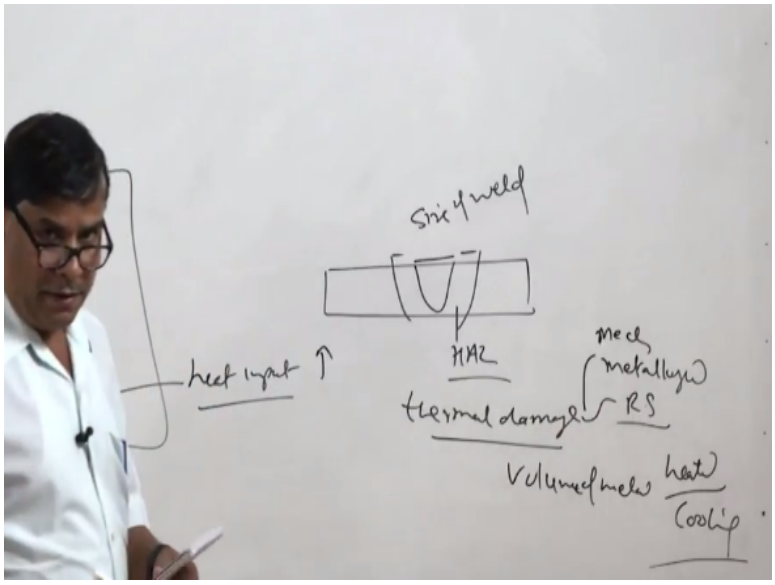

As that is why, if this is the weld line then proper placement of the electrode is done and through the welding tractor the proper guided welding torch is moved along the line of the weld, so the metal is deposited at the place wherever it is desired. So this is one major drawback where we are actually not sure of where metal is being placed. So we need to ensure first the positioning of the torch and the electrode.

So that the proper weld along the suitable line can be ensured. So this is one thing and another, the heat input is very high. Heat input used in the welding process is very high. So high heat input causes a lot of damage to the work piece. Say this is the weld, so due to the high heat input size of the weld is large, heat effected joint is also large and so related thermal damages to the work piece are also large.

So larger size of the XZ means more deterioration in the performance, more deterioration in properties, mechanical and metallurgical properties of the heat effected joint due to the greater thermal damage are bound to be there during the high heat input is used. So this is one aspect and another is larger size of the weld and larger heat effected joint increases the volume of the metal which is volume of metal which is heated which is subjected to the heating followed by cooling.

So heating and cooling will be causing the expansion and contraction and which in turn subsequent at the end of the welding will be developing the lot of residual stresses. So thermal damage in terms of the mechanical metallurgical properties it also causes the problems related to the residual stress. Residual stress is obviously they are tensile in nature

in the weld joint which in turn lowers the load carrying current capacity of the weld especially in terms of the fatigue and the tensile loads.

So it is not considered to be good further presence of the resoluteness also promote the distortion tendency wherein the plates being welded using high heat input can go out of the shape and out of the geometry which is not expected so that will require further post treatments to bid the things back in its position.

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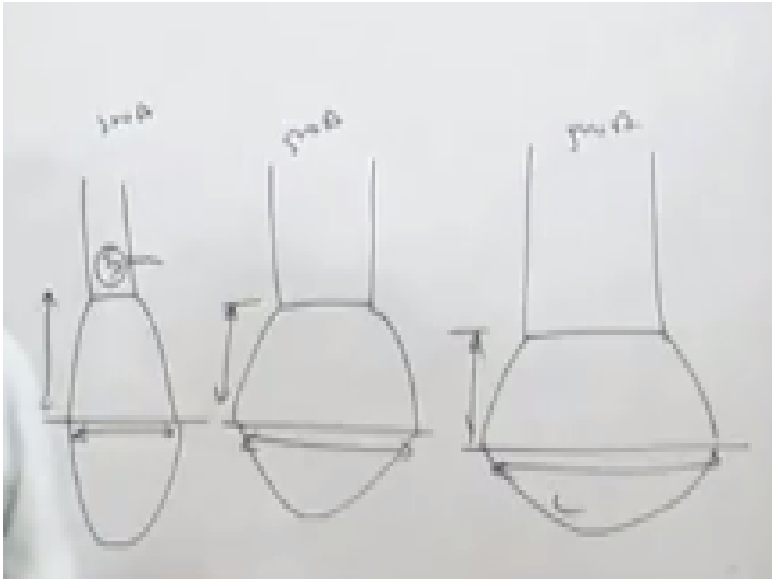

Now, I will talk about little bit the bead geometry aspects like for a given current, for example, 100 ampere current being used using these 3 different electrodes say one 2.3 electrodes we are using say 3 mm size, 4 mm size and 5 mm size electrode. So the size of the arc like this, like this and like this.

So now you see the weld width here is this much in one case of the 3mm size electrode each of the 500 ampere, 500 ampere, 500 ampere welding current is supplied in all these 3 cases. But with the increase in the diameter of the electrode the width of the weld increases. So the things are simple, our power density is getting reduced for a given heat generation. Arc length is same, arc voltage is same and the current is same.

So the reduced power density, increased width will be causing more penetration in this case, somewhat lower penetration in this case and further lower penetration in this case. So basically for a given value of current with the diameter is increased the power density decreases and the heat is spread and distributed over the larger area and that in turn affects the

penetration, we get much deeper penetration for the final diameter electrodes as compared to the large size electrodes.

So, it means for a given welding conditions change in geometry of the electrode can also effect the change in the size of the electrode can also effect the geometry of the weld or the depth of the penetration of the weld.

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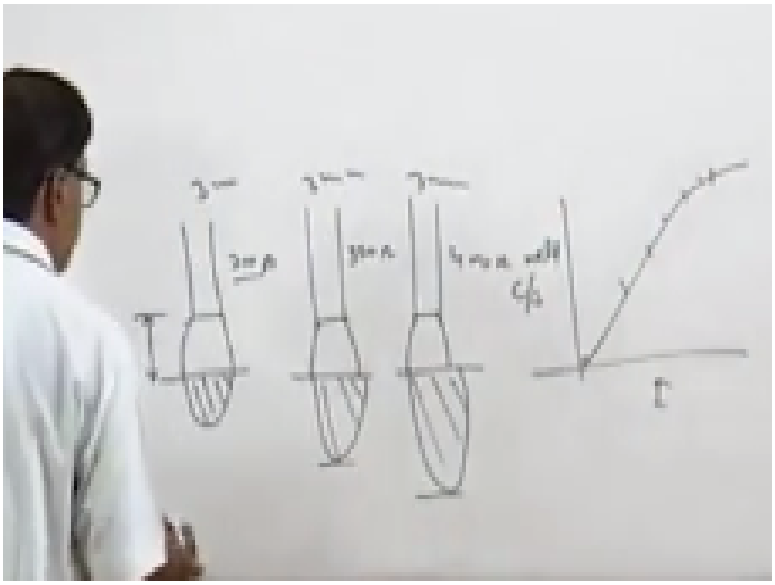

And the same thing we can say otherwise for example, if the diameter is same and the current value is increased under the identical conditions what we will get that is what we can see arc length is same, diameter is same say 3 mm in all three cases, arc length is same in all 3 cases. So, changing the current say from 200, 500 sorry, 200, 300 and 400 amperes.

So increasing current will simply increase the arc voltage is fixed IE is being increased so our heat generation is being increased under the identical conditions of their speed less heat will be generated in this case, more heat will be generated in this case and further more amount of the heat will be generated in this case. So this will simply increase the area of the weld linearly and depth of the weld also increases under the identical conditions.

So, if we just try to plot here the welding current and the weld cross sectional area then this relationship initially is found to be like this only where increasing current directly increases the cross sectional area of the weld due to the increase in heat input, increasing the volume of the base metal which is being melted and that internal increase the volume of the weld.

But it starts getting saturated after reaching certain limits, it is always good to select the proper combination of the welding current, welding speed, voltage, electrode so the selection of this parameters, appropriate selection will help us in achieving the proper weld geometry. So, now I will conclude this presentation. In this presentation I have talked about the fundamentals related to the submerged arc welding.

What is the role of the fluxes and what are the how the electrode, the welding current and other parameters effects the weld geometry and the soundness of the weld joint and things which are actually important for the performance of the weld joint being made by the submerged arc welding process? In the next presentation, I will talk about the electro-slag welding and the electro gas welding process. Thank you for your attention.