Welding Processes

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Melting rate of consumable wires

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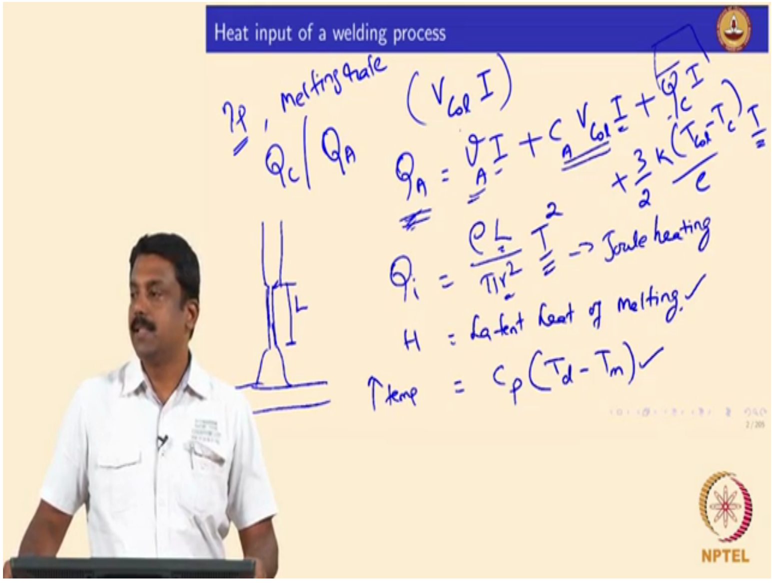

Okay, so we were looking at last class two things the efficiency calculations eta p and then the melting rate and efficiency calculations we were driving the heat in anode and cathode, Q C or Q A so based on the polarity we can assume that the work piece is anode or cathode, so the amount of (())(0:43) heat which actually goes in to the work piece it determined by the polarity, if you are using in straight polarity or reverse polarity.

In GMAW process it is both Q C plus Q A because whatever heat is generated in the cathode it is also transferred back to the work piece so if it electronegative. So in GMAW process it is addition of both Q C and Q A that is why in GMAW process the efficiency is much higher. And then the efficiency is also determined by the this term, so this is the term which determines the heat generation in the arc column.

So when you are looking at Q A for example so this we were driving equation is the heat generation in the anode plus I plus the amount of heat transferred from the arc column to the anode so that not all the heat is transferred only fraction is transferred based on the radiation conduction, convection from the arc to the anode so that is again determined by the fraction and then V column and times I.

And how do you calculate this value? So V column I this can be transferred into I times V equal to V is IR and then it becomes I square R, how do you calculate R? This is electrical resistivity of an arc we derived an equation from that, so we derived equation to calculate the electrical resistivity of an arc. So that we can use it we calculate resistivity of an arc so that we can calculate the heat generation in the arc that is why derived that equation to calculate this term.

So again so the efficiency is also determined by how much heat is transferred from the arc column to the anode if it is Q A in the work piece. And then so in anode you also add the heat from the work function by the work function is spent in cathode that is gained in anode when the electron reach anode, so this is the work function of cathode times again current plus the electrons also get heated up and they also carry heat to the anode because when they enter the arc column they get heated up from the temperature of the cathode to the arc column temperature.

So we can measure that from the Boltzmann and then this is the column minus T anode this is T column arc column minus cathode because electron is coming from cathode only divided by e times I. So this is all plus term in anode that is why the temperature is always higher in anode, in the cathode we have minus terms where the work function is spent, simply electrons also gets the absorbed heat while the electron gets heated up to the arc column temperature. So now this is the heat available in anode and the cathode.

So now with this equation so this is the main heat is available for droplet to melt, suppose if you are making your consumer electrode as an anode the heat available to melt is this so that is what heat is there in the anode and then we also have a additional heat which is coming from the resistance heating. So this is the main heat available in the anode for droplet to form, okay.

So that is the heat is coming from the arc for the melting of the electrode plus we also generate heat in the anode if the consumable electrode is anode so that is the Joule heating then the resistivity of the wire and then equation is e L by Pi r square (very good) and then so this takes care of arc. So what is the equation to calculate the heat from the resistance? I square R. So that is the heat generated by resistance by Joule heating at the wire.

And what is L here? L here is stick out length, suppose you have on a contact tip and then wire will be sticking out the consumable wire and then it will form the arc the base material the distance between the contact tip to the arc so this is the stick out length generally we define and this is very crucial parameter in GMAW so when you are setting it up, that is what we saw in the previous class also.

And these two are the heat gain so this heat generated if your consumable electrode is anode so this is the heat generated and can be spent for melting. And then so we have additionally two terms the first term is latent heat of melting this can be exothermic and endothermic based on the system, most of the time the heat should be supplied for the melting so latent heat which is H and then. So once you melt it droplet will not be in same temperature melting temperature, it would be heated up to a temperature at which it can be transferred.

So from the melting temperature it should be heated to at droplet temperature, it may not be at the melting point, it has to be heated up in order to separate, we will see in subsequent classes in this class itself in the later stages, so what will be temperature of the droplet? Because if it is a melting point just exactly melting point and the droplet the surface tension will be very high and you will also have if an instability the droplet cannot be detached we can call solidify.

So the droplet should be super-heated then only can detach the moment the droplet forms it is exposed to the arc it is also heated up. So the additional term which actually consumes during melting process is to increase the droplet temperature from the melting point to the droplet temperature, so that term is say for example the heat needed to increase the temperature so that is function of specific heat capacity times temperature of the droplet when it is getting detached and the melting point, so simple. So by balancing these 4 we can calculate the melting rate.

So this is the entire heat balance used for melting, there is no other heat there is no other consumption, only these 4. So latent heat can be positive or negative so when during melting some system may send heat so when some system melts it can be exothermic so then this term becomes positive, system tend to melt. In most of the cases we supply heat for melting that is why it becomes endothermic, so either can be positive or negative. So by adding all these 4, we can calculate the melting rate.

So in these 4 equations most of them are material specific and then process specific that is why we looked at it. For example in this case the only variation independently we can vary with respect to material is current and then stick out length for a given diameter of the wire these two L and I square we can vary, okay so this is a material function again this is the material function and in this Q A term so this is material function, of course if you take I out this becomes material function and this is process specific if you fix a process into shielding gas this is fixed.

And in this case V A is the voltage in the anode drop zone again this is a process specific so the main variable you here again I and all other things are either material dependent or process dependent. So now for a given material for a given process condition process condition includes shielding gas. So the important variables what you see over here which controls the melting rate are the current stick out length for a given diameter, okay so these two mainly the current and stick out length you can independently vary for a given process for a given material of a given diameter.

Suppose if I give you 1.2 mm diameter carbon steel ad I ask you to weld using GMAW using arc as a shielding gas so all other things are fixed only two parameters you can vary is current and stick out length to change the melting rate. So the most of the welding process specifications when you are generating for a given diameter wire for a given process we generate as a function of these two parameters stick out length and current, is it clear?

Because these two are the independent parameter we can vary for all the process and the material specifications, is it clear? So we derive the melting rate equation kilograms per second so that is the equation what we get so then we can do a balance and identify the equations.

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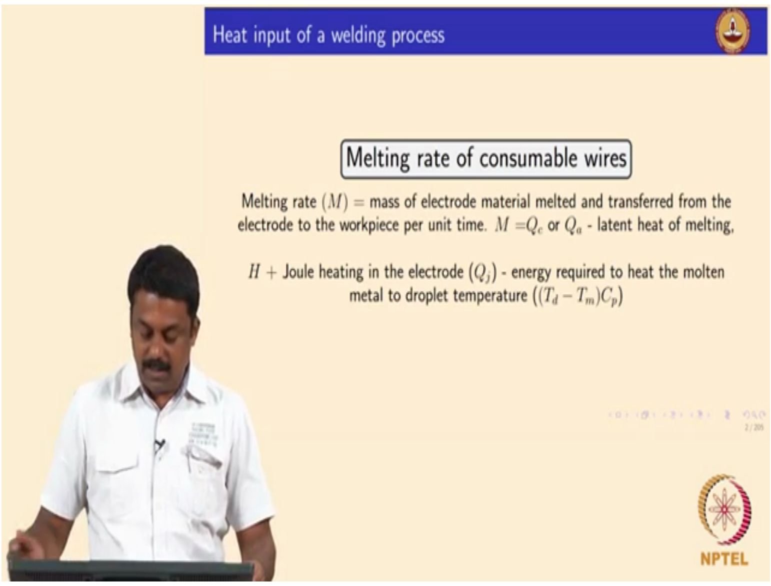

So this is what I have written here, in this case Q A and Q C so what polarity will be more advantageous if you want to melt more? Which polarity is better? Reverse polarity so making consumable anode, why? All the positive terms, so heat is high in the anode. So if you want to melt more if you want to deposit more that means that you need to have a high heat Q A must be used because anode is there the heat is maximum because all the positive terms.

So if you want to melt more volume per time per unit time you can make your consumable electrode as an anode that means that reverse polarity in DC. So that means that you can increase the melting rate so when you are doing a welding in the polarity selection it is not just like that you do an direct current DC electrode positive or electrode negative so we need to take into all the physics so that is a lesson, okay so it is not like a thumb rule or just rule of mixture or just like that you weld with argon or with straight polarity and start depositing because you are changing the physics entirely.

So it is extremely important to understand what this polarity mean and how they can interfere the various as varying levels. So in a consumable welding process it can considerably change the melting rate because heat in the anode is changed if I changing from anode into cathode if you are making from the electrode the reverse polarity into straight polarity so you have less heat in the (())(13:54) so you are melting the decreases, if I making it as a cathode, right.

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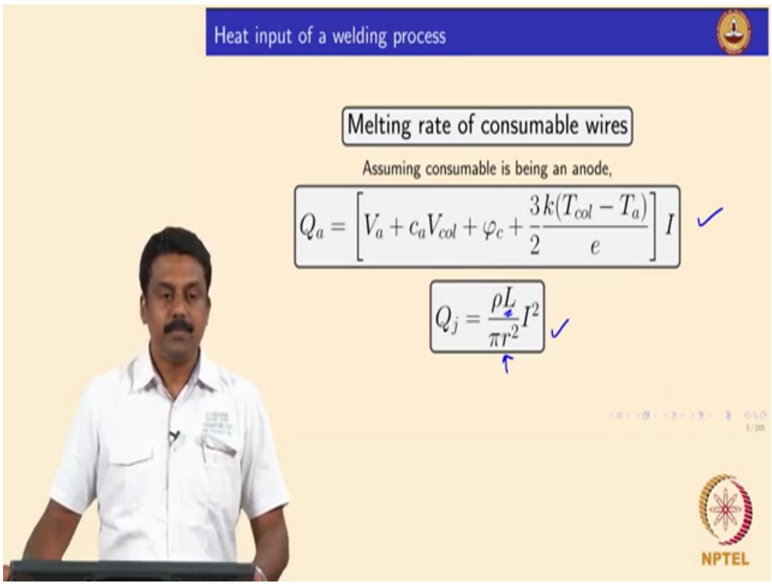

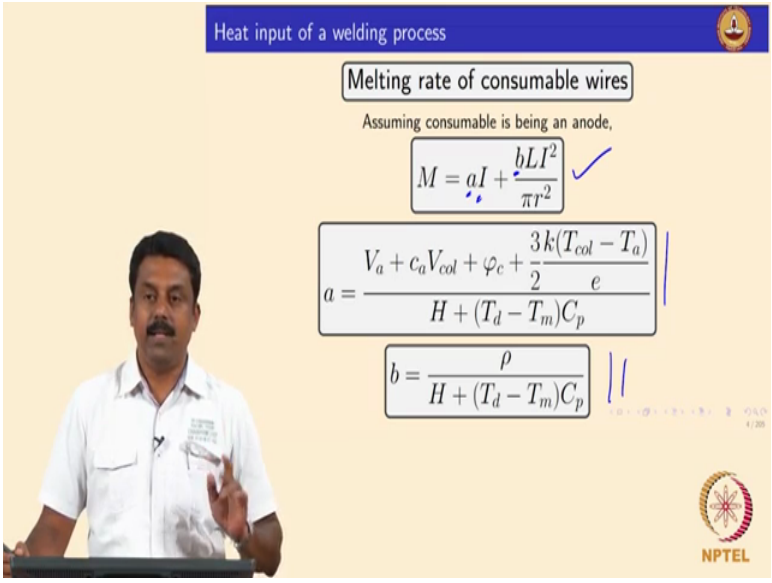

So we can derive a very simple equation by looking at the heat balance so Q a if consumable being an anode which is the most likely situation and if you want increase of productivity you always make your consumable electrode in anode so that all positive terms will increase the melting rates and this term is a resistive heating term and L is a stick out length and r is the diameter of the filler radius of the filler.

And using that we can derive a simple equation because there is I term in the Q a term an I square term in the Joule heating term and a and b is the constant for a given material and the given process conditions. So we can take the a and b out because they are constant so ultimately end up getting an equation like M aI and then plus bLI square by Pi r square and a and b we can calculate for a given process condition or for a given material.

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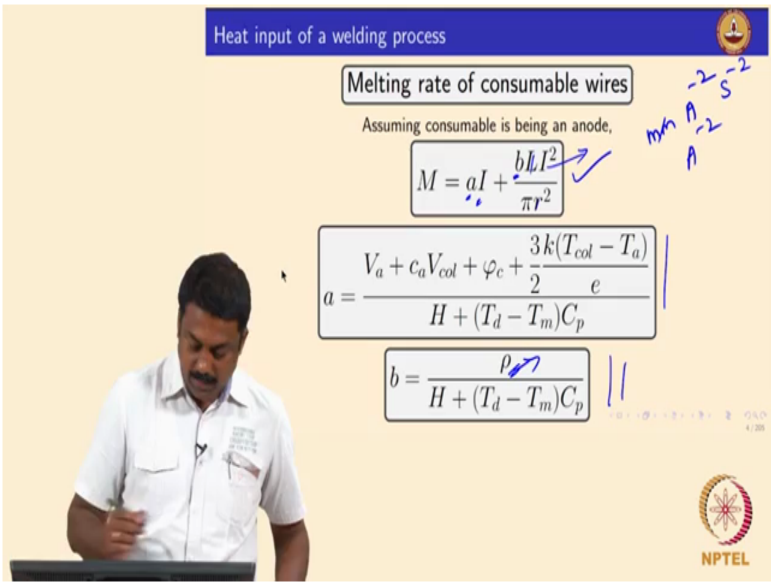

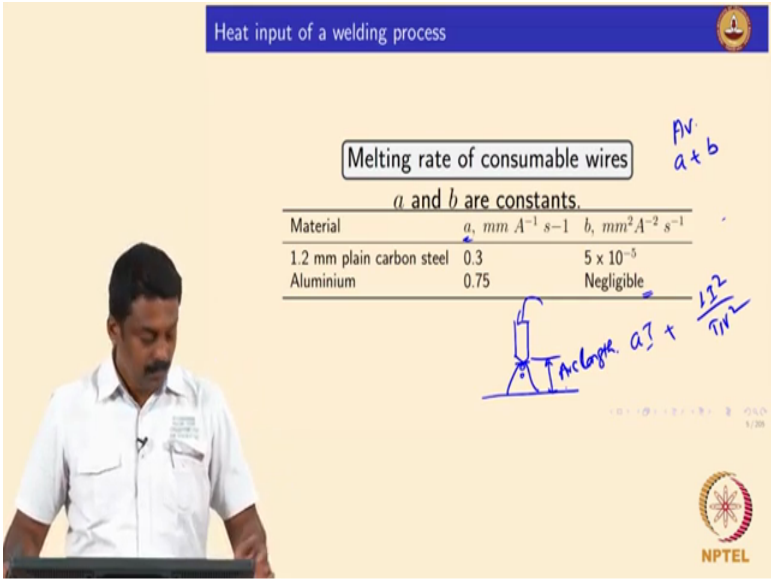

So for example I just calculated few a and b, so in this case so a and b for 1.2 mm plain carbon steel which is most commonly used filler wire, for argon atmosphere shielding gas is an argon and if you use argon shielding gas for 1.2 mm plain carbon steel everything is fixed so process is fixed GMAW argon atmosphere so the arc column, heat generation is fixed and then so what are the varying now the a is fixed and b is fixed, only two parameters we can vary they are stick out length, current to change the melting rate.

So only for aluminium so this term really negligible so this goes away so b goes away so we can simply assume that this aI plus LI square by Pi r square so this is again is 1.2 mm so this case the b is negligible. So once you know a and b for a given stick out length and current anyway. So once you know a and b so we can calculate the melting rate which is alpha I and then plus beta LI square by Pi r square, so a and b is material learned composition specific so that is what you need to see here.

So once we know this so now we can calculate the melting rate accurately and then the (()) (16:46) of this is it is very important to calculate the melting rate for a given wire to keep the wire the arc length constant. Suppose if you are doing it in a constant voltage welding the arc length should be constant that means that whatever amount we melt is also feed. So suppose if are melting and you want to keep the arc length constant suppose this is my wire and then I am making an arc and this is constantly melt and then transferred to the work piece.

Now if you want to have an constant arc length the wire feed rate should be same as melting rate. Suppose if you want to maintain the arc length constant we will have to see that the arc length kept constant by constantly feeding same wire feed rate as the melting rate otherwise your work length will change your voltage will change. So now in order to keep the arc length constant and the power source should be capable of calculating the melting rate for a given wire composition in the process so that is where it goes into the microprocessor control system.

In GMAW so suppose if a wire feed rate should be kept constant that means that the system the power source should be capable of calculating the melting rates, so that it can feed the wire the same rate can melts. Suppose if you are changing the stick out length so obviously the system should identify and change in the voltages such a way that if there is a change in voltage means the arc length also changes. So automatically the system should correct for it, so that we can do it in a constant arc length weld.

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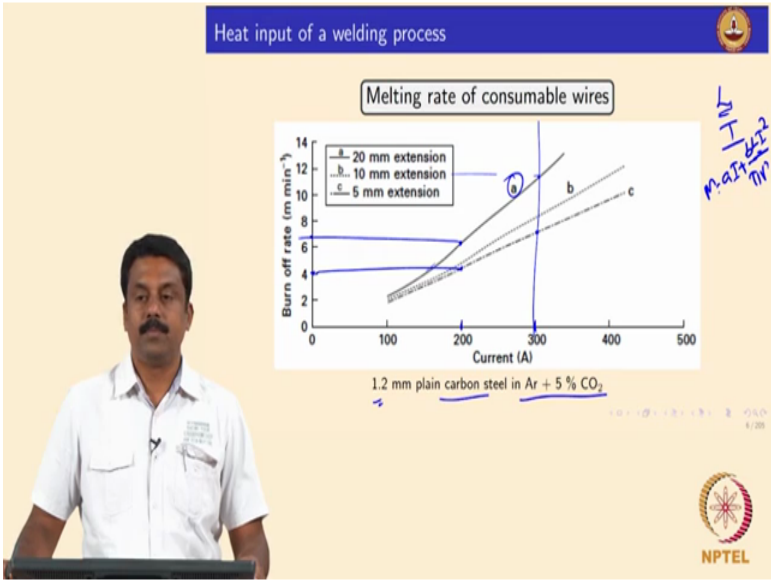

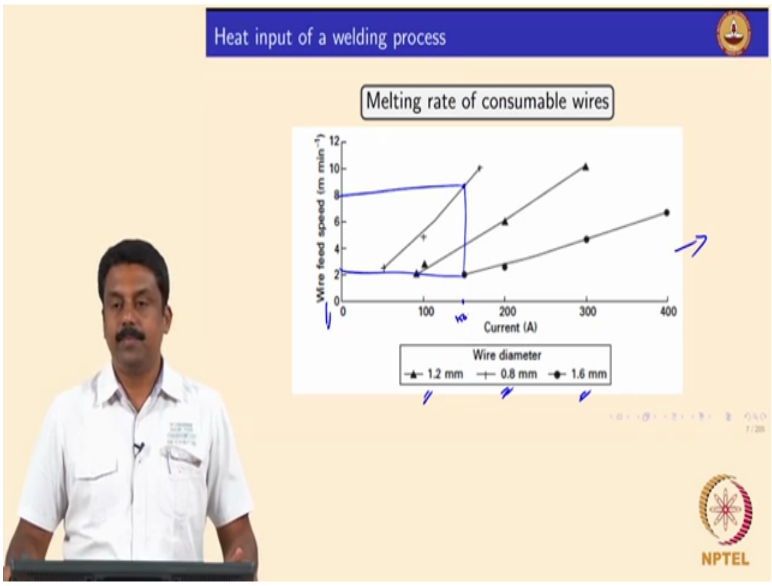

So now if you look at it two examples I will show you two independent parameters we are looking at it. So that is the stick out length L and the current I, the first the effect of stick out length, so what is the relationship between stick out length and the melting rate? If stick out length increases melting rate also increases because melting rate is aI plus bLI square by Pi r square, so if L increases melting rate increases.

So in this case everything is fixed 1.2 mm diameter plain carbon steel argon and fiber CO2 atmosphere. So now the two parameters can be varied, current and stick out length. So for change in current for a given stick out length this is my melting rate okay so this is 20 mm extension 20 mm stick out length. So suppose if I reduce the stick out length for a given current for a say 300 amperes my stick out length is say 5 mm in this case the melting rate will be lower than if my stick out length is say 20 mm, obviously right.

So by changing the stick out length for a given current melting rate also changes, is it clear? Say suppose if you have 200 amperes current is used and say 5 mm stick out length, 20 mm stick out length. So you have a melting rate or burn off rate changed from say 6 point or 7 to 4 by change the stick out length from 20 to 5, is it clear? (Very good). And then we will go to the second one similarly so you can also change the melting rate by changing the diameter, what is the relationship? Inversely proportional, if you change the wire diameter so in this case the melting rate for a 3 diameter 0.8, 1.2 and 1.6 and which will have a highest melting rate? The smallest diameter.

Say for example for a given current say around 250 amperes which will have a lowest the lowest melting obviously will come from 1.6 mm so that is the largest diameter, the maximum melting will happen for the smallest diameter which is 0.8 mm, so we can change changing diameter from say 0.8 to 1.6, so we can change the melting rate from 2 to close to 8 these are (())(21:57) observed values, is it clear?

So how the melting rate is influenced by the diameter and the stick out length? Obviously current also (())(22:09) so if you in case in current obviously melting rate also increase significantly for a given diameter and this case the stick out length is fixed when you are doing experiment, I think 10 mm stick out length. So diameter is changed independently to see the effect on the melting rate, is it clear? Good.