Welding Processes
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Submerged arc welding

So we will begin. So in last class we were looking at the advancements that were made in GMAW. So we looked at two important advancements, pulsed GMAW and then we looked at the controlled short circuiting deep transfer. So we were looking at the waveforms characteristics of both the processes and then how we have achieved the metal transfer which is required for in both the processes which is unique, for pulsed GMAW and then controlled short circuiting deep transfer, in both the cases, right?

It is very important to understand the significance of this waveform control to achieve the desired metal transfer. So this waveform control during welding is achieved by the power source, the advancement that we saw in the power source manufacturing. So the microprocessor control rectifying by the power source, which could give us the controlled waveforms because these waveforms are smart, they will have to talk to each other, the various aspects of the welding system shall be talking to each other, otherwise we cannot achieve the waveforms.

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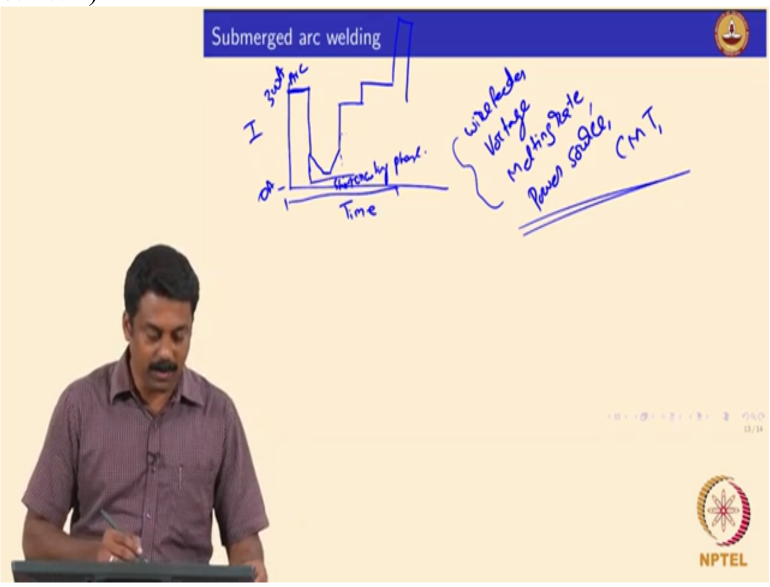

For example, in controlled short circuiting transfer the waveform if you look at it, it is not like a simple pulse or simple DC. So when you look at the currents versus time, so initially we have one arcing current and then during welding, so we do not keep the current constant throughout the pool or we even do not do just simple pulsing, is not it? So what we do is upon achieving droplet at the tip, the wire is moved and during this process when the wire is fractionally moved towards the weld pool, the current is also decreased.

And then the moment the short circuiting is established, so we reduce the current to a very low level, even sometimes even to 0 so that the droplet is not exploded because of the accumulation of the Lorentz force inside the droplet. So the current is decreased considerably to maintain the droplet intact and then we give a delay, so in that delay so basically what we do is we immerse the droplet into the pool and then subsequently we retract the wire and during this process we increase the current slightly in such a way that we form a nick and then because of the surface tension of the liquid pool the droplet can be detached to the pool.

And then the wire once it actually retracted back upon reaching a typical length, we sought another increasing current to ignite the arc and subsequently we can follow the same step. So this would be yeah, same current level. So this is arcing current, right? And this is the short-circuiting phase. Short-circuiting phase, so it will be somewhere over here until this. So now we will have to make our system as smart as possible. We will have to have the control over the wire feeder and then we will also have to measure the short-circuiting event.

So then we will also have a voltage sensor, is not it? So voltage has to be measured so that the moment the short-circuiting happens, we will have to make the current to zero or low level. And then we will have to do the calculations about the melting rate so that we also know when to retract and when to send the wire towards the work pool, weld pool. So then we also need to have a power source capable of changing the current abruptly as a waveform I showed you in this picture.

So you also need to have one power source capable of generating the waveforms with the current varying from say in this case 300 amperes to 0 amperes. And this time entire cycle can be few microseconds. Suppose if you are doing a 50 short-circuiting event in a second, so that is the time control we need to achieve to get this waveform. So the power source should be capable of generating such pulses and the variation in the current. And then this cannot be carried out by conventional magnetic amplifiable power sources or simple transformer power sources. So we need to have rectifier inverter system with the microprocessor control.

So generally we can achieve this power source. So once you achieve that using online senses, we can measure the voltages and the melting rate can be calculated using the equations I told you. And then we can develop an individual welding program for a given composition of the wire and the diameter of the wire. So these advantages are all possible as I said because of the advancement, the understanding in physics of welding process.

So once you have, once you know that what is going on during welding, so then we can all play around. So when you are short-circuiting, you cannot just like the transfer, okay, it will explode, the weld pool will collapse. So then we will have to manually adjust the current and the voltage waveforms and then identify what is the effect of waveform on short-circuiting, then we can program it, make it automated. Is it clear?

So again the morale of this unit lesson is understand the physics so that we invent new things, that is important. So it is not like repeating someone or something else. We always understand, try to understand the physics behind the process. So then you can play around and then invent so new methodologies, new processes and which are ultimately beneficial for various applications.

So now the cold metal transfer, short-circuiting transfer is widely used for various sensitive applications because you can use now GMAW, it is like transferring a casting process because the melting point, the droplet temperature is not going beyond the melting point. So you are transferring a molten liquid from largely to a weld pool, it is as simple as that. So you are just giving a molten liquid which is at the melting point, close to melting point, so that is why it is actually very beneficial because you are not superheating the weld pool and you are not increasing the heat input.

You are not affecting the surface microstructure. So now that is the reason why this process is very widely used nowadays for welding the similar materials. For example, see an aluminum weld, so you will have to avoid intermetallic formation, so then you will have to minimize the heat input arc energy. So this process can be used very widely because you are just wetting. It is clear? Good. So now we move onto the last welding process in consumable welding is submerged arc welding. How many of you have seen submerged arc welding process? None, right?

We used to have one very nice setup in IIT Madras, so unfortunately we condemn that setup. It is actually very neat setup, the process itself is same as GMAW, there is nothing different. So the schematic and everything is the similar, shall we use a consumable electrode without any flux? It is like a wired electrode, wire technology is much larger than what you use in conventional GMAW. Conventional GMAW is 1.2 mm, not more than 2.2, whereas in submerged arc welding we can use much larger diameters.

So we looked at the efficiency, when you are looking at efficiency of the process, the efficiency determined by, so whether you are using of course the electrode positive or negative, suppose if you are using an electrode as an anode, so if it is the electrode it is positive, so then the efficiency determined by what factors?

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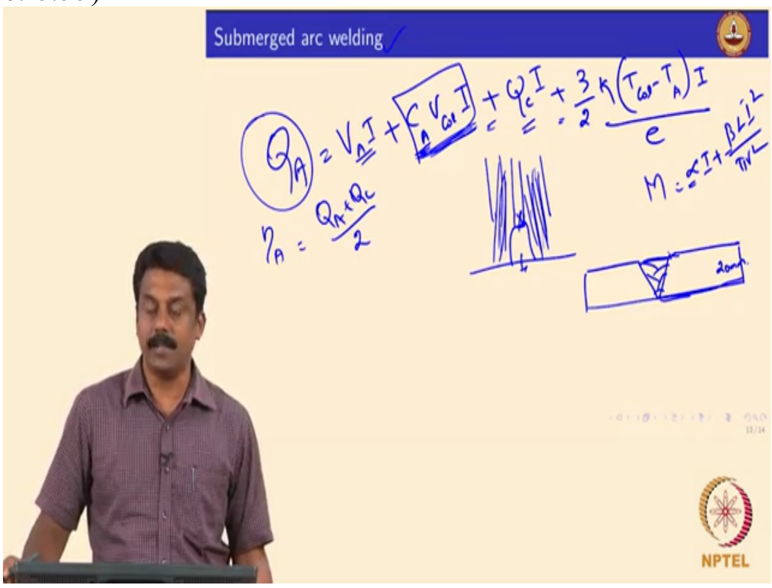

Q A, okay, what is the equation? What is the efficiency when it is used as an electrode positive? GMAW, forgot? Come on guys, it is not long ago. So what is the Q A? How do you calculate the heat of the anode? I am older than you guys, right? I still remember. So V A by I plus C A V column I plus both function at the cathode and then I plus…

Student: 3 by 2 k.

Professor: 3 by 2 k, what is k? The poor guys, right? And then something is missing, you referred your notebook, right? Yes, very good. So now the important part over here which controls the efficiency, of course if it is positive, if it is anode, then this becomes positive, is not it? And in consumable welding process, efficiency is Q A plus Q C divided by 2, is not it? So if it is an average, because the heat is already going into the Q C. So now in this process the important parameter which determines the process efficiency is the amount of heat coming from the arc column to the anode or cathode.

Because this is fixed, so these are all fixed, the only parameter which actually here can affect the efficiency is the CA factor, the factor the amount of heat is coming from the arc column to the anode or cathode. That determines the efficiency of the process. Again how does the heat transfer from the arc? By conduction, convection, radiation, right? So the heat transfer or heat loss from the arc is defined by the conduction, convection, radiation which we already looked at.

So now suppose if you want to increase efficiency, so we will have to minimize the heat loss from the arc so that the amount of heat from the arc column goes to anode and cathode can because maximized. If you contain the heat loss from the arc, to only to anode and cathode, so then we can increase the efficiency of the process extremely high. So this factor CA become close to 1. So how do you do that? Then we will have to protect the arc from the atmosphere so that we can avoid the conduction, and the radiation heat loss.

So how do you protect the arc? We cannot just simply know you put a mask or something like that, that is not practical. So what people thought about it, okay this guy the heat which is actually going from the arc to the anode and cathode determines the efficiency if you maximize the heat transfer from the arc column to the anode and cathode, so we can also heat the anode and cathode much more effectively.

Ultimately the Q A will go high. If you see a factor, it is increasing if it is close to 1. So what we thought about, okay, so instead of having one flux coated on electrode, we cover the arc with the flux. So you have an electrode, and then coming, so this is the base material and this is an arc. And you have additional chamber and you pour fluxes, flux part it is surrounding the arc and electrode. So the entire arc is covered with flux, that means that the arc heat loss is extremely minimized because the flux would contain the heat in the arc and the heat from the arc would be transferred to the electrode and the base material.

And in this process the flux will also melt. That can also favorably influence the arc stability and the metal transfer. Like suppose if you have a titanium oxide, total based fluxes, so that can also change the surface tension and then increase the metal transfer frequencies. You can also change like we looked at it, when based electrodes how the metal transfer change. So by adding fluxes as an envelope to the arc, so we can also protect the arc, we can maximize the heat transferred from the arc to the anode and cathode. And doing so, we can increase the efficiency, melting efficiency.

Again you calculated the M, so we used the same terms, the melting rates. So this term is still there, so we took the I out and then M becomes alpha I plus beta L I square, divided by?

Student: Pi r square.

Professor: Yeah. So when you do an alpha and beta, again the same equations whether it is an anode or cathode, the electrode we use the same equation to calculate, to derive what? The melting rate. So we can also increase the melting efficiency by increasing this factor, the amount of heat transferred from the arc, whether to the electrode or to the work piece. So in this process so what we do is in submerged arc welding process, the efficiency can be increased to close to 100 percent. The efficiency of submerged arc welding process can be as100 percent by completing protecting the arc from the atmosphere by fluxes.

Okay, so that is why the process is known as submerged arc welding. The arc is submerged in flux. By doing so, we can increase the efficiency of the process and we can also increase the productivity. So we can use the much larger diameter electrode, so that we can weld or we can melt more volume, is not it? Because the effectively transferred to the electrode tip, so we can melt more for a given unit time. So instead of using 1.2 mm diameter of the electrode we can use 3 mm, 3.5, even 4 mm and we can effectively melt and then deposit because we have more heat available, the arc heat can be contained.

So by doing so, by melting more larger diameter wire, we can also weld thicker sections, right because we can generate more liquid which can fill more volume of the base material. And all came from the fact that the efficiency of the process increased by containing the heat radiation heat loss by conduction, conduction from the arc to the atmosphere. So by doing so, we can melt more volume of electrode, we can create more liquid metal.

And if you create more liquid metal, obviously we can fill more cavities. So we can weld thicker sections. Say for example, if you want to weld the 20 mm thick a steel plate using 1.2 mm diameter in conventional GMAW, we need at least 6 process, 6 times you will have to do. So we have weld cavity. So now suppose if you have such a weld cavity, you need to fill it with conventional GMAW. So we will have to do, something like 6 process you will have to do if it is say 20 mm because you cannot melt more than that, because the heat loss is so high.

Then you will end up not properly melting the wire. So the same process if you use in submerged arc welding, you can use much larger diameter. So if you use 3.54 mm wire, and then you can melt in single pass, you can fill close to 20 mm the single pass. That means that productivity increases significantly, is not it? And the cost of welding is also increased, decreases significantly because you can fill the entire cavity with one pass. So this all happened because of increasing efficiency. It is clear? So that is why it is known as submerged arc welding.

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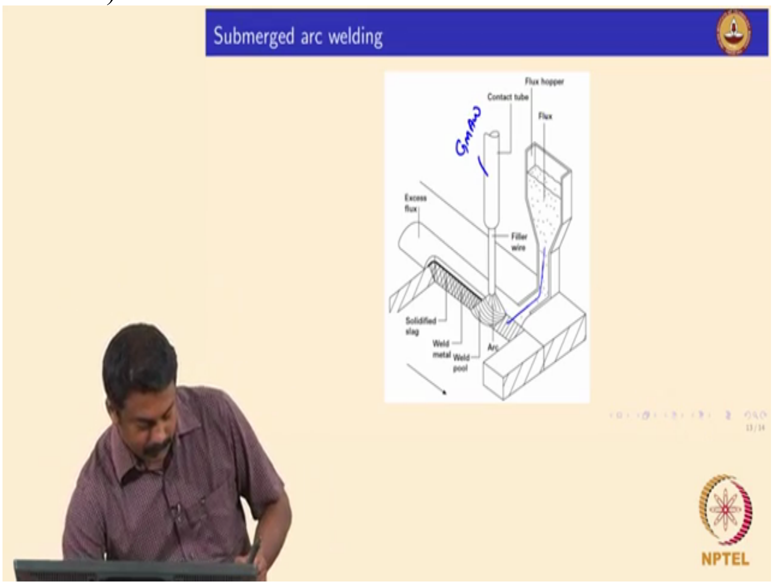

And basically it works schematically as shown in this slide. So we have similar the GMAW setup, so this is contacted. And we have an electrode, generally in submerged arc welding diameter is much larger than the conventional electrode and you form an arc. By doing this process, we also send the flux to submerge the arc. So you will not see the arc visible outside. So this schematic can be very tricky but I will show in video, so it will be very clear.

So the flux would act as in the same way as it acts in MAW or in flux code arc welding. We looked at it in detail, right? So the role of fluxes in metal transfer as well as to generate shield gas if it is necessary. So all the functions these fluxes can carry out. By doing so, so we can now increase the productivity by melting more. So the video I will show, then it will be clear, then we will come back to this.

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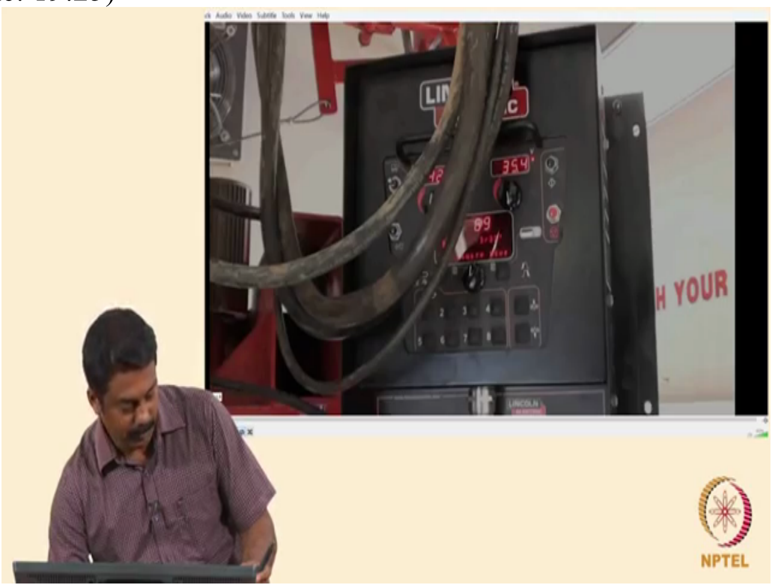

So this process actually what I show over here it is to weld a pipe of 20 mm thick. In conventional GMAW, we were using six passes but by changing from that to submerged arc welding we could weld in single pass. So these are all the power source. I will show it from the beginning.

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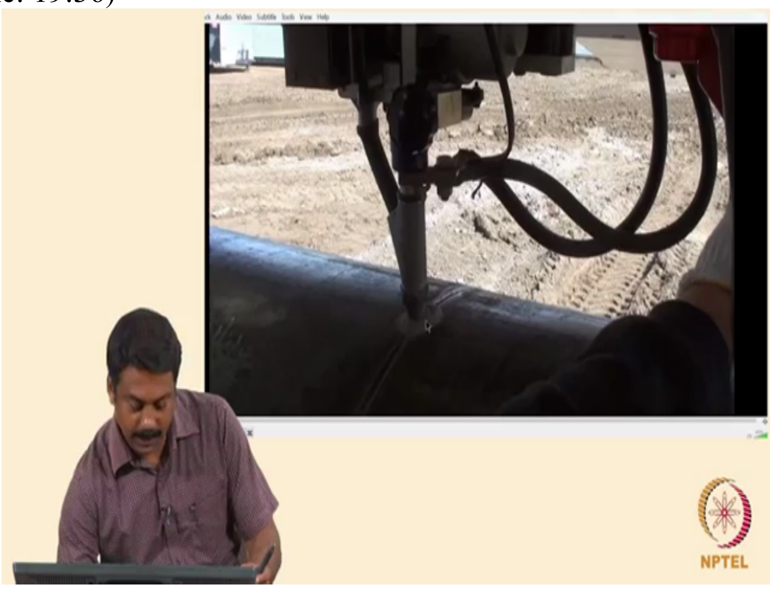

So this is the schematic, so are welding two pipes joined. You see this, can you see an arc, alright? So you have a flux hoper coming in this case and coaxially fed. And the arc is completely submerged and this flux can be recycled. So no need to worry about it. We will not throw out any flux.

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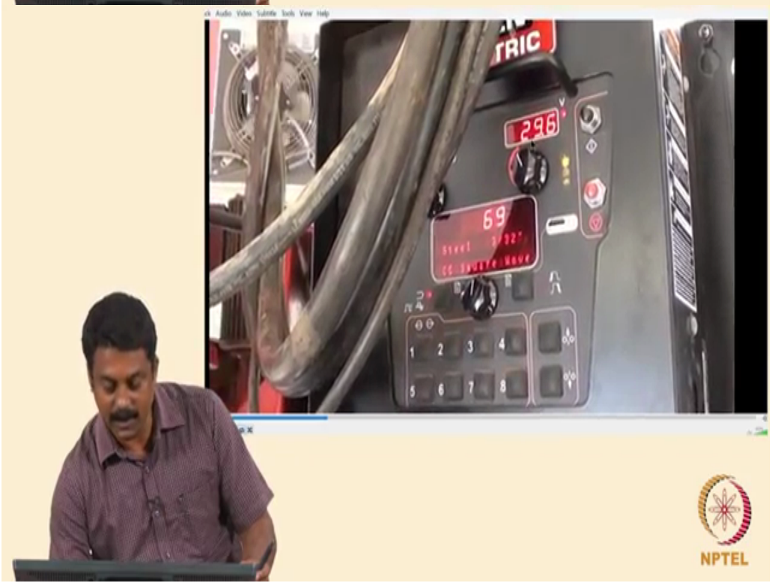

And the wire is coming. So you would see the thicker, thick section. In this case I would refine diameter the wire. So wire continuously fed. So voltage is slightly higher because of the higher the arc length as well as the wire diameter.

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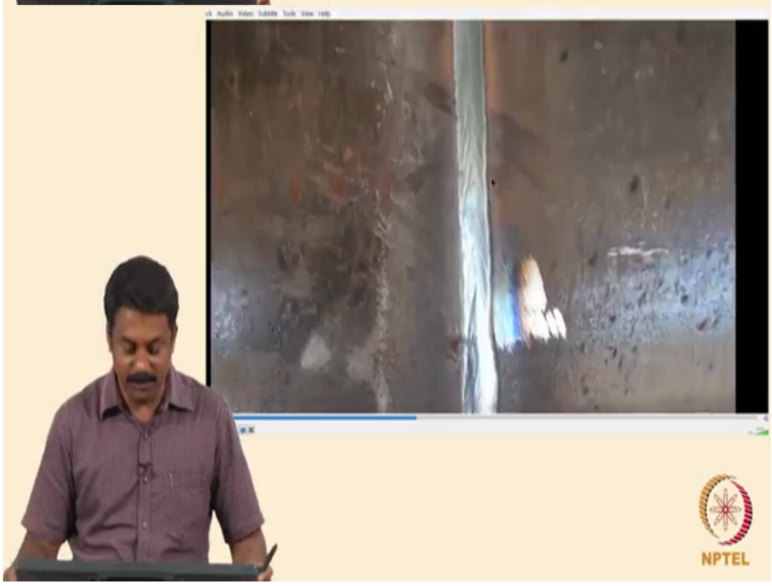

So in this case pipe is rotating, you see that it is already welded. And this 20 mm cross-section pipe is welded in a single pass, is not it? So otherwise if you are doing a simple GMAW, and we have to do it in a say in this case 5 or 6 passes, so we could weld very nice beautiful weld. It is always I feel nice looking at fantastic welds. So one pass, 20 mm thick. It is going to be pitted again.

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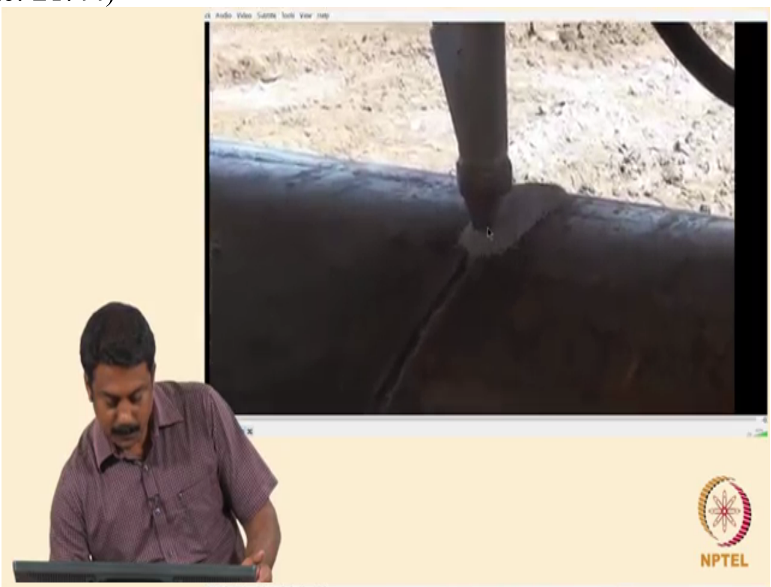

So we are starting from here. In this case pipe is rotating and then you can also, this process can be used for flat plates, so only problem here is we need to have one container for fluxes. So it is not really portable process, so flux has to be, now if you want to make it portable, and you will have to carry every time a bag of flux with you with the hoper. And the hoper contains the flux.

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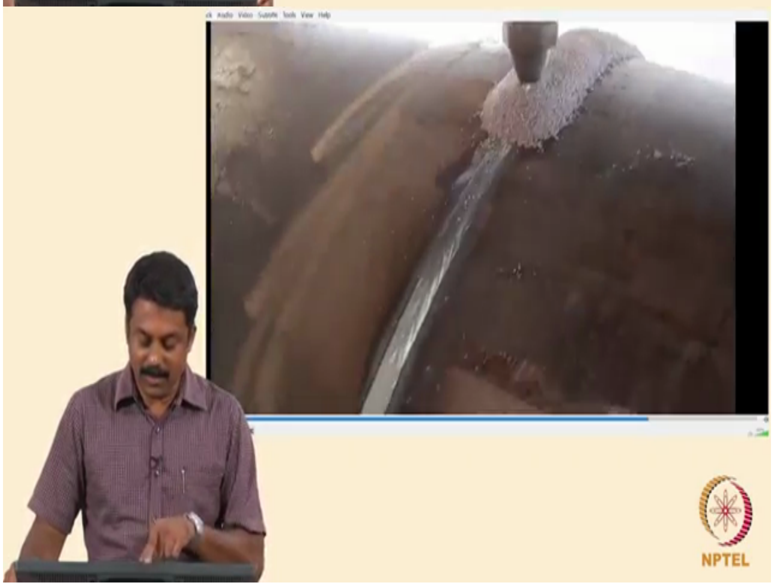

So in this case this guy, so it is like if you go to flour mill, you see, you actually pour wheat and wheat comes down and it mixes, same case. So this is the power source, this is very famous brand Lincoln. And in this case you no need to play around with the pulsing parameter and that. Generally we do it in a simple direct current constant current and voltage configuration. And we will have a very nice weld made. So now such a high efficiency is possible because now the heat from the arc is not lost to atmosphere. It is very effectively transferred to the cathode and anode.

And then we inverted this process because we thought that, so the fact which actually controls the efficiency, the amount of heat transferred from the arc column to the anode or cathode can be improved by shielding the arc and we end up generating such process. It is clear? Okay, so we stop and then we will move onto the some of the aspects. We will wind up.

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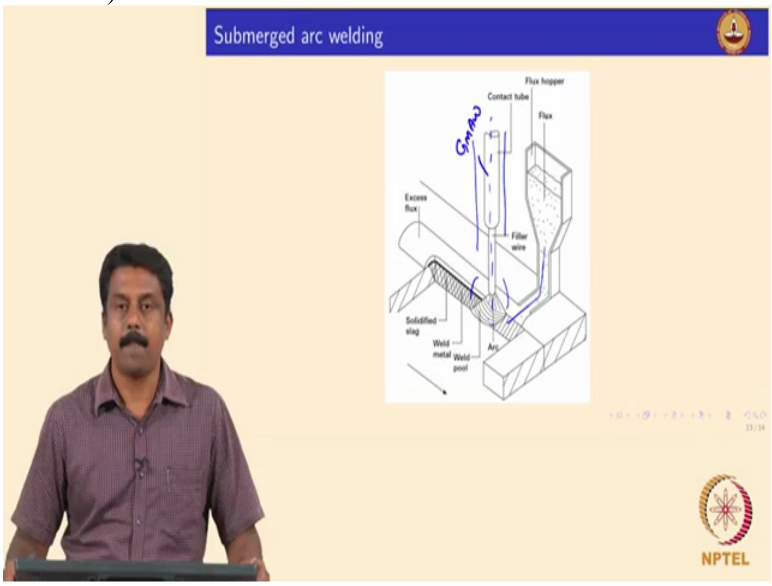

Okay, so this is now clear schematic, so we have a hoper and then it chains. So in this case the schematic shows not coaxially fed. So coaxial feed means the flux will also be going coaxial to the electrode wire tip. The video I showed you it was actually coaxially fed as shown in the schematic. In the schematic we can also have the flux going and then covering the arc like in a sideways as well. That is also possible. And then the flux melts and forms a slag layer to avoid the oxidation. So if you look at the weld which is made immediately, it is not oxidized at all. It has a complete protection. The flux melts and forms a slag layer to have a complete protection and then that can be removed. You see one guy was actually rubbing with the steel brush to remove the oxide fluxes.

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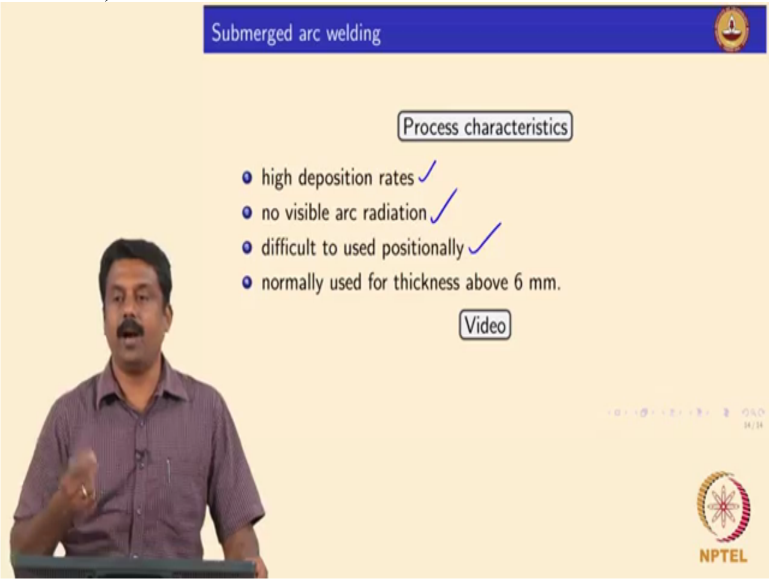

So the process characteristics if you look it, the high deposition rates we achieve by having the high efficiency of the process, the efficiency can be 100 percent. If you look at this process, the heat is not radiated at all, you hardly see the arc, is not it? So because we do not see arc, there is no visible arc radiation, you do not need protective glasses. So the workplace safety can be really enhanced. So the arc radiation can be extremely thin. So for workmanship, the welders, it is extremely important not to look at the arc directly because the ultraviolet radiations if you look at the wavelength, it can go from 4 nanometer to 590 nanometers. In fact it can go up to 600, even beyond.

And if you stare this wavelength obviously, the radiative heat transfer radiates and it can come to your eyes, it can affect very significantly. So this process brings that advantage because there is no visible arc radiation. So there is a protection itself and which is beneficial. So for workmanship, it is very beneficial. So because there is not arc, visible arc radiation, the other problem over here in this process is because we always have to carry the flux, so the maneuverability is difficult.

So if you want to do it in downward welding, how do you feed flux? So those kind of applications it is very difficult. So generally even the pipe I showed you and if you are going for an offshore pipelines.