Marine Construction & Welding

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Module No. # 01

Lecture no. # 27

Welding methods

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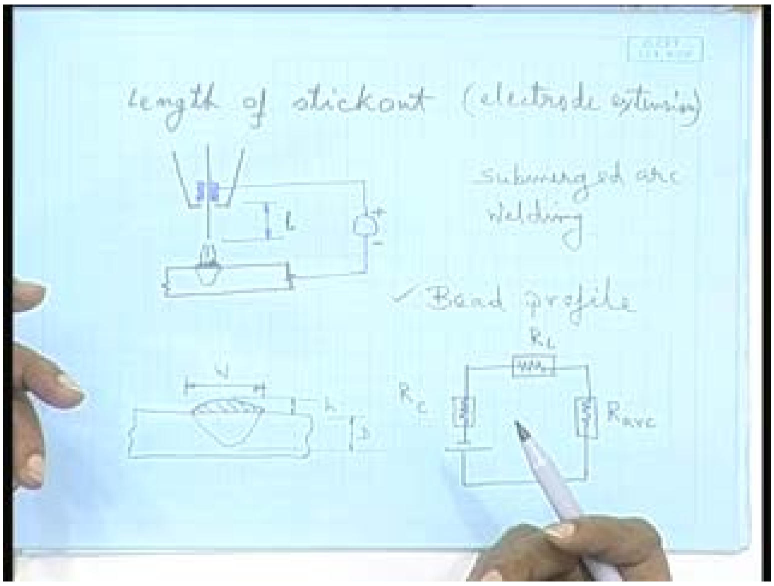

Well, today we will take up welding methods, but before we go to that, some bit of welding parameters are still left. Let us continue with that. We have seen the effects of current voltage speed diameter of electrode. Now, let us see what length of stick out is. Something I talked about is length of stick out or which can also be referred to as electrode extension. Well, this particular parameter is start relevant in all type of welding processes.

It is relevant in some such situation, where you can see, I have schematically drawn this by welding so-called torch through the centre. You have the welding where or the electrode coming out, wherein the power is fed at this position. The power to the electrode is fed. So, let us assume the power is being fed here, and the job is connected to the power and this particular length, which is sticking out from the welding torch is referred to as the length of stick out. This length of the electrode as you can see in this figure, so that is what is referred to as length of stick out. This situation occurs in a welding process called submerged or welding. We will see what is this welding process little later, submerged arc welding in this particular welding process.

This situation arises, means this particular aspect of length of stick out plays a role in the welding process. It plays a role in the well deposit. How it affects the well deposit or the bead profile? This is a term. Bead profile is nothing, but when you do the welding, what you see on the top is the weld bead what has been deposited. So, it has a width bead width, it has a height bead height. So, this w and s defines the bead profile. This length of stick out plays a role in the bead profile as well as plays role in the fusion depth.

This is my fusion depth, like we have seen the welding speed or the arc welding voltage. All that has or welding current has an effect on all these fusion zones, fusion depth, bead profile. So, similarly length of stick out plays a role. What happens is if I make a small equivalent circuit of this, if I draw, it would look something like this. You have the, say there is one resistance. You have the power supply here. I put another resistance like this. So, this is my load resistance or the arc resistance. That means, the resistance of the arc column, this is my, well say resistance in the circuit or in the cable resistance, internal impedance etcetera. This resistance is due to this one. This length if stick out, if I increase this length, this Rl increases because current is flowing through this. In this cabling, you have RC. This column you have R arc, and this length of stick out, this electrode extending the small part, that is Rl. So, if I increase the length, I have higher Rl. If I decrease, the Rl is less.

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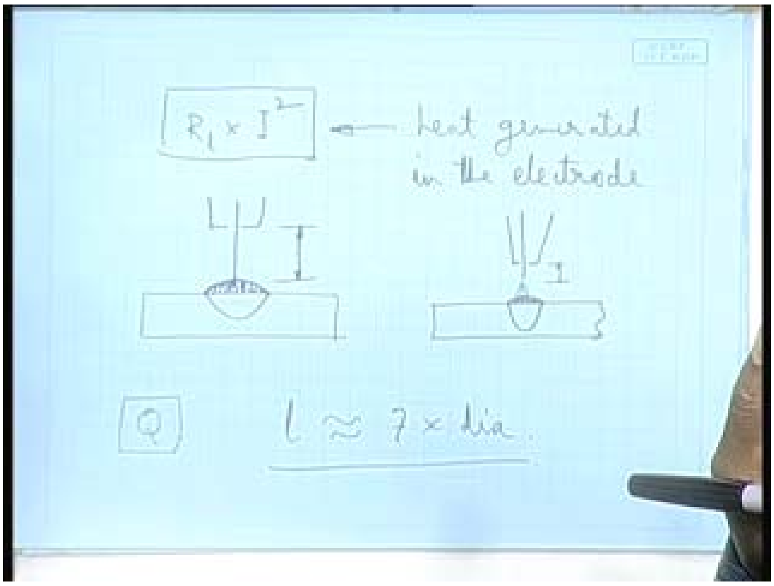

So, what happens, this R l will contribute towards the heat generation also. How? Because through this R l, this current is passing, welding current. So, this much of joule heating would be there. That means, if R l increases, this part increases. That means heat generated in the electrode. Which part of the electrode? That electrode extinction, that part, the heat generated in this. So, what is happening, this heat gets added up to the heat due to the arc column. So, over all you have, if my length of stick out is more, I have more heat, but more heat in the electrode, not in the job.

So, if a situation is like this, so I will have more melting of the electrode. If I have a smaller length of stick out here, I had higher length of stick out here. In this case, I have a smaller length. So, what happens is your R l is less. In this case, R l is high, so here your bead width or the bead profile would look something like this. What is the difference? That means in the second case I have more penetration. Why more penetration? Because ultimately the same power is being used, the total power is remaining same. The total power is essentially spent. Total power is same when I am increasing this. So, I am having some of the power dissipated in the length of stick out, and that is getting heated up. So, more melting of electrode is taking place, additional of melting electrode is taking place. So, I have a higher deposition. So, I get a wider bead width, a higher bead profile, more deposition is taking place. So, less heat is going into the best metal, so thereby I have little less penetration, whereas in the other case, less heat is generated in the electrode extinction, so less melting of the electrode.

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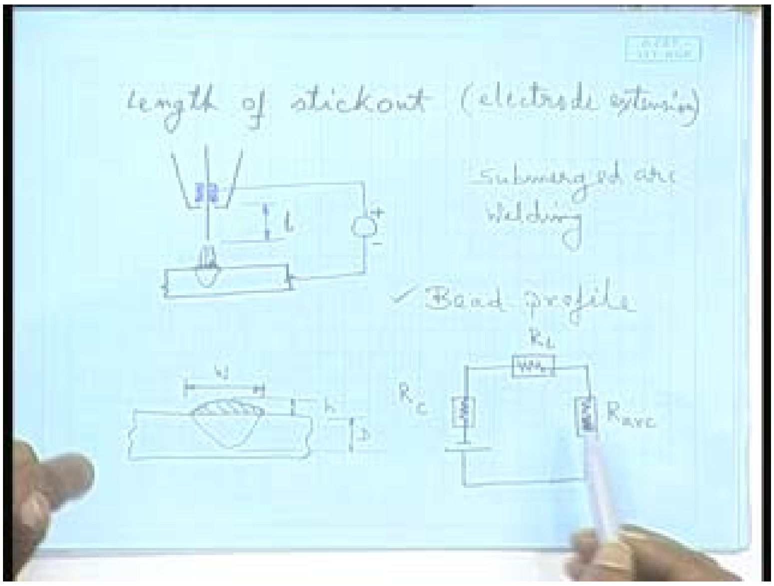

So, I have a narrower weld bead, and more heat is going in the best metal. So, I have more this thing. A penetration part means what is happening the total power in the circuit is remaining the same. Here, I do not have the drop here. So, then if R l is less, then what is happening, my current for the same potential, my current will be higher. So, that current will work here. That R arc, the heat generated in the arc will be more. If this resistance drops, then over all current will increase.

So, heat generation in the arc will increase, and the heat generation in the arc increases, more heat is going in the plate because the arc heat is directly going into the plate. Here, the joule heating or that I square R l heating is taking place in the electrode. It will melt extra electrode here because I am having the resistance more, here I am having resistance less. So, R l is falling, I is somewhat increasing, but R l is falling that effects and also, this becomes more prominent when there is a certain level of current density. Of course, this becomes more prominent. If it becomes more prominent when you have a certain amount level of current density, I do not recall immediately. That means a certain level which the current density more than the effect of length of stick out is more prominent.

So, when you need a wider deposition, you get a longer stick out. When you need a narrower deposition, you give a lesser stick out, but you go on increasing the length of stick out, go on increasing this. R l does mean that your melting rate of electrode will go on increasing. It will have other adverse effect. When the electrode length will be, it become too long, then what happens is the electrode is getting heated up. So, it loses its directional stability. When it is coming down, then it may not go properly down to the welding joint.

So, generally this length of stick out taken is of the order of 7 times, that diameter of electrode generally. So, this is a, though I mean it is not a parameter which is to be this. These parameters are for fine tuning of weld profiles, bead profiles, primary is voltage current speed, all that, but they can play an additional role. That is how and well, as we see this primary, this becomes effective only in case of somewhat dark welding. Next was electrode polarity.

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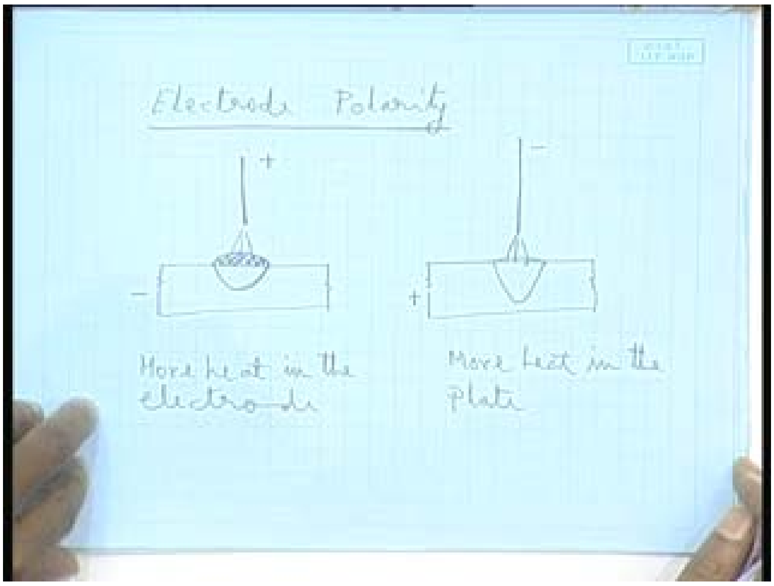

As we have said that, we generally go for DC power source. So, that means there is a positive negative thing coming into the picture. So, electrode polarity plays an important role in the bead shape. As we can see, if I keep the electrode positive, and the job or the metal piece negative, then I get such a situation where in I can see that I have a thicker weld bead. Whereas, in the reverse case, if I make the electrode negative, I have thinner weld bead and differ penetration. That means, when electrode is positive, more heat in the electrode. Here, in the reverse case, more heat in the plate.

So, if there is more heat generated in the plate, then I have deeper fusion, deeper penetration. If I have more heat in the electrode, I have more melting of the electrode. So, lesser fusion because there heat is constant, so less heat is going into the plate.

Hereby, your fissional will be little less, will be less, and your bead will be thicker. So, if you have weld, a thinner metal, then probably it is preferable to have the base connected to plates, connected to negative terminal and the electrode positive because if say, a 4 meter plate of being welded, I connected to positive terminal, it may cut through. The penetration may become too much. It may cut through. So, yes this happens. Well, this happens. Why it happens? Because when you have the electrode positive, and the plate material negative, plate material negative means, it is connected to the positive terminal and it is connected to the negative terminal.

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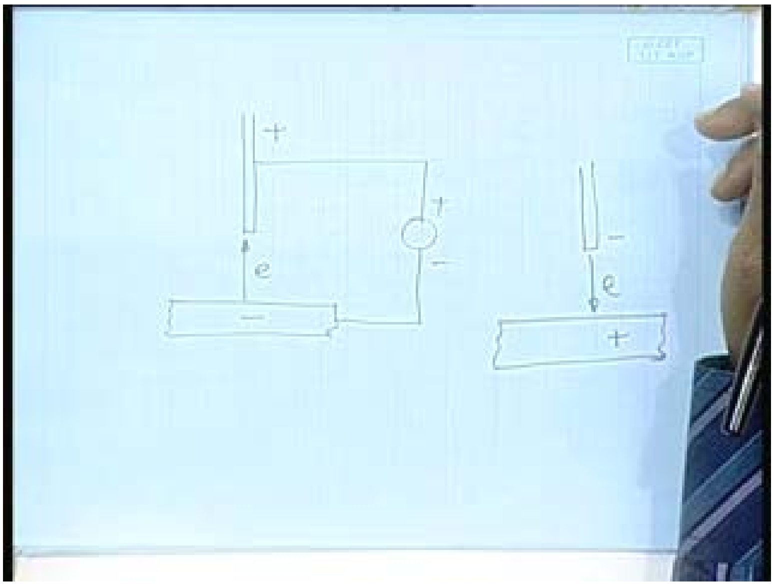

So, we know that the electrons, they move from the negative to positive. Though the direction of the current flow, we say that positive to negative, but if you concentrate the movement of the electron as if they move from the negative port to the positive port. So, there will be a kind of flow of electrons taking place in the reverse direction. So, these electrons, they apparent I mean, well why the heat is generated? This is explained in this fashion, that is the electrons, they bombed on the metal electrode tip thereby increasing the heat there. In the reverse case, when in the reverse, it is just reverse means electrons; they may come and hit the plate, more heat in the plate. That is how the terminal which is connected to the positive pole generates more heat and thereby more fusion.

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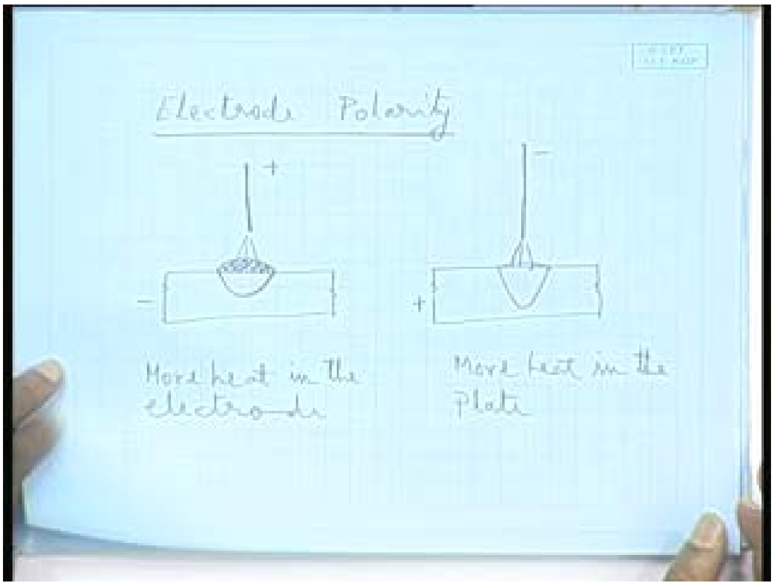

So, more fusion means, leads to higher penetration if the plate is connected to positive and needs to higher deposition, if the electrode is connected to positive terminal.

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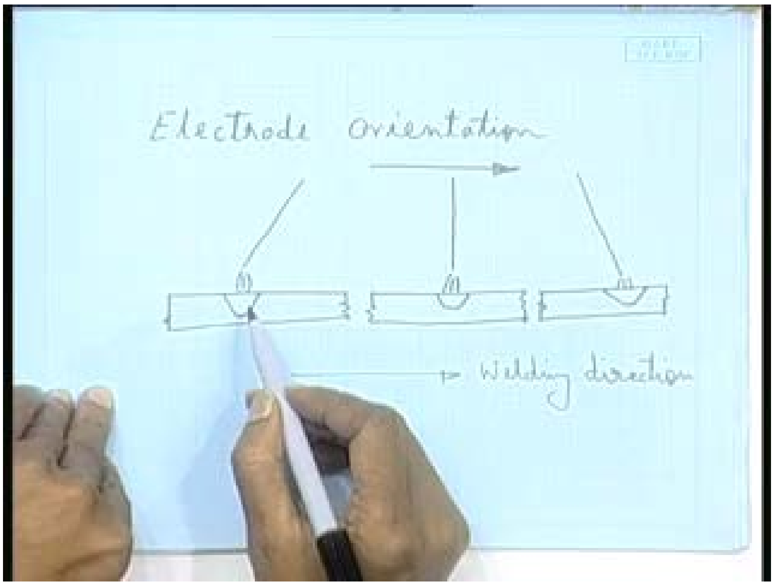

So, that is how the electrode polarity, it plays quite a significant role in the formation of the weld bead. There is another thing, another aspect which is electrode orientation. Here I have drawn 3 pictures. This is my welding direction. In one case as if I am dragging the electrode here. In this case, I am giving in vertical line moving. In this case, I am pushing the electrode as if pushing it. So, in one case, it is dragging neutral, just metal vertical.

Another, just it is pushing. So, if the electrode orientation is changed, then also it has been observed that you have some changes in the metal deposition, as well as the fusion zone pattern, as well as in depth of penetration.

In case, when I am dragging the arc, it is observed that you have more, what do you call penetration reverse. When I am pushing it, it is observed, it is having less compared to the dragging one, little less the movement. It is always like this. The movement you have less penetration, you have wider profile, wider bead width. The movement you have deferred this thing, you have bead width little reduces because the heat is constant. More heat is going down.

So, less is going in, in the top surface. No, it is not a question of better or worse. It is essentially well. If you really think better, then well it deferred penetration narrower is the better. Why? Then, what is happening in that case, your heat available at the upper layers of the plate, and the bottom layers of the plates that the difference is less, bending will be less because bending movement generate will be less, deformation will be less. So, there is something called laser welding.

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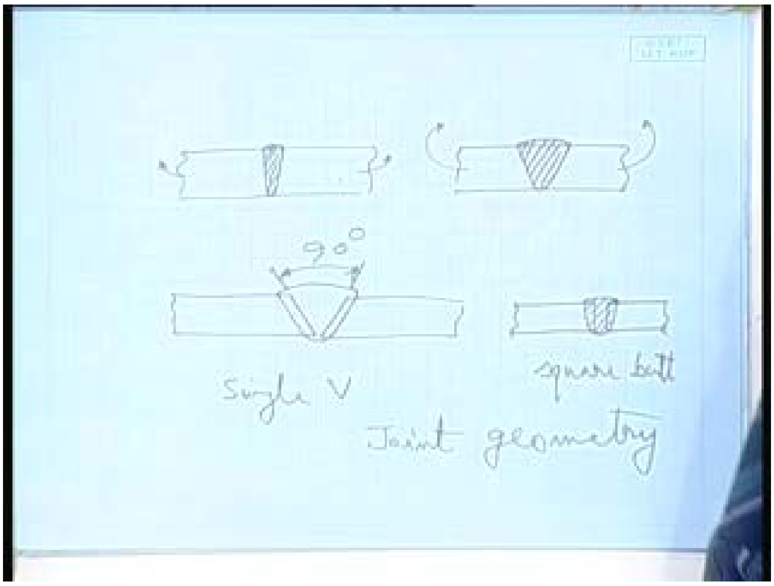

In laser welding, even one can have a bead as narrow as like this. So, this is definitely better compared to a bead shape of compared to a fusion zone of like this. This will generate the moment. Here generated would be much more than this one because here there is a temperature gradient will be less across thickness. We have seen the movement is generated because of the temperature gradient along the thickness. Here the temperature gradient is less, here it is more.

So, obviously a welding procedure which is giving a more uniform fusion all through, the thickness is preferable, but of course that is not only the deciding factor always because when you do aluminium welding, you will have to have a welding variant. The edge preparation is very wide 90 degree. That wide edge preparation is there.

There is some other reason because preferably, of course without edge preparation, it is called square butt. Square butt means remaining square. This is called single V. In square butt, what is happening is when I am welding, my fusion zone tends to be more uniform automatically, more uniform compared to this here. Because of my edge preparation, my fusion zone automatically is very wide, I mean very much V shaped.

So, we have more of this bending. That means from deformation point of view, this is bad, but there are other overriding factors for aluminium welding, where you will need a very wider edge preparation, but steel, that problem is not there. So, in steel plate welding, we will try to keep the angle as well as possible, but well objective is not only to minimize distortion, but also to get the proper fusion and proper joint. So, keeping everything into account, we will have to see, but design the joint geometry. So, that is how joint geometry also has a role to play in (( )). Yes, so those things are to be sent. How to prevent that little bit will see that.

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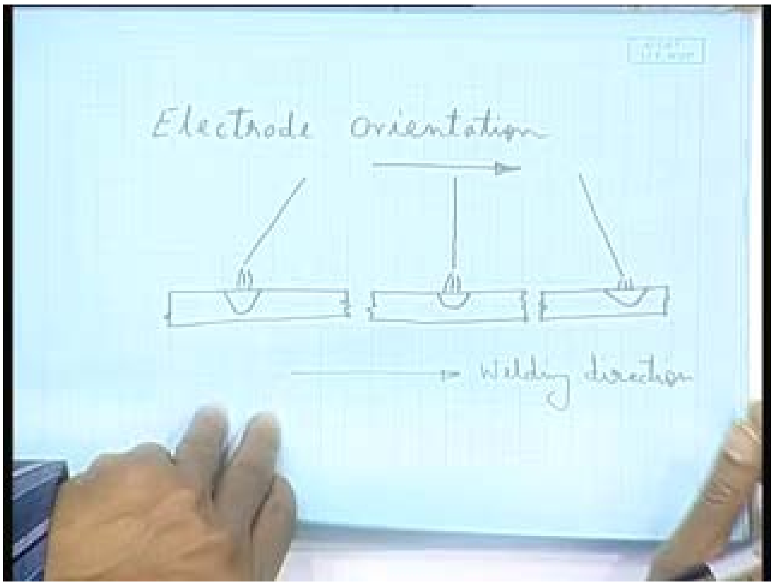

In any case, so electrode orientation we see, if it is a case of dragging, we have a little more of penetration. If in the case of pushing, it is little less. This happens apparently because of the dragging of the electrode, and pushing of the electrode the behaviour of the arc changes. Behaviour of the arc changes because of the angle, and this pushing orientation, this angle dragging orientation and there by the fluid metal movement in the weld pull changes. In one case, we have higher sort of little higher penetration and other case, little lesser penetration and well, vertically electrode just in between these two.

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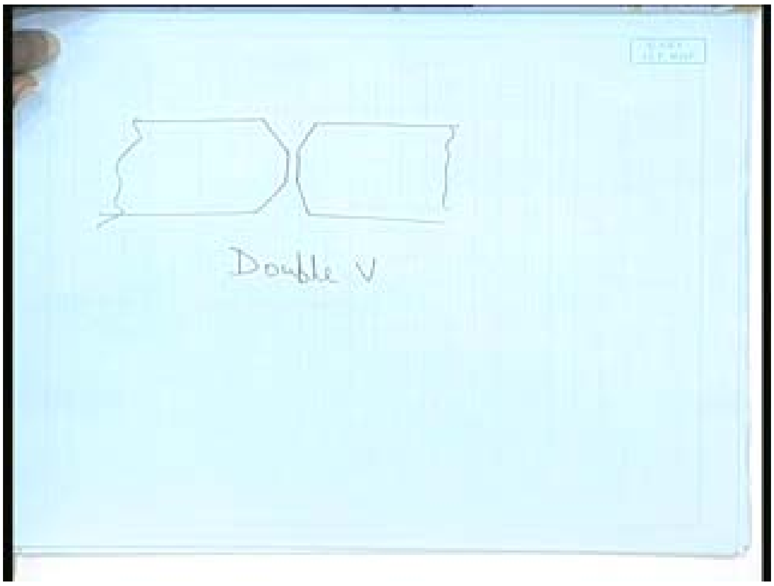

Well, joint geometry as we have been talking, single V square butt. If I welding a thicker metal, much thicker, then we use some such joint geometry which is referred to as double V. This is a double V.

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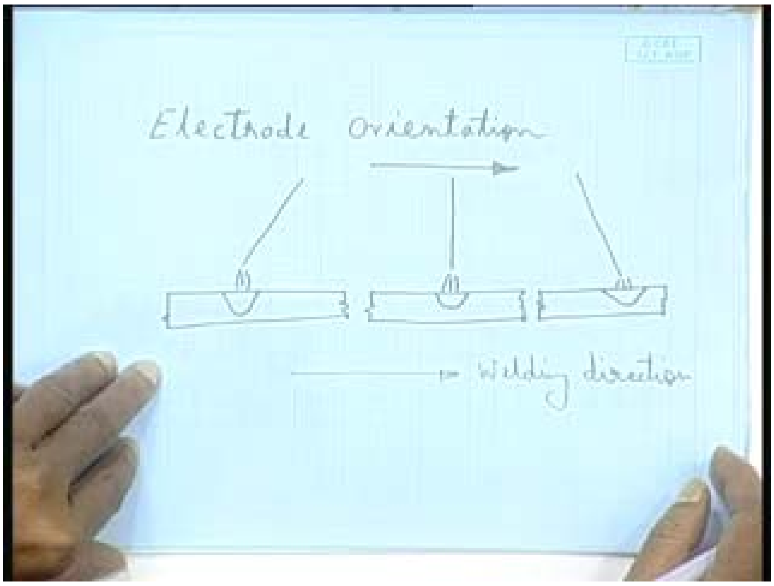

One V this side, another V this side. (( )) yes electrode orientation. What I have been saying in this case, it is dragging the arc as if dragging the arc. So, here because of this in the dragging situation, the arc behaviour and thereby, the fluid metal movement inside the weld pool is affected.

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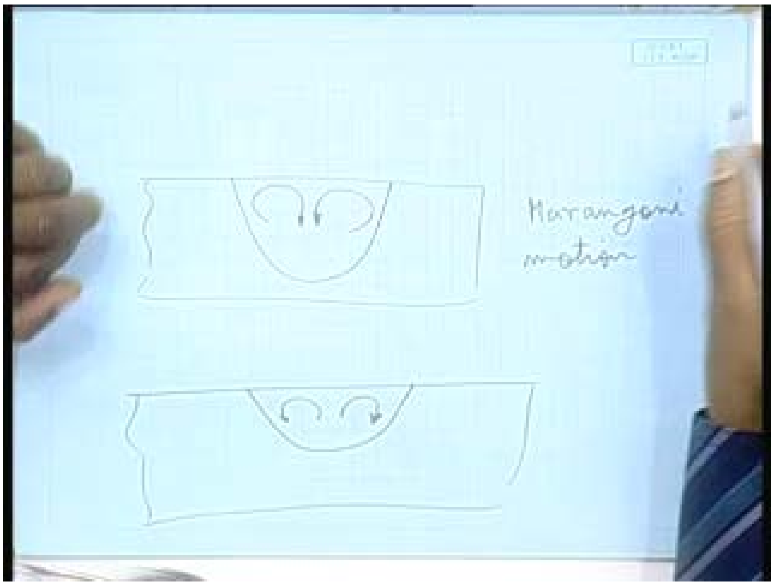

What happens in the weld pool? When you have the molten pool, so depending on situation, either the molten particles will have a motion like this or it will have a motion like this. If it has a motion like this, then you have a wider profile, lesser penetration. If you have a motion like this, more penetration, lesser this thing because this is as if hitting downwards, it is hitting outside on the boundaries. So, it has become wider. It is becoming narrower and deeper. So, depending on, I mean these things happen. Also with the electrode polarity, it changes and also because of this dragging and pushing.

In case of dragging, it is possibly this kind of movement occurs because this will be difficult to confirm because to see what is happening in the small weld pool at that temperature, seeing is very difficult because it is a high intense light to filter out that and photographing. That is extremely difficult. These are called Marangoni motion. These are affected by the electrical field generated there because of the convection forces generated in that convection current, thereby established in the molten pool. It is a very complicated phenomena takes place there. So, either it will have this kind of circulation or in the reverse circulation.

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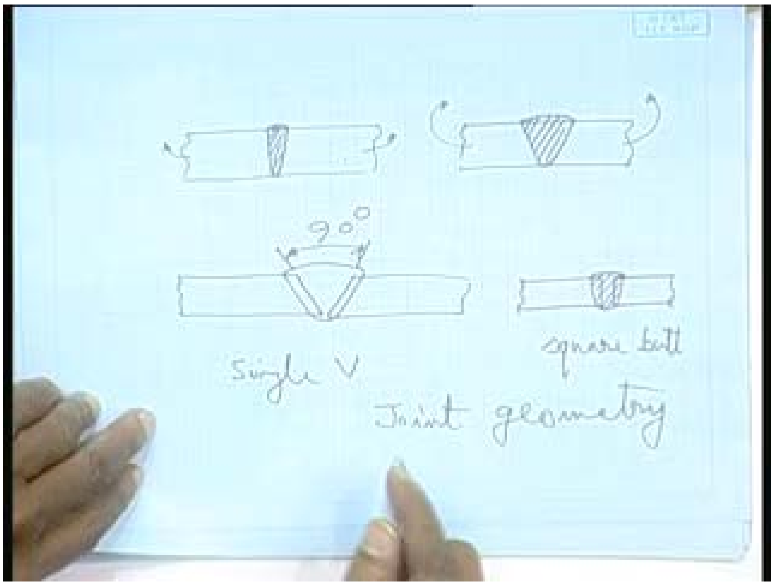

So, depending on that, your pool behavior may change for the same heat input. So, that is what essentially happens when I change the electrode orientation. See in one orientation, I have this kind of motion. In another orientation, I have this kind of motion and thereby, there is a change of fusion zone and bead profile takes place. Well, as far as this joint geometry is concerned, we have seen that, this can be referred to as square butt. Refer to a single V and this particular specific case is single V with 0 root phase. What is that root phase?

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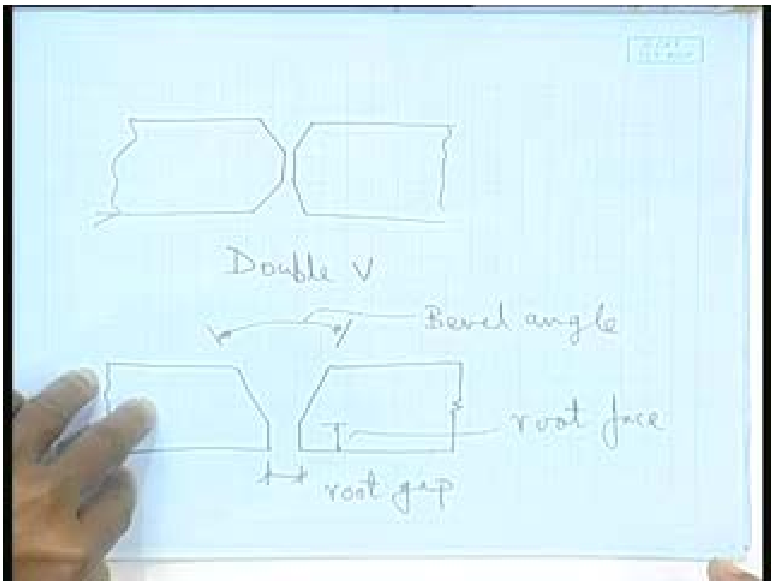

Let us, I mean well it is worthwhile to see the various terminologies of joint, so-called joint geometry or also refer to as the edge perforation. So, this is my root gap. When you are doing butt welding, this is referred to as root gap, this is referred to as root face. This is my bevel angle.

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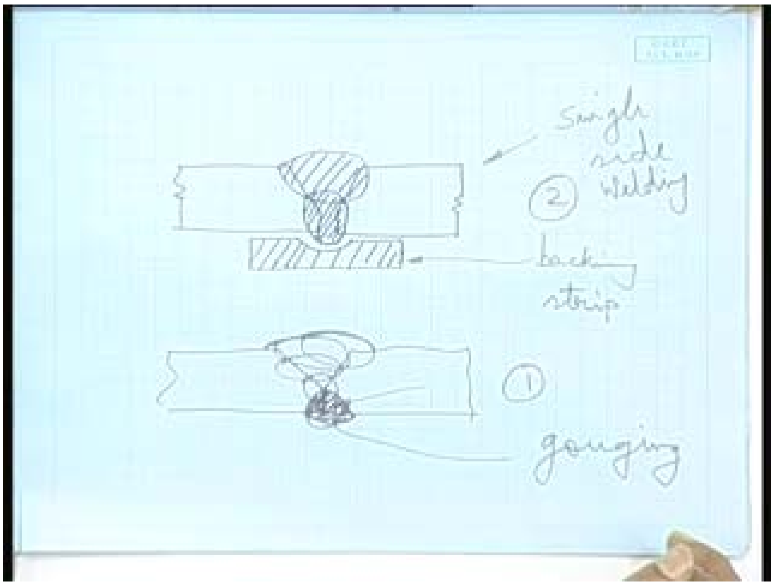

So, a joint geometry or the edge preference will be defined by this three parameters. Here in case of a, this is also a single V, this is also a single V, this also a single V, but here my root face is 0, root face is 0, here I have a root face. Now, what is the role of this root face? So, when you do a butt welding, depending on what method or what technique of welding you are using? You will either keep a 0 root face, or you will keep some root face value or you will either keep some 0 root gap or you will provide some root gap. It depends on your method of welding technique, of welding parameters all those things. Essentially what happens is that, suppose well if I keep like this, and try to weld, it may melt through the molten, metal may drop off.

So, what I one can do is, you make the root gap 0 and give a welding one run of welding like this. So, what happens? Nothing is falling through. I am controlling all the parameters, such that penetration is not more than this, so that it does not burn off, not fall through. Then, well I give another run and then, possibly two more runs such that I finally get my full deposition, but here is a position left un-welded that you cannot leave.

So, then you turn the structure plate, you cut it off. This much is cut off. This cutting of is referred to as gauging. How that gauging is done? It is also using a carbon electrode, carbon electrode like stick. You will have to strike an arc and blow a compressed air jet, so that will blow off the molten metal, and you get a smooth cut through that. Then, again you weld it that, again deposit metal. So, it is done. Sorry, so that is one way.

Another way, it could be that you provide a backing bar here, a support, some kind of support refractory, support which can take, which can withstand the temperature of molten steel. This is referred to as backing strip. So, by providing this backing strip and then, you weld, set the parameter in such a passion, you provide certain root gap, such that now I intentionally want that to take total fusion, total fusion to take place. I have provided a backing support which will hold the molten metal. Below this can be a ceramic backing support. This can be a flux based backing support, which can hold the molten metal. So, I get it and then, I give the necessary remaining welding runs. It could be one single run. I can deposit the metal depending on the thickness. If it is thicker, I made it multi run.

So, what is the difference between this previous process, this process 1 and process 2. Process 2 is, I do not need to turn the structure, and I do not need to do gauging. So, it can be referred to as a single side welding. That means, I weld from one side only and I achieve full fusion, fusion in the root, all right. So, that is how, now there it depends whether how much root phase I will keep, whether it should be 0. How much root gap will keep, all those will come into picture while working on these aspects. That means how I am going to weld. So, that is what the thing of joint geometry is. Well, now let us come to, so we have seen what all parameters are. How they play a role, in case of electric arc welding.

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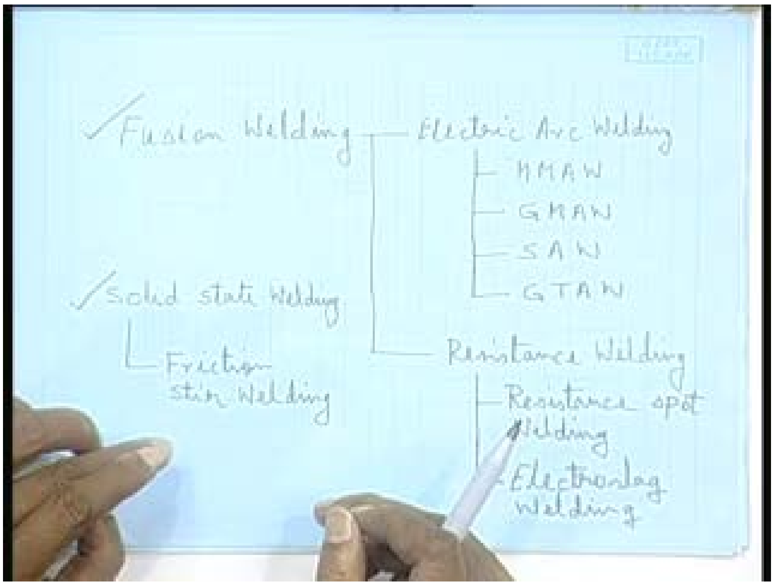

Now, we come to the actual welding methods. Well, as far as welding methods are concerned, as I said broadly speaking it could be a fusion welding or it could be a solid state welding. Fusion welding or solid state welding, what is the difference? In fusion welding, as you can see the name, melting takes place in solid state. Melting does not take place. It is a fundamental difference. Solid state welding, we have one method called friction star welding. You just hear the name. I mean we will not go in much details there in. We use a particular tool is used. There is no external heat applied. The friction of the tool with the metal plates generates the necessary heat.

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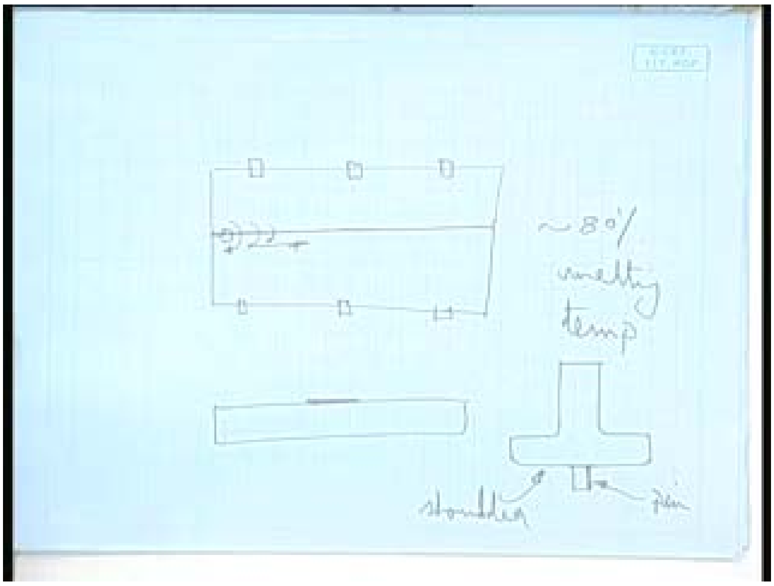

That means it is schematically, it is something like this. We have two pieces of plates needs to be butt welded. They are properly clamped together. I mean they are put face to face clamped tightly, and the tool is plunged in here which rotates at a certain RPM. You put a toll, it rotates at a certain RPM and it moved. So, what is happening? Why it is rotating at certain RPM and pushed inside? So, that frictional heat, the heat generated due to friction will soften the material along this, along the joint. Softening the material and basically, what is happening, it starting the material means, it is taking the metal from this side and putting it back continuously, continuously putting the material as if starting it, and pushing it back and going ahead.

So, that is why the name is friction star. It starts the soft material because when the temperature is increased, the metal become softer. So, the temperature attained is around 80 percent of the melting temperature. So, its soft metal is soft enough and the tool progresses in the welding direction. So, thereby your joint takes place. So, here you have no concept of bead profile. Firstly, fusion is not there, and the joint would look absolutely flat. It remains flat because there is no question of bead profile because it is sitting on the tool and the tool schematically looks like this, the friction star welding tool.

So, it is like this, means this is my shoulder. This shoulder rubs against the surface and this is the pin. This pin is plunged inside the metal. So, friction of the pin surface and friction of the shoulder surface generates the heat and you need to have a backing bar at the below. So, the pin depth, this pin height will be just less than the thickness of the plate. So, this is in the schematic form. This is what is friction star welding. Here, you have the advantage of; you do not have the disadvantage of the fusion. That is how we can say because fusion brings in lot of defects in the, could bring in lot of defects in the weld metal by the way of slag inclusion, by the way of porosity. So, all those defects related to fusion of metal or eliminated, this is the fundamental advantage in this process.

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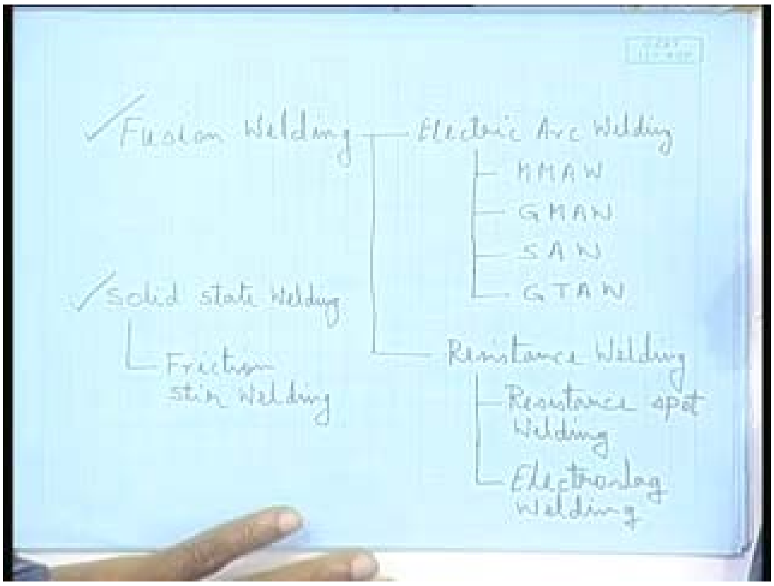

Well, otherwise this is, slowly this friction star welding is becoming gaining importance and became a porous, a very new method, very new, means only way back in 1991, it was so-called invented you can say and now, today it is being implemented quite in a good way in welding of aluminum alloys for aircraft industry as well as ship building industry always fusion welding. Well, broadly again we can divide in electric arc welding and resistance welding in electric arc welding. I have mentioned here only those which are mostly used in ship building industry, that is manual metal arc welding. That is nothing, but the conventional welding with coated electrodes.

Next is gas metal arc welding which is nothing, but your, I was just talking about MIG, metal inert gas also referred to as, but more general form is gas metal arc welding. It means, here you have the welding electrode. Shielding medium is inert gas. That inert gas can be CO2, it can be nitrogen, it can be hydrogen, sorry argon, helium. Generally, argon, helium or CO2 and there can be addition of, not nitrogen, that is not used, mainly organ helium or CO2 or mixture of them. For ship building, it is primarily CO2. Also, it is also referred to as c on 2 welding at times, CO2 welding at times, CO2 welding and thereby, we talked about the metal transfer, yeah.

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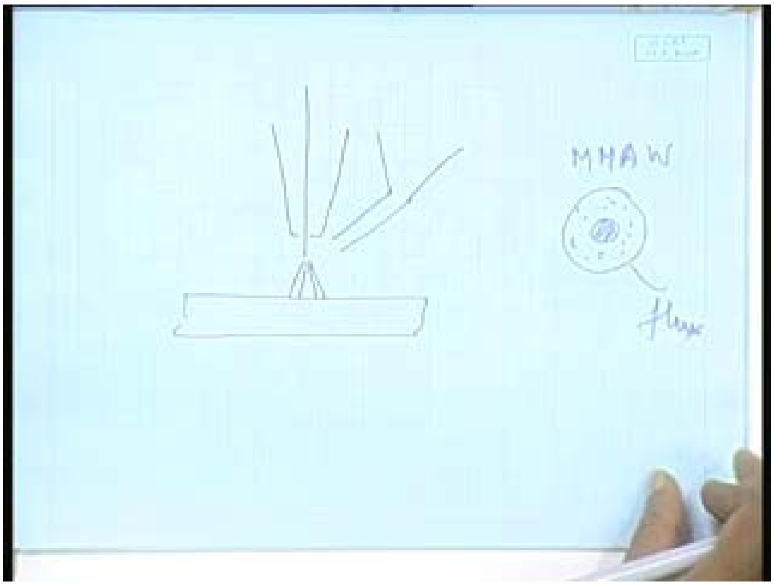

Then SAW is submerged arc welding. I had been just talking about the submerged arc welding. Well, here why it is called submerged arc? Because if I see in a schematic fashion, it is something like this. You have the welding torch, here is my welding arc, and there you will have a mechanism of putting flux because in welding, you need to shield the weld pool, as well as the electrode, as well as the arc from the atmospheric medium. So, here one way of shielding, it is done by manual metal arc welding.

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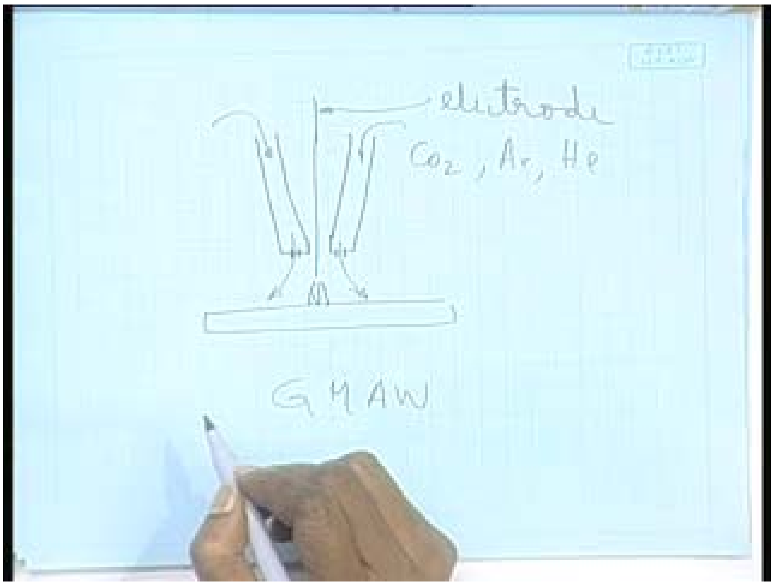

We have been using electrode, having a coating. This is my electrode and it has an external coating of flux. This was flux. We have seen this, such electrodes; this is used in manual metal arc welding in GMAW. It was a gas shielding. Gas was there. How the shielding gas was coming? Well, let us see that. That means, you have again kind of a welding torch.

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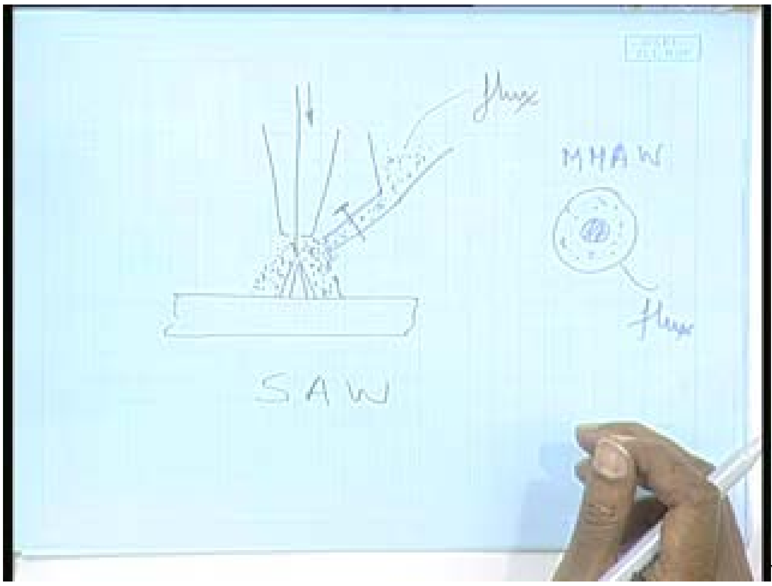

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So, this my electrode which is being a fake, a continuous electrode in both gas metal arc welding and submerged arc welding, you have a continuous feeding of electrode. This is from a pool it comes. So, you continuously do welding can have an automated welding station.

So, in gas metal arc welding, you have a properly designed nozzle, where in, you can inject the inert gas CO2 or argon or helium. So, this gas comes out from here. This is a, there are holes in this nozzle, suitable holes, so that it forms a cone, a cylindrical cone sort of a thing, a shielding cone which protects the molten metal as well as the welding arc. So, that was gas metal arc welding and in some was arc welding. This is an additional. Along with this, there is hopper kind of a thing in which you keep granulated flux. This is a flux. Flux granules are kept, so you have a sort of a stopper here. Just before the welding starts, you open the stopper such that this thing will fall, and cover the entire region, say like this.

So, in the process what is happening, the entire arc is submerged in flux. That is how the name submerged arc welding. It has nothing to do, it submerges in water. It is not an underwater welding process is the arc is submerged, so in all the other welding processes, you need a dark glass, you need a shield because otherwise your eyes will be affected. Here, you do not need anything because you do not see the arc. It is totally covered.

So, when the welding process, a welding continues, so you have a continuous cover of this flux going on top of that. So, the part of the flux can be recycled back, but gets burned, and forms the slag that has to be thrown. So, that is what is submerged arc welding. Well and then, you have gas GTAW, Gas Tungsten Arc Welding. Gas tungsten arc welding is nothing, but your welding process in which you have a non-consumable electrode, tungsten electrode.

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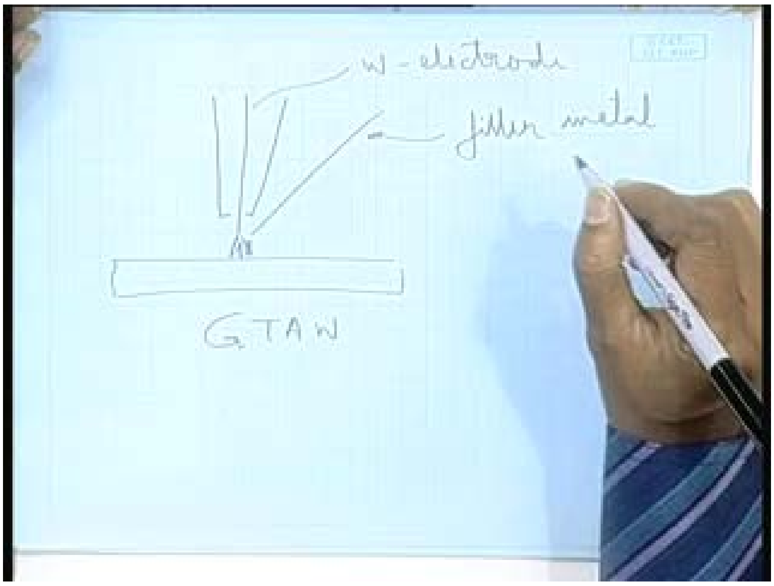

So, here the thing is, you have the tungsten electrode where ever you are doing welding, and you need filler metal, separate filler metal. This is tungsten electrode. Well, gas tungsten arc welding is only used for; it is not used for heavy production cases. It is only for some somewhere some repair welding or some very precision welding, for that purpose for major welding purpose in ship building. It is primarily manual metal arc welding; submerged welding and GMAW gas metal arc welding, manual metal arc welding. Gas metal arc welding and submerged arc welding, these are the methods where in you have the maximum use in ship building.

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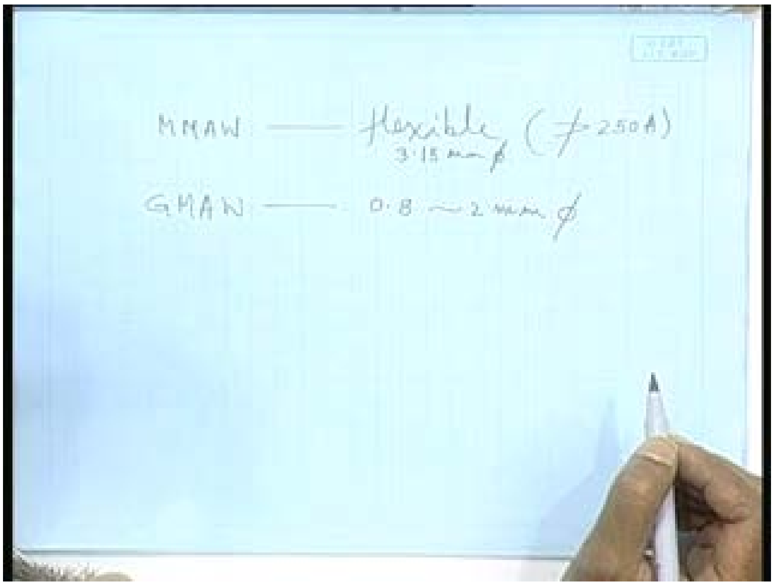

Manual metal arc welding, you have the most flexibility, the most flexible in nature because it is a manual process. You can go anywhere, any place, any welding. The welding current range generally, generally you do not exceed around, say around say 250 ampere. The electrode diameter is of the order of 3 millimetre, 3.15 millimetre, whereas gas metal arc welding, it is a semi-automatic process manual metal.

Arc welding is totally manual process means feeding of the electrode movement of the electrode are manual in gas metal arc welding. It is the feeding of the electrode is automatic. Only movement of the torch is manual. That means, you hold a torch and the electrode is fed continuously from a spool. So, as long as you can go on welding, it is a semi-automatic process. Here, the electrode diameter is of the order of the 0.8 around 2 millimetres. There can be 0.8, 1.2, 0.1 millimetre, 1.4, maximum 2 millimetre it goes.

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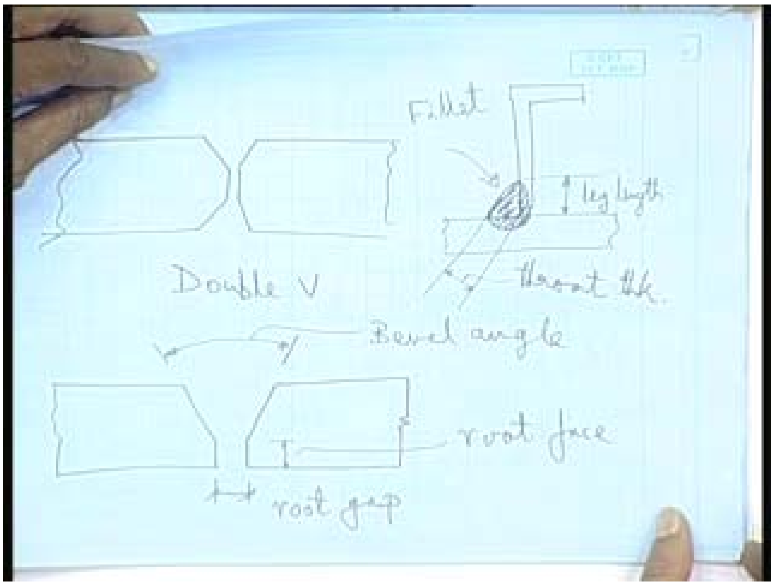

Manual metal arc, it is generally 3.15 millimetre. Here, it is even final. So, the gas metal arc welding I can control, when I have to do a fillet welding. When we have been talking about this, here we talked about all, but welding cases. This is a fillet welding, means when suppose you are with the flat plate, and you are welding some stiffener. So, this is called fillet. The fusion zone is somewhat like this, this. The fusion taking place and this is my, so this is referred to as fillet welding. This length is referred to as leg length. Leg length this particular thickness, throat thickness.

So, this fillet weld, it is called fillet weld. So, in fillet weld, we have so much of leg length to be deposited. It is not worthwhile to over weld. That means, suppose my requirement is 5 millimetre of leg length, means I should be able to do 5 and not 8. Over welding means wastage, first. Secondly, more heat, more deformation, more distortion, more heat effected zone, all adverse things.

So, if I use a gas metal arc welding, then I can fine control that because I have a thinner electrode. I can use if need a 3 millimetre fillet. I use a 0.8 mm electrode and I can control it, reduce it. I mean keep the current within the permissible range, so that necessary fusions.

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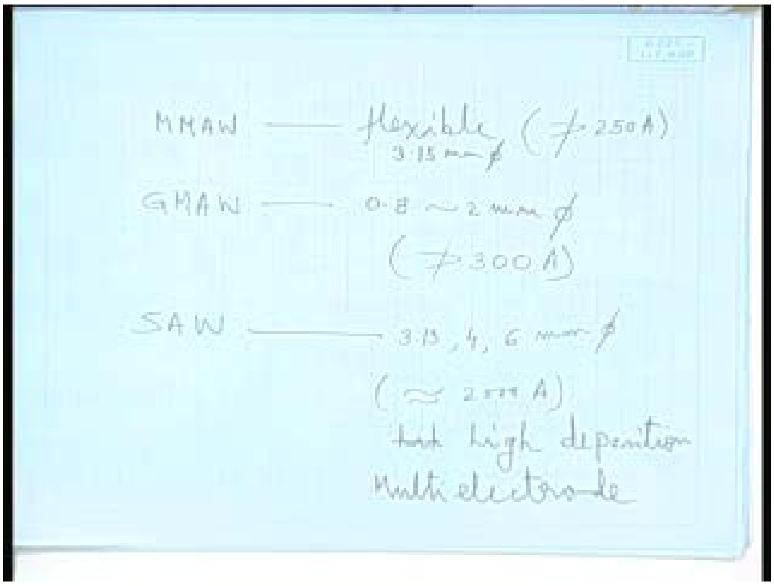

So, here the current range is of the order of, well generally we do not go beyond. These are all figures. I meant not 100 percent, I mean these are not absolute values. These can be 310, 320. This is the order gas metal arc welding. We go well, may be maximum 300 ampere which is also not very frequent case. Frequent could be 200 on 50 ampere even.

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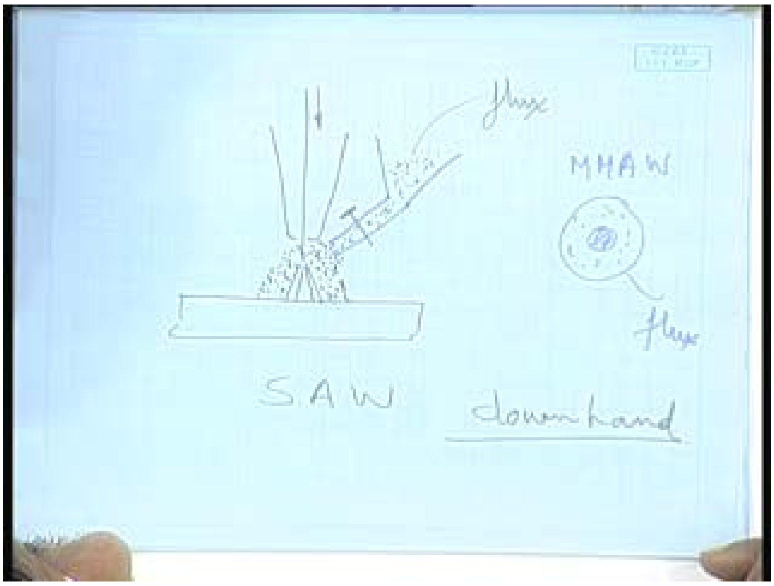

Whereas, some was arc welding. It is a fully automatic process; means feeding of the electrode as well as the movement of the torch, both the operations are automated and as you have seen the process schematically, as you have seen that process is always for a down hand welding because the flux will fall under gravity. So, it has a limitation only. Down hand welding position can be done down hand, whereas gas metal arc welding or manual metal arc welding can be all positional. Welding means you can do over head, you can do vertical, you can do horizontal.

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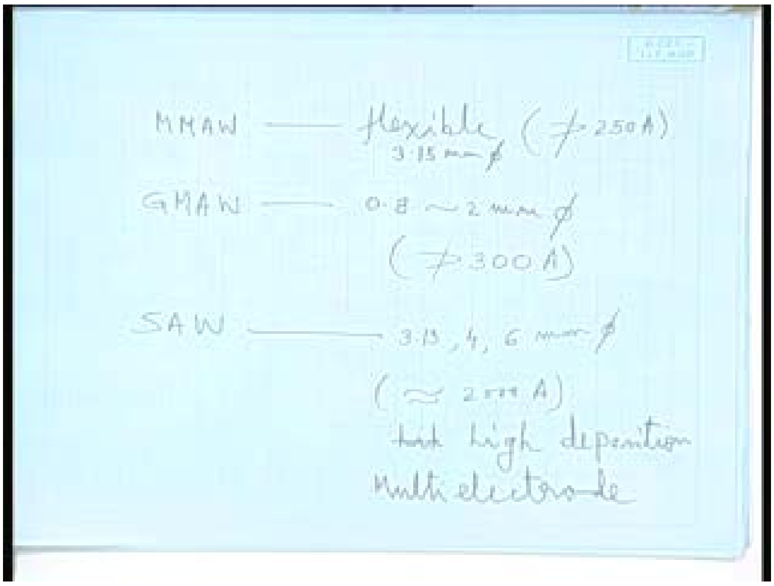

So, here it is an automated process as well as only down hand. Now, what is the electrode sizes are generally used here is well, 3.15-4 and even in some cases, 6 millimetres and the current could be of the order of even 2000 ampere. It does not mean that all welding, we do with 2000. We can also do it is 600 ampere submerged arc welding 800 ampere, but what I am saying, the order, the maximum order it can be of the order of 2000, whereas in gas metal will never go to that this thing current level. Why we are going to this? I am using 6 millimetre welding rod welding.

So, here this is a process, high deposition process. It is a high deposition process means, assume I use, say 1500 ampere and 4 millimetre electrode, so I can deposit lot of metal and also I have a high speed of welding, and here we get a very good quality of welding because both the parameters are, both the things movements are automated. So, thereby your, I mean your fitting rate is constant, moving is also constant. So, thereby we can go for flat characteristics submission power supply and as if quite a good well deposition. So, that is what is submerged arc welding.

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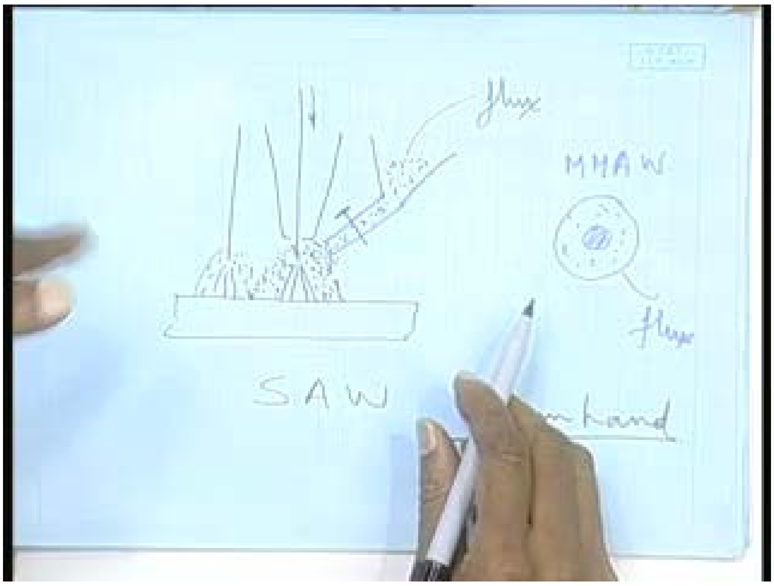

Now, in this submerged arc, there is another aspect in all these. Whereas, a single electrode submerged arc could be multi electrode. What does that mean? That means, you have this one electrode coming here, and as well as you have a trilling electrode which may have also powered, which also may have connected to power, or may be a cold electrode. Cold electrode means, I am utilizing this heat and like a filler metal, I am depositing. I can have 3 electrodes going in tandem.

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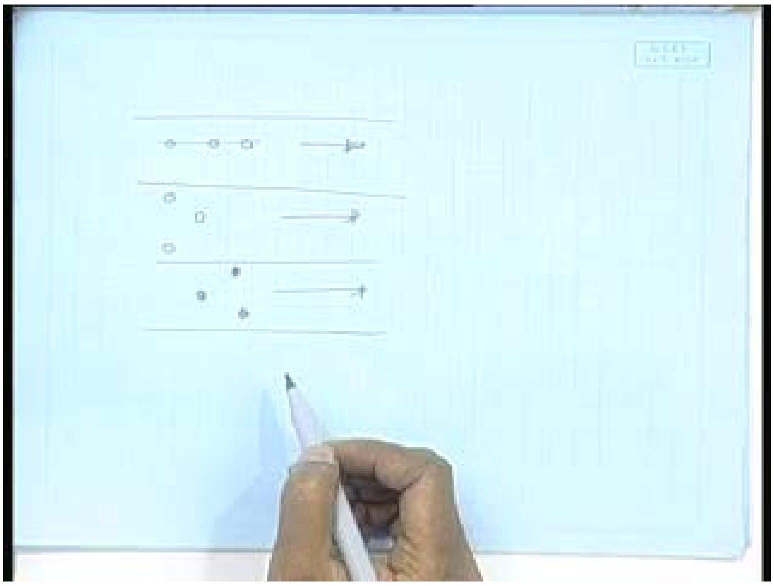

I can have different orientations of electrodes. It means different orientations of electrodes. I can have 3 electrodes going in tandem in welding in this direction, all kinds of orientations. These are my electrodes. This is being welded. I mean on plates this is in one line tandem. Here it is a rectangular form; this is a reverse rectangular form. So, there are all kinds of things are possible. That means we can have a multi electrode, this thing. So, if that we do, then we achieve a further higher deposition rates. So, many plates with a single run with a suitable backing strip in single run, it can be welded. So, that is what is submerged arc welding.

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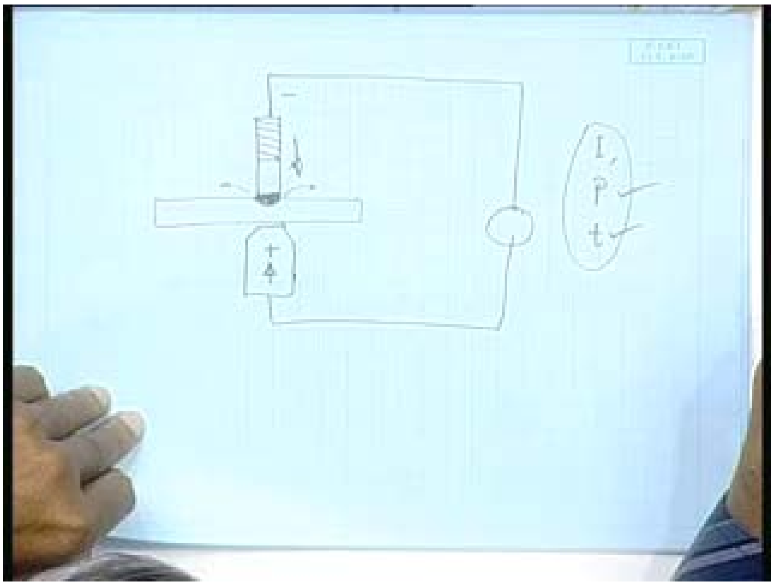

In resistance welding, we have resistance port welding and resistor slag welding. Resistance port welding is nothing, but we use the resistance of the interface. That means, it is generally used in case of a welding, say the studs. Stud means the bolt heads. Suppose, some such, this is you know the bolt, the only threaded part. The head is not there. So, you have to weld it to this plate. How do you weld? If I conventionally weld it, then there will be a metal here, so that I can see total communication gap. Please sit.

So, here it is connected to power like this. So, this is positive terminal and this is the negative terminal, and to this plate, so here you have the parameters are current and the force, the force you are applying pressing it. You have to press it, and the time duration you are applying the current pulse because here you do not apply a continuous current. You give a short pulse of power. First apply force, hold it down strongly, apply the current for the short pulse. What will happen, this interface resistance will generate enough heat it to melt it down here locally, and it will fuse. So, if my current duration is more, more it will melt, and it will punch inside the metal expelling molten metal in this way. If the current is more and time duration is more, that means a suitable combination of these 3 parameters are needed, such that this expulsion of the metal does not take place as well as a proper nugget formation takes place.

So, that gives me the (( )). No. Yes here, whether it is positive or negative does not make much difference because here, we are using the resistance of the interface current is same. Here, it does not really make difference as such because here, your whether, well how much it makes because here, there is no arc column as such. Here is the resistance of the interface. So, the question of that electron heating even if it takes place it this way, we think that that electron heating in this case, this is positive in the plate and place in this here. Yeah, here more important is, what time you are keeping because the pressure for a given current, this is a very fraction of second.

So, it does not take much difference to my knowledge, but could be some difference will always be there definitely, but often I do not know whether there will be qualitative difference, definite qualitative difference in changing this.

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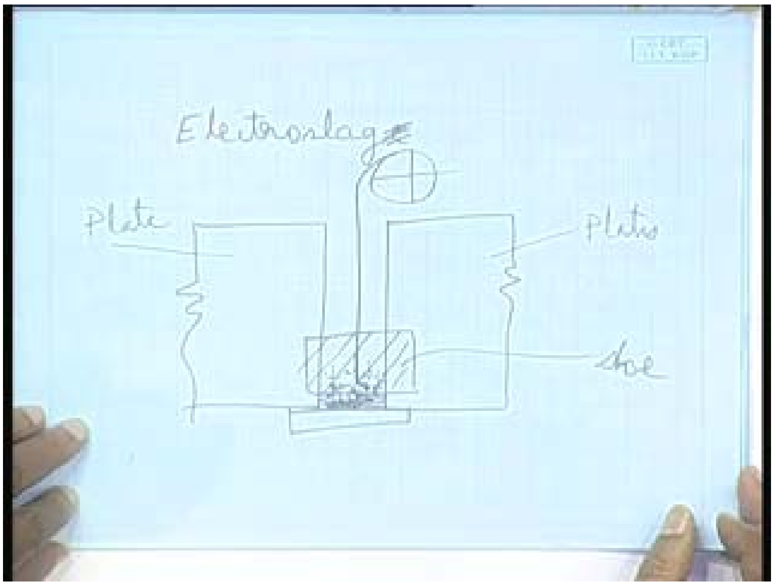

Next is electro slag welding. In electro slag welding, we basically take help of the resistance of the molten slag. So, schematically it is like this. You have two, and here, you have a supporting medium. You have another support at the bottom. Here it is filled up with flux and your electrode comes down from top, which is again fate from a coil of electrode which is push down. These are the two plates being welded. Assume the two plates of two blocks side shells. Assume the side shells are being welded; two blocks are aligned vertical, side shell being welded.

So, what you do is, you first initiate an arc. That arc will lead to the requisite heat which will melt, and burn the flux and it will remain as a molten slag state. The slag will remain and that heat of the slag. Then, the current will pass through the electrode will deep only in the slag. So, current will pass through the molten slag. So, the resistance heating of the molten slag will generate the required amount of heat to melt the parent metals as well as the electrode.

So, what will happen, this particular, this is a shoe kind of a thing from both sides. It will keep moving upwards, and the electrode is being fate. So, these two are synchronized. So, what happens, electrode melting is taking place, and gets deposited at the bottom and the molten slag. That means there will be solidified metal, molten metal and molten slag floating above. That is what is electrode slag is used for vertical plate welding. We stop here today.