**Welding Metallurgy**
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**Lecture – 24**
# Effect of Welding Parameters

Welcome to the lecture on effect of welding parameters. So we discussed about the heat flow during the welding we talked about the different equations which represent the heat flow equations and also about the temperature distributions in the welding you know zone that is where the molten metal is there and then heat is dissipated from that zone towards the parent metal site.

So then we will talk about the effect of different welding parameters like you have the pool shape, the velocity of welding and all that. So in this lecture we are going to have the discussion about those issues.

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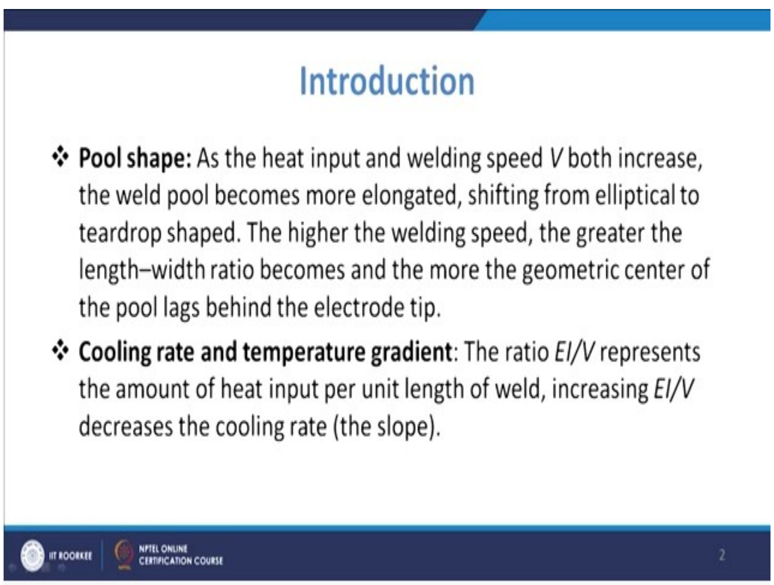


So now coming to the you know effect of the pool shape so as the heat input and welding speed V both increase the weld pool becomes more elongated shifting from elliptical to teardrop shaped. So basically as you increase that heat input and welding speed both in that case initially when your V is less and heat input is also less, then the pool is basically in the in the form of elliptical.

And then so because you are moving in one direction so you will have elliptical type of pool but as you increase so as the speed is increased then the length width ratio becomes you know more and more the geometric centre of the pool lags behind the electrode tip. So we can see that you know when if there has been work carried on and as you increase this velocity suppose the GTAW of stainless steel 304 was carried out.

And the you know the velocity was increased and also other parameters. So how you know the pool shape looks like.

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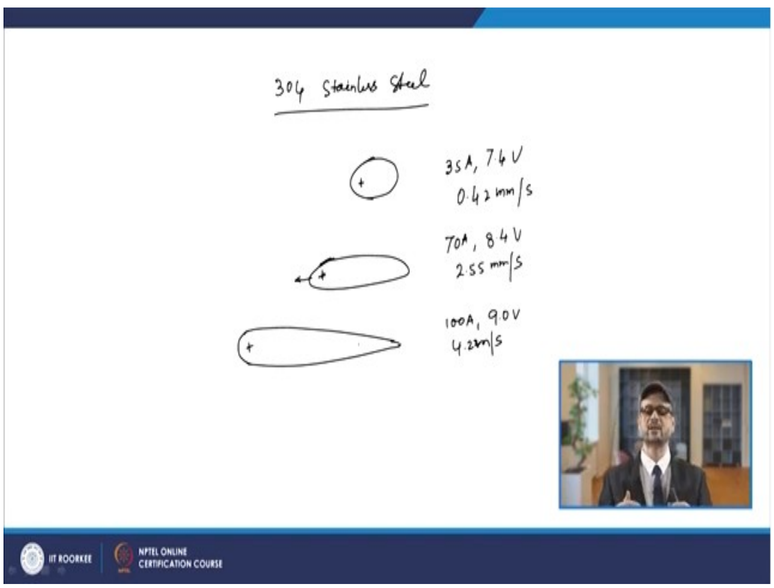


Like when your so you have the 304 stainless steel welding and this was done using the GTAW. So what was seen that when you know so when your you know the parameters are liked it is done at 35 Å current 7.4 you know voltage and the velocity is taken as 0.42 mm per second.

So at that point of time your weld pool shape was going like this so this is the tip of the electrode so and if you know you increase so as we discussed that here we are increasing the Q also by like the heat input and that will depend upon the you know current and the voltage. So if you increase this to 70 Å and the voltage is increased to 8.4 volts suppose and also the velocity is increased velocity is increased to 2.55 mm per second.

So in that case your pool will change and this pool will be now looking as if it will go like this so it will be your pool will be appearing like this. So in this case so this is your in this direction you are doing the welding so the pool earlier it was elliptical and now it is elongated and if you further increase the current to 100 Å and if it is you know the voltage is to 9 volt and the velocity is further increased to 4.2 meter per second.

So it is the work by molten that is reported. So then in that case your you know pool becomes it goes like this so the pool will become in the shape of the teardrop so visibly it can be seen that as you increase the heat input and also if the velocity is increased in that case your you know pool shape becomes changed. So it is changed from the elliptic to the teardrop type of case shape and that will be you know normally so you are moving you know you are doing the welding in this direction.

Now if you do for the stainless steel and if you do for the you know aluminium then also you can have a visible you know you can visibly more visibly see in the case of stainless steel because aluminium is more conductive so even for the there has been a certain you know observation and it has been seen you know with a particular you know heat input and also the velocity especially at larger velocity to us seen that your pool sharp pool was seen sharp pool end was seen in the case of stainless steel.

So it is because of the you know larger velocity which is there in the case of you know this you know that basically the larger velocity will give you such kind of the pool shape. Now if you know there is another curve which will talk about the variation of the cooling rates and that can be seen so that is another you know effect which is to be understood by us. So that is the cooling rate and the temperature gradient.

So this is another you know parameter which is important one where the we have to understand that the ratio EI/V it represents the amount of heat input per unit length of weld so and we have if you increase the EI/V that will decrease the cooling rate. So that means the slope basically changes so that can be seen by you know by looking at again the another kind of curve.

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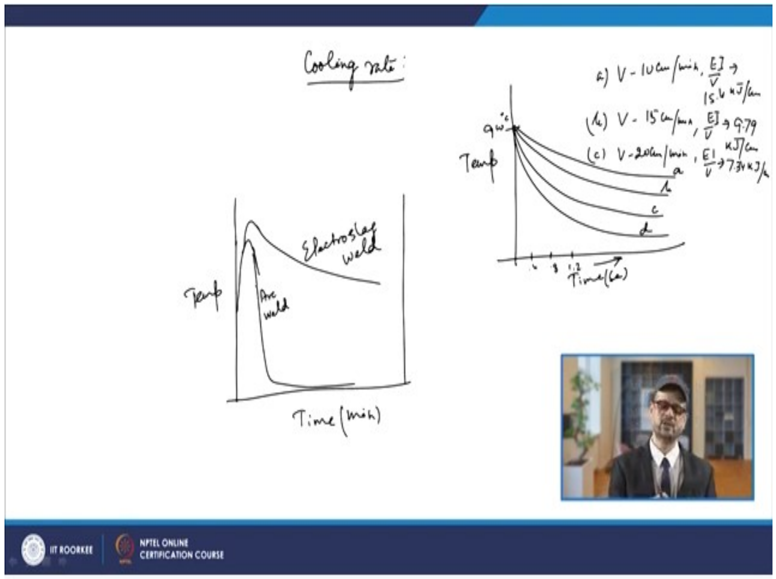


So if you go for the you know effect of cooling rate so the cooling rate as we discussed that you have the you know once the liquid metal is you know is there and it is dissipating the heat towards the all the sides. So depending upon how it is dissipating the heat you will have the presence of the cooling rate you will have the setup of cooling rate depending upon the change in temperature what you observe at different positions from that point.

So if you do the cooling rate for if you have if you are having you know the different velocity and you have different value of the EI/V. So based on that you will have you know the temperature you know distribution so that can be found out. So if again we will see that how it varies so for the you know aluminium it was done. So there is you know work by Li.

So that tells that when if you take the temperature in the ordinate axis and C side if you have the time. So you know if you plot so you have plots coming like you know this one you will have one plot this one you will another plot so this way the plot you know goes. So you will have you know a, b, c and d like that the plot varies. Here you will have the you know temperatures it is some somewhere close to 900 $^0$C.

And this is the time so time is in in terms of second and second is 0.4, 0.8 then 1.2 like that it moves in this fashion. Now this a, a was corresponding to the V of 10 cm/min and EI/V this was you know 15.4 kJ/cm. So this is the value of the EI/V for the a curve and if you go for b, b is corresponding to V of so 15 cm/min and EI/V value for that is 9.79 kJ/cm.

Similarly, c has V of 20 cm/min and the EI/V is having a 7.34 kJ/cm. So that way you know now as you see this value will be changing. Now what we see here it can be seen so that is the seen that your if you increase the EI/V it will be decreasing the cooling rate. So you know EI/V value increasing. Now what you see from this curve the temperature is decreasing with time.

But in this case your temperature time you know the difference of temperature with time will be more in case of d as compared to a. It means that if you increase if you increase the EI/V value that is in this side so if you are moving if you are increasing this EI/V value so towards a, your temperature difference is less and once your temperature difference is less it means your cooling rate will be less.

So cooling rate will be more in case of curve a as compared to curve you know b and then b is less as compared to so go to c. So c has more cooling rate c experiences more cooling rate then you know b and b more as compared to a so like that. So that way it can be seen that as you increase this EI/V value. So increase you know so that way your decrease of the cooling rate is observed in such cases.

Now this has also been seen for the different you know welding processes and for different welding process the curve was drawn again and if you compare so you can have the comparison for the different welding process like you have the arc welding or you have the electroslag welding. Now in the case of arc welding that EI/V value and you know they are Q/V value and in case of you know the electroslag welding Q/V value will be different.

So what was seen that in the case of the comparative study between the you know time and temperature, temperature and time for the two welding process so for the arc welding what was the it was seen that it was coming like this. So this was going like that so this is for the arc weld and if you look at the electroslag weld. So for electroslag weld it goes and then it will be moving like this. So this is for the electroslag weld.

Now you know if you see in this arc weld your temperature will is coming down very quickly you know and here the temperature basically is very, very you know it goes somewhat higher and then it comes very slowly in this fashion. So the cooling rate in the case of arc weld is quite high because the slope is quite high in this case of arc weld as compared to electroslag welding as you also understand that in the case of electroslag welding the heat input that is Q/V basically Q/V value, Q/V value is very high in this case.

And because the Q/V value is very high in this case so your cooling rate is very small in such cases in the case of the electroslag welding. So now the thing is that you know you have the effect of the heat input then also you can have the variation of the cooling rate by the action of preheat. So you know welding speed preheat you know all these have the effect on the cooling rate.

So many a times we do the preheating and then because once you preheat the cooling rate will decrease. So that is you know another way you know to have the different kind of structure because ultimately these you know so these lines these temperature and time histories they are basically instrumental in predicting the properties of the material because we will study about it that they are useful for knowing that what kind of transformation will be you know going further.

And what type of transformational products will be formed. So that can be you know understood by these processes.

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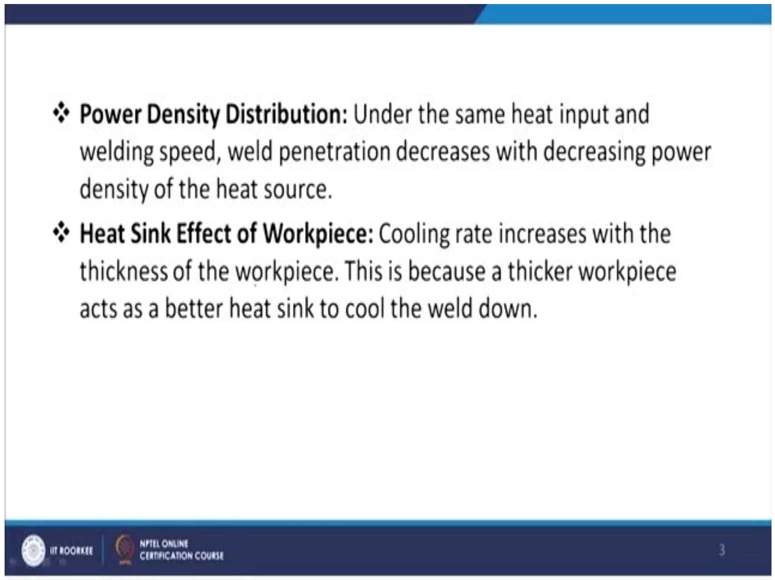


The next you know parameter which is important is the power density distribution. So power density distribution you know you have the you know power density distribution of heat source as an important parameter and you know so under the same heat input and welding speed the weld penetration will decrease with decreasing power density of the heat source. So you have different type of heat sources and you have the different power densities. So that can be understood you know by the you know by the figures.

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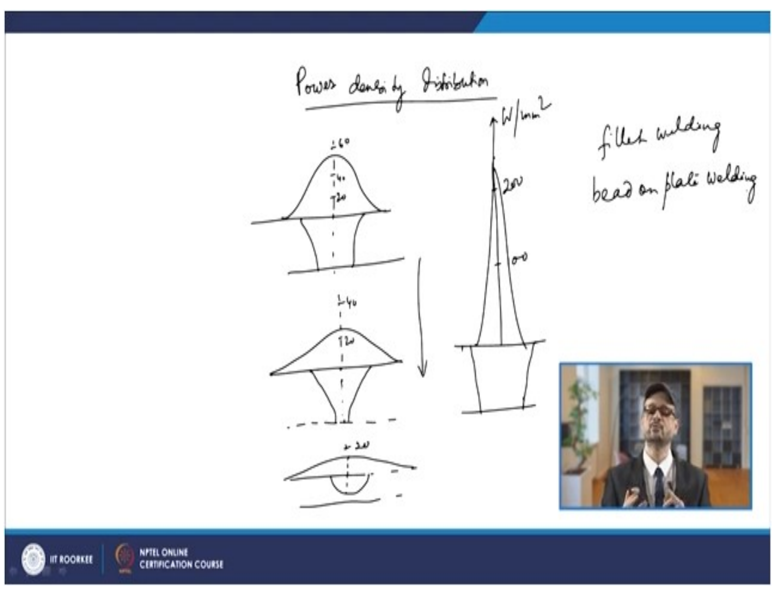


So you will have the you know the effect of the power density distribution. Now you can understand that if you have the different power density distribution you will have the you know different weld shape. So if your power density distribution that can be you know you have the

Gaussian type of we take that Gaussian shape so you know if you take that power density distribution as the Gaussian one.

So what we see? that if this is like 20 then you have 40 and 60 $W/m^2$ that is the power density. Now for such cases if you take the weld shape so weld shape go like this. Now if you change the power density so if the power density distribution is changed to this size suppose it is goes like this where this is your 20 and this is 40 so it is changed now. Now if the power density distribution is you know changed.

Then that will lead to the pool shape and it will go like from here it will come and then it is the power density so the pool shape will go like this. Now if there is further the change in the power density distribution and it comes of shape the shape say further less so it is coming like this. So this is 20 $W/m^2$ in that case your weld pool becomes like this. So what we see that there is a visible change in the case of the weld pool shape you know or the penetration in the case of the change in the power density distribution.

So the weld penetration will be decreasing so as you are decreasing the power density in this direction you are decreasing the power density so the weld penetration is basically here the penetration is quite high. So if the penetration suppose if you are taking the penetration and the power density very, very high say if the power density is going like this and this is you know 200 and this is 100 so that is your you know W/m you know $mm^2$.

So this is your density of the power you know the power density the distribution that is in terms of $W/mm^2$. So in this case what we see that you have if this is from here this is 4 mm so your you know your pool shape goes like this so it will be you know its penetration will be quite high. It will be quite large penetration it will be providing when your power density you know density distribution is quite high.

So the thing is that it also depends you know under the you know same heat input and also the you know same plate thickness. If you have two you know you have two types of welding you have the fillet welding and if you have say the bead on plate welding. So if you have two types of you know wielding carried on. In that case your the cooling time is shorter for the you know fillet welding so that is for that is the effect of basically the you know heat sink.

So what we have understood for this case what we have seen the effect of the power density should be one of the heat source. Now the next you know parameter which we are going to discuss will be the heat sink effect of the workpiece and in that basically the cooling rate will increase. So cooling rate increases with the thickness of the workpiece and it is because a thicker workpiece acts as a better heat sink to cool the weld down.

So next parameter which is there is the heatsink effect of the workpiece and as we see that the workpiece basically works as a heat sink so because the heat which is generated that is being taken away you know by the workpiece itself. So now in this case as you increase the thickness of the workpiece. So you know it will be acting as a better heat sink to cool the weld down. So that way you know so we are having the example of the fillet welding as on and also the bead on plate welding.

So if you take the you know two cases and if you have the same heat input and for the same thickness. So the cooling time will be shorter for the fillet welding you know so and as compared to the bead on plate welding because of the greater heat sink in this case in the fillet welding. So that is the difference of the you know the heat sink you know different type of that you know heat sink effect of the workpiece.

Now so what we discussed in this case you know we discussed about the varying parameters and in that we talked about the pool shape we talked about you know the cooling rate and the temperature gradient. So again that temperature gradient and cooling rate that can be seen from one curve and from there as we see you know so far different you know EI/V value, how the cooling rate can be found and then its effect can further be predicted that we will see later.

Then we talked about the power density distribution, now in the case of you know power density distribution as we see the power density distribution will be governed by certain you know physical parameters like if you look at you know the if you see the electrode tip angle so basically it has been seen for the you know gas tungsten arc welding.

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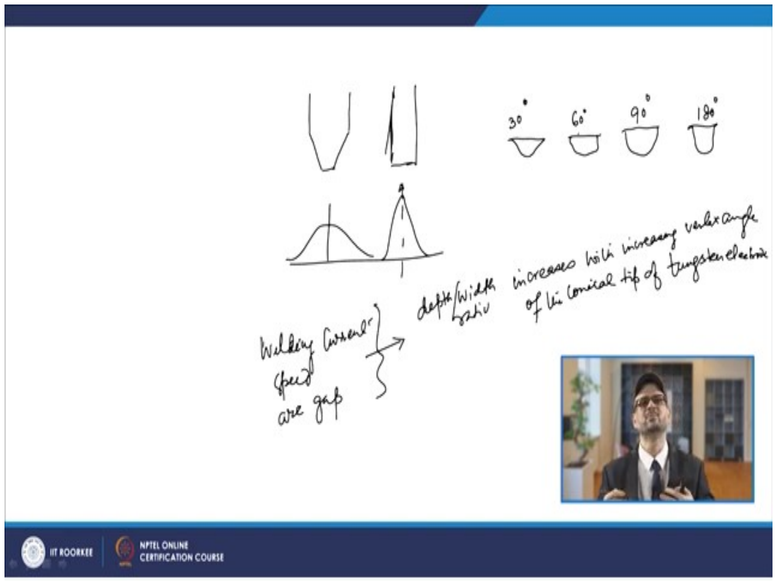


When it was seen that your tip angle is you know smaller and if you make this tip angle blunt so you may have the you know the tip angle so in this case it is blunt and in this case it is made you know taper. So in this case what we see is that your power density distribution now in this case your power density so if you look at the power density distribution in this case so if you draw the power density distribution you will be following like this.

In this case whereas in such case the power density distribution moves like this. So the power density distribution basically it will be depending upon the tool tip size tool tip shape also because that will be you know for the shape your power density distribution will be varying. Similarly, this will be also depending upon the vertex angle of the conical tip of the you know tungsten electrode.

So if you change the vertex angle also of the conical tip of tungsten electrode then as per the observation by the key so if your vertex angle is say $30^0$ in this case. So you know in that case the shape of the gas tungsten arc welder will be like this and if it is $60^0$ so in that case your shape will be going like this then further if you have $90^0$ and the shape comes like this and if it is $180^0$ then the you know shape of the gas tungsten arc weld will be moving like this.

So basically you know it has also the similar effect you know in the case of you know if you look at this this will be the effect of the electrode tip geometry that is on the shape of the you know gas tungsten arc welds so that is how you know it looks. So these are you know this way this power density distribution you know is very important parameter also in the case of welding. Now you have also there are different methods also to measure this power density distribution.

And there has been methods like split-anode method which has been you know said and you know for simplicity we take this power density distribution to be of the Gaussian shape in normal circumstances. So this was basically this observation was made by one of the researcher that is Savage and he has found that if you keep the welding current and you know the speed and arc gap if you are keeping these parameters as the constant.

So he found that the depth/width ratio so this is what we see in this case. This is the depth/width ratio, so depth/width ratio he found this is increasing so this increases with increasing vertex angle you know so that is of the conical tip of the tungsten electrode. So just two we discussed about this because you should have we should have the idea about how this power distribution varies.

And basically how your you know how your tip geometry basically will be affecting you know the arc you know arc welds. So as we see that if you are increasing the vertex angle in that case if you increase then the depth to width ratio that will be increasing. So in this case the depth is increasing as the vertex angle is increased and it has also been you know reported by another researcher that was Kee.

So he has also seen for the you know with arc shielding he has observed the similar phenomena. So in a nutshell you know we talked about today about the different welding parameters and you know how they affect the you know the output parameters like how there will be change in the cooling rate or how there will be change in the pool shape and how that will be affecting you know ultimately the welding processes.

So that is what ultimately our aim was and we will more talk about you know the you know the other aspects of the heat flow and it is you know related you know consequences in our coming lectures. Thank you very much.