Welding Processes
Professor Murugaiyan Amirthalingan
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras
Flux cored arc welding - Process characteristics

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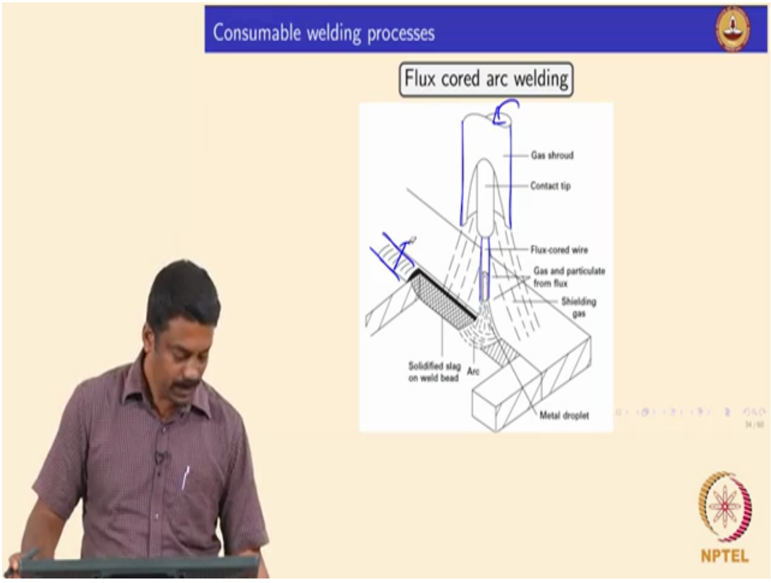

So it is schematic it is very clear, right so same as the gas, so in this case you can also have process done in a using a shielding gas, ok so in SMAW in most of the cases you do not need shielding as all self-shielded whereas in flux cored arc welding we can also play around the composition of the flux, in some case so you want to have a maximum alloying so you want to reduce the concentration of the flux especially calcium carbonate for example, so then the shielding gas which you generate is not sufficient to have a sustained arc, so this process can also be now shielded by external shielding, ok.

So in that case so you can reduce the gas tone rating components compounds from the flux you can add more element of align elements, ok so in that case your process should be ed increases ed is similar to GMAW the advantage is the you get the efficiency of GMAW and you also have advantage of FCAW by having flux, the flux interfering with droplet transfer enhancing the (drop) kinetic surface transfer also protecting the weld pole by the flux, the slag, yes it is clear, ok.

We will see one by one when we go further, so sometimes you may also sent the shielding gas and if you are using an a self-shielded FCAW you do not need shielding gas because flux itself can generate shielding gas, right it is clear, so then you have a slag depositor on top of the weld pole and then you can break it after welding, good.

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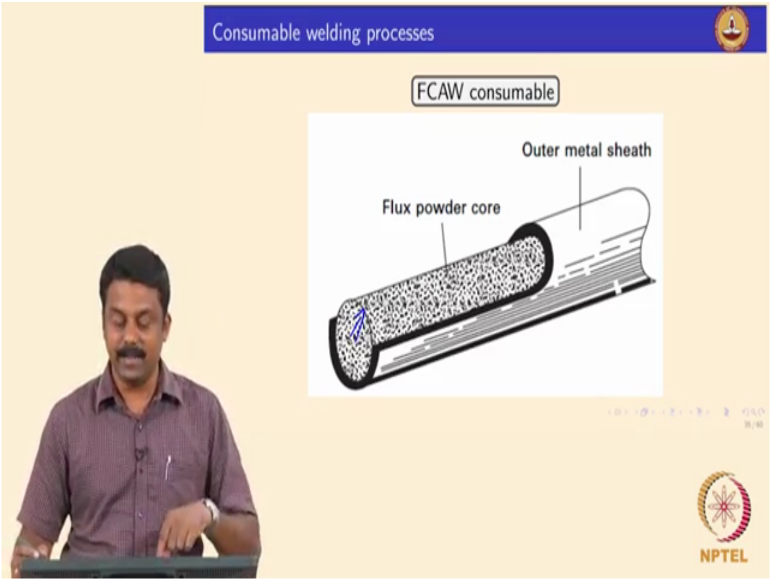

So this is the cross section of the electrode which is saw in last class as well, right so you have an outer shielding and then the flux is inside, ok so now these are most compacted, so you can have look at it and then, so this is 2 point 4 mm diameter FCAW it will not come out even if you tap because it is already compacted, right so it is already compacted with binder, so the all the compounds or the flux added inside.

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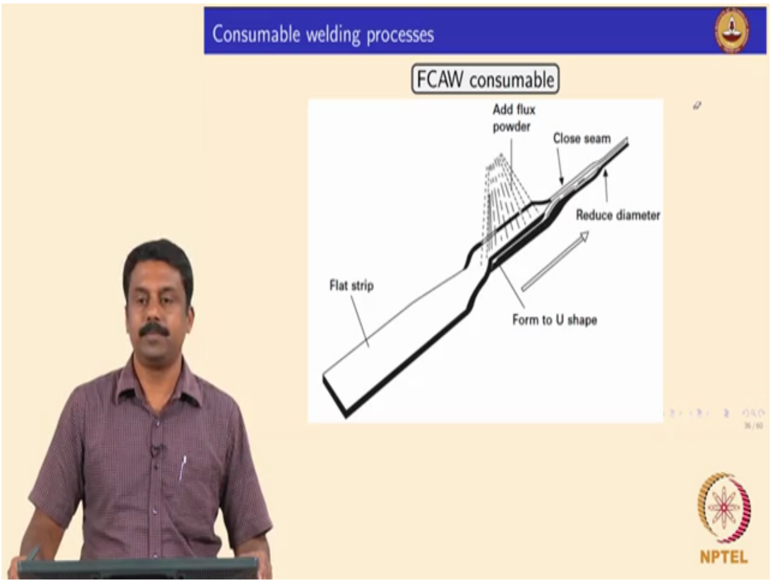

And then the electrode is made from the flat strip and then you add the flux powder and then you see close it and in most of the cases most cases it is not really welded it is just simple folding, right they so just fold it and then close the seam and you can generate as much length as possible and then generally we make it as similar to GMAW electrode filler, so we will have a spools of electrode made with varying weights and length and that can be fit into the power source, yes it is clear, good.

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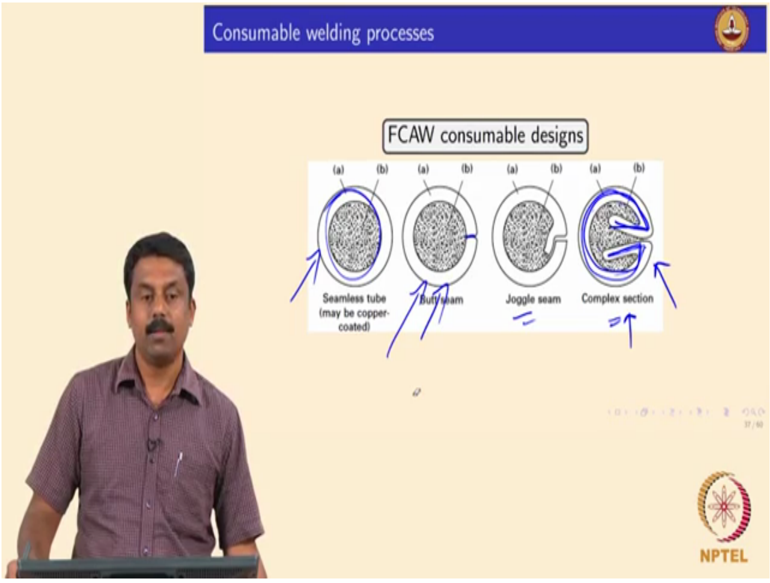

So typical cross section looks like, so we can make in a seamless tube, right so you are also have a butt seam and this is the electrode I gave you it is butt seam electrode, ok whereas a simple joint or you can also have an varying joggle seam and the complex section, so in this case so you can also improve or increase the amount of alloy (melten) molten, so in this case the cross section of or the length of the metal is much lower than when you have such a geometry so (sufo) if you want to increase the liquid metal droplet the contribution from the actual the metal so you can also change the this sheet geometry in such a way that in this case you melt more metal and then you have a little amount of flux surrounding the metal sheet.

So this kind of electrodes the amount of flux is which is there it is not sufficient to produce an off shielding, ok so because here the metal volume is much higher than the flux volume, so such a geometry complex section geometry is used with conjunction with the shielding gas, ok in most of the cases self-shielded FCAW would have an design of an seamless tube or butt seamed the electrode, so for an complex section or joggle seam sectioned the FCAW consumable generally you need to have an extra shielding because the volume fraction of flux with respect to the metal decreases significantly, so you need to generate more gas, so you may have to use an external shielding, yes it is clear.

So these are the commonly used the design for the FCAW, the one is circulated this actually butt seamed FCAW consumable, ok good, any question so far? Move otherwise, good.

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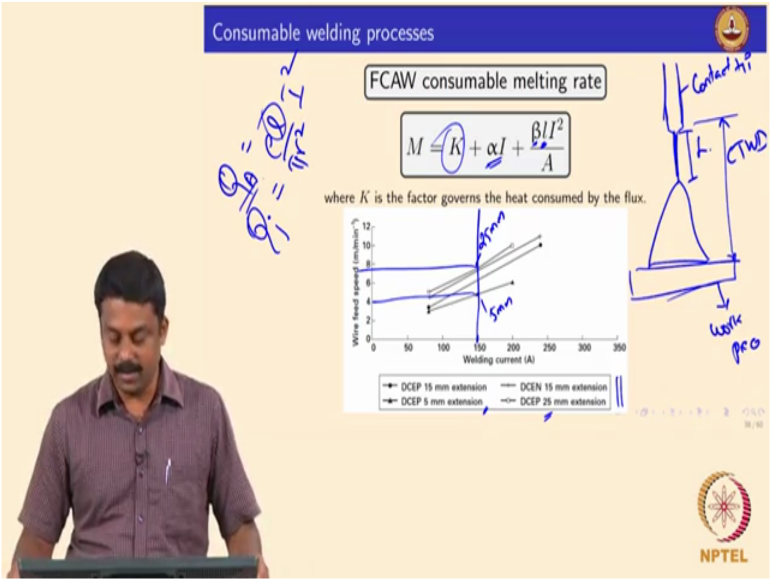

So melting rate, in GMAW what is melting rate, so this goes away, right in GMAW the melting rate of the consumable is alpha times I beta L I square by A, what is L here?

Student is answering: (())(06:04) stick length, stick out length.

Professor: Stick out length exactly, so you have an electrode tube, contact tube, ok and then so you have an electrode coming in and form an arc simple and this is stick out length L, ok so this distance what is this distance? This is contact tip and this is work piece, is not it and what is this distance?

Student is answering: (())(06:49).

Professor: This is contact tip to work place distance, ok is very simple, so CTWD and that is what we define all the time CTWD minus arc length is a stick out length, right so CTWD defines the distance between the contact tip to the work place and that is very important parameter, right so CTWD is important parameter because that would determine the stick out length and the arc length, if you are doing an a constant arc length case at a given CTWD then your L should be based on your melting rate, is not it.

So in a conventional GMAW, so we use an I plus I square relationship whereas in this case we also have to have another term because the heat is also consumed by the flux is not it, so when we did the heat balance to calculate the melting rate, right so we looked at four important parameters, is not it when if a consumable is anode, right the heat generated in the (())(08:09), so that is Q A is not it, plus later heat of melting, right and then heat generated in the anode by resistance heating and then the heat needed to increase the temperature of the droplet to the droplet temperature, ok that is a heat balance we did it to calculate the melting rate, right.

Apart from this four there is another factor here when you use a consumable welding which factor is that? So heat observed or heats eaten away by the flux, right so there is another component comes in when you are doing a mass balance or heat balance is the K factor, so that factor governs the heat consumed by the flux, so again that is a function of the composition of the flux whether you have an rutile based or basic flux or cellulosic material.

So again the as a function of stick out length we can also calculate the wires field rate, so if you increase the stick out length what happens to melting rate? So if you increase stick out length for example 25 mm for a given current or 150 amperes stick out length increases means melting rate also increases, is not it so this is the low stick out length 5 mm and this is 25 mm, is not it so this 5 mm, so at 150 amperage your welding of an 2 point 4 mm flux core arc welding just by changing stick out length it almost double the melting rate, ok is not it from 4 mm per minute to 8 mm per minute it is almost double, is not it.

Student is questioning: Current is same?

Professor: Current is same, so why the melting rate is changing?

Student is answering: Melting rate is changing so we can do (())(10:21).

Professor: See if current is a same your question is why does melting rate increase, look at this equation.

Student is questioning: Stick out length changes?

Professor: If stick out length changes melting rate increases, ok because the more the length the more joule heating, ok so you have looked at joule heating, right so what is joule heating formula? I square r, rho l by pi r square I square, is not it so that is why we deriving the melting rate equation by heat balance is not it, so what is l here? l is this stick out length, so more the stick out length more joule heating then more heat is there for melting, right so heat is again the heat balance what it derive.

So just by changing the his stick out length you see that already the melting rate can be doubled, right so that is what though by all other parameters in this equation are fixed that is why we take it as constant and because the process efficiency is depending on the shielding gas the characteristics of ionisation the reactions, the heat generation which is happening that is what the equation I first time I derived, right the electrical resistivity of an arc, ok that is determine by the arc characteristics, right so that is fixed for a given process for given shielding conditions and given polarity, ok.

So what are the factors that can influence apart from that is your composition, so composition is fixed if a composition is changing latent heat of melting is changing, right and the h is changing and then you also change Cp specific capacity, Cp changes then also change the heat require to increase the temperature of the droplet, so now you fixed the process, you fixed the chemistry and what are the parameters you can contribute? Ok.

So in this Q c Q A term the only parameter which is changed irrespective of process and the composition is current, ok so the current can changed, ok and the resistance heating part and joule heating part there are other parameters is diameter and the length, ok so he fixed a diameter for a given weld diameter consumable diameter, so what are the factors can be changed in the length, right the length is stick out length l, right.

So two parameters independently can change by fixing everything say suppose that is (imp) that is why it is call it independent parameters because that can also change person to person, so you weld today morning and next guy come is and weld and if changes stick out length everything is same shielding is same, the (vol) process is the same, right material is same, diameter is same and even if you fixed the current if you change the stick out length their melting rate change, right it is clear.

So this graphs clear shows in FCAW with by changing the stick out length you can almost double the melting rate, yes it is clear, ok good. So the K factor takes care of the heat consumed by the flux by decomposition to generate hydrogen the gases carbon dioxide as other shielding gases, good.

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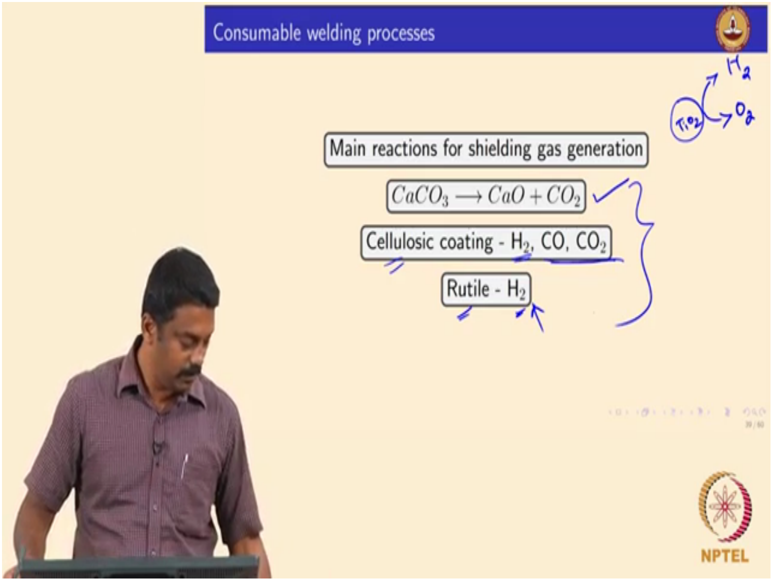

So the main reactions for shielding gas generation in this flux coated electrodes or FCAW electrode is calcium carbonate burning into calcium oxide and CO 2 and calcium oxide founds a slag and CO 2 is a shielding gas, ok. So in cellulosic material the fluxes carbon monoxide and carbon dioxide and also the hydrogen, ok so cellulosic material they content a titanium torch generate hydrogen.

In rutile based fluxes the main shielding gas is hydrogen because titanium oxide can effectively reduce the water into hydrogen and oxygen flux, ok so that is why the titanium oxide now days is very commonly explored by the Nano guys to generate hydrogen by photocatalytic, so nano titanium oxide rutile used as a catalyst to so decomposed water into hydrogen oxygen, ok so titanium oxide has an photocatalytic effect so when the other droplet comes to do the surface of titanium oxide it promotes the disintegration of water into hydrogen in oxide, ok.

So titanium oxide now a days people explore left and right to generate nano titanium oxide used it as an photocatalytic (ka) agent to generate hydrogen, so hydrogen field cells you may see they use nano titanium oxide, rutile and we used it in welding also but we do not really call ourselves nano guys because ultimately when titanium oxide is add in the flux it would disintegrate it becomes nano titanium oxide and we generate hydrogen, right that is why we call welding, welding is does everything, ok.

So we make steel making, we also work on you know hydrogen generation, right so but it is been done for several years and we do not climb ourselves as an advance researchers so we player low level, ok but still we use a titanium oxide to generate hydrogen for shielding, right. So these three are the major reactions that are happening to generate shielding gas, so if you reduce the flux concentration increase the metal volume fraction then you need to use some shielding, ok.

So in self-shielding self-shielded electrodes we do not need external shielding because the flux decomposes and generates enough shielding gas for arcing, right it is clear, good we will move on.

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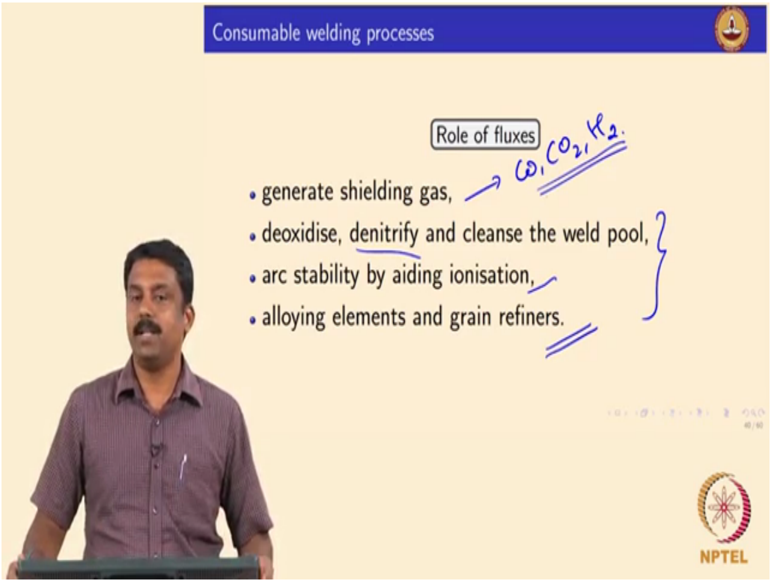

So I just put four important roles of fluxes in the SMAW and FCAW the main important function is obviously it should generate shielding gas, right. So either be carbon monoxide or carbon dioxide or hydrogen, so the that is the main function to generate shielding gas and apart from this there are some secondary functions these fluxes do they act as a deoxidizer for the weld pole, ok and they also denitrify and cleanse the weld pole and you can also have depolarization, desulphurization and done by adding an as a elements which promote deoxidization, denitrogenation, desulphurization or dephosphorization, ok.

So to clean the weld pole and then to improve the arc stability because we know that you know the oxides very low ionszation potential, so they also promote ionisation, so if you improve the ionisation so obviously arc stability increases again ultimately the basic term condition of arc is sustained discharge, so discharge is sustained to have a stable arc, so if you promote ionisation by adding oxides so arc stability increases automatically of course these fluxes can also be added to change the alloy composition of the weld mat, ok so you can also add presentation in using elements like ferroniobium, ferrotitanium in steels and you can also add as an grain refining elements in the fluxes.

So these are all the secondary functions when the primary function in this is a processes to generate shielding gas, right good.

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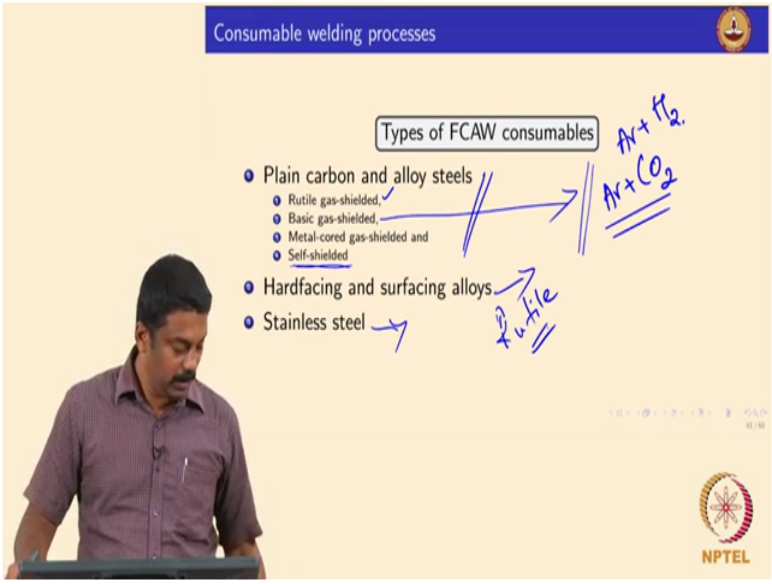

So what are types of the commonly used flux cored arc welding electrodes, so as the for plain carbon steels so we have a rutile, so if you use a rutile obviously if you do not have a flux to generate to shielding gas you need external shielding, so rutile (ga) the electrodes with gas shielded, so that means that you need to have an organ cylinder if you want to use an organ so then becomes organ plus hydrogen shielding, is not it right because rutile can generate hydrogen and then organ can come from the bottle and then the shielding would be from organ plus hydrogen, right.

The basic gas shielded shielding will be organ plus Co 2, right and in SMAW so most of the cases organ plus Co 2, right it is because in most cases you will have a calcium carbonate fluxes, so you will have a an organ and external shielding and then Co 2 generated from the burning of the flux in self-shielded electrodes which I circulated this self-shielded electrode so where you have a maximum amount of flux generated maximum amount of gas generated by the decomposition of the flux, right so we do not use any extras shielding for the electrode I just incent around because these electrode is self-shielded where the flux inside the core of these electrode burns and generates carbon dioxide.

So this is self-shielded carbon dioxide electrode and you can see the video the process when we welded this electrode.

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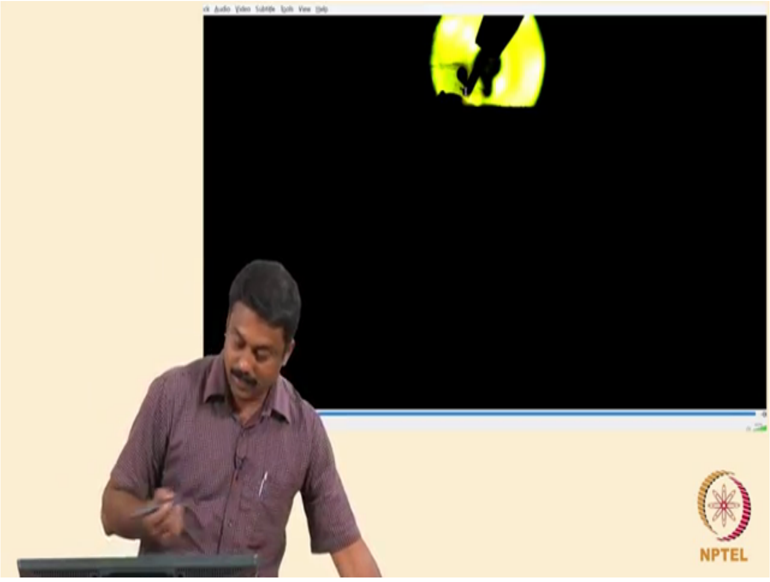

So this is the electrode which I centre on, ok and you see the metal droplet formed and most of the cases the droplet transfer is rippled globular, so the flux burns and generate the required shielding gas you see the disintegration of flux, right the flux actually goes in and then it burns and generates the shielding gas required, so these are the fumes that are generated by the burning of flux and sometimes we may also have if you have an metal added in the flux and you may also have vaporization of metals for example if you look at this fumes over here so suppose if you have an a for a chromium added suppose if some guy wanted to I want a chromium in the weld metal ,ok so you need to add chromium for a chromium when for a chromium burns and it can also generate for a chromium and the extra avail chromium vapors.

So the amount of vapor you generate by burning these fumes are huge, ok so this kind of carcinogenic fumes are very bad for the welders health, so the generally these flux burns and generate the shielding gas in this case it is self-shielded FCAW the electrode and carbon dioxide is generated as an arcing gas, so you see that you know the this is an basic electrode that means that there is no titanium oxide you see the electrode the droplet diameter it can go as high as double the size of electrode diameter, is not it.

So the droplet still intact sticking to the electrode tape, highly discussed the surface extension still keeps the electrode intact to the tape, so if you add some amount of titanium oxide the droplet attachment can be promoted because titanium oxide is known to reduce surface extension, right so in this case you see that so droplet still attached can you see the droplet? Now it is masked by the arc, yeah see the droplet is attached by the surface extension, right you can see that? So this is droplet and this is the filler and arc is there generated by the burning of the flux and these molten droplet is exposed to the atmosphere and doing this process the molten droplet also vaporized, so that is you generate the fumes, right.

So now these electrode if it contents slightly higher amount of titanium oxide or some fluxes which can reduce the surface extension then droplet diameter can be smaller and it can be detached easily, so that is the role of the fluxes, ok so in the self-shielded electrode which is primarily a calcium carbonate based you see that it is still attached and we are burning for a quite some time, so I do not know this video make contain yeah so now it is almost like a deep transfer, it is still attached you see that and it is diameter is more than 5 mm, so finally it goes into with weld pole by the deep transfer, right.

So another video you see that clearly, so is almost like a deep transfer, yeah you see that surface extension yeah, see it goes up even it does not want to go down, right so because of the highly discussed liquid which is there, so this droplet transfer can be changed by changing the flux composition. So these are commonly used the electrode types rutile, basic, self-shielded and self-shielded also basic but in basic electrode the volume fraction of the alloy the metal wire is much higher than the self-shielded, ok.

And the electrode which are used for hard facing and stainless steel they are all (())(26:26) steel rutile based electrodes, ok so rutile based electrodes are commonly used for hard facing and surfacing alloys because of improved list possibility and you can also use hydrogen as a shielding for stainless steel, is not it so the austenitic stainless steel there will not have an embitterment problem, good any questions so far? Then we will move on to the metal transfer in this process in this case.

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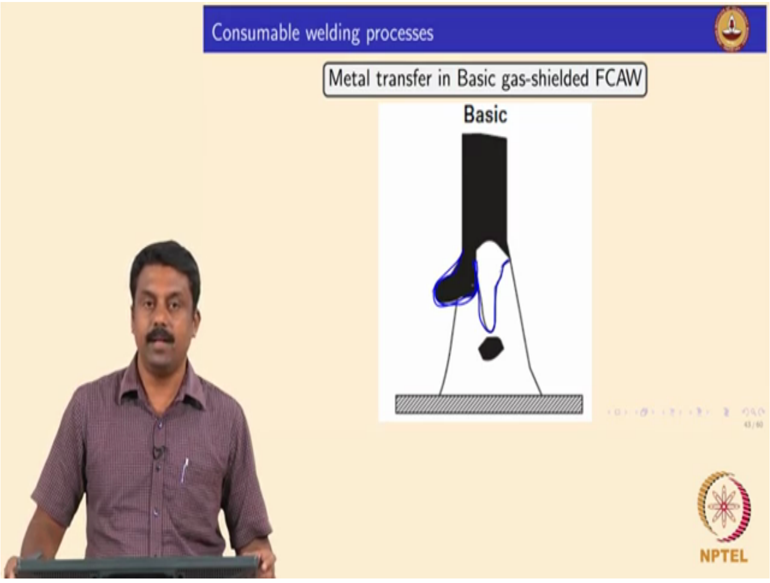

So in the most of the rutile based electrodes the metal transfer is same as GMAW because rutile reduces surface extension, so droplet can be transferred it which smaller diameter, right and you also have an free flow transfer when you have a rutile based transfer rutile based electrode transfer and you will have a simple free flight droplet transfer and a droplet diameter can be much smaller because titanium oxide favorably change the surface extension and that improves the transfer characteristics, right so that this is the simulise say yeah simple schematic professor John Norrish is given in this book.

So where the rutile electrode promotes droplet transfer characteristic with much smaller diameter by influencing the surface extension, the video I showed you that is not rutile electrode that is an self-shielded in the electrode where the droplet is not transferred at all I mean for keeping longer time droplet is still intact, ok so by just adding throwing some titanium oxide and we can promote the droplet transfer much more effectively by achieving surface extension, right it is clear.

So in basic shield electrode that is what you showed you, so in most of the cases droplet would be attached, so and then you would start striking an arc between the droplet and then you still have an finger developed by the molten fluxes attached to the electrode and which is commonly seen, so you will have rippled transfer and then finger pattern develops at the electrode tip by the molten fluxes and by the decreasing a by the surface extension the molten droplet would be sticking to the electrode tip and farming an a rippled globular transfer, yes in a basic gas shielded flux arc welding.

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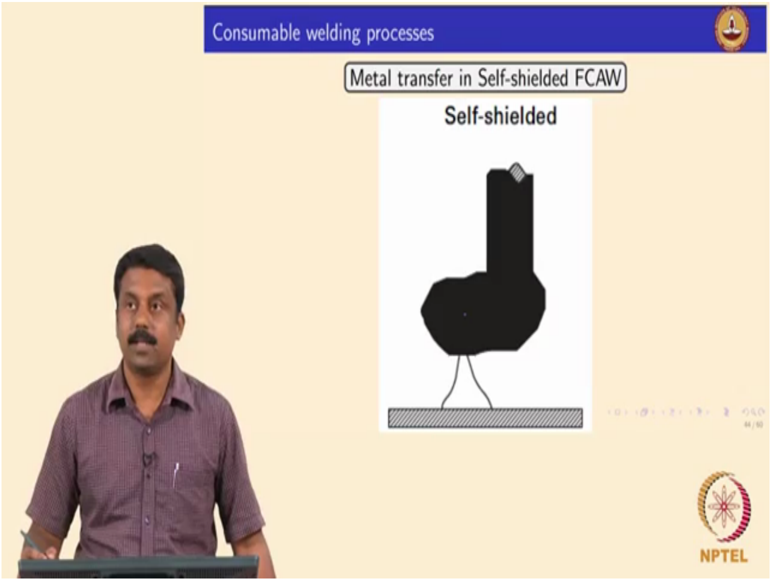

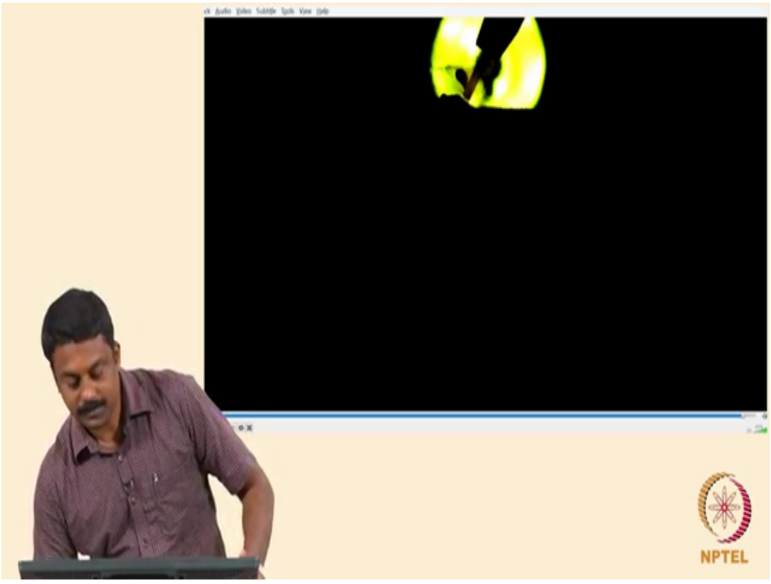

In the self-shielding it increases even further like I showed you in the video in the second video the predominant the transfer mechanism is a rippled globular, right so you want to see the video again, you see that so this the electrode becomes see that rippled mode the transfer, so this is tip of the electrode and this is the contact tip and this is the stick out length, right yeah so you see that upon increasing in size you have already established in a starts equating and the deep transfer.

The moment deep transfer happens because of increasing Lorentz force and this would explode, yeah it is now exploding you see this, you see the explosion, yes see because of the explosion it is also still push top and surface extension is so strong it keeps the droplet attached to the electrodes surface, yeah it is clear. So this is most commonly observed in self-shielded FCAW in the arc self-shielded MMAW electrodes where the droplet transfer is always rippled globular because of the increase surface extension, yes it is clear.

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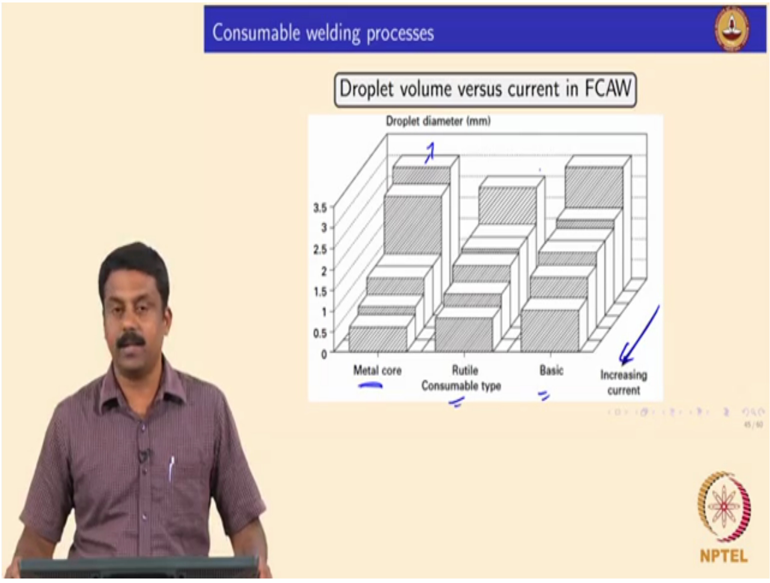

So this is as an graph showing the droplet volume versus current in FCAW and MMAW, so metal cored electrodes MM electrodes and this is rutile and basic and easier than rutile based electrodes so the droplet diameter is always smaller at any case, is not it this is a current and this electrode diameter you see that for a given current the rutile based electrode who always transfer in smaller diameter, why?

Student is answering: Ti over 2 surface extension.

Professor: Ti over 2 surface extension, ok so you will always have a smaller diameter transferred in rutile based electrode that there is an basic and metal cored obviously this also contains a basic fluxes where in basic fluxes droplet diameter will always be higher, yes it is clear.

Student is questioning: Then what needs to be done?

Professor: You need to be done because you going to add titanium oxide to this, so then you will also generate hydrogen, right so we can have we can think about adding some other fluxes which can favorably change the surface extension for example fluorides, ok so fluoride or silicate that can be added but then if you add fluoride silicate there are other complications, so now you will have to play around with the flux chemistry, so you can add you can think about adding an titanium oxide but the hydrogen can should be pin by some other elements like for example boron, ok so it can also form boron hydrides it can be removed as an slag then will the systematic solution be done to achieve and the required droplet transfer.

So if once you understand the science behind the process then we can tackles in very common day to day problems, right so it is clear. The rutile based consumables always give a smaller droplet diameter because of the reduction surface extension of the droplet, ok.

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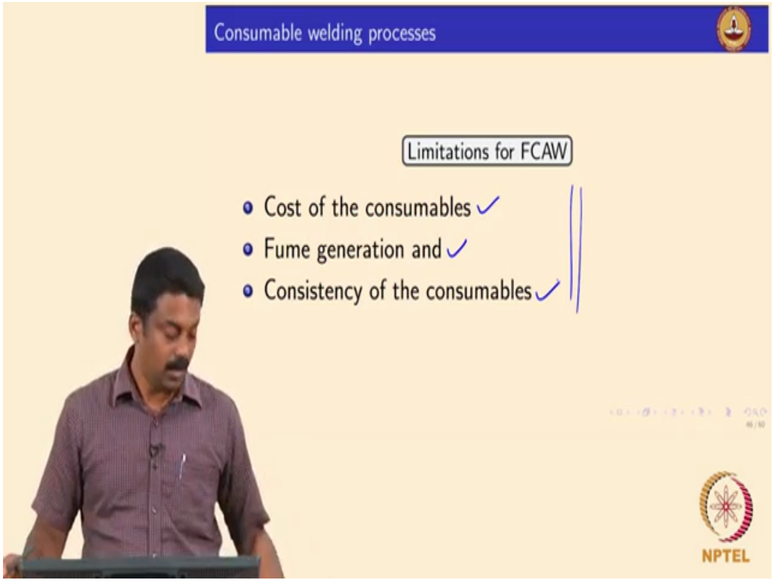

So what are limitations of FCAW? The cost of the consumables as I said in a last class the consumables are much more expensive than the wire although if you look at the actual investment we put up for an factory to make an these electrodes are much you know reasonably small but the flux compositions the work you do to achieve the composition and then generate the electrodes with the flux coating or the with the flux cored arc weld electrodes and it makes the consumable expensive compare to GMAW, right.

And the other the important disadvantage is fume generation by the burning of the fluxes and then ferrolysis you have in flux and then consistency of the consumables that is also problematic because the achieving a uniform flux coating it is also very tricky these are powder based we will have to mix it binder and then deposit you need to achieve homogeneous mixing of the fluxes the ingredients in the fluxes.

So you always have some difference in consistency across the length of the electrodes right so these are the some disadvantages but these can be overcome by the advantages of the process.

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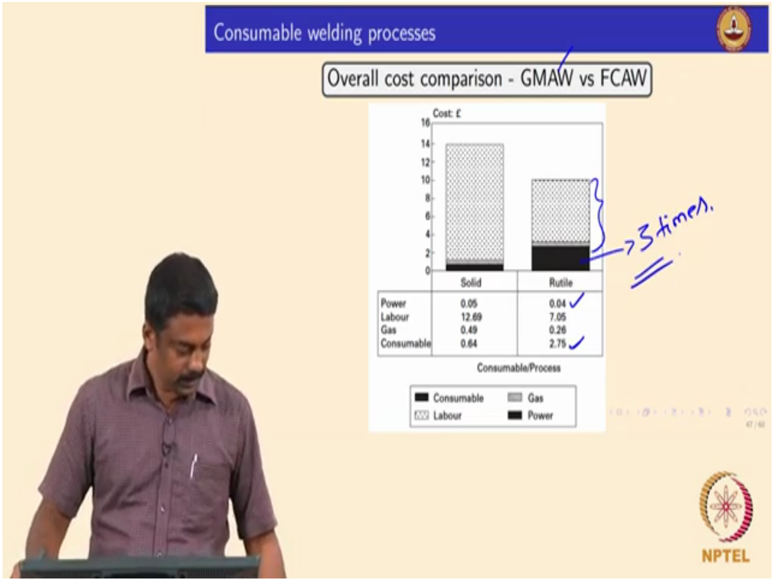

For example if you look at overall cost comparison between GMAW and FCAW, GMAW is gas metal arc welding and this is (afs) flux cored arc welding. The consumable is always three times higher in a flux cored arc welding or in SMAW, the cost, right but you overcome that by other factors for example you do not need shielding gas if you use a self-shielded the electrodes, right or even if use an a rutile based electrode the shielding gas necessary is much less than what you need for GMAW, ok and then you also have an improved efficiency from the process.

So you need an a less power or also the shielding gas which you use also ionize much more lower temperatures and of course in GMAW it is more labor laborious in the consumable it is almost three times expensive, so if you add all these cost together these FCAW and MMAW is much more cheaper than (MMA) GMAW, right it is clear, ok good. Any question so far?

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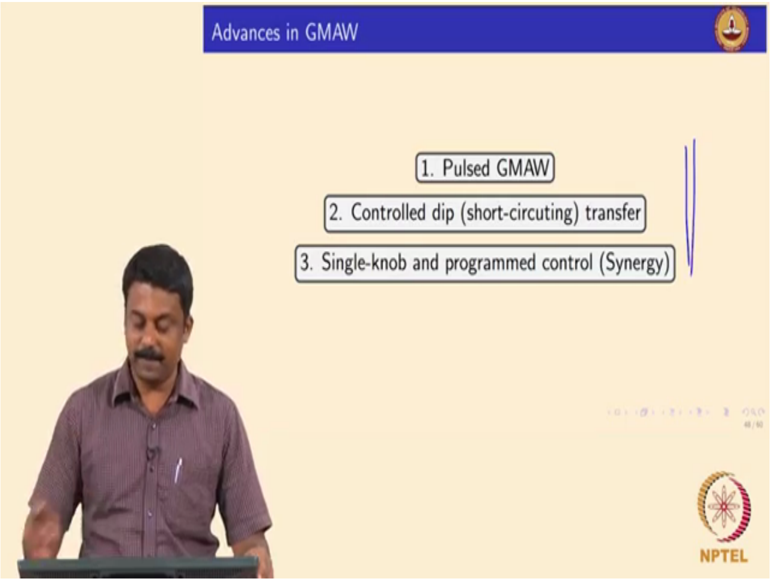

Otherwise we can see whether we can go to the next chapter.