Marine Construction and Welding
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Module No. # 01
Lecture No. # 31
Gas Tungsten Arc Welding

Today, we start with Gas Tungsten Arc Welding. We have been continuing with different methods of welding. Obviously, you will be highlighting only the welding techniques which are suitable or applicable in the so-called Marine construction field. There are various types of welding methods. Naturally, we will not go in details of all those methods; we will only look into those which are suitable for our purpose.

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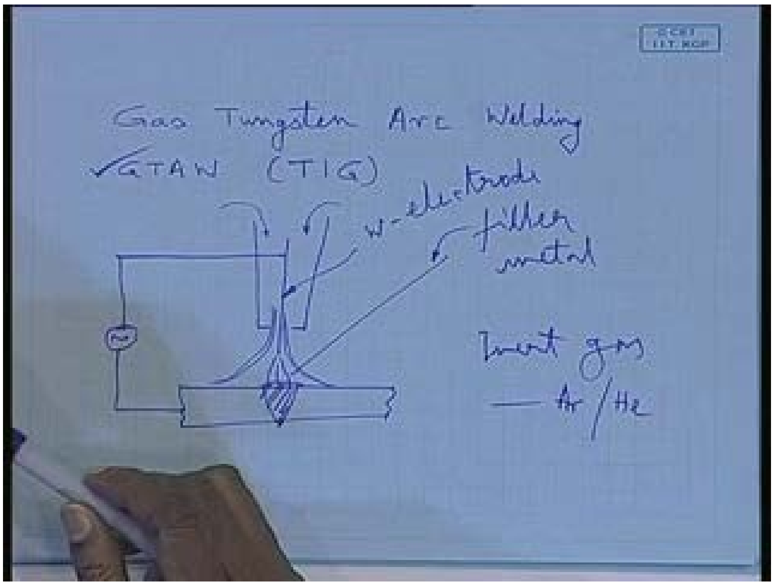

So, today, we will look into Gas Tungsten Arc Welding which is also referred to as GTAW in short and popularly also, at times, it is referred to TIG Tungsten arc welding. This GTAW is more universally accepted abbreviation; however, TIG is also used. So, as you can see the name Gas Tungsten Arc Welding, here, you have the welding torch; essentially, schematically it is somewhat like this; that means you have a Tungsten electrode and the job which is being welded. So, the arc is struck between the Tungsten electrode and a separate filler metal is put; that means a filler electrode is put.

So, you have the power supply to the job and the Tungsten electrode. This is your non-consumable Tungsten electrode (Refer Slide Time: 02:07). Obviously, it is the difference between the other welding processes which we have seen. The difference is that here the electrode is a non-consumable one - the Tungsten; that means it continues. So, the arc is struck between the electrode and the job. In that heat, it fuses the metal as well as the filler metal which is put to do the to get the proper fusion and the metal deposition.

So and the shielding is done by means of by injecting inert gas such that you have this (Refer Slide Time: 02:06); that is how it protects. There is an inert gas is put, and generally, in this case, inert gases used are well Argon or Helium, or it can be the mixture of them; generally, Argon or Helium, or a mixture of them like we have seen in gas metal arc welding. There even CO 2 is used, carbon dioxide, but here it is purely… I mean not that active gas like CO 2, but Argon and Helium.

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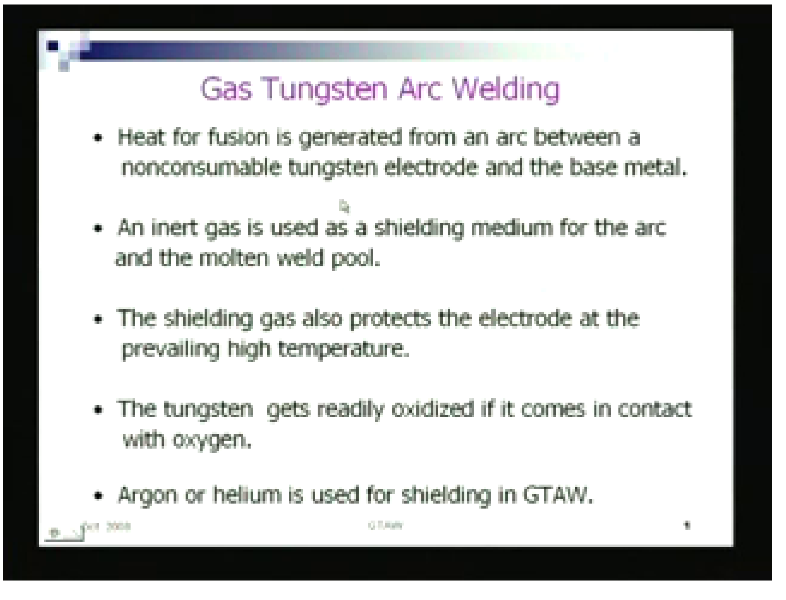

So, what do we see in this gas Tungsten arc is that, here, the heat for fusion as we have already talked about, fusion is generated from an arc between the non-consumable Tungsten electrode and the base metal.

See, it is a non-consumable electrode. Till now, we have seen the electrode itself is consumed; that means, the electrode itself acts as the filler metal, but here electrode is not a filler metal. It is somewhat similar to, analogous to gas welding as if in gas welding what we have a heating torch, wherein by burning the gas, you get the heat. Here, having the similar kind, I mean torch where it has a Tungsten electrode and the arc is struck between the electrode and the job. In that arc, there is the heat that is somewhat equivalent to gas flame as if that melts the metal and as well as the filler metal and welding is done.

Though it is referred to as non-consumable electrode, but in true sense, it does not mean there is a slow consumption of Tungsten takes place. Obviously, ideally it should be 0; that means why Tungsten electrode? Because that withstands the temperature, because Tungsten's melting point is around 3 and half 1000 degree centigrade, 3500 approximately.

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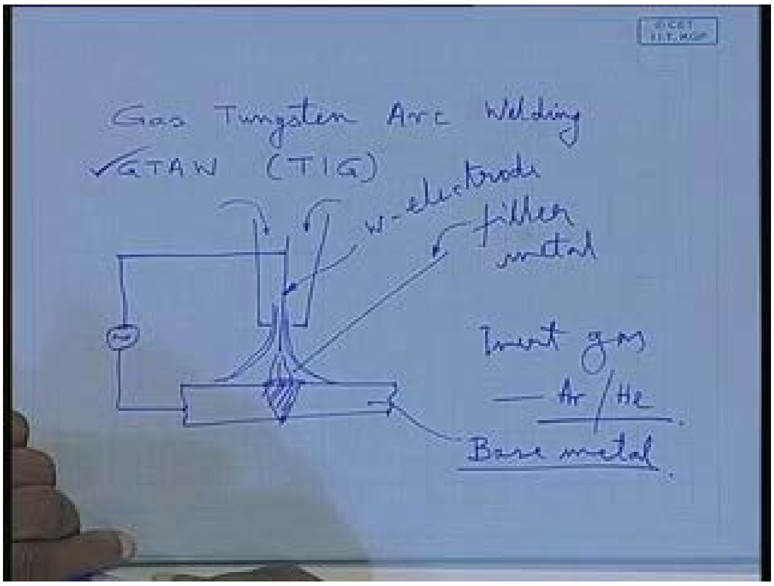

So, you control the heat such that it does not attain that temperature, but still there is a small… always a consumption of transition takes place, and thereby, after certain hours of usage, you may have to change the electrode. But obviously, that is not a good sign from the point of view Tungsten getting consumed. And secondly, if it is getting consumed means where it is going?

It is essentially going into the weld metal and that is also not good for the weld metal. That will be some kind of inclusion, foreign body inclusion taking place in the weld deposit. So, that is also not good; that means, the process should be such that Tungsten consumption, in fact, should not happen. How that can be restricted? By restricting the heat being generated; that means undue high temperature; the Tungsten electrode should not attain a undue high temperature. So, in fact, this welding torch also has a circulating water, I mean cooling mechanism by circulating water through it such that the Tungsten electrode is always kept in a… I mean the heat is taken out; whatever heat that through the conduction heat is going into it is taken out; that is one aspect. And then, we will see the polarity; whether we keep it positive or negative, that also you know, the heat generation changes.

Sir, do we have filler metal?

The filler metal obviously will be, will be of course, whatever base metal is being welded, depending on that, the filler metal will be the composition of the… Suppose, they are welding steel, a certain type of steel; so, filler metal also will have similar composition.

Sir, is it an autonomous supply?

No.No.No.No. yeah, here it is again a process which is essentially a manual process. Manual process means you go on feeding the filler metal in one hand; in another hand, you have the torch. So, it is a slow process. It is not a very fast high deposition process. It is not a high deposition process. It is something like the shielded metal arc welding wherein you are giving the filler metal in a manual process; all manual metal arc welding in a manual process.

Difference here is there the electrode itself was getting consumed, getting melted and deposited here. That electrode is held separately and also difference is the well the shielding is being done by an inert gas. So, the primary advantage in this is that, this method can be used for very precision welding. This method can be used where you need to deposit very small amount. That means fine thinner gauge material. The sheet material if you will have to weld, there this gas Tungsten arc welding works very well because here you can use literally much lower level of current; so, less heat is generated.

So, thereby, the control on the deposit is much more; much more precise control can be achieved and also with this method, since you are using only inert gas like Argon or Helium. So, it can be used for welding of several other ferrous and both non-ferrous materials also.

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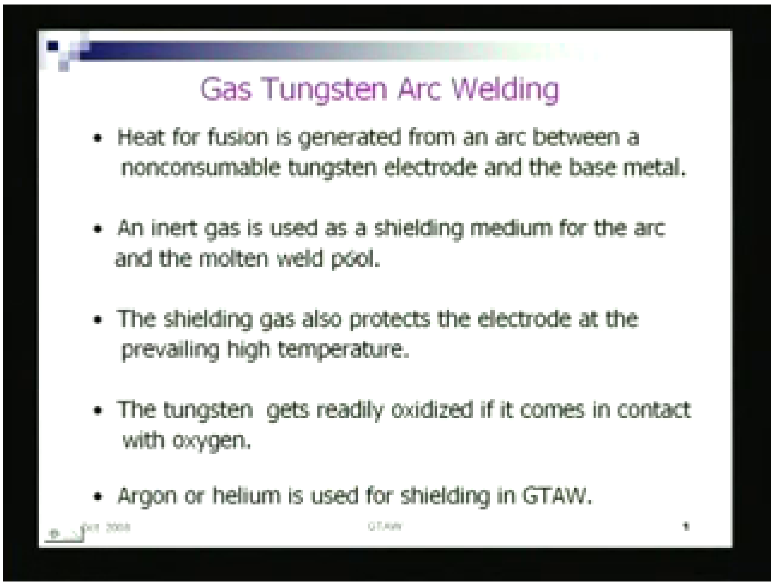

Anyway, so, here, what we see the inert gas is used for shielding the as a shielding medium for both the arc as well as the molten pool and that shielding gas also prevents the electrode from getting exposed to the atmospheric oxygen because Tungsten electrode also gets oxidized very readily at that high temperature, if it comes in contact with oxygen.

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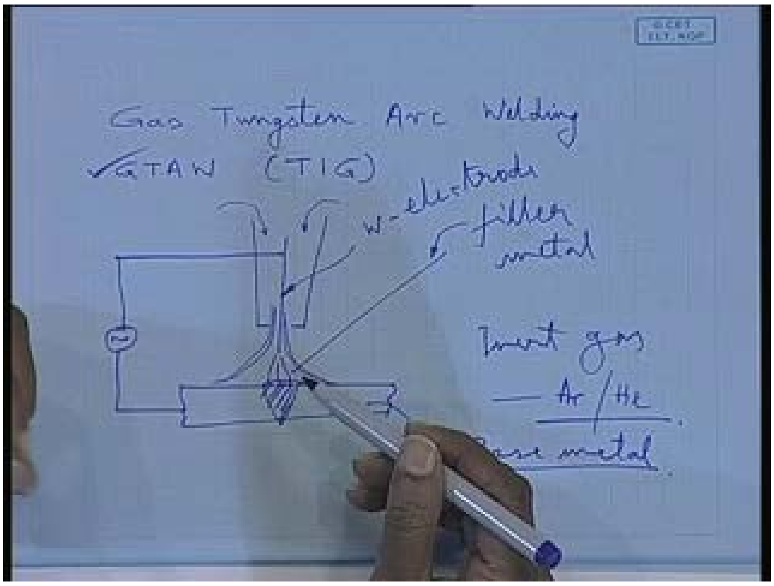

So, the welding nozzle is designed in such a fashion that the flow of inert gas should be such that it will provide a proper shield to the…because here (Refer Slide Time: 09:23), you see the metal transfer is not from the electrode; it is from the filler metal. But also you will have to shield - the electrode, Tungsten electrode because otherwise the Tungsten electrode will get oxidized.

So, here, we see the shielding gas also protects the electrode at the prevailing high temperature; otherwise it will get oxidized. All Argon or Helium is used as the primary shielding medium.

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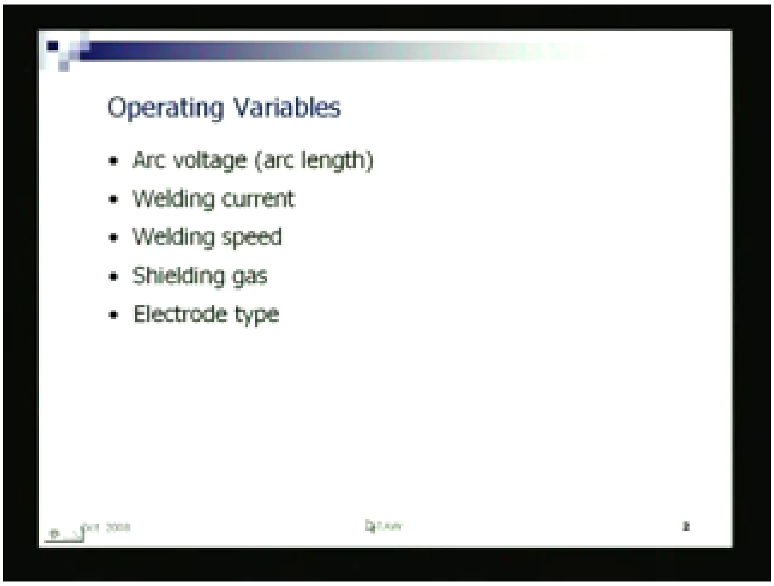

So, what are the operating variables? Operating variables, as you can see there, the arc voltage, welding current, welding speed; welding speed means speed of movement of the torch; not speed of feeding of the filler movement of the torch; that is the welding speed. Then, obviously, shielding gas: Because depending on the type of shielding gas, your heat generation or the property of the plasma changes, the arc plasma. Then, obviously, the electrode type means the Tungsten electrode type; what type of Tungsten electrode?

Here, the direction of welding does not make much difference because here what is happening is by changing the direction of welding, the fusion pattern, we have seen that, that changes; either it has a wider fusion on the top or a narrower fusion; means wider bead profile or narrower bead profile. Little bit of variation in the depth of penetration also could be achieved, but here, that is not very important because the filler metal is separately fed. It just gets melted and gets deposited there. And that means orientation of the electrode does not make much difference. Of course, here, one aspect I have not written, that is the polarity of the electrode; polarity of the electrode is also important.

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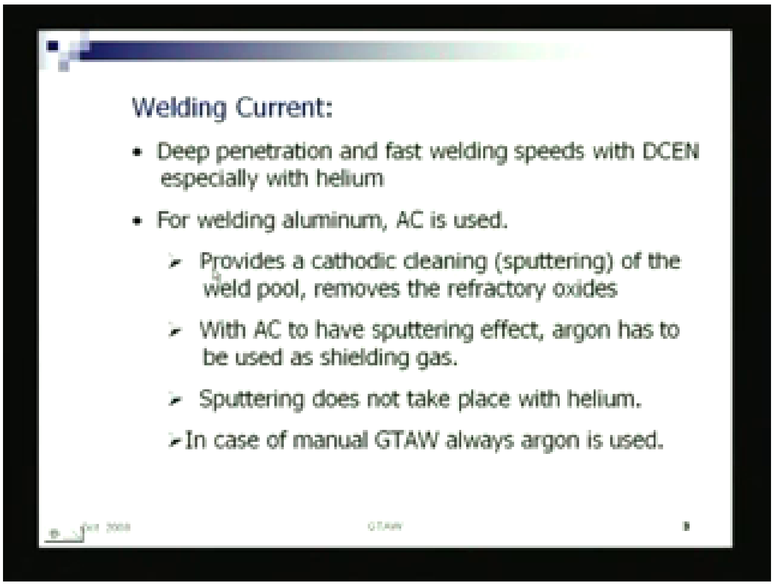

Well, the welding current: This is obviously, in in all welding processes, primarily the welding current is one of the most important parameter because of the simple reason that, that generates the heat; that is the prime mover for the heat generation.

So, deep penetration and fast welding speeds with Direct Current Electrode Negative especially with Helium as the shielding gas: That means, if one wants to achieve a deeper penetration that means comparatively thicker material. When welding is done for thicker material, it is always preferable that Direct Current Electrode Negative is used generally for thicker material.

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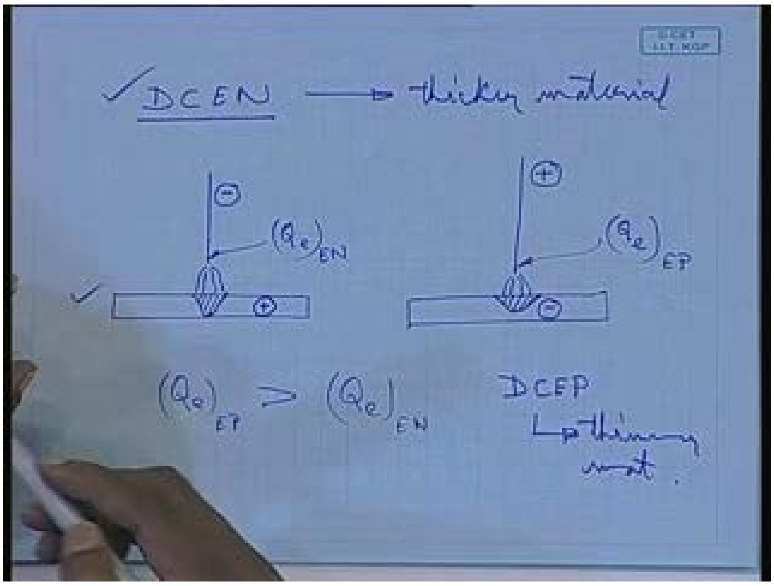

What we will see is that DCEN is the preferred mode of power supply, for the simple reason, in this mode, electrode does not get heated up; overheating of electrode does not take place; whereas, DCENEP - overheating of electrode will take place. Why? What happens is, suppose if we see schematically, this is one situation; this is the, say, other situation here (Refer Slide Time: 13:17) I am keeping the electrode negative and the job positive, just the reverse. All other parameters remaining constant, what we will find? The heat generation in the electrode will be more; that means, if I write it as Q electrode and heat here, electrode negative electrode positive. So, we will always see that Q electrode positive will be higher than Q electrode negative.

If the electrode is connected to the negative pole, negative terminal; that means if we have a direct current power supply which generally is used for welding, we have seen that direct current power supply is preferable to alternating current, for the simple reason you have a continuous flow of current. That means it is not in alternative current. What happens? You have a positive cycle, you have a negative cycle; in between there is a 0. So, in real sense, the arc gets extinguished. So, there is a continuous variation of heat and continuous variation of heat means variation of metal deposition.

So, that is how direct current power sources are more preferable. So, if here is direct current, then you have two options, that you can either make the electrode negative or you can make the electrode positive. Also, it has been observed that, if you have electrode negative, then more heat is generated in the plate, in the job which is being welded; if it is reversed, then more heat is generated in the electrode. So, even there can be a difference in the fusion I think we have talked about it in our previous classes. So, in fusion pattern, the depth of penetration also will be different because here less heat is generated.

Why this happens because the bombardment of the electrons, the flow of current; in this case the flow of electron is from the negative terminal to the positive terminal. So, as if the electrons, they come and hit the plate, so there is a more heat generated. Here, the opposite thing is happening (Refer Slide Time: 15:57). Electrode electrons are heating the tip of the electrode; so, more heat is generated. So, that is how, as you can see, with DCEN, you have more penetration in the plate. So, thicker material, but if you are welding a thinner gauge material, then it is preferred DCEP; DCEP for thinner gauge because otherwise it may melt through thinner material. And also for deep penetration, means if you use Helium, that generates more heat because it is because with Helium, you will have more concentrated heat in the plasma column; that leads to even deeper penetration compared to Argon. Well, so, that is what we see. That is the general feature as far as the Gas Tungsten Arc Welding is concerned.

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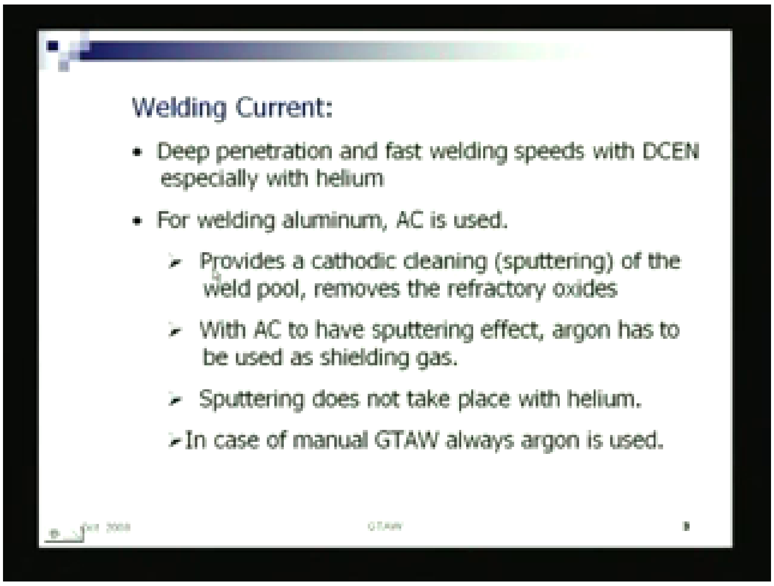

Now, we see for welding of Aluminium. Just now, we have been talking about, we generally use DC, direct current sources, but here we see, for Aluminium AC is used. AC use that There is a very specific reason for it. Why? Because it provides a cathodic cleaning of the weld pool while AC is used because what happens is, when Aluminium is welded on the surface, it has Aluminium Oxide.

So, Aluminium oxide has to be removed before welding, but in real life situation, what happens? Literally, it is a wire brushed to remove it, but whatever you remove, Aluminium being very active material, it get oxidized very fast. That means always there is a thin fine layer of Oxide remaining there. So, whenever you are welding, that oxide does not melt. So, that goes as a that that go in the weld deposit as impurity. Now, if that can be kind of some cleaning action, by cleaning action means you take it out from the molten pool; that happens if you have a …that is what is referred to as cathodic cleaning.

That means if the electrode can be made positive and the job negative, the Aluminium plate which is being welded, make it negative, then that cathodic cleaning takes place through by means of so-called sputtering. That is what it says, that provides this AC power provides a cathodic cleaning action of the weld pool and removes the refractory oxides. So, welding of Aluminum, Magnesium, it causes refractory oxide means oxide which has a very high melting point. With AC to have sputtering effect, again Argon has to be used as shielding gas.

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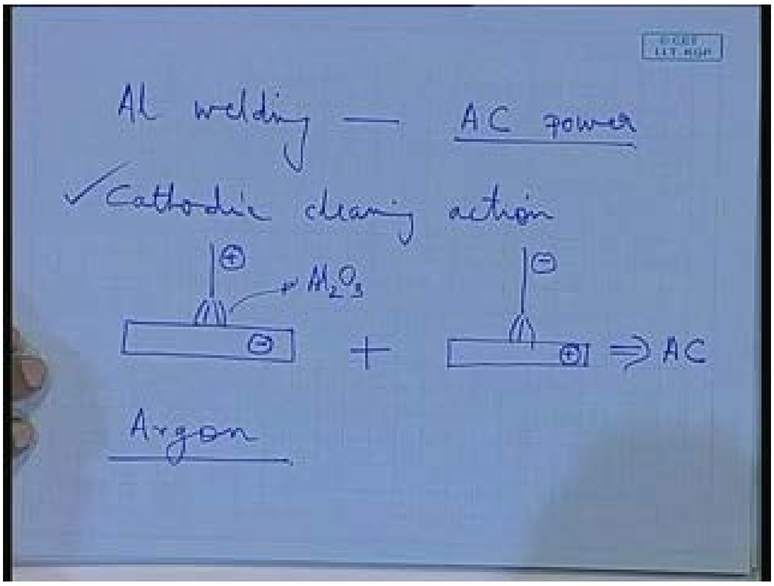

So, for Aluminium welding, in fact when if Aluminium is to be welded like in shipbuilding or main construction you have primarily steel and then some part of

Aluminium is… also there are Aluminium fabrications, Aluminium hull or Aluminium superstructure; so, Aluminium welding is quite common in shipbuilding.

So, there, we will have to use AC power supply. Why? Because of this cathodic cleaning action because to achieve best cathodic cleaning action if you have to as you can see the name cathodic cleaning action; that means the best cleaning would have taken place if I could have kept the job as cathode and the electrode as anode and do the welding.

Then what happens? Then you have that problem. That means if I use a DC power source, make cathode the electrode positive, the job negative, then I have a very good cathodic cleaning; that means removal of those Aluminium Oxide layers becomes very effective. So, from that point of view, a DC power source with this configuration is very good. But then, the problem will be, the electrode will get heated up in the process that will get, I mean after little bit of welding, electrode will get heated up much heavily and then electrode consumption will take place; means, the Tungsten vaporization will take place and Tungsten contamination will come in the weld deposit.

On one hand, it will help, this configuration will help to remove the Aluminium Oxide; that means so-called to remove the Al 2 O 3 from the molten metal; it will come out as a dross as a slag as a slag on the top. This Al 2 O 3 will come out as a slag on the top which can be removed later, after the welding is over. So, with this, that removing action will be good, but unfortunately, your Tungsten electrode will get heated up and thereby Tungsten contamination will take place. So, this is the compromise. That means what is done is if I have this configuration now, that means the electrode negative and the job positive, then your Tungsten contamination reduces; electrode heating reduces. Again if I continue with this electrode negative, then removal of Al 2 O 3 becomes very poor; that is why AC.

That means you make use of both; you make use of both, which actually is nothing but a AC power, or in other words, in one cycle, I keep the electrode positive; thereby I have a good cleaning, this cathodic cleaning action. In the next cycle, I keep the electrode negative; thereby I cool it instead of having the electrode continuously positive, it will go on getting heated up.

So, in one cycle it is getting heated up; the next cycle it is getting cooled; thereby there is a balance is maintained. That is why in Aluminium welding, AC power is used. That is the reason AC power is used with Argon as shielding gas.

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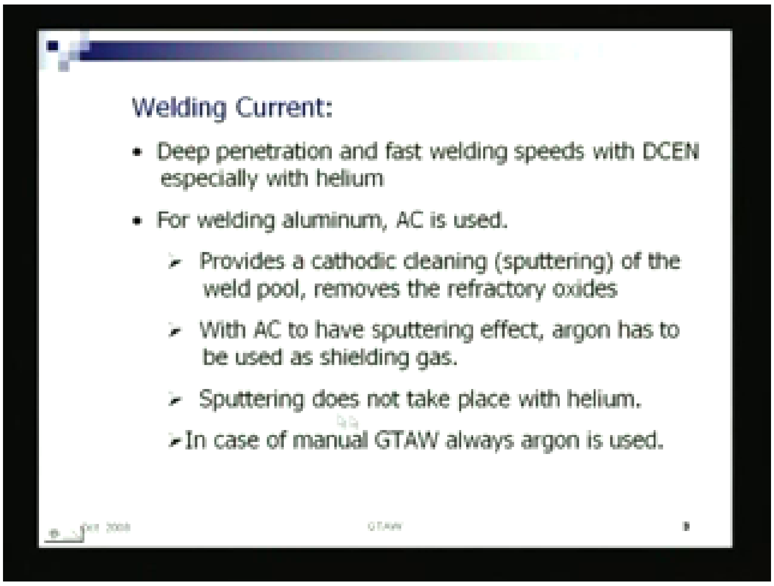

So, that is what we see - the sputtering. Why Argon because if I use Helium, then this whole aspect of sputtering does not take place. Why it does not takes place? Those are somewhat beyond our scope.

As a user, we know that, if I use Helium instead of Argon, then that cleaning action will not be proper; that is the end result. So, for this Aluminium welding, it is always it is preferable to have, I would not say always, but it is preferable to have AC power source with Argon as the shielding medium. And in case of manual, I mean this whole process can be automated also, but very rarely that automated Gas Tungsten Arc Welding is used. So, in manual, always Argon is used.

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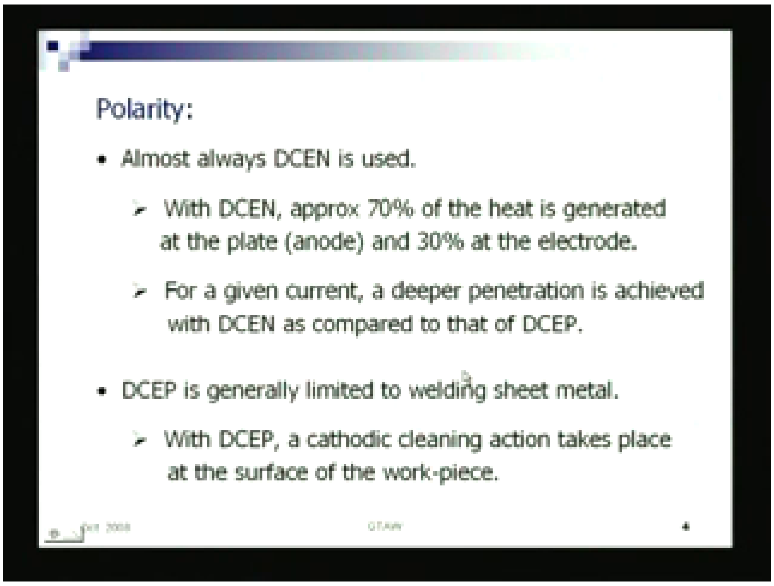

Polarity: Here, the polarity. We have already talked about that. As we can see, that almost always DCEN that means electrode negative is used in all cases; I mean wherever we use it. For steel welding, when we if gas Tungsten arc is being used for welding of steel, then obviously the question of that sputtering or cathodic cleaning does not arise. So, there, you go for a DC power source.

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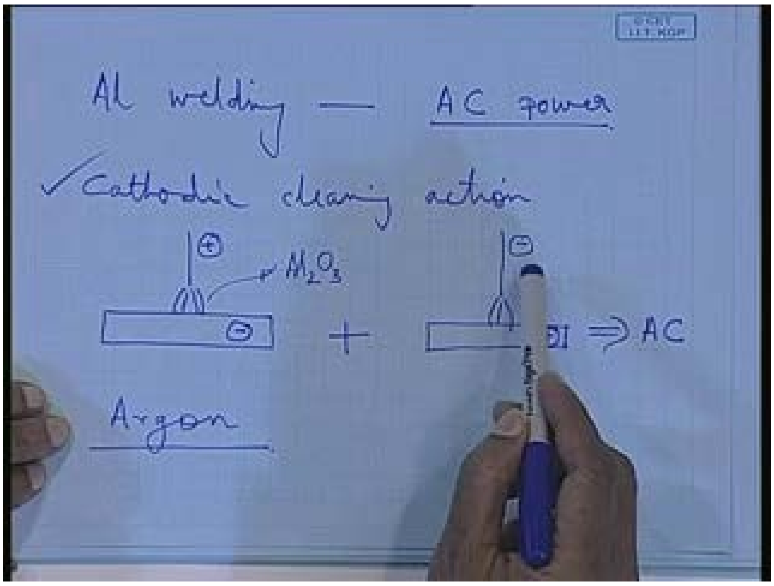

There, we go for DC power source. That means since why DC power source because we take the continuous benefit of keeping the electrode negative because here, you always have some overheating is taking place because half the cycle it is going positive (Refer Slide Time: 25:12).

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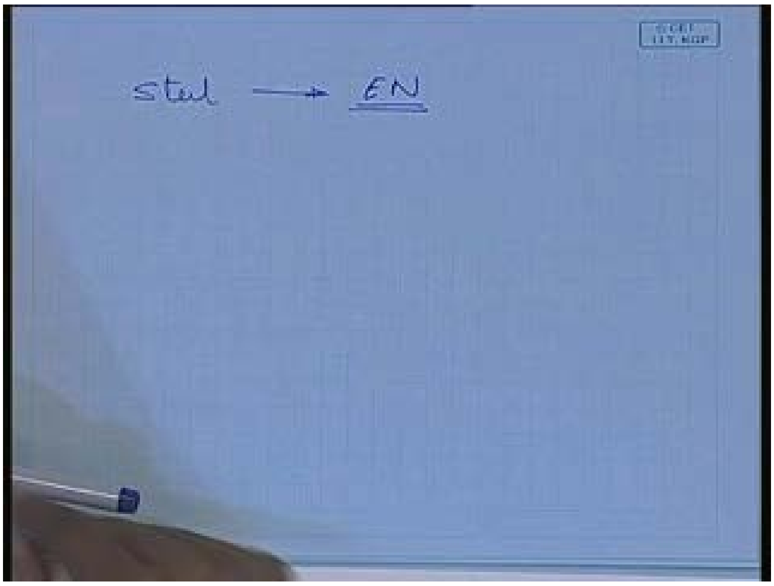

So, for steel welding, it is always you keep electrode negative, but again, if the metal becomes too thin, then we go for electrode positive. Then, if you say, then what is happening? In that case, answer is simple because when you are welding a thinner gauge material, your normal heat input is much low. So, the electrode getting overheated - that question is not there.

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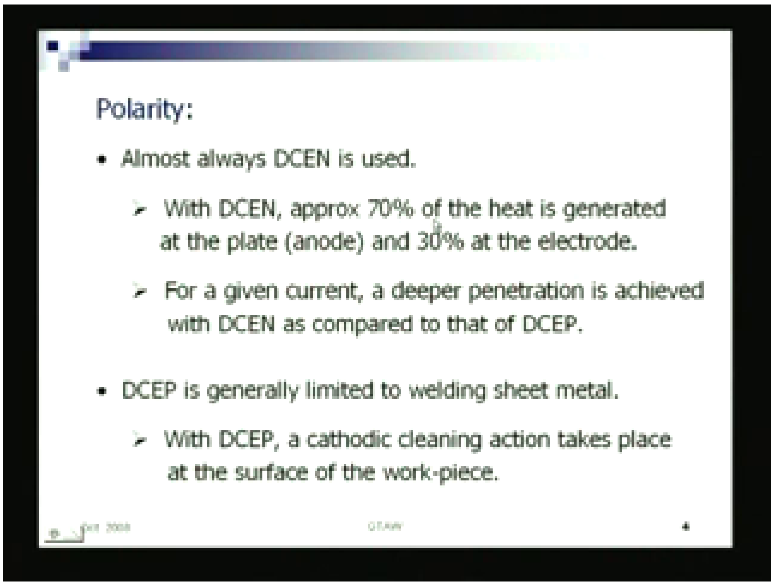

So, what we see that with Direct Current Electrode Negative, approximately 70 percent of the heat is generated at the plate, whereas 30 percent at the electrode; that is the kind of total heat distribution because the total heat is nothing but voltage into current; that is remaining constant whether I am keeping the electrode positive or electrode negative.

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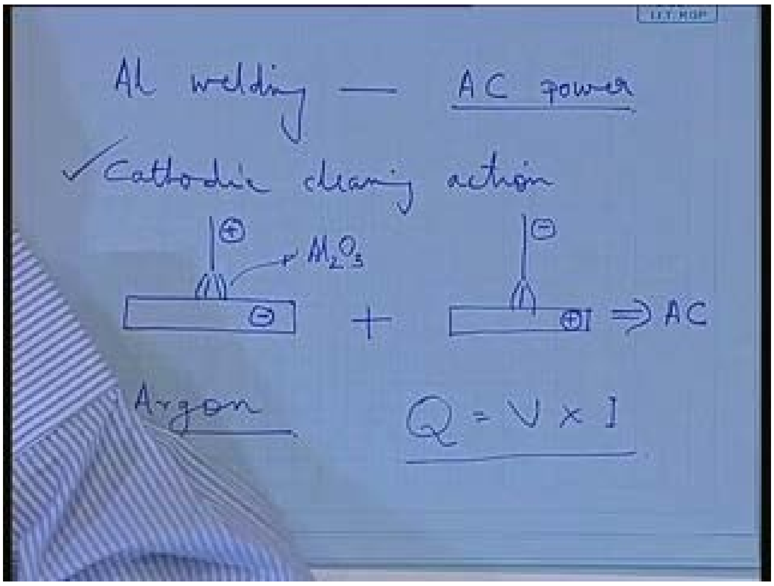

Total heat that is Q that is nothing but essentially the total power being consumed and this is the total power being consumed, voltage into current. In the welding circuit, whatever current is flowing and whatever is the arc voltage, so, that gives me the total power consumption and that gets converted into the heat through this plasma action of the arc column. Now, distribution of this heat depending on electrode polarity is something like this.

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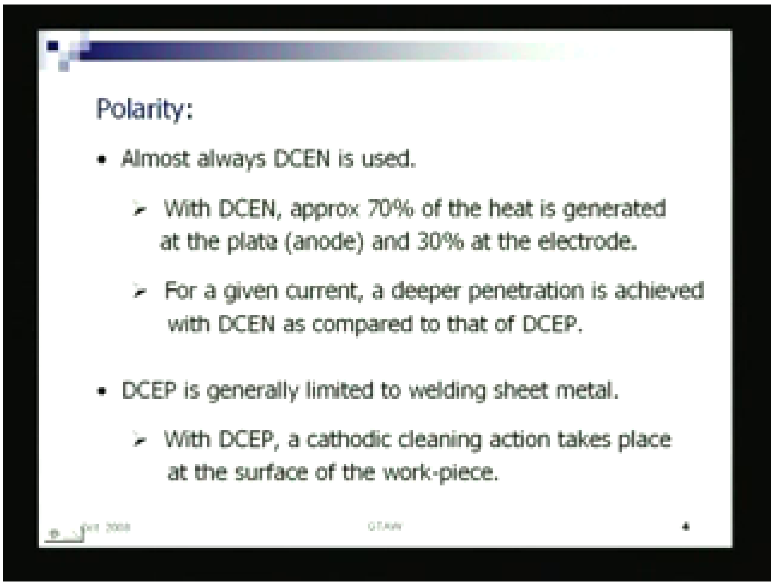

With DCEN, 70 percent of the heat is on the plate that means at the anode and 30 percent in the electrode. For a given current, a deeper penetration is achieved with DCEN.

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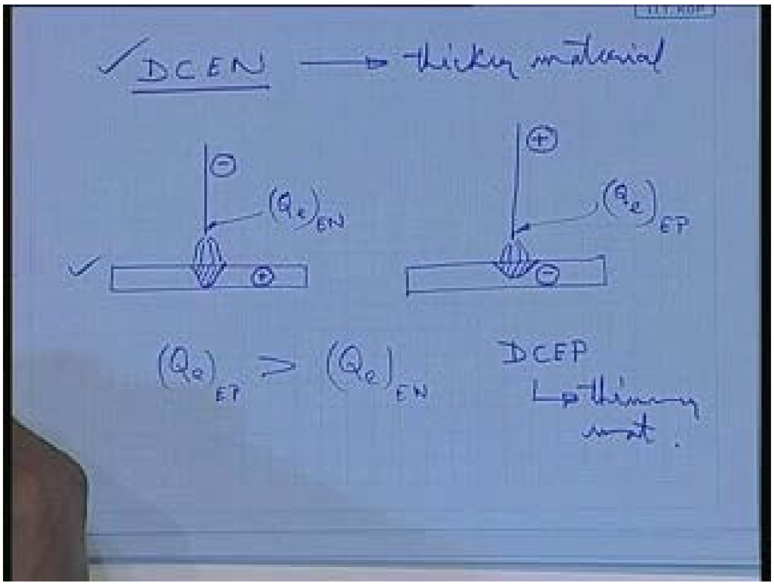

Obviously, of the same current, like we have seen for the same current with DCEN, you have a deeper penetration; whereas, with a DCEP, lesser penetration because less heat is generated in the plate. Well, here, we see with DCEP; instead, of for sheet metal welding, cathodic cleaning action takes place at the surface of the work piece.

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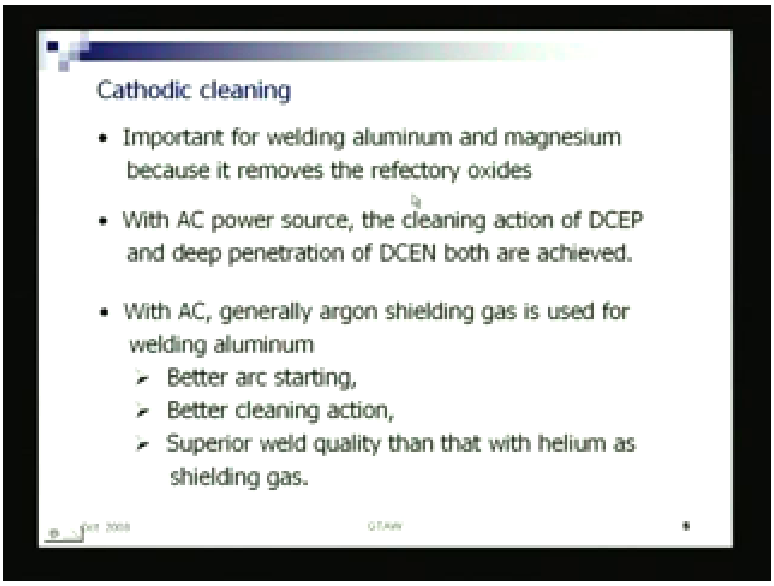

Here, we have talked about once again about the what is this cathodic cleaning. It is nothing but it is important for welding of Aluminium and Magnesium removes the oxides with AC power source. This action, DC action of DCEP and deep penetration of DCEN, both are achieved; basically AC power source. We take benefit of both; may not be equal benefit but benefit of both means DCEP and DCEN.

With alternating current, generally Argon shielding is used for welding of Aluminium. Why? These are some of the reasons that, firstly you have a better arc starting because welding means you will have to have a stable plasma column; stable arc is needed; that is what is called the welding stability of the welding. If the arc is arc becomes unstable, then your welding will be non-uniform; arc unstable means what? That means the arc characteristics are changing very frequently; arc characteristics changing means essentially heat generation is changing; that means the fusion melting is changing. So, deposition and the fusion pattern will be very erratic, will be uneven.

So, anyway, that is we see that, with Argon as shielding gas, it gives you a better arc starting, better cleaning action and superior weld quality, than that with Helium as shielding gas. Helium can be used as shielding gas when we are welding steel because that gives you a much higher heat. So, one can go for high deposition welding even with gas Tungsten. Generally, gas Tungsten arc welding are low deposition welding why because here, you have a manual feeding of electrode.

So, it is essentially manual process, but if you automate the process, that can be done. You mount the torch on an automatic carriage and make an arrangement of feeding of electrode, like you have in the gas metal arc welding. There the electrode itself is getting the current. I can feed it separately also in automated through a feeder mechanism. So, the whole process can be automated even in gas Tungsten arc welding. So, there, that automated process, if you use an automated process that means there I can go for higher current. There one can go for Helium as a shielding gas such that more higher current is used, higher heat is generated; so, higher melting. And that gives you high deposition rate.

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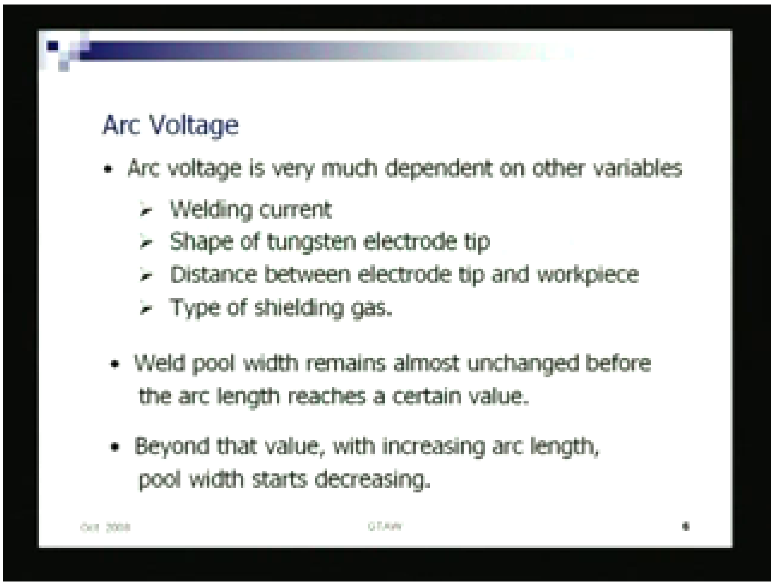

Arc voltage: This arc voltage, as we can see, obviously, it is dependent again on other variables like: welding current, shape of the Tungsten electrode tip, distance between electrode tip and work piece, type of shielding gas. That means what would be the arc voltage? That will also depend on this shape of electrode tip.

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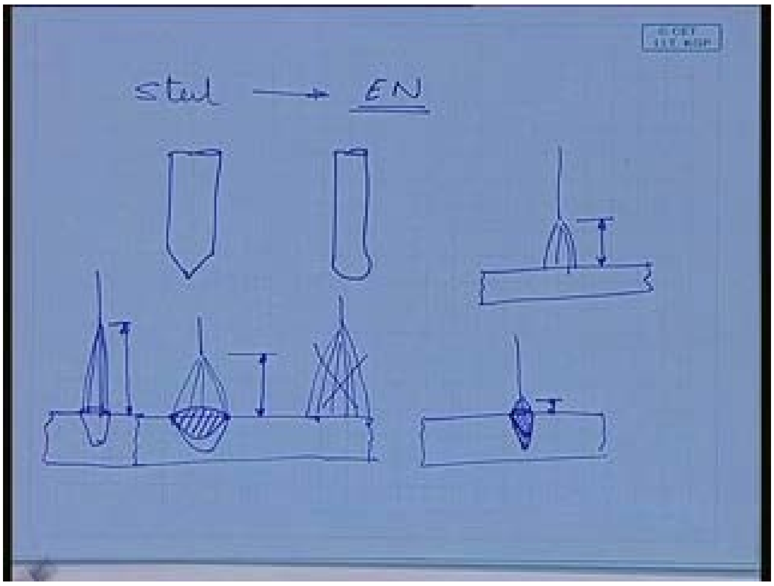

The arc characteristics changes depending on the shape of the tip. Some electrode tip could be like this; some electrode tip could be spherical one; both are Tungsten electrodes. In one case, it can be quantum; one other case it can be blunt. So, depending on what type of electrode is being used, also the extent of arc voltage may be different. And obviously distance between electrode tip and work piece because the distance between electrode tip and work piece, the voltage will be different, for the simple reason because as the arc length increases, that is the distance between the tip and the job, as the arc length increases, we have higher voltage.

So, depending on how you are holding the torch, whether because here you see, in gas metal arc welding, we have seen cases of self-regulation of arc length. If you have a constant potential power supply, constant voltage power supply, it will automatically maintain a constant length between the electrode tip and the job. Why because, if I bring it too close, the voltage will, the current will increase; there will be surge in the current and more tip material will melt. And thereby, fixing the distance, bringing back the distance to the required value that is what is called self-regulation, but here, the question of electrode melting is not there. So, by changing of height of the torch, position of the torch, I can increase or decrease this value, this distance between the tip of the electrode to the job. Now, if I increase it, arc voltage increases; if I decrease it, arc voltage decreases because that is arc voltage is the voltage drop across that gap.

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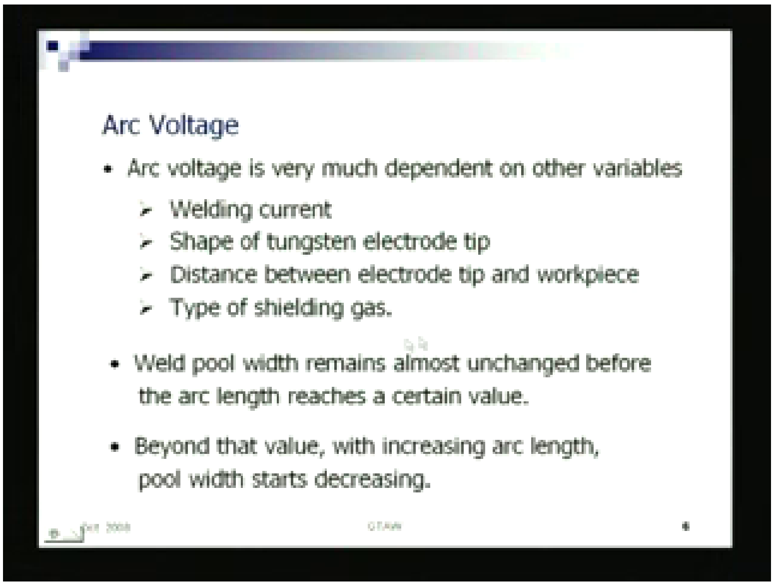

Depending on shielding gas, the arc voltage will change. Right Depending on shielding gas because of the characteristics of the concerned shielding gas whether it is a Helium or Argon depending on their ionization potential.

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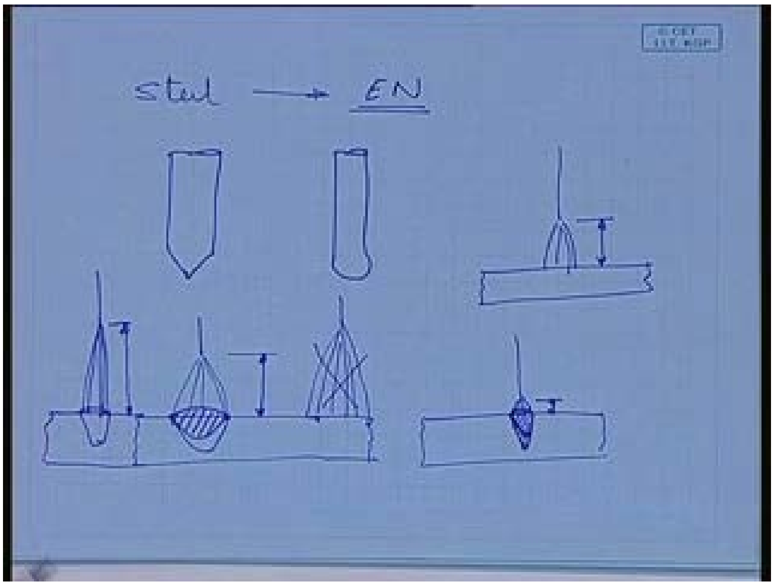

So, what we see that the weld pool width remains almost unchanged before the arc length reaches a certain value. What does that mean? Because we have already talked about the effects of welding parameters in the one of the general effect of welding parameter, general effects of arc voltage on the deposition pattern is like this (Refer Slide

Time: 34:12). If you have a very…I mean if you have a longer arc, then if we draw it in little exaggerated fashion, what I have tried to do, of course, is somewhat exaggerated. That is when I have a higher arc voltage, and here, I have a much lower arc voltage; the arc length is very high; arc length is very small; if I have a high arc length, you have a wider bead profile; the fusion and the top is wider. Once that happens, obviously your penetration also will be less. Actually, it should be somewhat like this.

Penetration in the metal will be less, whereas when you have a short arc length, your bead profile also will be narrower and penetration would be deeper. Why? For the simple reason, the same heat is there

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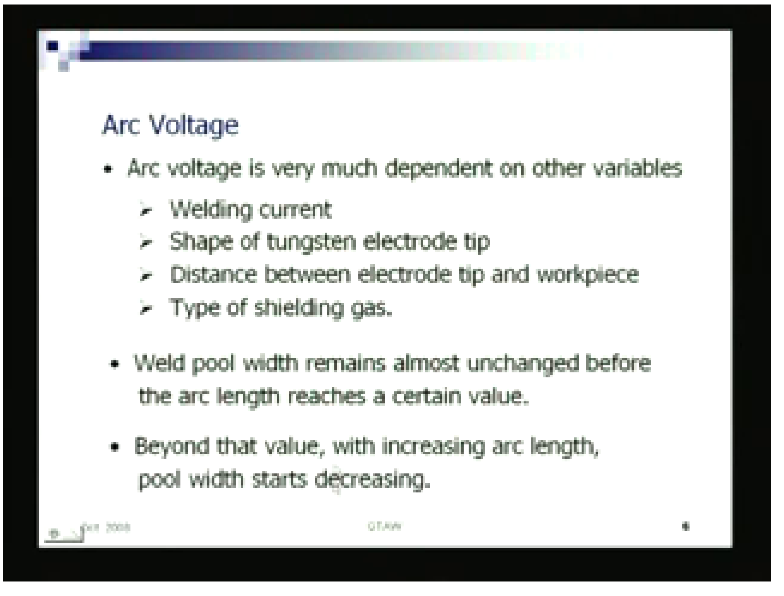

So, more heat is getting conducting below. So, here, what I meant to say that the weld pool width remains almost unchanged before the arc length reaches a certain value. That means it does not mean that I go on increasing the arc length; it will go on becoming wider and wider. No, definitely not. That is obvious, beyond a certain arc length, it will arc will become unstable; simply arc will extinguish.

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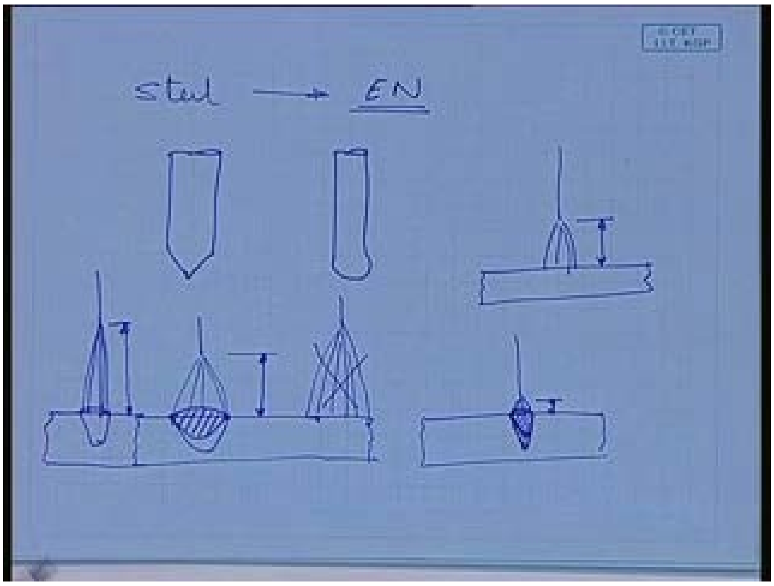

And here, in this case, in the Tungsten electrode welding, there is also another phenomenon, that beyond a certain value the pool width again will start shrinking. That means beyond a certain value, if I take it further up, this is of course, we are drawing with a much exaggerated, then it it it… sorry,it is not; anyway, let me draw in this side

So, here, in this case, I have further increased the arc height or the arc length. So, what it says that beyond a certain arc length, again arc will start getting narrower; it becomes narrower; that means, to start with, as the arc length is short, we have a narrow width. As you go on increasing the arc length, its width becomes wider; you further you increase the arc length; then again, it narrows down; that means beyond a certain critical value, the increasing arc length pool width will start decreasing. that That is the thing what happens.

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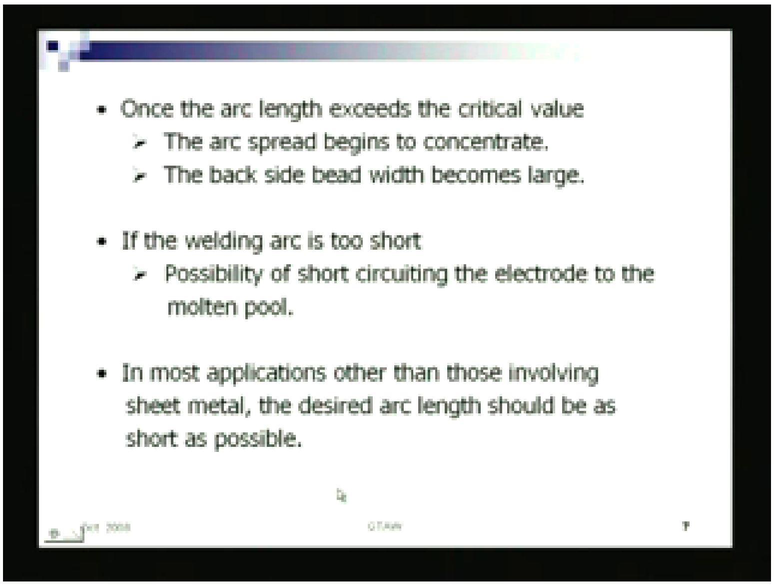

So, once the arc length exceeds the critical value, the arc spread begins to concentrate.

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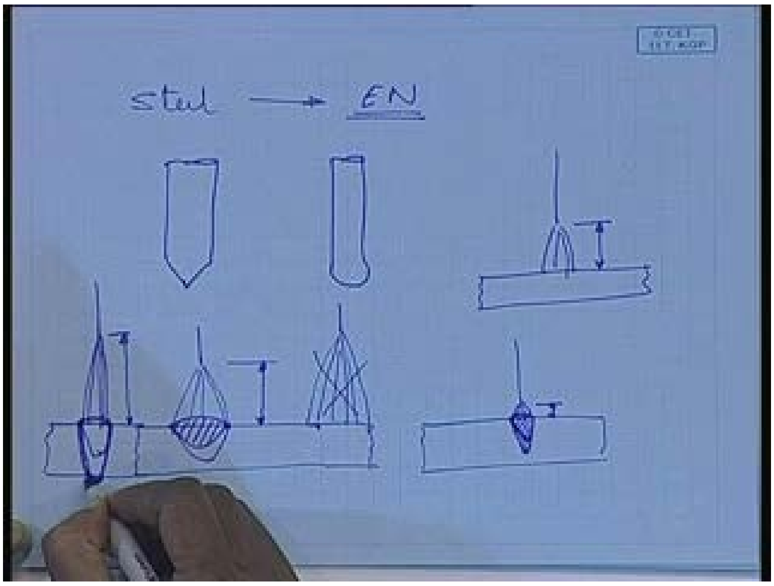

So, if this is my, say, critical length, if I increase beyond that, then the arc spread starts getting concentrated and the backside bead width becomes larger; means the bead width at the back; where, in other words, it gives a more narrower fusion and more deposition going at that. That means, with this length increasing means your this becomes narrow the bead width becomes narrow, the fusion increases, and you have a over reinforcement, over deposition at the bottom of the plate. Fine. These are some of the peculiar phenomena's phenomenon that takes place in case of Tungsten arc welding.

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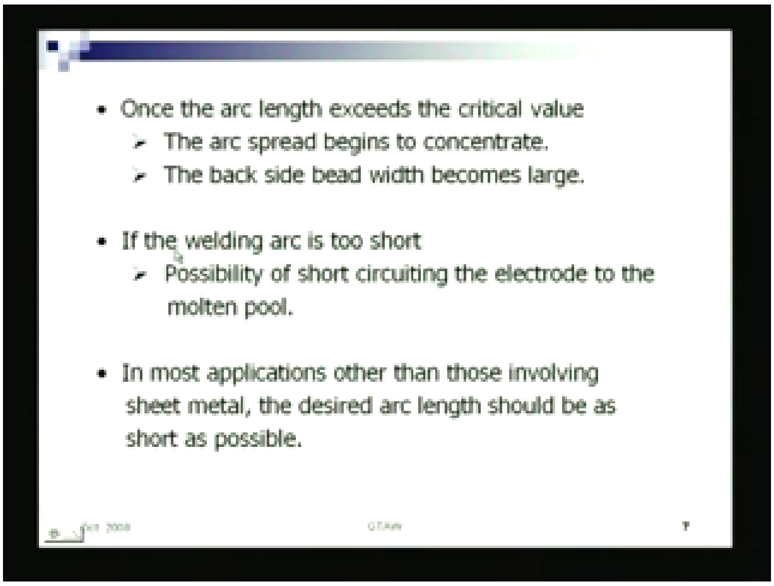

Now, on the contrary, if the welding arc is too short, just the reverse of it, it is becoming too short, then there is a chance of short circuiting the electrode to the molten pool. When I am making shorter and shorter, then there is a possibility of short circuiting, obviously, if it short circuits means, there your Tungsten electrode touches the weld metal. So, that is obviously, the welding process will stop because there will be certain drop in the current because of the short circuit; certain drop in the heat generated; so, welding process you will stop, and at the same time, the electrode will get damaged because there is a different phenomena; the electrode will have aluminum contamination.

Suppose, you are welding aluminum, it is more. So, in case of aluminum welding, if there is a chance, by chance you short circuit it, there is an aluminum contamination. So, that is why another aspect is there - how do you start the welding? It is by striking an arc.

So, every time you strike means you physically touch the metal plate. So, with a Tungsten electrode, it is touching the aluminum means some bead of aluminum contamination is taking place in the electrode tip as well as the at that location, aluminum is getting contaminated with Tungsten. So, both ways it happens; that means every time you start a welding process, you start the arc. There can be a case of small contamination in the plate which is being welded and also the electrode gets contaminated.

In most applications, other than those involving sheet metal, the desired arc length should be as short as possible; that is another channel rule that you see here. It has been mentioned - other than those involving sheet metal; what is meant by sheet metal? what do you mean we are referring to thinner gauge material, say 1 millimeter 2 millimeter thick sheets; if you are welding that, then it is preferable to have little wider, little longer arc length. Why because if you have shorter arc length, the penetrating effect is more; the depth of penetration increases with shorter arc length.

So, depth of penetration is increasing means there will be possibility of cutting through the metal. So, when there is a thinner gauge material, it is preferable to have a rather longer arc length; otherwise, it is as short as possible.

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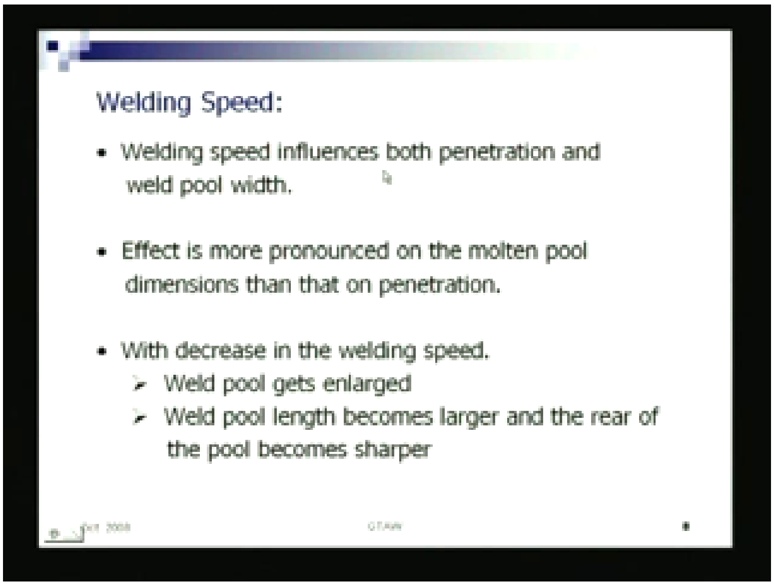

Then, welding speed: Obviously, welding speed, of course, is one of the important parameter because this determines the productivity.

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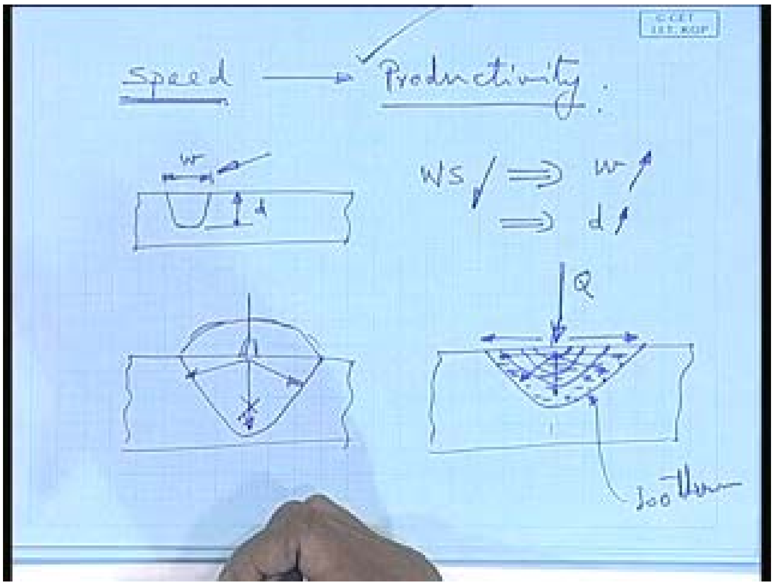

That is one of the important aspect because the speed, apart from anything else, it determines your productivity. So, you see, in a production process, if you see the interest of the so-called management, the ship yard owner, or one who is sort of responsible for the overall production, he will be interested in productivity to know, what is happening, how much production is taking place because he will take it for granted that, it is as per quality because quality has to be maintained.

Obviously, maintaining quality; what is the rate of production? That is what is important; that means how much productivity? I mean what is the level of productivity? Higher the productivity, more efficient the process is; more the profitable the inter venture is. So, this speed is that particular parameter which refers directly to productivity because faster you can weld, more your production rate. fine

So, that way it is one very important parameter in a welding process. So, naturally, one would like to increase the speed of production. So, what happens if the… what do you see? That the welding speed influences both penetration and weld pool width; it has effect on both. The penetrating effect, how much it will fuse through in metal depth as well as what would be the pool width? So, effect is more pronounced on molten pool dimensions than that on penetration, though it effects both the both your fusion depth as well as on the width in both these aspects, but the effect is more pronounced in the fusion way, effect is more pronounced. Actually, what happens? I mean from common sense, one can see that if the welding speed is decreased, then it will give rise to increasing weld width as well as increasing welding depth. As the welding speed is decreased, welding speed decreased means what? You are holding the heat at a point for a longer time. So, you are allowing, in that case, you are holding the heat in one place for a longer time means you are allowing the heat to flow in all direction for a longer period.

So, we expect a more wider and more deeper fusion, but in reality, what happens is as you go on reducing the speed, as you go on reducing the speed, it will happen in fact like this (Refer Slide Time: 45:44). That means the whatever well let me take by here, the Q is going. So, it will penetrate like this; that means this increase, so much will not take place; always we see that the more heat will flow across transversely than in the down than in the thickness direction. What is the reason? Reason is, what happens as the heat is flowing because as you have the heat source on the surface of the plate, obviously, it will have, it will flow equally in all direction. This is my plate surface; I am applying some heat; it will flow across the depth and transversely, radially, in all directions.

What will be the effect immediately? I mean if we can take in a so-called nanosecond basis what is happening, we will find first a small molten pool will form; then gradually this molten pool will go on extending like this (Refer Slide Time: 46:56); otherwise, or in other words, these are my melting temperature isotherms. These are basically the isotherm, and here, we are drawing the melting temperature isotherm; means, this is my boundary of the molten metal to the solid metal.

If it is still, say this is the 1500 degree isotherm, so what will happen? This will keep growing in this fashion. Why it is growing in this fashion because beyond a certain point, it will not further grow in the thickness direction because here, it will be all molten metal and the heat conductivity or the thermal conductivity of molten metal drastically reduces.

If we see the variation of thermal conductivity with temperature, one can see that the thermal conductivity at room temperature of steel is at some lower level; as the temperature rises, it increases; then beyond a certain point, again it starts decreasing. The thermal conductivity, it varies with temperature and the thermal conductivity is sufficiently low at molten temperature, at melting point temperature of steel. So, the flow of heat, heat conduction will be less; that is a simple reason heat conduction that means the molten metal will act as a kind of an insulator, as if as a kind of a cushion which will cushion the heat flow, which will insulate the parent metal, the solid metal below, from further melting.

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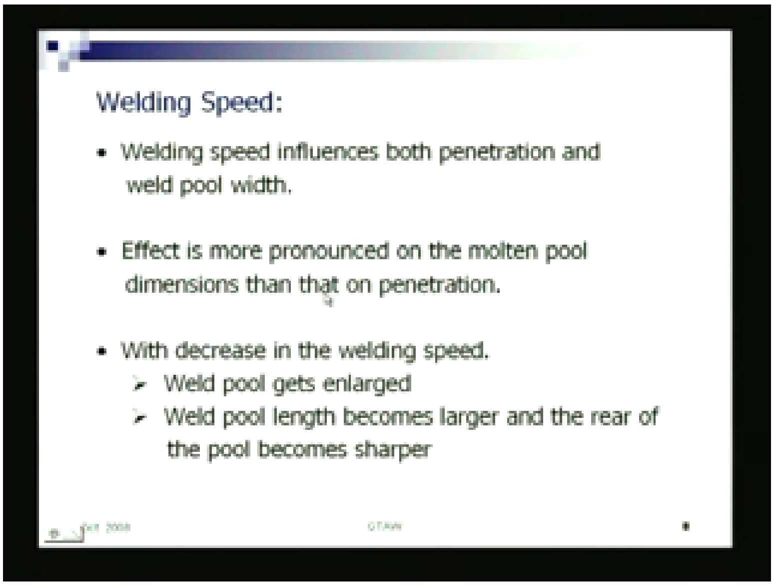

Thereby, the fusion, that means the that is why it says, it has a more pronounced effect on the on the weld pool width than on the penetration. So, by decreasing welding speed, we do not… so if you have to increase fusion depth, if you have to increase penetration, then welding speed should not be reduced; that is the ultimate, I mean, net result. Net lesson what we get is, for controlling the depth of fusion, welding speed is not the parameter.

It will have a rather if you have to increase the depth and also as we go on reducing the speed, what will then happen If I go on feeding the electrode? Obviously, in gas Tungsten arc welding, that we can control because feeding and movement - they are independent. So, if you go on feeding it, you will have a higher deposition at the top.

Sir, after a certain time, the sides also does not support the weld joint.

Yes. I mean all these are obvious. This does not mean that you just keep on holding the torch at one place; it will go on melting. No. Again, a steady state condition will come because what is happening? When I am reducing the welding speed means what? Essentially the maximum reduction is what making the speed 0. If I say I am reducing the welding speed, how much I can reduce? I can make it 0; that means I hold the torch at one place. So, continuous heat is going on the arc and continuous heat is going on. So, what will happen in that case?

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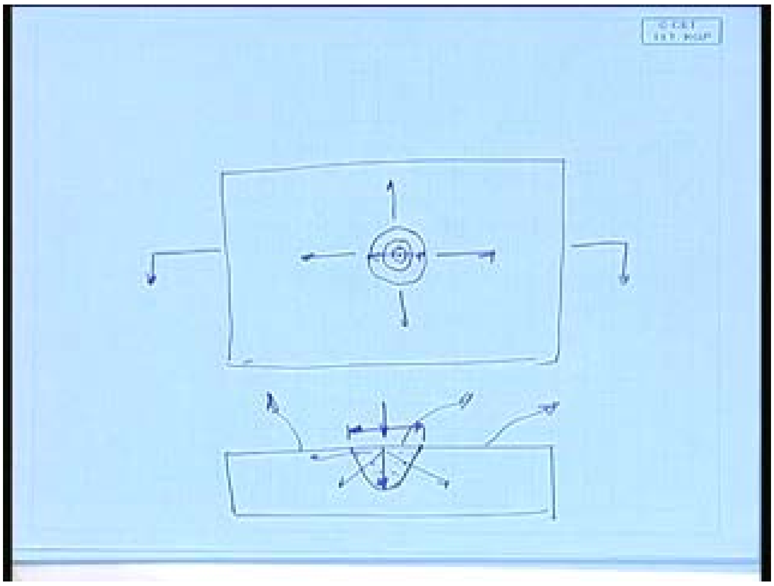

Suppose, if I see a plan view, say this is the plan view; I am having the torch perpendicularly like this. So, instantaneously, if I can go on taking photographs, suppose if that is possible, I will find, instantaneously there will small weld pool will form; means a molten metal pool will form; forget about feeding of electrode, just the heat torch is there. Gradually, this will increase; that means the diameter of the molten pool will increase. Now, how much it will increase?

Obviously, it will not go on increasing infinitely; no, definitely not. Why because what is essentially happening here? This is my cross section; this way; this is the molten pool which has formed. So, whatever heat is going in, whatever heat is coming here (Refer Slide Time: 51:39); so, it is getting conducted. It is getting conducted in all directions. Similarly, it is getting conducted in all directions. So, at one point of time, it will attain a steady state; means also getting radiated, convection, cooling - all these things are happening.

So, whatever heat is going on, it is getting distributed. So, a certain width of pool will be there; it will not go on extending beyond. Point is, the effect will be more pronounced in this direction than in this direction; that is the point. Effect is more pronounced from the heat is flowing across the plate than along the depth of the plate; that is what; that means if we go on reducing the speed, then weld pool width will increase. This will increase the width of the bead compared to the depth of the bead; that is what is the main point.

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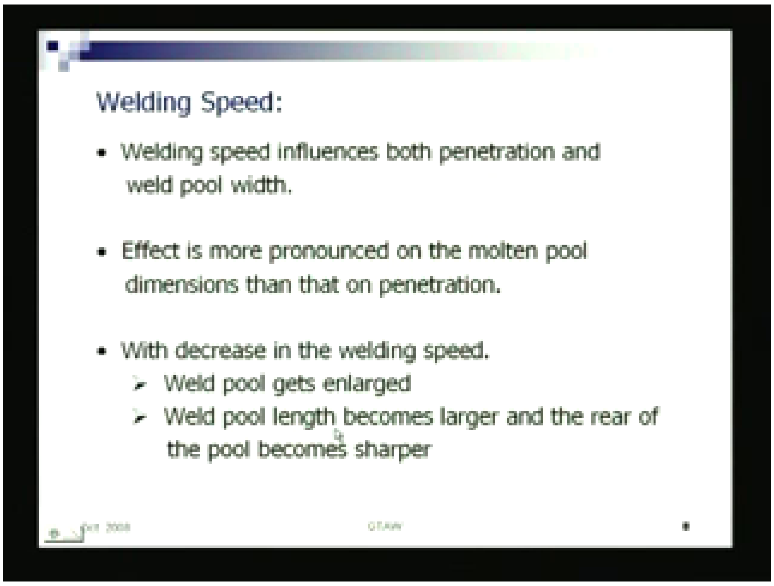

So, with decrease in weld speed, here, we have summarized: the weld pool gets enlarged, weld pool length becomes larger and the rear of the pool becomes sharper.

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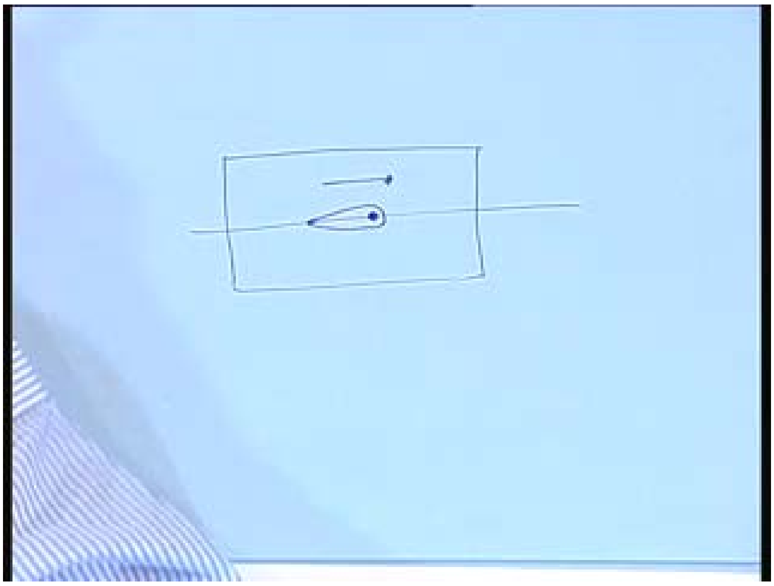

It is nothing but this is in the static condition; that means you are holding the electrode at one position; otherwise, the electrode if you move the electrode along this, then then it will become, it will become sharper; here is the arc; so the pool length becomes larger and the rear of the pool becomes sharper. That means welding speed obviously you will have to decide on. As I said, the primary aspect is, it talks about productivity.

So, always the objective would be, how we can keep the speed high, but obviously, you go on increasing speed means what? I do not give enough time for the heat to flow.

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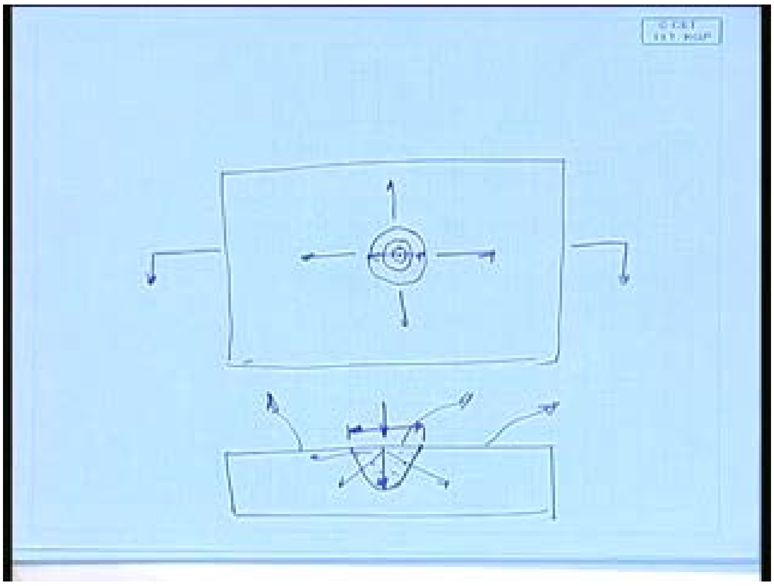

Here, what I have seen? I am giving time for the heat to flow in all directions. If I do not give time, then the fusion zone will be very small;l it will not achieve the desired fusion. So, that is how, all the in fact, all parameters are interrelated; thereby, you will have to achieve; also you will have to achieve the interfusion; at the same time, you will have to see that overheating is not taking place; excess heat is not going in the plate - all these aspects.

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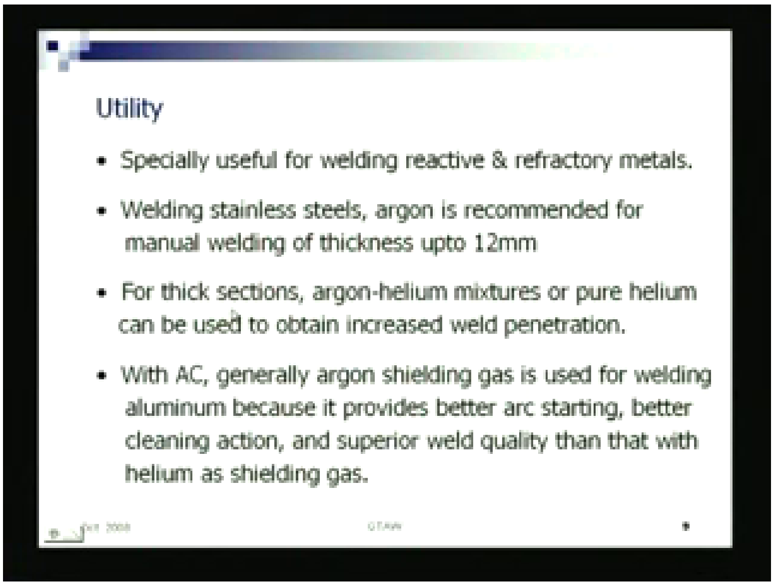

So, what are the utility of this process? It is especially useful for welding reactive and refractory metals. By refractory means, well magnesium alloys, aluminum alloys. It is especially useful.

And welding stainless steels: Argon is recommended for manual welding up to thickness of 12 millimeter; beyond that Helium; basically, what you meant by this? That means stainless steel. If you want to weld, stainless steel is what? It is a high Nickel, high chromium alloy. So, if it is high chromium alloy, then it becomes difficult because its carbon equivalent becomes very high.

So, if you weld by conventional means, it may crack. So, Gas Tungsten Arc Eelding is often used for of welding stainless steels, but as we see, for manual wielding up to around 12 millimeter thick plates Argon is recommended; otherwise, you go for Helium or go for Argon- Helium mixture. Like for thick sections, Argon- Helium mixtures or even pure Helium can be used to obtain increased weld penetration. But as you go for Helium, pure Helium, then it is preferable to have an automated welding process with AC.

So, in these methods, when you are welding steel, then generally one goes for this direct current electrode negative process, but for aluminum, you go for AC.

With generally, Argon shielding gas for welding aluminum because it provides better arc starting, better cleaning action, and superior weld quality than with Helium as the shielding gas. It is interesting that in aluminum it is preferable Argon because it has another additional business to do - cleaning action because of the refractory oxides.

In any case, Gas Tungsten Arc Welding is not heavily used. As you can see, as far as steel welding or marine construction is concerned, it is mostly used where ever there is an aluminum fabrication.

Well, that is all. We will next look into Submerged Arc Welding.