Welding Processes
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Square wave, variable polarity, GTAW with filler, hot wire GTAW

So we will start from last class. We were looking at some variations that we have introduced in gas tungsten arc welding, right? So we are looking at pulsed GTAW, so instead of using constant current by using pulsed DC we may achieve some good arc characteristics. For example if you want to have a deeper penetration so you need to increase the heat input significantly, so then the I mean should be increased, is not it, so the mean current should increased but instead of using direct or constant DC with higher mean current by doing pulsing, so we can reduce the heat input because…

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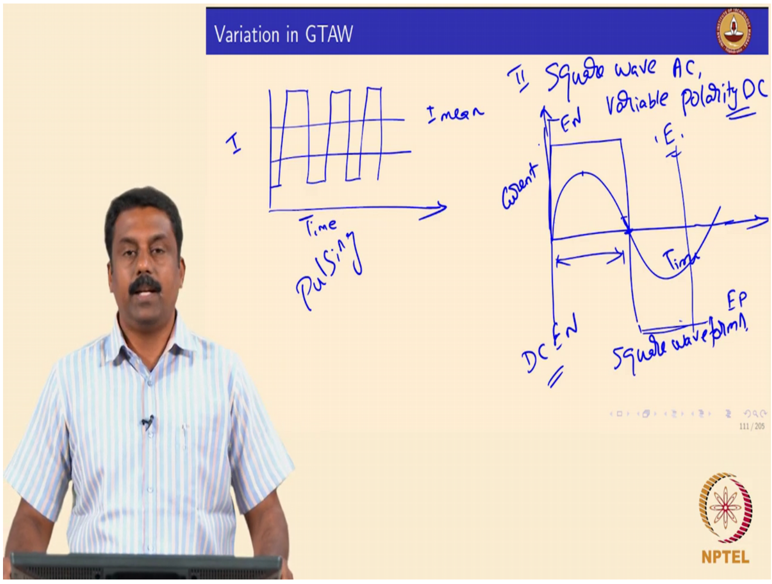

For example if you are welding at let us say current versus time. If you are using in a constant current I mean, so you may have to increase the heat input in such a way that you can increase the penetration or you can improve the arc characteristics. So instead of using higher I mean we can use pulsed current so we start with background current where it is just enough to keep the arc ignited and then to have a continuous arching and then in between you can pulse the current in such a way that we can generate much more stable arc with high stiffness, stiffness means the core, the arc core where you have a plasma jet formation can be widened.

Okay, that means if plasma get is widened or core is widened then you will have a somewhat deeper penetration in the material and by doing this process if you calculate the average or current over this wave form, I mean decreases significantly, is not it?

Since that is high current and you can reach the higher penetration and good stable arc with good stiffness by little low current, so that is an advantage of using in a pulsed GTAW okay and this is also the pulse DCD it is also very advantageous and GMAW gas metal arc welding but we will see that when we are looking at gas metal arc welding but in this case because of using pulsing we can increase the arc stiffness much more effectively by doing pulsing with a much reduced mean current that means heat input decreases but you will be increasing the penetration, higher, right? Because you are improving the arc stiffness, the arc core, yes it makes sense, right?

So the pulse GTAW can be used and then…so this is one improvement we have done in improving the arc and the second one you are looking at is variable polarity square wave AC, is not it? Square wave AC and then variable polarity DC, so in this case we looked that in the last line just before we completing, see we have a problem using sinusoidal wave AC, so in sinusoidal wave AC so if you look at current versus time so you will see in the convincing AC current so you will have a sinusoidal wave and this sort of wave characteristics is not good for an arc, so what I am saying here is so in this case the current field is continuously changing, is not it?

Say for example you start with one value you go to an amplitude, peak amplitude but in this case the E what you look at, the electric field density it continues the changes when you are applying such a way form. That means that the arc heat generation, the arc mechanism at which they arc heat generates when we look at based on the E it is also continues changing that means the arc characteristics also change while applying an AC wave form, is not it? And we also have a problem here, so at one point in time the current always goes to 0, is not it?

That means that when the current goes zero, obviously the arc would extinguish, so even if you have a very high frequency alternating current at one point in time you always have a situation where there is no current to sustain the arc. That means that when you use a sinusoidal wave, the arc stability decreases significantly because at this point there is no power in the arc because E is completely 0.

Similarly during this process the current is not constant at all, it is continuously changing so you are increasing E and decreasing E and then completely goes to 0 again it changes the polarity, so such a wave form it is not good for our characteristics to keep the stable arc throughout the welding process because you are continuously changing the heat input as well when you are changing E.

To avoid this problem we can use square wave forms that this much more beneficial, so instead of using sinusoidal wave form thanks to the modern power sources we looked rectify inverter or transistor based power sources, so instead of having a sinusoidal wave form we can have a square wave form so in this case so instead of having a sinusoidal wave, so we will have wave forms generated in such a way that instantly we go towards a peak current and then we maintain the current so that is good for the arc stability so the E is maintained or constant and then we can reverse the polarity obviously by using a proper transistor systems and then we will keep the arc constant because rapidly we are decreasing it and then we can also still the power source when the current become 0 obviously you can supply at high voltage to reignite the arc continuously.

So the arc stability increases significantly because the moment it becomes 0 we can know that when the current become 0 then superimpose high-voltage ignition to ignite the arc and this process can be made into extremely rapid whereas in the previous sinusoidal wave conditions it is not possible because there is a range in which the arc is going to get extinguished when it goes below background current whereas in this case we avoid that problem so by having in a square waveforms, right?

So we increase the current in such a way that we keep the mean current constant over a period of time and reverse the polarity. I am doing this process when we can know that when current become 0 we can superimpose high-voltage surge in the system to keep the arc ignited all the time. So this is much more advantageous than using a simple sinusoidal wave, so when you are using an alternative current for welding, in most of the cases modern power sources give square wave forms okay, so that is the most common wave form because of the advantages what I am trying to tell, right?

And the same can be applied to the variable polarity DC as well, so instead of using single polarity for example for GTAW what is the most commonly advisable polarity for GTAW? Electrode must be negative, so DCEN is the most common polarity what we generally use because you do not need to overheat the electrodes okay so the electrodes is always cathode which is connected to a negative terminal but sometimes if you are welding aluminium alloys so you need to change the polarity as well, is not it?

So we can also generate the similar characteristics what you get in alternating current by changing the polarity rapidly by using DC current direct current okay there are some advantages because again so the waveform has to be corrected for alternative current. But if you are using direct current you do not even have a complex transistor system to generate the alternating current curve waveform, you can still have a simple DC current only thing is you can change the polarity okay, so instead of having an AC current supplying transformer you can happily use only rectifier system which can give you reverse polarity to change the polarity rapidly such a way that you have another…

Sometimes electrode negative and then upon keeping for some time you can reverse its polarity such a way electrodes become positive, so you can gain advantage of the modern power sources which can switch the polarity from electrode negative to positive alternatively and you can change the duration of the polarity change. For example you want to achieve a good penetration, so that means that you can use electrode negative but you also need to cleansing action but cleaning action you do not need to keep it as same as the welding action.

So you can you can reduce the duration at which you keep the electrodes positive okay in such a way that you maximise the electrodes negative, so that you will have good penetration characteristics and then you leave it for shorter time, so that it will also clean it, right? So that is beneficial compared to the square wave alternating current using reverse or the variable polarity direct current with varying amplitude and then time at which you switch the polarity, yes, is it clear? And you can also change the current amplitude one case higher than the other case so various possibilities are used to achieve required welding characteristics, is it clear?

So these are some of the advantages and then we can also use both pulsing and reverse polarity together, so that we can maximise the effect of the pulsing and its variable polarity yes is it clear? And these are commonly used to weld very critical geometries and thin sheets for example sometimes you need to have a good geometrical accuracy by controlling the distortion because that is very important so because if you welding a thin sections distortion effects are very high, so in order to control the distortion the pulsing commonly we use pulsing in DC for welding titanium thin sheets, so square wave were variable polarity DC can be used because titanium also has sometimes oxides and surface as well as aluminium okay, so welding aluminium if you are using DC you can use variable polarity direct current with pulse yes, is it clear? Good.

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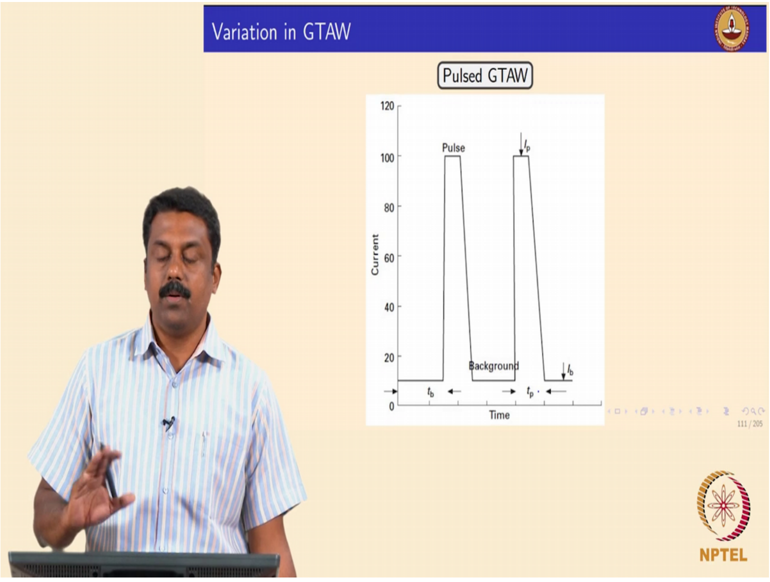

So we move on to that so we have looked at the pulsed GTAW, the effect of pulsing so the important parameters are Ip and then tp, so we always keep Ip and tp ratio constant for a given material okay.

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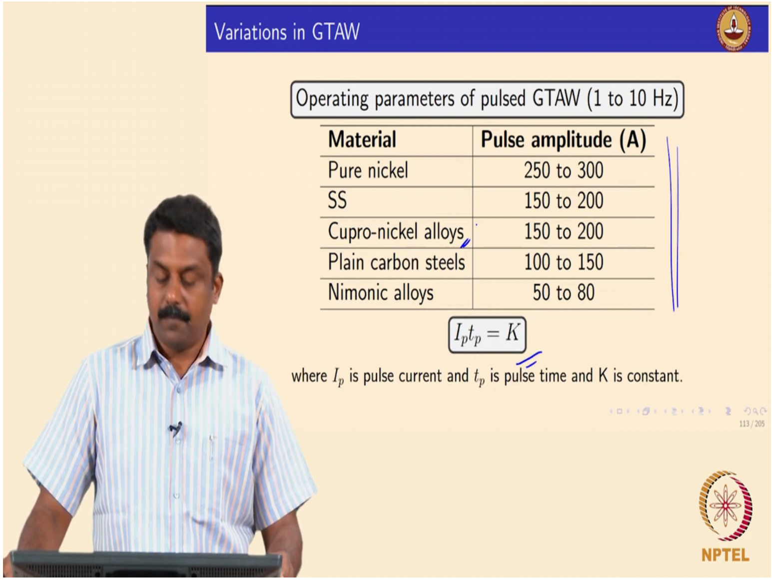

So we looked at yesterday so generally we keep the Ip and tp constant for a given material and we can work on the pulsing frequencies and the amplitude based on the material and thickness need, so these are the common pulsing parameters we use. For example pure nickel be pulsed 250 to 300 amperes and stainless steel, Cupro-nickel alloys. Cupro-nickel alloys are widely used for marine applications propellers because they have very good corrosion resistance and plain carbon steel and nimonic alloys based on their thicknesses we can chose the currents and the pulsing frequency what we need, good.

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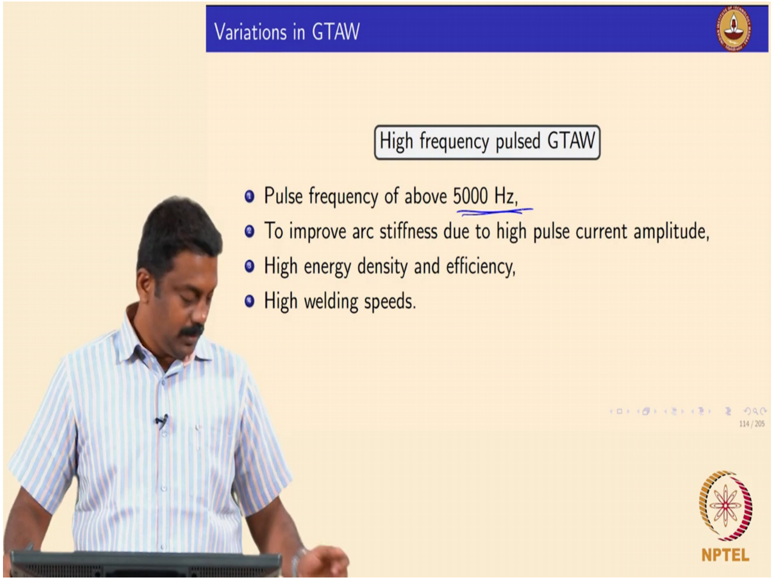

So pulsing frequency can be increased to very high frequency, so we can go up to 5000 hertz based on the power sources and we found that the arc stiffness or the arc core characteristics improve significantly by being pulsing, yes and we can achieve very high energy density because the core becomes enlarge that means that the plasma jet you form and the Centre of the core can be increased in such a way that you will have a very good penetration and due to that you can also have the highest welding speed, yes it clear? Because productivity increase because arc energy increase, the efficiency increases so you can also increase the productivity, yes is it clear? Good.

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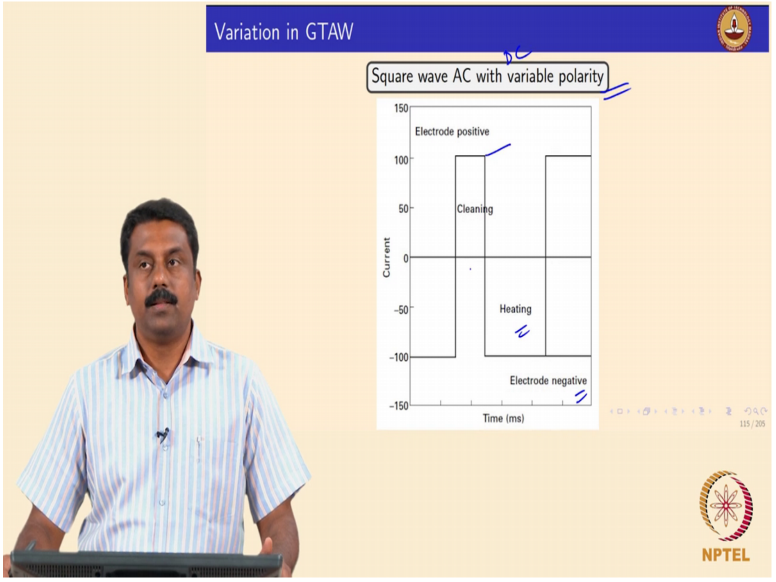

So square wave that is what I just talked about (())(13:58) AC with variable polarity and DC with variable polarity, so basically what you do is we reverse the polarity such a way that we keep it electrode negative, so that we will have a good penetration bit formation and then you can switch polarity in such a way that if electrodes become positive you will have a cleaning action, right? And we can change the amplitude of the current as well as we can also give pulsing in this line as well to get the both characteristics, so this is what we saw in last class we will continue from there.

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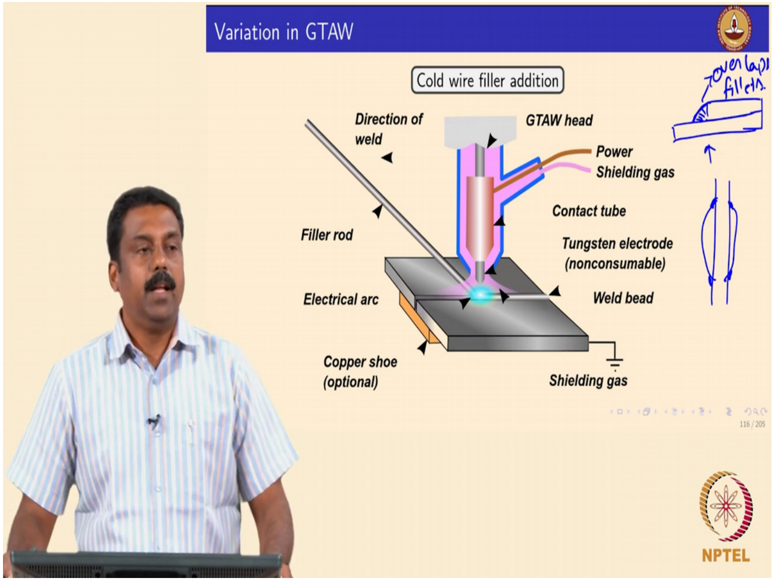

To other modifications we introduce in GTAW and some of them are very widely used in commercial applications apart from the pulsing and then square wave, so one of these modifications like you know adding filler to GTAW, so in previous classes we saw gas tungsten arc welding is commonly used in autogenous mode. Now what autogenous means you do not have any extra material, right, but you can also use GTAW with a filler, so this is beneficial especially if you want to make affiliate welds, now what is affiliate welds means in all of configuration.

So in this configuration suppose if you want to join most commonly we need to fill this gap, so in this case so we can use affiliate welds that means you can use GTA torch and a filler and then we can fill it and GTA with filler is very commonly used. If the weld is exposed or weld is naked we call it naked welding, so naked means we do not use any painting now this is very commonly done is the weld is not painted can hide, so if you are welding and the weld is going to be naked, naked means no painting so it open, so aesthetically you need to generate very good weld it should be very good looking at it and you do not feel like some porosity or some spatters.

So in those applications GTA with filler is the best you can get because the aesthetic appearance of GTA welds are very nice productivity is very low but you see some sort of stitching some artist worked on it, so it creates a very nice structure so any naked welds, the welds are not going to be painted on covered under the surface, so in this obligations we use GTAW with fill up okay so it is a bit tricky because to welder has to use both hands because with one hand he has to feed the filler and the other hand he has to keep the torch okay, generally when you welding it up we do it on a weaving action okay it is not like you can draw a line with the torch because you will have to spread the liquid pool so you make a weaving action to fill the weld cavity and also create an aesthetic applications, right? So the filler addition in GTAW is commonly used for filler joints overlaps and fillets, right?

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And if you look at the weld it is very beautiful, this is one of the pictures I took in Spain. This is actually made in Philippines but welding was done in Spain Look at this GTA with filler so what I was telling about similar to fillet all configuration and look at the weld it is like a beautiful rangoli, is not it? And this is done with an expert welder but in this case when you welding it, you should not be welding it in a single line and you are not going to get good property because the fluid flow will not assist to make aesthetically good weld as well as properties will also be bad because when you do in a single stroke, you may also have under cuts because the fluid flow may not be sufficient to fill the entire weld cavity.

So in that applications you have one nitric welding torch and then add a filler and then do a welding action. Okay so both hands should be coordinated in such a way that you create a weld with overlaps like that, is it clear? So this is very commonly used as I said when the weld is open. You need to compromise on productivity, so in this case if you use GMAW, aesthetically GMAW welds are not as good as TIG with filler, so GMA welds they are not as good as TIG weld because in this case you just fuse…melt the filler and then fuse it and you can control the flow very nicely like a cradle okay.

So we make reciprocating motion with the filler so that we make such a beautiful weld. So now we do not need to do anything, so in this case this is stainless steel filler and I think this is stainless steel 316 pipe. So the moment you fill it by the weld and that is it, no need to paint and no need to worry about it okay because this is aesthetically very good alright, is it clear? Okay so the problem here in cold wire, the wire at room temperature is in productivity, so you can improve the productivity by heating up the wire, so wire can be heated up so that the temperature….you do not really reduce the (())(19:54) temperature by adding it up, adding a cold wire and also if you are heating up, you also increase the productivity by melting more, okay.

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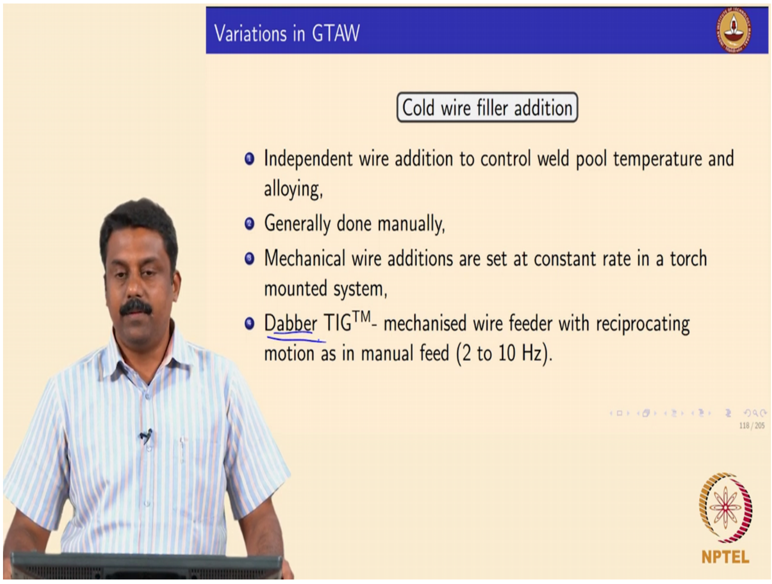

So the modification is again a hot wire filler, okay so the advantage what I have talked about cold wire filler is also here, so it is like an independent wire addition to control the weld pool temperature because in GMAW you filler itself it is melting, so in this case you can control the feed rate independently because you are adding it okay. Most of the cases it is done manually because of the coordination, so you need to have a proper weaving pattern achieve. It is very difficult to mechanise that okay so by having both reciprocating motion and then filler addition, so generally done manually but only one system I remember they automate

(())(20:46) is Dabber, so they made mechanised wire feeder with reciprocating motion to have an appearance of a manually made GTAW with filler.

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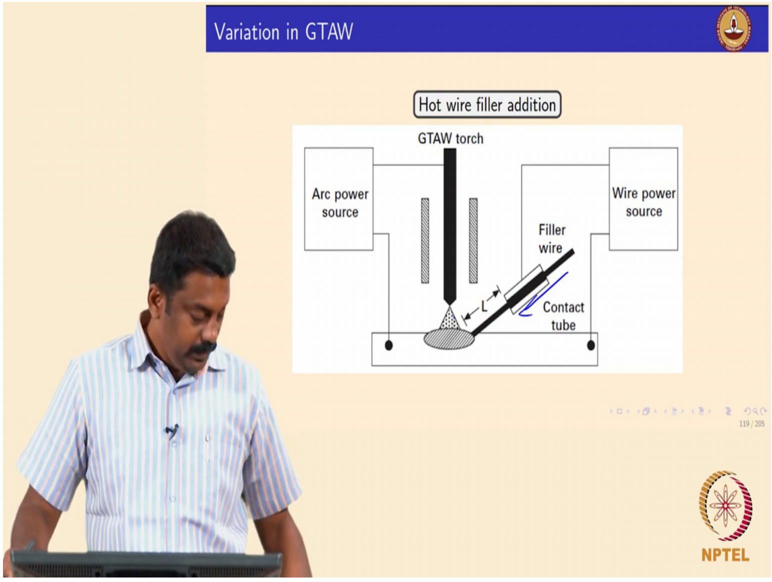

So as I said the productivity of this process is very slow, so we can heat up the wire to reduce the temperature of… Temperature reduction problem you have seen cold wire addition as well as wire can be heated up to a high-temperature so you also increase the melting rate okay, so the principle is simple only thing you need is an additional wire power source to heat up the wire, right? And then you need to make an automated wire feeding mechanism because wire can be heated up to temperatures where you cannot hold it by hand.

So by creating the mechanism by which you can have a wire feeder and then the power source which can heat up the wires to a temperature in a way that you have the filler you do not reduce the weld pool temperature significantly otherwise in previous case in used to also mind that when you are adding a filler and in most of the cases the add filler in GTAW not to the arc but the molten pool okay, so we do not add filler to the arc because then you cannot control the melting rate, so in most of the cases the trick is also very clear, so in this case we are not adding to the arc, right?

So we will add to the molten pool, right? So this is very important because when you are adding it to an arc you cannot control the melting rate then the purpose of using GTAW is last you can very well use GMAW, so you will not get aesthetically good weld because then you can have GMAW it is the same as using GMAW okay but when you are adding a cold wire to the molten pool you also reduce the temperature of the pool, so the temperature of the pool is also reduced so that means that it may solidify early or it may solidify rapidly in such a way that you may end up having under cuts.

Do you know what is under cut? So under cut is for example you have a weld cavity, so you will have to fill the entire weld suppose if the weld is not fill and you have a geometrical discontinuity and this is not good because you have an undercut and this will create a problem when the weld is supplied with a load okay then you have a notch leading to a crack formation and it will fail and this is because the welds solidifies and the liquid pool is not wetting the cavity completely and if the temperature is low and it can solidify instantly leaving an undercut formation. So in this case the heating of the wire is advisable because then you do not reduce the temperature significantly compared to cold wire additions, yes, is it clear? Any questions so far? Otherwise we will continue.

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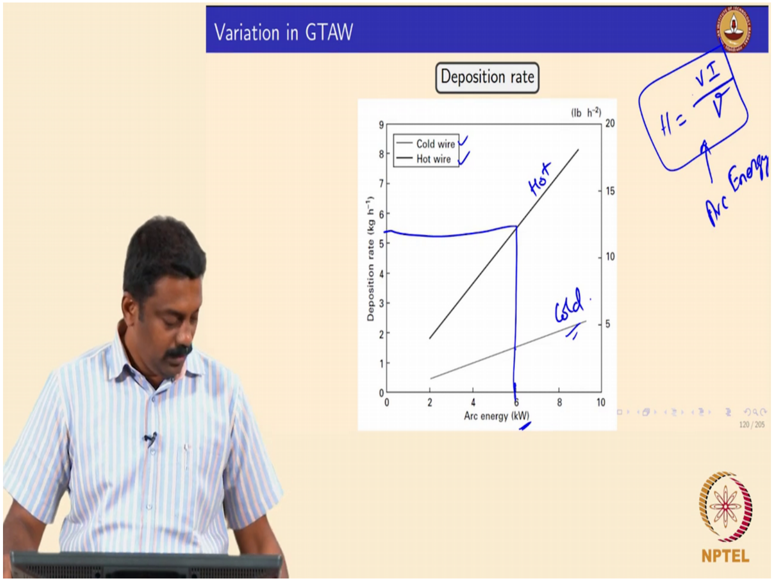

So you can see deposition rates, change in deposition rates comparing the cold wire and then hot wire and this is hot and this is cold and this is functional arc energy, so what is arc energy? So what is difference between arc energy and the heat input? What is heat input? What we calculate heat input in GTAW equal to VI by speed and this is heat input or arc energy? To calculate heat input you need to put efficiency, is not it? So in most of the cases this is the constant okay so we may neglect this guy and basically this is the arc energy because that is the energy generated in the arc, is not it?

And how much is transferred that is written, right? So you multiply that with the efficiency… we will see in GMAW in details so what are the relationship right now you can say because you plotted the graph here, so it says arc energy so arc energy is without efficiency, yes is it clear? So in GTAW you will have their own efficiency, we will see in subsequent classes but now you can clearly see deposition rate as a function of heating the wire and not heating the wire filler say for example if you have an arc energy of 6 kilowatt.

So by using hot wire TIG, we can increase the productivity much higher about 5 to 6 kilogram per hour you can melt. Whereas in cold wire TIG, it is not even 2 kilograms, so the melting rate or deposition rate increases significantly by heating the wire and in most of the cases we will be heating it up to 400 - 500 degrees centigrade, the wires right? So too high end so anywhere between 200 to 500 degrees centigrade in hot wire TIG, okay good, is it clear? So how the productivity increases? Basically you heat up so that you do not weld, you want to cool the weld pool as in the cold wire additions and heating the wire, it also increases the productivity because obviously you need to reach the melting point to melt the wire, the wire is already heated up it melts quickly yes, is it clear? Good.