Marine Construction & Welding

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Module No. # 01
Lecture No. # 26
Welding Parameters and their Effects

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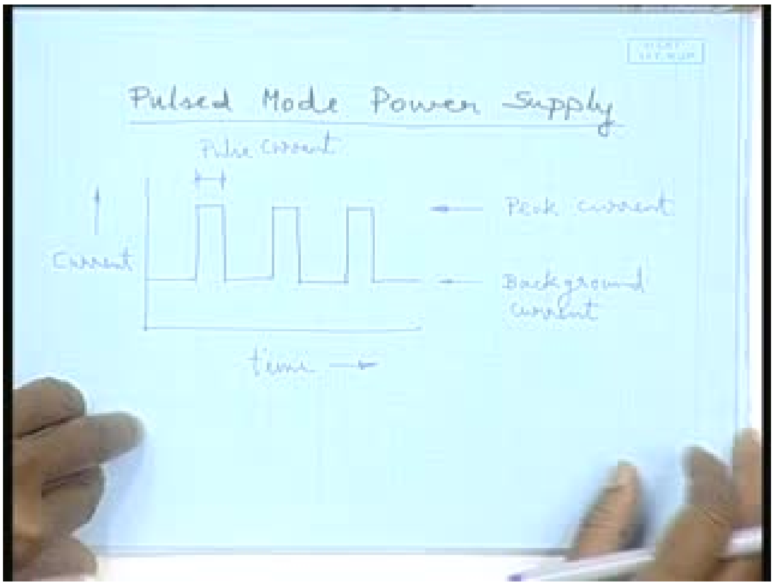

Well, today before we start with the welding parameters and their effects, little bit is left from yesterday's regarding power supply. We will do that and then, go over to the welding parameters and their effects.

So, we have seen constant current power source and constant potential power source. There is another mode which is referred to as pulsed mode power supply. This is also a DC supply, but it is in a pulsing mode, like we have seen both. I mean constant current or constant potential, it was a DC. The characteristics we have seen that with current dropping or current remain, remaining flat with respect to voltage, but essentially if you see the current voltage verses time, it is a straight line. Here, it is in a pulsing mode.

So, generally what we see is, it can be schematically shown like this. If we plot the current verses time, it would look something like this. That means with time, the current I am fluctuating it, fluctuating in a predetermined fashion. It is not a random fluctuation.

So, what I have here, I can refer to this current level as I am seeing that over time, that is minimum. I am coming down, I am not going below that, so that is my background current that is referred to as background current. So, that is held constant. I am not going below that. Here, I see this level again held constant at a higher level, and that is also I am not exceeding, so can be referred to as peak current. That means, I am having that much as peak current, and this duration of time is the so-called pulse current. I can name it as, means the pulse is being given. The pulse of peak is being given for that time period, for that duration.

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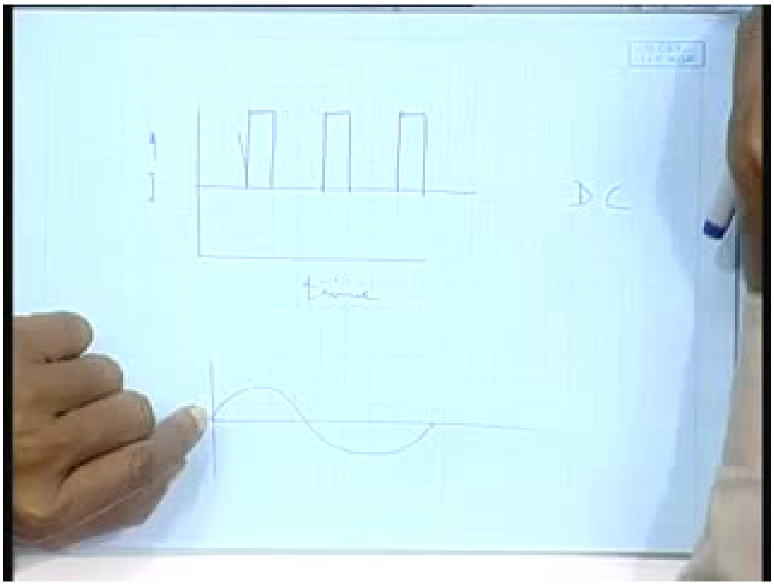

Yes, on time this is the current, because a DC supply would have been like this, straight line. If I plot the current, there is no variation of the current with time. Had it been AC supply, then it would have at varied potential, would have at varied, so that thereby depending on with the resistance etcetera, current also varies same way. So, here what I am doing in this, in this current, as if I am imposing a peak current. If this is my DC supply, I am having assumed the circuit resistance is remaining constant. So, I will have a straight line with time.

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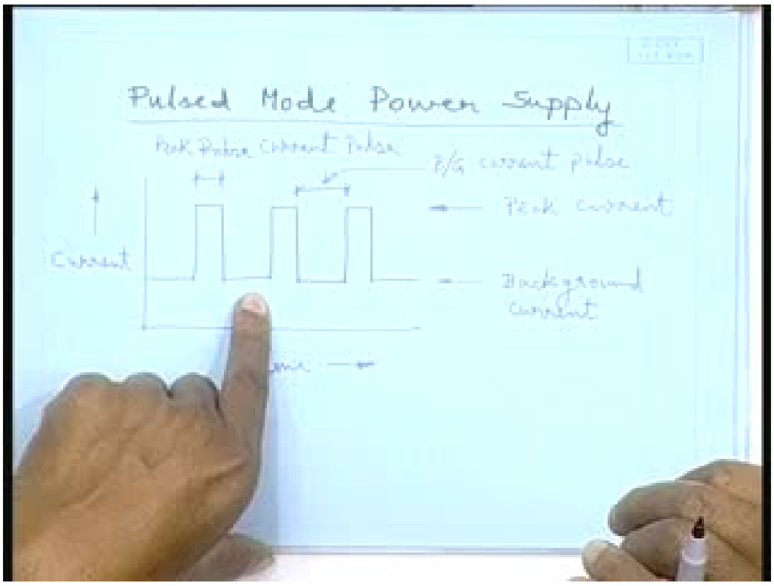

There is no variation in the resistance. So, current in the circuit is constant, but now if I impose on this, certain pulses of current like this, then it becomes my pulse mode. That means for a certain time, I am having this current level. Then, certainly I am increasing the current. I am giving more power. Here, it was continued to 200 ampere. Suddenly, I am making it 500 ampere, 200 ampere for certain time, 500 ampere for some time. Again, coming back to 200, 500, 200, 500 same like that.

So, that is what this peak is referred to as pulse, well peak current and this time is the pulse current, this time for the peak current, and this is the interval time for the background current or background current pulse. Actually background current pulse, this is better we write peak current pulse, otherwise peak current pulse is a background current pulse.

So, what do you see here, that I do not unnecessarily give continuously a high current in what I have done. Suppose, for doing welding I need an 800 ampere, but if we really see, I may find out that I do not need it continuously. Only I need one metal transfer is taking place or if we see the metal transfer, how the metal is getting transferred because we said that current causes the heat melts the metal, and that metal is deposited, but what is happening is the metal melting at a continuous rate is the deposition as the continuous rate or at a discrete rate.

So, all those things if we know, then we can think off whether I need a continuous supply of power or an intermediate supply of power. By intermediate means, a kind of this, a pulse mode, then what I achieve through this is that I am saving terms of power because for this period, I am consuming less power. Here, I am consuming more, again less. So, I save in terms of power, I save in terms of heat, going into the plate because more heat going into the plate leads to more heat related problems, thermal deformations, thermal stresses, residuals stresses, so that is also called reduced.

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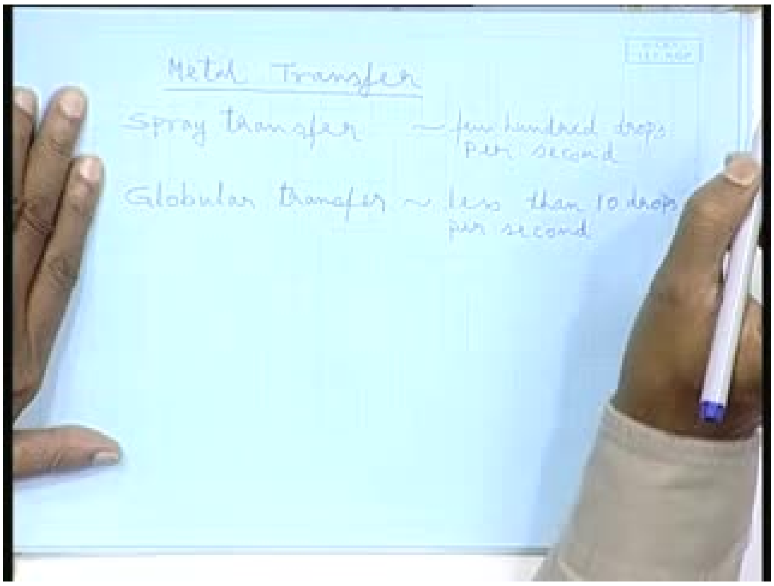

So, this is what is a pulse mode power supply. So, this is in relevance with the metal transfer mechanism how the metal gets transfers. So, let us look at how metal transfer takes place. So, metal transfer mechanism, metal transfer, well metal transfer means from the welding electrode, the molted metal is getting transferred to the weld pool.

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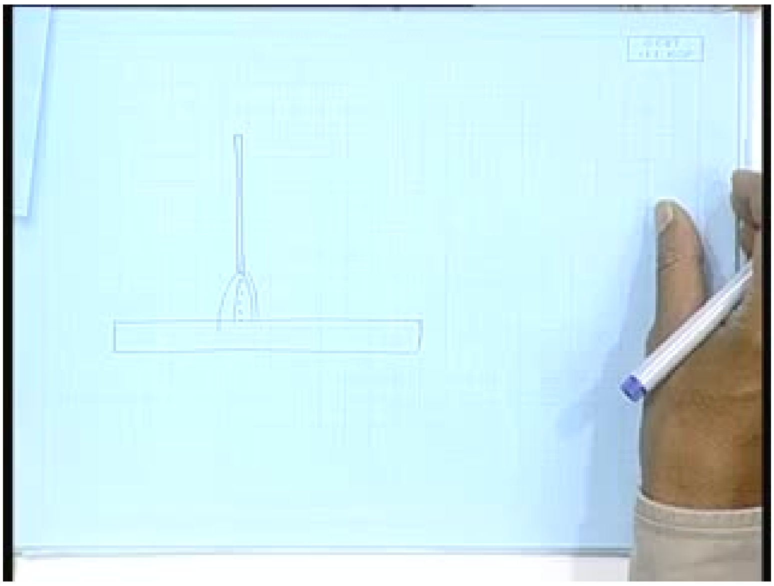

So, we see that when a welding is being done, if we have a very high speed camera, and you can capture the picture in the welding arc because metal transfer will take place through the arc along the arc that a transfer will take place. That means, you have the plate, you have the electrode and there is arc.

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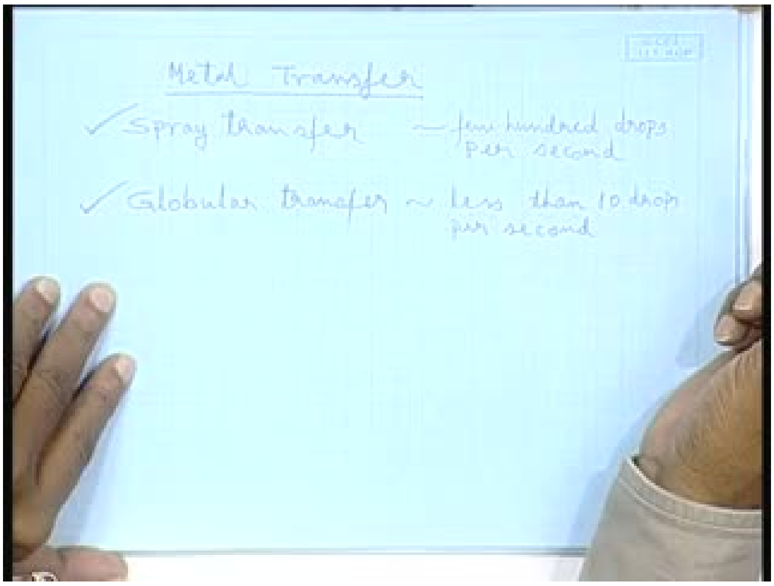

So, through this, your metal is coming down. So, if we can look into this, then what has been observed, that depending on conditions, depending on the various conditions of the welding arc, condition means the composition of this plasma. Column means, whether it is a argon plasma or CO2 plasma or helium plasma, whatever that means what kind of fumes are there, what kind of gases being used, what is the current, what is the diameter of the electrode.

So through that, it has been observed depending on situation, either we have a case which can be referred to as spray transferor, we have a case which can be referred to as globular transfer. That means, two modes of metal transfer was observed. What are those modes? Spray transfer. In that mode, what was found that, about few 100 drops of molten metal per seconds, that means, the molten metal transfer taking place per second appeared to be in 100's.

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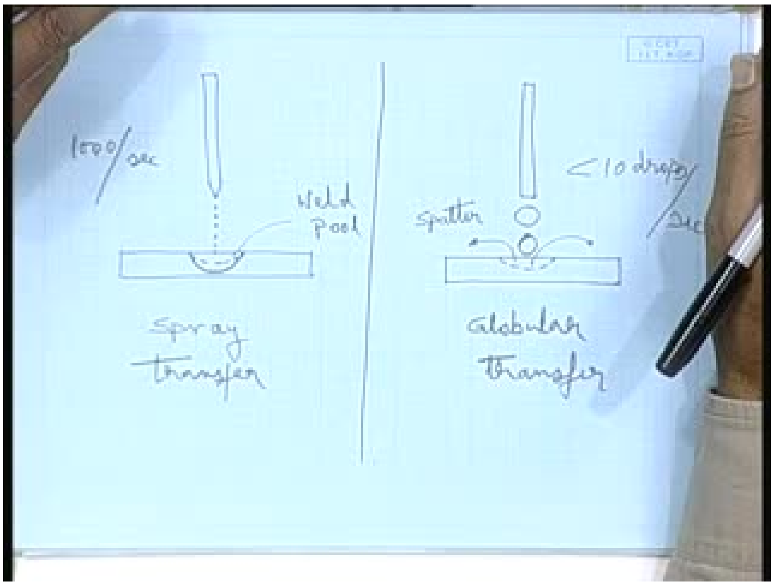

So, schematically it can be shown something like this, schematically it is shown something like. This is your spray transfer and in another situation with changed welding parameters, we saw that the metal transfer is taking place in the form of globules. Here is your molten pool, this is my weld pool. So, this is referred to as spray transfer referred to as globular transfer. So, what we see the difference between these two, that in one case, I have small droplets and this small droplets could be few 100's per second. How many? Around 100's per second 100's of drops.

So, as if the metal is getting spread here, it is few drops less than 10 drops per second. That is also globular transfer and this were calling globular because globules of metals are falling big droplets as if, how big. Well, it could be even little bigger than the diameter of the electrode. Even it could be little bigger than the diameter of the electrode. What is the electrode diameter? What is the order for manual metal? Arc welding electrode diameter is 3 millimetre, around 3.15 for gas metal, arc welding electrode diameter could be 0.8 millimetre, 1 millimetre, 1.2 millimetre in that range. So, if with that, my globule diameter could be of the order of 1 millimetre, one and half millimetre like that, whereas in spray transfer, they are fine droplets, very fine and there will be hundreds of them per second. That is how it is referred to as spray transfer. Other case, it is referred to as globular transfer.

So, they are the two transfer mechanisms. Now, what is it so great about them? I mean what happens in these two cases? Physically what we see is, if it is a spray transfer, then the very nature of the metal transfer says us that, it has a higher kinetic energy in it. That means the flow metal gets transferred with a higher energy in it, high speed in it.

So, in the process, pre-transfer may lead to higher depth of penetration. Means, it may cause higher penetration depth for the same heat, for the same welding heat. Why? Because when you are forcing the metal in the weld pool, so it is causing a kind of turbulence in the weld pool, there by the thermal conductivity. That means the metal mixing is taking place, and leading to, it will lead a better penetration in the molten metal as well as because of the metal transfer is taking place, not only by gravitational force. So, out of position, welding is better done by this method spray transfer mode. Out of position means overhead welding.

Generally, down hand welding is called positional welding. All are out of position, when I am doing a vertical welding or a horizontal welding. Suppose, on the wall, a horizontal welding I am doing, so metal is getting transferred like this. So, there is always a gravitational pool acting. What I am doing over at it? Just the opposite metal transfer is taking place against the gravitational force. So, all metal is not supposed to go up. It is supposed to come down, but it goes up. How well? Apart from surface tension forces, this spray transfer mode helps. So, for overhead welding, it is preferable to have spray transfer.

Overhead welding, if I use a method wherein I have globular transfer, then I will have a very bad metal deposition because metal will continuously tend to drop off only by means of. Because of surface tension forces, some other metal will stick, otherwise it will fall off. So, these are one of the basic aspects. Other aspect is as you can see the varying nature of a globular transfer. So, when it drop, this is a metal drop. Molted metal drop falls in the pool. What will happen, immediately there will be splashing of molten metal, splashing of molten metal leading to spatter. Leading to spatter, that means you will find if you have a well welding procedures, such that your metal transfer mechanism is globular transfer all along the wide line, you will have droplets of metal beads.

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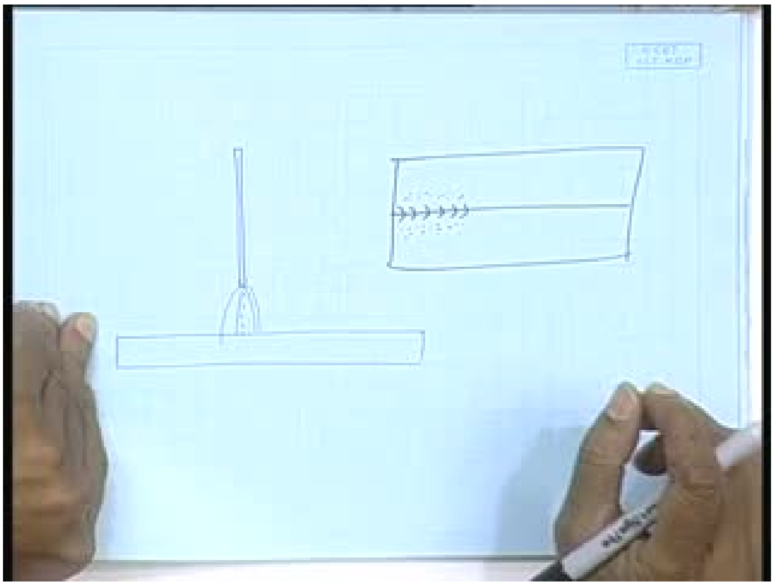

Along the weld, these along, this you have done welding on the sides. You have metal beads, something like this. Suppose, this is your welding line, that means the welding has been done like this you will find all along the drops. Metal bead is nothing, but metal has splashed. This is what is called spatter. Spattering has taken place and this spattering, well not only your weld metal has got wasted, but also it may lead to because when it is falling, it is splashing. It may lead to entrapment of gas and thereby causing porosity also possible.

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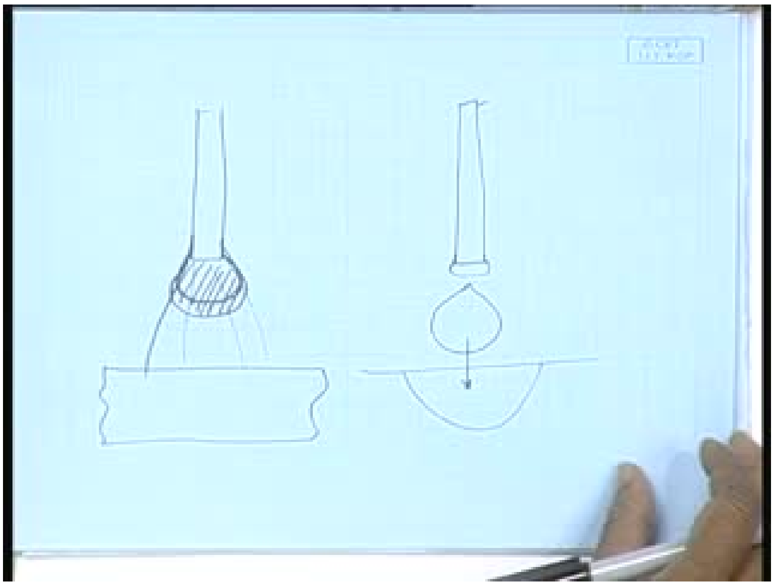

Well, so if we little bit more we look into this globular transfer, but how it really happens is something like this. You have the electrode. I am drawing it in a somewhat enlarged view. So, this welding arc is established. What will happen? This tip will get heated up in the welding arc, start melting, and a sort of a molten ball will form, somewhat like this. It will melt and a globule will form sticking to the electrode. Why will stick to the electrode? Because of the surface tension will stick to the electrode. Gradually, the size will increase with time, it will increase. Still the weight of this ball exceeds your surface tension forces. So, what will happen is, it will get detached.

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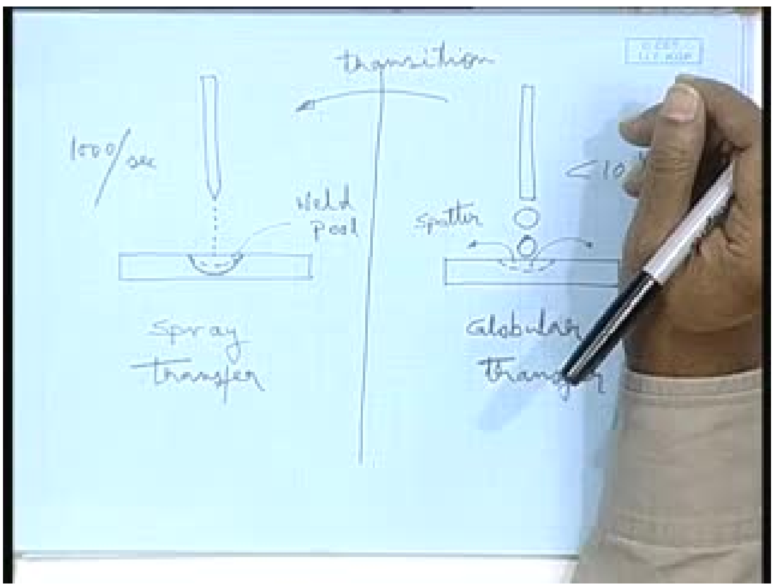

Next stage, it will just get detached. It will get detached and again it will start forming, get detached and in gravitational force, it will drop in the molten pool. So, it is a continuous repetition of this process. It will melt a globule form, grow in size, get detached, and drop. This process will go at what rate? Around few drops per second. So, the diameter of this globule will be bigger than this electrode for obvious reasons, and when it will falls, it will cause flashing and all that. Whereas, in this case, spray transfer mode, the electrode tip will after attains that necessary temperature, it will become pointed. Automatically, it will become pointed and fine drop plates will start coming out.

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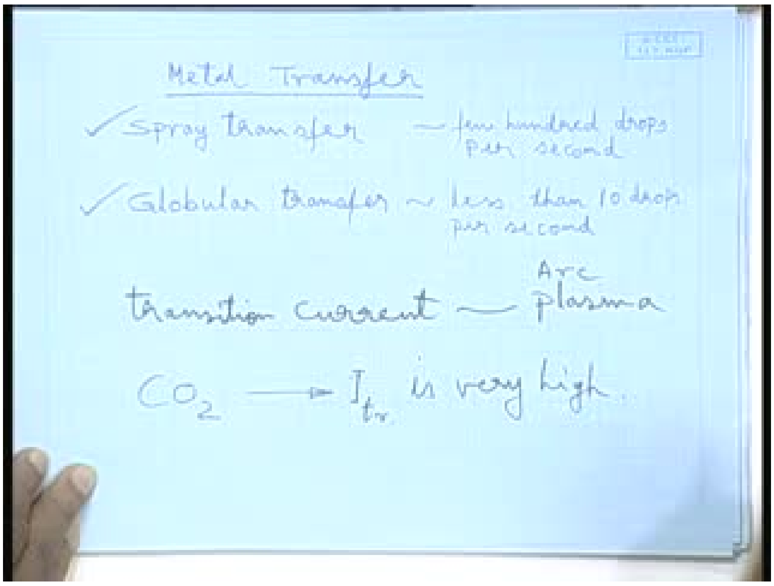

When it happens, well there is when this spray and when this globular mode, the transfer from globular to spray happens with an increase in welding current, there is something called transition current. As we exceed the transition current, then the globular transfer changes about to spray transfer. How much is the transition current? That depends on the property of that plasma column. That means depending on the shielding gas medium, this transition current depends. That means, there is something called transition current and that will depend on the property of the plasma column of the arc plasma.

So, transition current is, that means for spray transfer mode, you always need a higher current for spray transfer. You always need a higher current compared to the globular transfer. So, now if we weld using CO2 as my shielding medium, then what happens, the transition current is very high. What does this very high means? Very high means, thing is like this, if you are welding a 6 millimetre plate, where in you require a current level 300 ampere. Now, just for the sake of converting it to spray transfer, if required is 600 ampere is the transition current, then I cannot go, I cannot increase the current to 600 because what will happen, then instead of welding I will cut through the plate because excessive heat I am giving.

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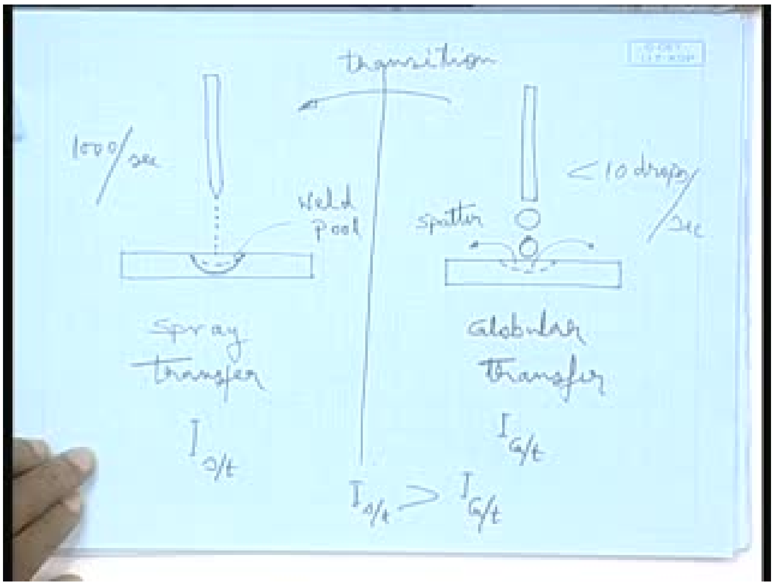

So, whether my welding will be spray transfer or globular heat transfer, though I find that in a spray transfer mode is an advantages mode, I do not have the problem of spatter. I can do good out operation welding. I have a better penetration. All are good in spray transfer, but the trouble is for spray transfer. I need a higher current. Generally, if the current level for spray transfer and current for globular transfer always it is higher. Spray transfer is always higher than the case that with globular transfer.

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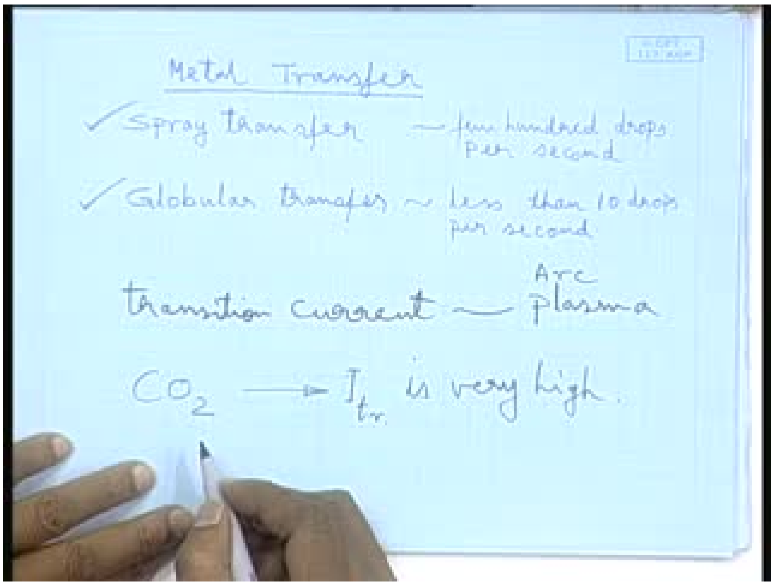

So, for the same thickness of material, if I have to switch from globular transfer to spray transfer, I will have to go for high current and what happens, it is Co2 welding is this high current required is very high.

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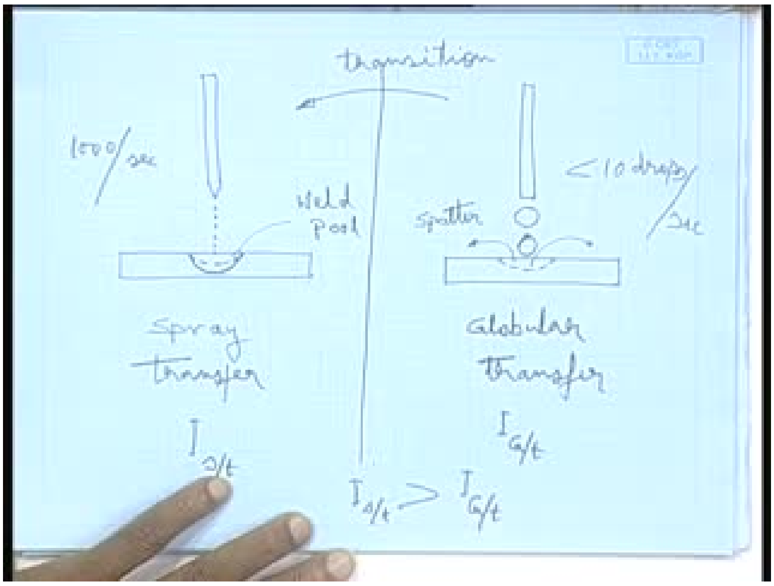

Because of the property of the Co2 plasma, Co2 gets ionized and that form the arc plasma. So, because of its property, your transition current is very high. So, thereby in Co2 welding or welding using Co2 as shielding medium, we never have spray transfer. It is always globular transfer, but still Co2 welding is quite widely used in ship building. That means desperate the fact, that it has lose due to spatter.

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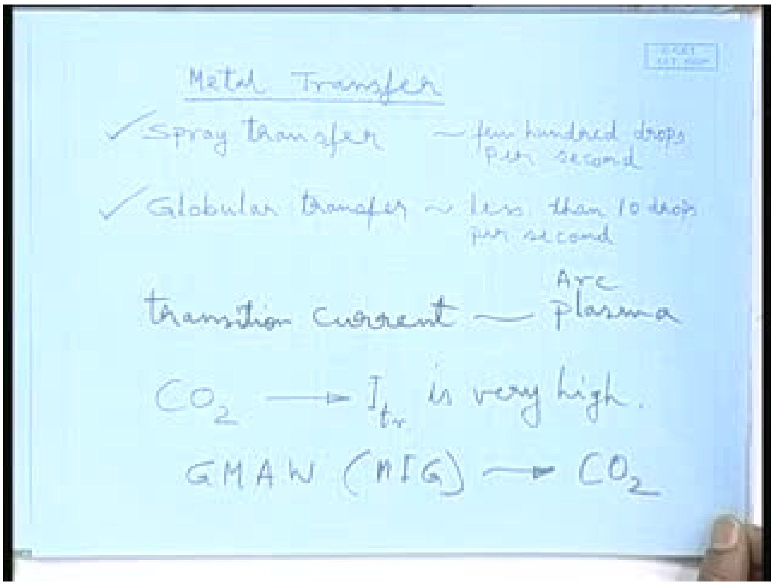

Desperate the fact that there can be some probability of gas entrapment and porosity, still Co2 is used. Why? Because well it has been found that despite all these, it gives us the required quality and Co2 as a shielding medium is much cheaper compared to argon. So, in gas metal arc welding, this is a welding process which is called gas metal arc welding also known as MIG, Metal Inert Arc Welding. Shielding medium for plane carbon steel is Co2 widely used.

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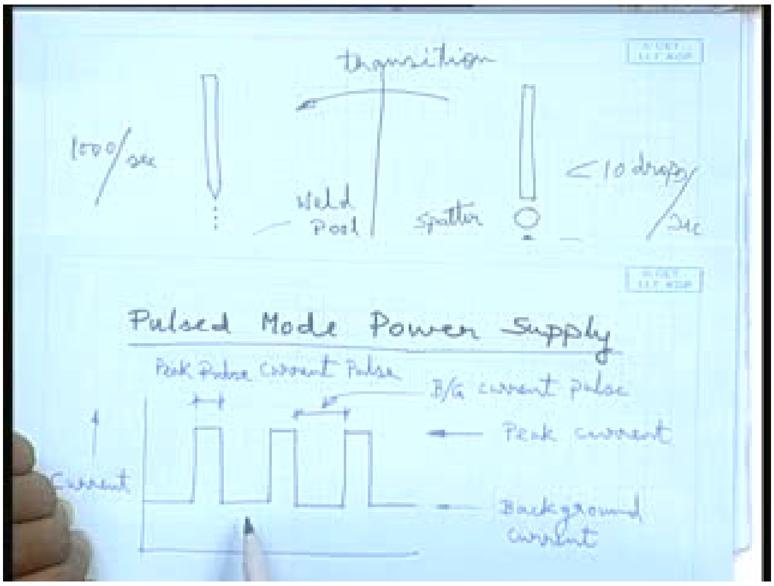

So, that is what in brief about this spray transfer and globular transfer. So, what relation it has with this pulse mode power supply, this is one thing. What we see here that this we had been talking about transition current, I need a higher current to have spray transfer. So, with a pulse mode power supply, I can adjust my peak pulses, such that suppose I give 150 pulses per second means 150 drops will go per second. I can control the metal transfer all together because this spray, this metal detachment or the spray, each droplet will get when I have the peak current.

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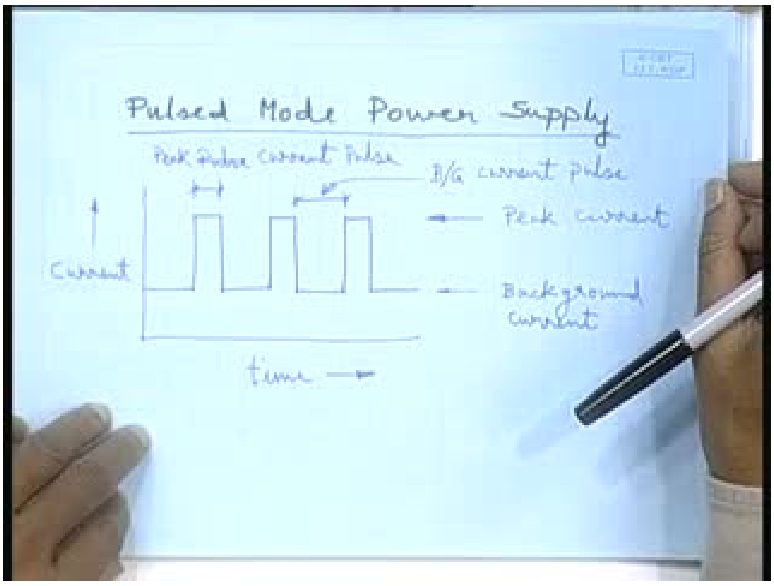

When it is in the background mode, there is no metal transfer. So, if I set the mode of pulse supply that there are 250 pulses per second which will imply 250 droplets per second, so I can control my metal deposition, fine, controlling of metal deposition, fine. Controlling of metal transfer can be done, so with a pulse mode power supply. Thereby, I said the peak current based on the requirement of transition current, I said the peak current pulse time based on the number of droplets to be deposited, based on the metal transfer requirement deposition requirement I said the background current, based on the requirement of keeping the arc ignited

In AC we talked about the arc gets extinguished. It brings in lot of instability, but here what we are doing, the arc is on arc never gets extinguished. It is only thing. It is generating less heat. It is not melting much, but it is keeping the heat on sort of.

So, that is how the background, current background current pulse. Again on the same logic that I am keeping the weld pool in the molten state, it is not freezing of. I am generating enough heat to keep the weld pool in molten state electrode tip just about to melt and then, I increase the current. I get one shot, one droplet out, so that is how all these happens in that speed, means say 300 peaks per second. The pulse is such the 300 peaks per second and so, all these are to be properly adjusted in the pulse mode power supply. You will have mechanism to adjust all these peak current background, current background pulse, all those parameters and you can achieve.

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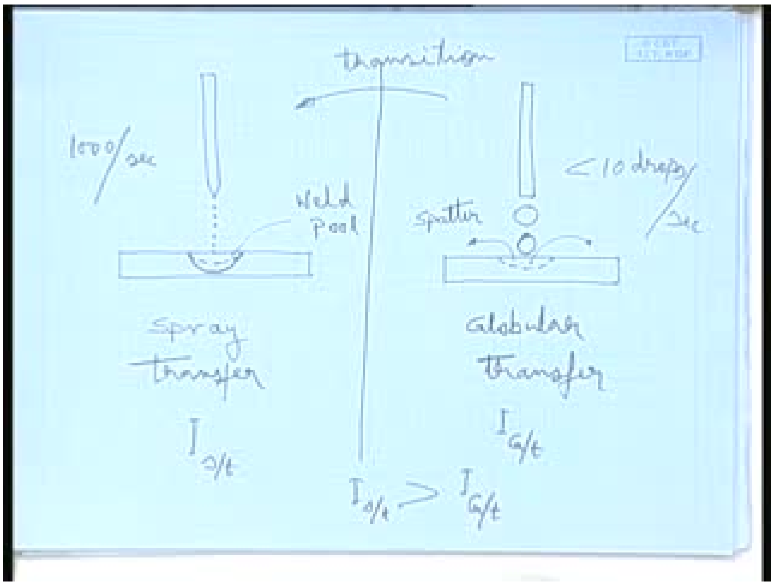

So, that is what is the metal transfer. In general, the metal transfer mechanism as we see that in spray transfer and globular transfer as well as their basic features, what they are about that, means how they affect the metal transfer and the weld quality.

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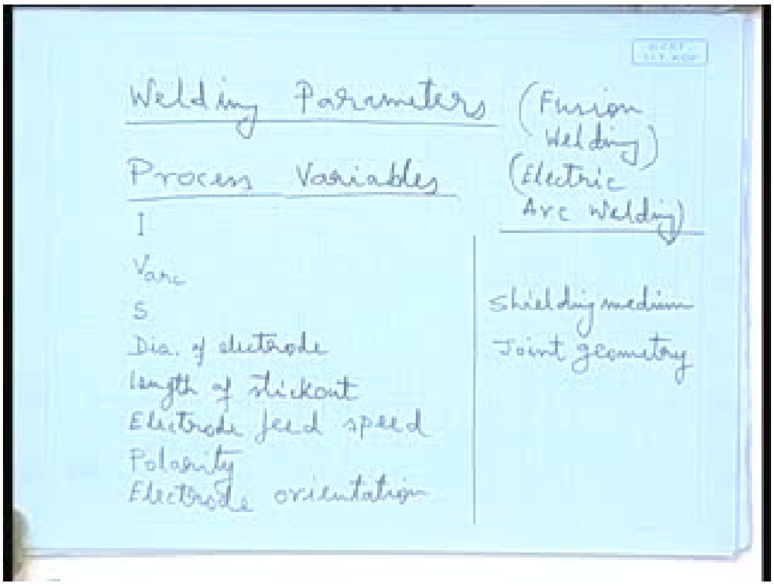

So, as we see that if argon or helium such inert gases are used, then one can achieve spray transfer, but if we use Co2 carbon dioxide, you cannot achieve. Well, so next will go to in fact the welding parameters and their effects. What is this welding parameter? They are basically the process variables. If we talk in general terms, if welding is a process, they are the variables. So, what are the process variables?

Well, first and foremost is the current. We have already talked about it because current is the main source of heat generation. Here, we are talking about fusion welding. This welding parameters, we are talking in context of fusion welding. If it is a different welding process, then weld parameters will be different and not only fusion welding, also in the context of electric arc welding.

So, fusion is being generated through the heat of electric arc because if it is electric resistance welding, then again some of the process variables will be different. What is that spot welding? Again, some of the parameters would be different. So, for the time being, we talk about the fusion of welding done through electric arc welding. So, first and foremost process variable is current, next is arc voltage welding speed, then electrode diameter. This is the electrode diameter. Then, you have something called length of sickout. There is something called electrode feed speed. We will come to that electrode feed speed.

Then we will have polarity comes in to picture. When you do welding with DC supply and generally, as we said DC is preferred. So, polarity plays a role. Then, we have electrode orientation and finally shielding medium. So, these are all my so-called process variables. You change any one of them, your net result of the welding process may change. So, these are the process variables.

Now, we will see and also, well to this we can also add one more, that is the joint geometry. This is an indirect process variable means, I am doing the welding. Where I am doing the welding? The geometry of that particular joint, if that is different then also some of these variables I will have to modify. I will have to change, otherwise my end result that means a intrical joint defect free joint, I will not be able to achieve.

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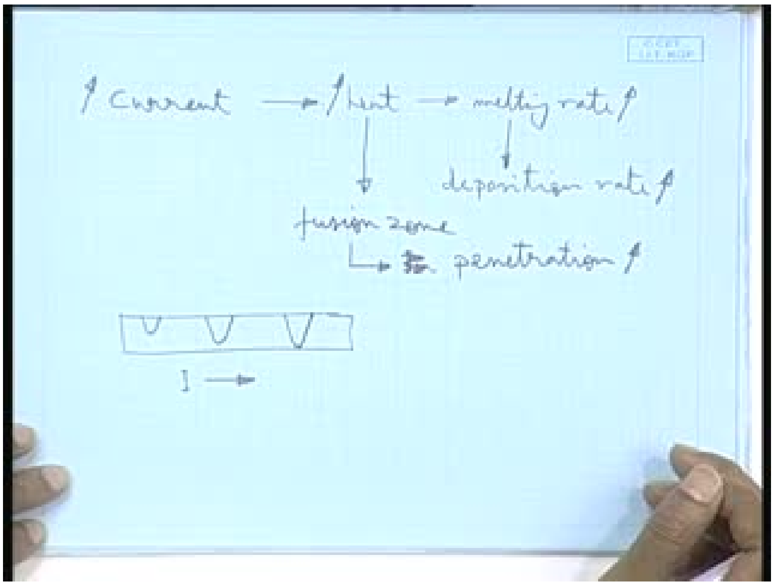

So, these are the basic process variables. Now, in brief we will see what are the effects of them with welding current? It essentially effects the heat generation, thereby it affects melting rate that influences deposition rate. By deposition rate you mean, how much metal filler, metal is melted and deposited. So, increasing current I will have that more metal imbalance. So, deposition rate will change also. Also, heat will affect the fusion zone. Basically, it will increase penetration with increasing current. Basically, it will affect the penetrating power means, if I increase current, penetration will increase. If I increase the current, heat will increase, melting rate will increase, deposition rate will increase, and penetration will increase.

So, if I am shifting from welding a 10 millimetre thick plate to a 20 millimetre thick plate, naturally I will have to increase my current or I am welding a 10 millimetre plate, let say 300 ampere, I will attain a certain level of fusion. I increase the current, the fusion level will increase. This is the current increasing the fusion level. This is the fusion zones as I have drawn. As the current is increasing, for the same thickness fusion will increase.

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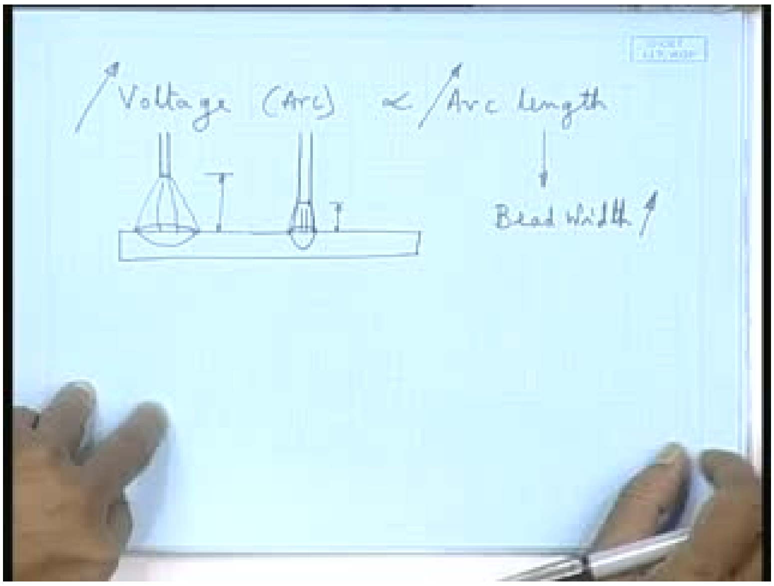

So, that what is the brought effect of current, about voltage. This is the arc voltage. That means, voltage drop at the arc voltage drop. At the arc means, if I have a, so what do you see from this. These two figures is that in one case, my arc length is quite high and in another case, my arc length is quite small. So, your voltage is directly proportional to basically arc length for obvious reasons because arc voltage is nothing, but voltage drop at the arc. So, it will be proportional to the arc length.

So, if I increase the arc length, my voltage drop at arc increases. What does that cause? That cause widening of the welding arc. Width of the welding arc increases when I reduce the arc length. Voltage drop reduces, the arc becomes narrower. If the arc length become too small, arc may become so narrow, it becomes unstable miniature. Middles transfer will not be proper if I increase the arc length too much. It becomes so wide. Again, it becomes unstable. So, that is how it affects arc length or arc voltage.

At the same time, what happens when I am having within the limits of maximum arc length to minimum arc length, then just by changing the arc length or changing the arc voltage, I can change the big size deposition size. Here, I will have a weld deposition like this. Suppose, for a given certain current is my penetration depth and in this case, your penetration would be little more, and the bead size will be narrower.

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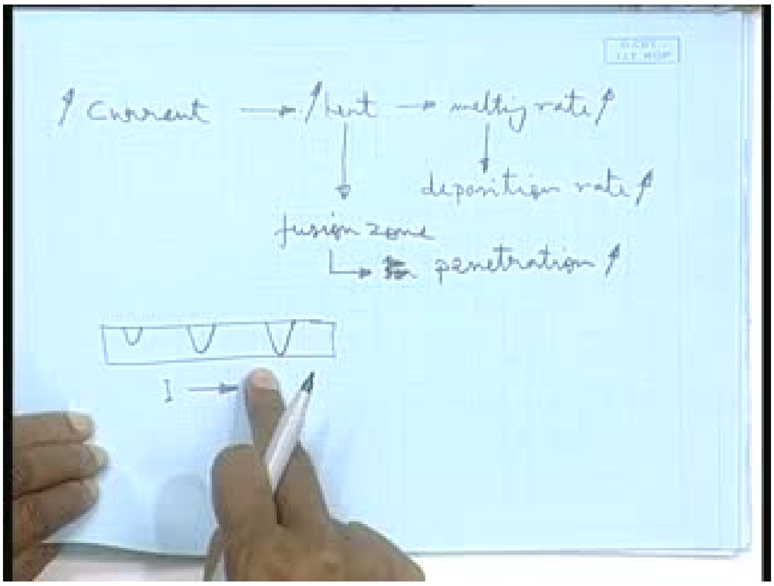

Means with wider arc voltage, with higher arc voltage because arc voltage will increase with increasing arc length. If it increases, it gives wider the bead width. This is called weld bead. The width of it increases. These arrows are to show the variations as the arc voltage is increasing. Essentially, it means arc lines are increasing. It is coming to this situation. So, thereby we see the bid. This is the weld bid. The width of the weld bid becoming wider when the arc voltage is low, weld bid is narrow arc, that is, what is essentially the effect, broad effect. All these, we have to take even we talked about current. As a current, I am increasing penetration is increasing, but width has remain somewhat same. Obviously, it will increase marginally, but more effect is on the penetration, more effect is on the bid, on the surface, but all these assuming all other parameters remaining constant.

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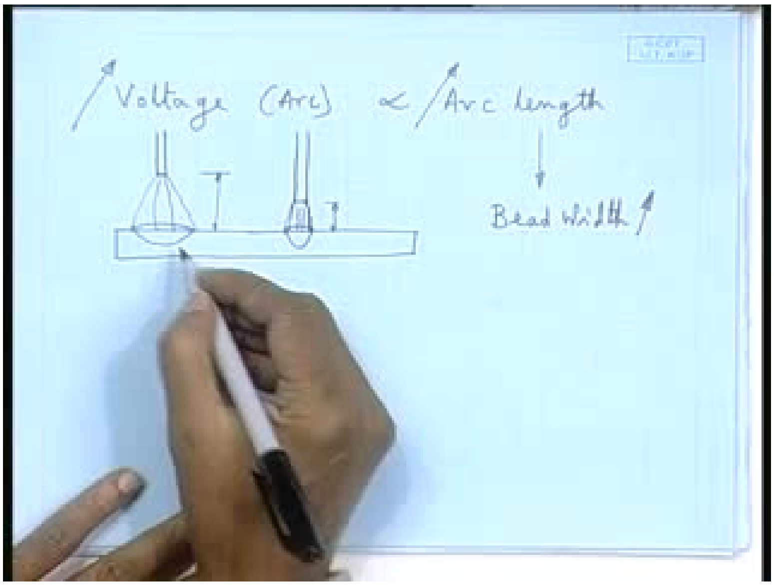

So, individually you are seeing, keeping all parameters constant. If I change current, this will happen. If I change voltage, this will happen. Similarly, if I go for speed, next we have talked about is here (( )). Here, I have marginally shown there is a little low penetration with a higher voltage and little more penetration. It will lower voltage. This is marginal effect. I mean penetration is not much effect. This is because the heat is more distributed on the surface here. Heat is more concentrated, so heat flow along the thickness will be more. So, effect, yes so that is why here we talked about only bead width. This is the primary effect, this is marginal. So if I have to increase penetration effect. I do not increase voltage, I actually try to increase current.

So, that is why in case of current, we have talked about this. Substantially is changing the penetration, whereas with voltage, substantially the bid at the surface, it is changing. There will be a marginal if you see also here. Though, I have not drawn very nicely, but still it is a marginal increase, but there is a substantial increase. That is what I want to highlight, the bid width. That is how, but obviously when you increase current substantially, then also you will have to increase voltage because there should be parity always. That is a different issue. Here, what we are talking about as if we are keeping all of the parameters constant, only one parameter at a time we are changing just to see its individual effect.

So, individual effect of current is essentially generation of heat and thereby, penetration individual effect of voltage is essentially widening of the arc length. Thereby, width of the bid profile, it is on the surface effect.

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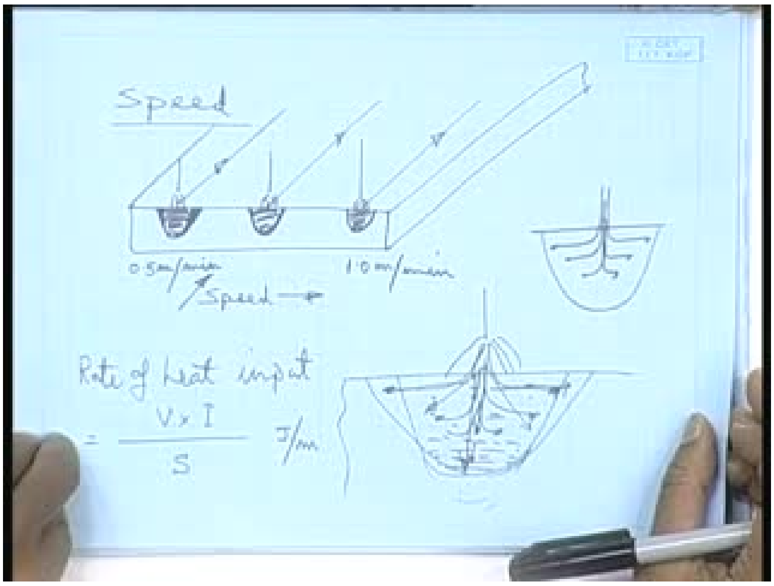

Next welding speed. This speed is welding speed. What is welding speed? It is the movement of the electrode because in welding process, we have two fundamental movements. One is the feeding of electrode and another movement of the electrode. As the electrode is moving, essentially the heat is moving, the arc source is moving. So, what happens with increasing speed or changing speed rather? You know if I have the welding being done at a certain speed, here we are just drawing as if in one section, three different electrodes with a different welding speed. We are welding as if this is my plate. What we will see as you go on changing the speed, say for a given set of current another parameters I increase the speed gradually.

So, what I am trying to show here is, here the speed is increasing. As I am going from this electrode 1 to electrode 3, the welding speed is increasing. The welding speed is increasing as I am shifting from electrode 1 to electrode 3. So, if the speed is less, means what I am giving more time for the heat to flow. Speed less means, I am holding the heat source at a point for a longer duration. So, I am giving more time for the heat to flow. So, if I give more time for the heat to flow, means more material will attain a higher temperature, will lead to a higher penetration, also higher bid width because overall fusion will be more, but as you can see the way I have drawn, try to draw here. Say here, we have shifted from 0.5 meter per minute speed to 1 meter per minute. Doubled the speed, but the change in the penetration is marginal, not much. That means by increasing, by decreasing speed I will definitely attain a higher penetrating power, but that is marginal, not like in the case of current. There it was substantial. But it is marginal.

So, if I want to achieve higher penetration, I do not actually decrease speed. I will rather increase current. Why? That happens, but logically if I hold the heat source here for a longer time, more metal should have at melted. That does not happen because what actually happens is, suppose this is my molten pool, molten metal and you know the arc is at the surface, so heat is getting conducted. Molten metal has a low thermal conductivity compared to the solidified metal thermal conductivity. Reduced thermal conductivity of metal is a function of temperature. It drastically reduces.

So, the molten metal at the bottom of the pool surface acts as an insulating medium means, not much of heat is transmitted. So, as the pool depth increases, beyond a certain depth, it will not increase further. I have shown that as the speed decreased. As we go left, there is somewhat increasing in depth, penetrating depth, but not substantial. Why? It is because it has attained saturation. I go for further lesser the speed 2.2 meter per minute, I will have more or less the same penetration

Well, because this depth has increased, so much has gone, such that it is giving an insulating effect, it is not further heat is conducting, such that more material gets melted. No, it is not happening, but in the process what will happen, there can be a case of this side widening. As I reduce the speed because this distance could be less, so heat is also flowing and here the heat flow is more on the surface. Gradually, it is reducing as we go down, the heat flow is reducing because if I see the heat flow will be more as I go gradually down. It will be gradually less and less, so with lesser welding speed, it may become wider and also what is happening with the speed is one of the important parameter for productivity.

If we can set the parameter in such a fashion that I can achieve a higher speed of welding, means I have my productivity increases. So, that way, it is one of the production characteristics, important parameter in welding. I should try to set all the parameters, such that I can attain the maximum possible speed. My productivity will be high. Another aspect of positive point of trying to achieve high speed is how much heat is going into the plate. That depends on the speed. Actually, rate of heat input because important is rate of heat input, how much heat is going in, how much heat is going in. It is given by your voltage into current divided by speed. So, this is so many joules per meter. So many joules per meter voltage in current is the absolute heat that is getting distributed as I am. So, if I increase the speed, this joules per meter reduces is not it so less amount of heat is going at a time at a point. So, less heat is conducted, so less deformation.

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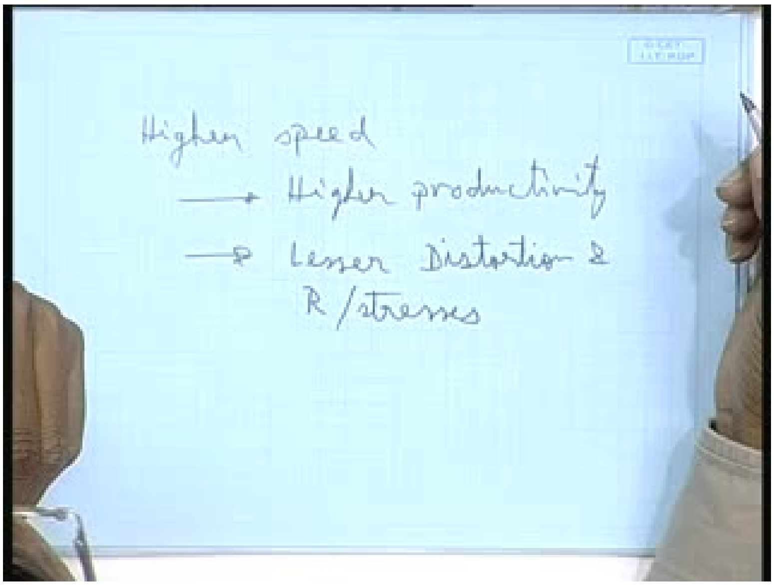

So, higher speed of welding is desirable. Higher speed is desirable from two basic aspects. It gives higher productivity and also it gives lesser distortion and residual stresses. So, two good aspects, so we should be able to achieve a welding procedure should be able to set welding process variables, such that I can achieve higher speed. Then, we have these two good aspects.

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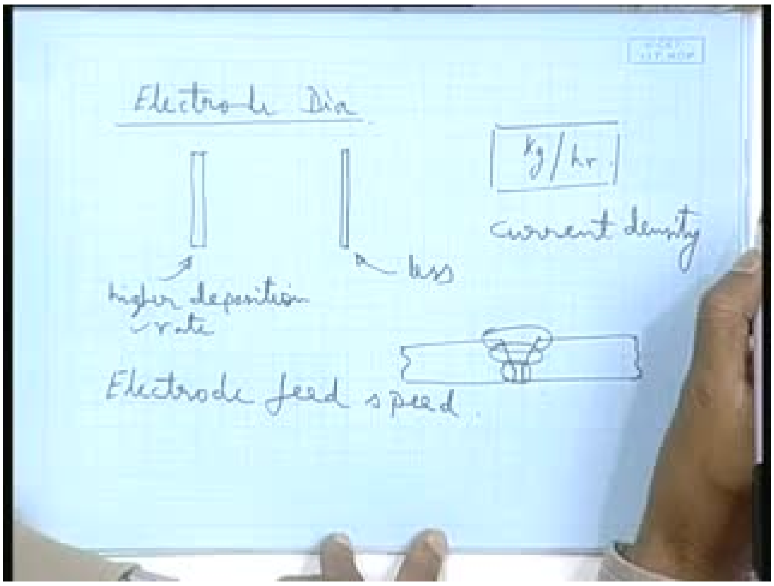

So, that is what is the effect of speed. Then, we see the effect of diameter of Electrode Dia as well higher the Electrode Dia. Obviously, you need for a given set of, well when you need a high deposition rate, means more metal has to be deposited. High deposition rate essentially translates to higher productivity also because many times, welding productivity is calculated by way of how much meter you have welded or by how much material you have deposited. More frequently it is in terms of so many kilograms per hour. This is the measure of welding productivity because how many meters you have welded again, it is little wage. Whether the welding is complete or not, I have welded 10 meters, but it needs to be re-welded again. Not re-welded, I would say another run has to be given because there can be a case of multi run welding is not it this is. We are talking about joint geometry. This is one of the joint geometry.

Suppose, I have the joint designed like this, I have given 1 run, 10 meters I have welded. I will have to give one more, probably another 3 runs. So, it is more important to talk in terms of how much of material has been deposited kilo gram per hour. So, a welder to assess how much work he has done, we will be assess through how many electrodes he has consumed or how much of material he has consumed in his working shift. So, that comes from this aspect of deposition rate. Now, to increase deposition rate, you have if I increase the electrode diameter, obviously it will give me higher deposition rate for the same feeding speed. There is something we have electrode feed speed along with this is the electrode feed speed.

So, if the electrode feed speed is kept constant with increasing dia, I have higher deposition rate with less, obviously less, but at the same time, when I am increasing the diameter, I will have to simultaneously increase current also because I need equivalent amount of heat to be generated. So, naturally with increasing, I will have higher current, but if I think in terms of current keeping constant, I am just shifting from 0.8 millimeter dia to 1 millimeter dia which is not a substantial increase. So, I may keep the current same. So, what is the effect? Overall effect would be lesser diameter means higher current density. Lesser diameter means higher current density. So, with higher current density, I can achieve a better penetration.

So, that is also is there that means electrode dia is not only to be related to the deposition rate, but also to current density because with less diameter of electrode keeping same current, I have achieved a higher current density and thereby, penetrating power is increased. So, that is how the electrode diameter plays a role.

Well, I think we stop here today. We will continue tomorrow with the rest of the items and then, in brief we will see what are the various welding processes used in ship building industry.