Welding Processes
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Resistance spot welding Part 04

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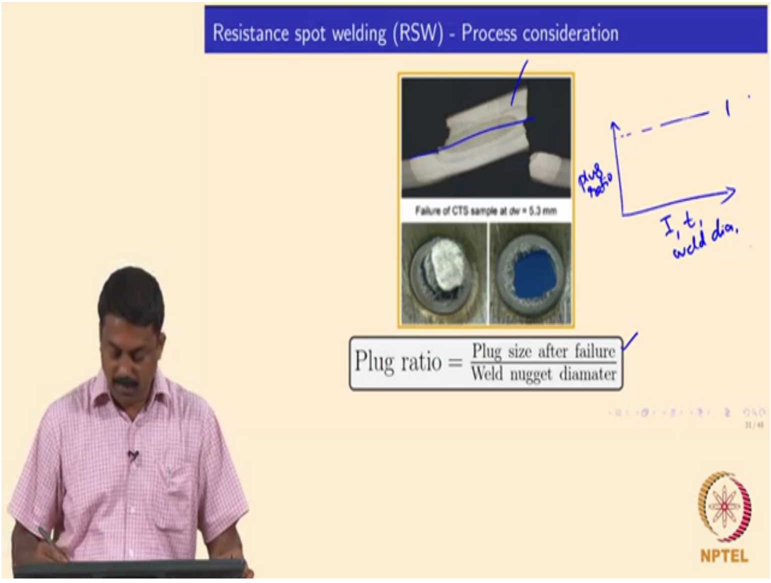

Okay, so now we will move on to the typical problems you may face in resistance spot weld, any questions so far? Mechanical testing of the resistance spot welds? So three important factors you measure the strength and ductility as a function of weld nugget diameter, identify what is the maximum strength at a given diameter. And then once you know that you can also look at the plug failure, plug ratio and identify which combination gives the best strength as well as the acceptable plug ratio and then you identify what diameter would give you that, so from the diameter you can calculate what current and time you need to achieve the diameter, is it clear?

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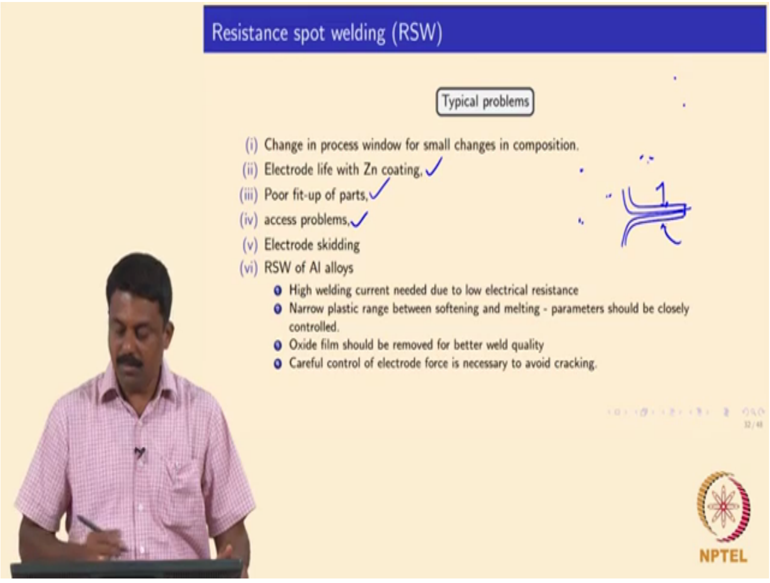

So what are the typical problems that generally associated with there is an spot welding. The process window is extremely narrow. So if you change the thickness from 1.25 to 1.3 so then you will have to invent all the parameters because the M the mass effect is very severe, so you will have to arrive at current and the welding time and then weld nugget diameter can also change.

So for a given thickness, for a given composition there is a process window, we can use it, if you change the thickness we will have to all the exercise weld growth curves, mechanical properties they all to be established to identify the process window. So that is the process conditions are very subjective, (())(2:01) thickness material, even if you are changing the supplier then the composition can be small slightly vary, when you want to buy a motor bike the dealers should also know how to service it, otherwise there is no point in selling it.

In similar way if steel maker is supplying to a customer steel makers duty to give customer what are the welding parameters he has to adapt because otherwise customer would buy it. So for a given thickness, for a given material this process window has to be generated, so this elaborate exercise because if you look at you go to steel making industry in a testing lab there are couple of engineers would always daily work on resistance spot weld you would do take it to and pull it and fill and identify the nugget size plug ratio and he plot generally he plots the weld growth curve as a function of weld metal properties and plug ratio that is his job, day and day out he would test only resistance spot weld because the number of samples he has to test is enormous.

So suppose a small change in a composition the process window will change. To achieve weld growth curve he has to do 100 experiments because varying current number of currents he has to change from 3 ampere, 3.2, 3.3, 3.4, 3.5 amperes until it is 8 amperes where I max would be, then he has to measure the weld nugget size and (())(3:39) sample he has to pull to identify the strength and the plug ratio, is it clear? And then he has to repeat it to look at the consistency in the (())(3:50) and then arrive at the process window, okay this is the process window, this is the current, this is the thickness and this is the material, this is weld nugget diameter you will obtain and then this will be okay.

And this is assuming that the electrode is good intact, so the second point is going to effect that. For example if you are using a zinc coated steel which is very widely used for automotive applications like galvanized steel. So if you have zinc layer so you would also have diffusion of zinc from the zinc galvanized layer to the electrode copper, so copper and zinc forms brass.

So if you are forming a brass if zinc diffused copper and then you also change the resistance of the electrode surface, so then the contact resistance changes contact resistance between the electrode and the sheet. So the entire exercise of generating process window, assuming that you have one electrode and the material. So over the time with the number of welds if the electrode surface is changed its condition is changed so then the weld nugget diameter will not be the same, so then you may also have defined weld nugget diameters or the shape of the weld nugget itself will change, if the zinc diffusion is not uniform if it is happening only at the edges for example and then you may also change the weld nugget diameter in consistently over the time.

So generally it is a big problem because a lot of resistance is going on to invent the electrode which can withstand for large number of welds. In some cases after 50 welds sometimes electrodes are changed and in some cases if the material galvanized layer thickness is different for example instead of galvanizing you can also do galvannealing, so there the zinc layer it is not as a pure zinc so the zinc layer is unhealed so to form an ion (())(6:02) just to avoid this problem, so that the zinc diffusion can be retarded because already a compound.

And there are some other alloying the coatings people also working on like in silicon base coating, aluminium base coatings, aluminium silicon base coatings just to avoid this problem. So the other development has happened is to replace copper with the some other alloys for example cobalt chrome or even doping copper with some (())(6:40) or having a coating on the copper without effecting the resistivity resistance of the copper electrode.

So the other disadvantage on the problem we faced this is spot welding is if the geometrical consideration is not taken care of so if L, L by 2 is not maintained so if you are not welding a good sequence if weld is placed in arbitrary manner then the (())(7:11) can be effected significantly. In order to achieve good geometrical and the load distribution obviously you know the weld has to be placed in correct location, otherwise it may lead to a poor fit up of the parts, is it clear?

And the access problem it is a big problem because in this case both the electrodes should reach a point of a component, so if it is flat that is okay something like this so we have two sheets this is most common geometry (())(7:56) so it can reach, the electrode can reach and then you do a spot weld.

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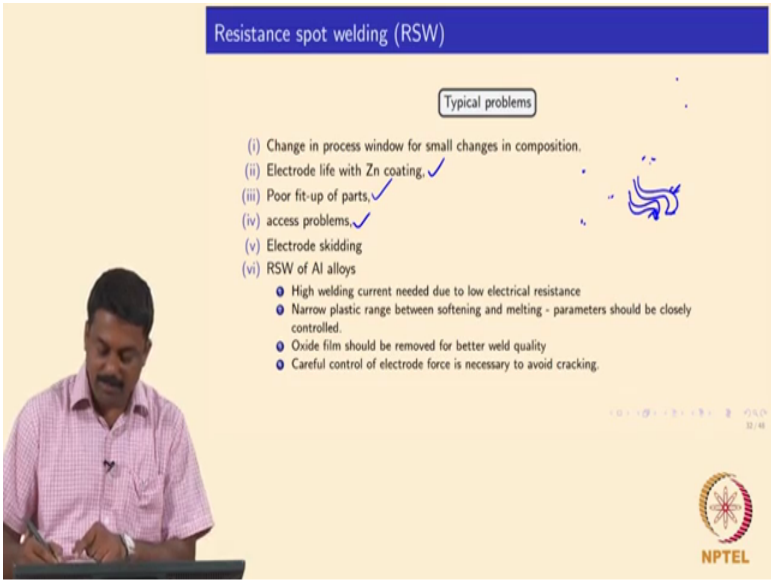

So some very ambitious recent engineer design spot like this, something like that and if you want to weld somewhere over here that is not possible because getting the robots or the access to that can be very tricky. So the access problem is huge so when the components are designed and they consider this factor that the resistance spot welding electrode should reach the part so that the welding can be done.

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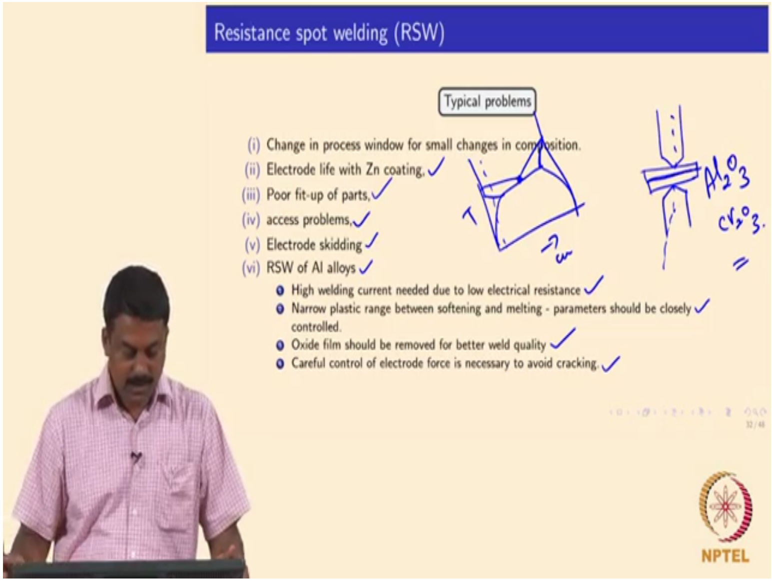

And then the electrode skidding is also an issue because when you are applying load if the electrode both the electrodes are not in access symmetric position it can also skid. So if the top electrode is somewhere over here and the bottom electrode is somewhere over here and you keep the plates something like that. If they are in different access or if they slightly tilted electrode then you may also have a skidding or shearing while applying the load and this can happen when the electrodes or the robots are not placed in a access symmetric positions or sometimes you may also have some lubricant at the surface when the surface is not cleaned properly then the issue would also be there.

And then the problem with the other than steels, aluminium stainless steel is a nightmare to weld with resistance spot weld because of the load we apply that can also promote the cracking so if the resistance spot welding of aluminium alloys the problem is we need a very high current because the (())(10:05) resistance itself is low as well as we have the surface oxides for aluminium, what oxide we have? Passivation layer with aluminium oxide Al2O3, similarly in stainless steel chromium oxide, so due to that so we will have to apply a high current.

The other issue with aluminium alloys is very narrow range between softening and melting, so that means that metal softens and immediately it melts so that is a big issue, so we will have to control it very closely otherwise you know metal become softens even at very low temperatures. So the oxide film issue it is always there and then the cracking issue, so aluminium alloys by itself you know they are (())(11:01) for cracking so because of the anisotropy when you develop during solidification, so load estimation is always there, so they are all pruned for hard cracking.

So that is why when we select the filler wire we always select the filler wire close to the eutectic point, so why do we choose that? Because when you know what is eutectic point? Eutectic? Non metallurgist, okay say for aluminium copper system so this is eutectic point (this is very bad phase diagram). So when we select the filler wire we always select the filler wire the composition close to the eutectic so that liquid is present to fill the crack so that is what we call eutectic healing, so we will study it in welding metallurgy and not here.

So that is the ideal conditions that is why if you look at the conventional used alloys for fabrications they are all reasonably weldable because the composition is close to the eutectic compilation so that the liquid can heal the crack which is formed. So suppose if you choose a composition somewhere over here and you have a large range of solidification so that means that this composition is pruned for cracking because of the broad solidification reach.

And apart from that we also have a load applied, so even though you apply compression on local it can also be tension in other direction so that can also lead to the cracking, good. So these are typical problems, so what are the other problems you may face?

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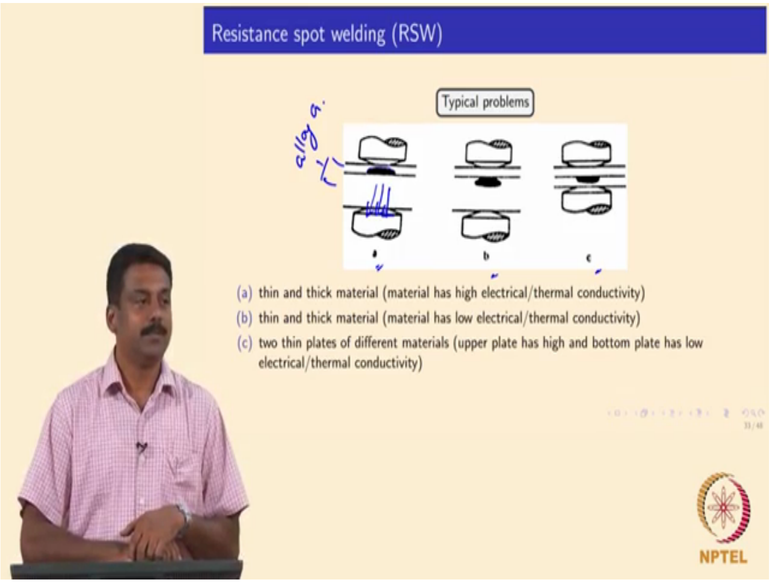

So other problems we may face when you have a dissimilar thicknesses or dissimilar materials. So I have plotted here the three schematics say a and b and then c, see you have a dissimilar thickness thin material and thick material of a same composition so this is thin and thick say alloy a, if this alloy a is very good thermal (())(13:35) conductor. So then what will happen because of the mass effect we will have a more heat transferred from the large volume, if the material has a very high electrical thermal conductivity heat cannot stay here in the large volume it can be conducted effectively because of the mass.

So you will end up making weld nugget only at the thinner sections because of the mass heat transferred will be very effective so you will end up making weld nugget only at the thinner sections.

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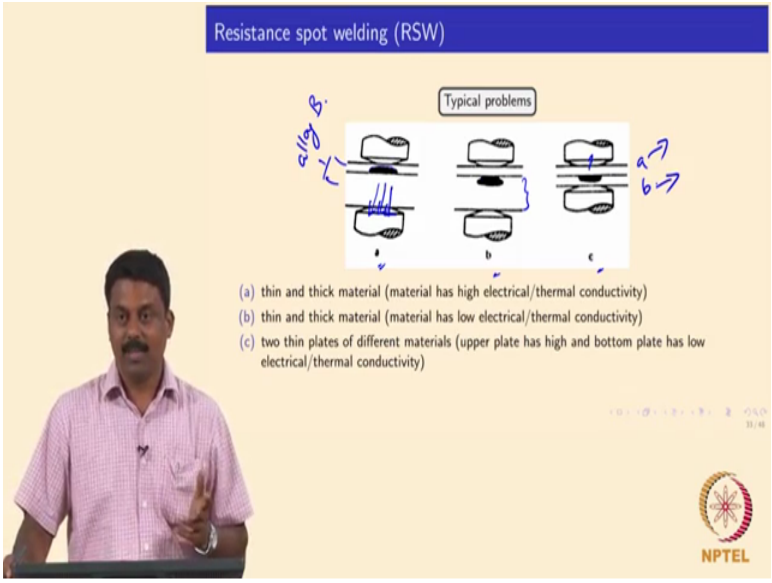

So suppose if you are welding the similar configuration thin and thick alloy b where alloy b has a very low electrical and thermal conductivity, now what will happen? The heat is contained effectively thicker sections because this thicker section has a low electrical thermal conductivity, so you will end up forming weld nugget only at the thicker sections, is it clear? So these are typical problems when you are doing dissimilar thicknesses depending on the material either you end up making welds only at thinner sections if a material has very good thermal conductivity, electrical conductivity. If the material has very low thermal conductivity a low thermal conductivity then heat is contained at the thicker sections, so you will end up making welds only in the thicker sections.

And same can happen if you have a dissimilar welding a and b you are welding the same thickness of a and b where would form weld? So a has higher thermal conductivity, b has low thermal conductivity, obviously you only make in b because heat is contained, a has good thermal conductivity the heat can be conducted effectively to the electrode, is it clear? And these are the common problems we may face apart from what illustrated in previous slide when we are doing a dissimilar welds.

So how do you overcome this problem? Simple way do not weld dissimilar thicknesses or you can also change the electrode diameter do not use the same diameter on top and bottom.

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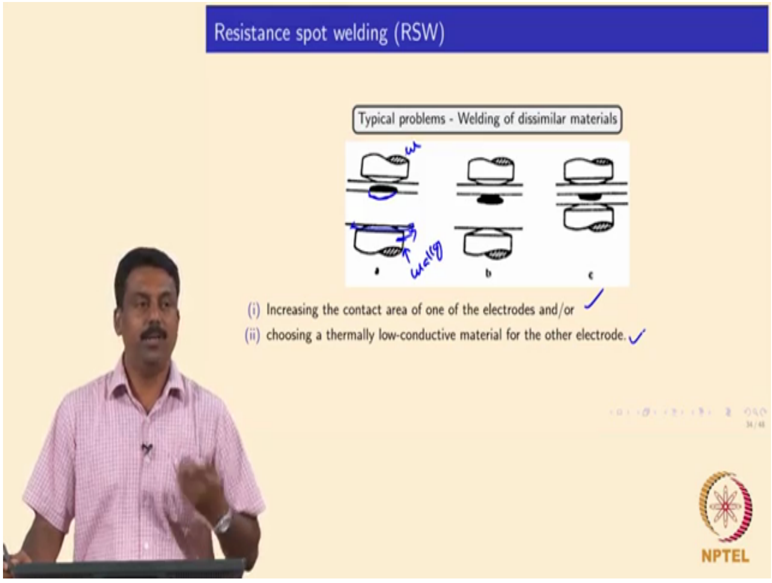

So you can change the electrode diameter in such a way that we can increase the contact area in one side, (())(16:14) wherever you are not forming weld you can increase the contact area that side so that you can generate more heat because the interface can give us the more heat generated so that this problem can be overcome, or you can also select the material of the electrode wherever you are not forming the or wherever you are forming the electrode so there you can have another copper or good copper conductivity, so wherever you are not forming weld so you can also change the thermal conductivity so that you are not extracting heat effectively, so the heat can be contained.

For example in this case you can use copper, since I am using copper you can use copper alloys so that thermal conductivity can be decreased so that the heat can be contained and then to form weld nugget because what is the reason why you are not forming weld nugget? Because heat is effectively transferred it is not used to melt the material because heat is transferred, why it is transferred? Because you are using very good conductor, so you change the material so you change it to a poor conductor so the heat is contained, that means that you can form the weld nugget.

Or you can also increase the electrode size contact area so that you generate more heat, so you can avoid the problem of say dissimilar thicknesses or dissimilar materials by carefully changing the contact area or the material of the electrode, is it clear?

Student is questioning: What is the configuration of mass effect?

Professor: The mass effect in this case again it is a combined effect so if you are doing a dissimilar thicknesses again you can also calculate for a given you can calculate the mass this case C P is changing, if you are doing dissimilar material.

Student is questioning: But this was the case in similar material.

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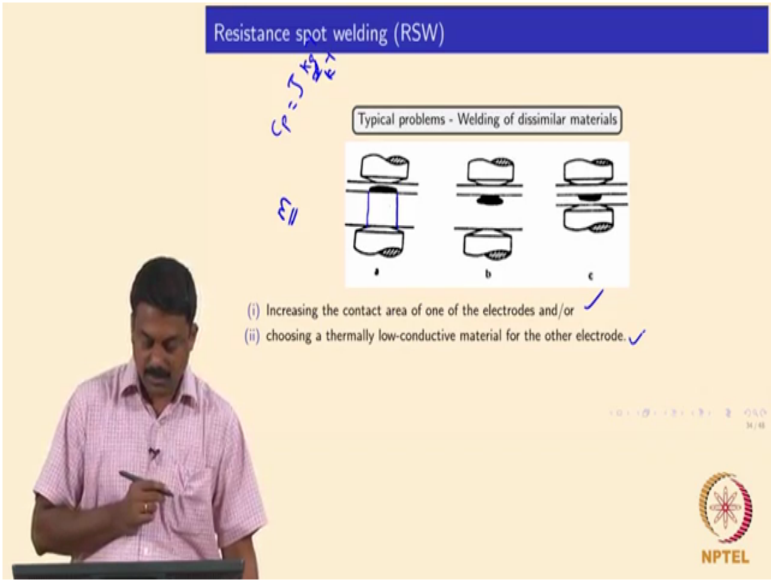

Professor: In similar material but in this case the M the mass effect the M its (())(18:22) so M you are talking about can also be different. So here you have more mass the C P is measured as a function of joules kilograms kelvin, so this is changing here also. So in a way the specific heat capacity is defined by the kilograms, here you have more volume of materials so more heat is needed so that is the C P effect the mass effect, is it clear? Good, any questions so far in these problems?

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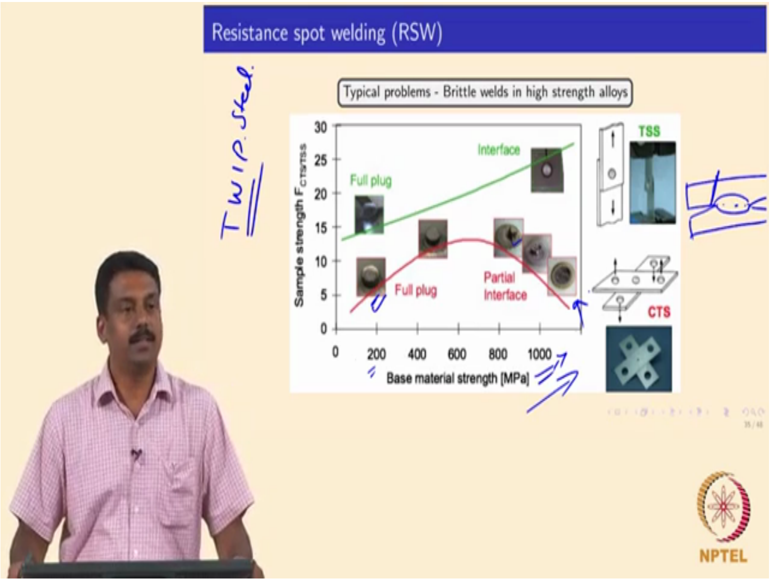

The other problem I already explained is weld brittleness because of the high alloying elements that is a huge problem, so this metallurgically it is very challenging to improve the mechanical properties. So first thing we tackle when we are developing a steel product we will have to identify whether the weld brittleness is not significant, so when physical metallurgy is working when they do research to develop a new steel composition, for (()) (19:45) metallurgies the welding is nightmare so they would add a phosphorus, silicon their role is to get a good yield strength at the tensile strength good elongation and good ductility as well as say for example deep draw ability, stretch ability and they can achieve with fantastic microstructures with the properties, when they give it to us they cry you know these guys are not going to come out and this material is not wettable.

So there are so many microstructures, fantastic microstructures has generated over the years with super properties like for example TWIP steel, what is TWIP steel? Anybody knows?

Student is Answering: Twinning-Induced Plasticity Steel.

Professor: Yes, Twinning-Induced Plasticity Steel, it has 12 percent magnetise (())(20:34) 12 percent magnetise, excellent material very high strength, (())(20:40), ductility can be as high as 30 to 35 percent can be used but it cannot be weldable, as long as it is not weldable it is not going to be commercially applied. So you may get a very good microstructure generated in steel and ultimately if it has an interface failure then it is not acceptable because weld properties are not good, so we will have to (())(21:08) for either modifying the weld thermal cycle in such a way that the weld properties are improved, not only strength as well as the nugget size, is it clear? Good.

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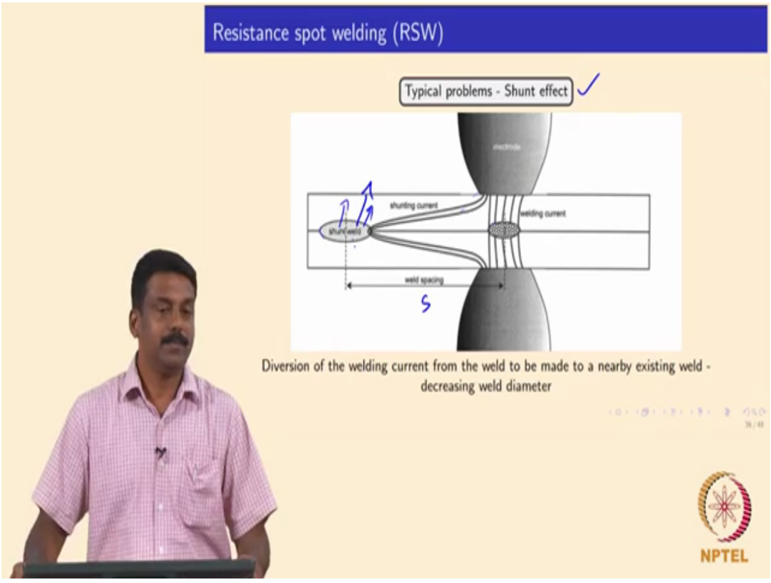

So there are some problems the other problems we will look at it and then we will wind up the class. So the two important problems that are commonly observed during welding is the shunt effect which already explained, so if the welds are not placed adequately apart so is S weld distance is the S, if it is not there so if it is very close enough then the current instead of flowing through the interface it may also bypass because then the least resistance distance is this previously welded region, so the electrons would travel through the previously welded nugget and then travel back.

So in this process the weld is already formed it is also heated, so when the electron travels obviously it has its bulk resistance, even though there is no contact resistance, the bulk resistance will lead to heating of the weld which is already formed, you will end up heating the weld and then you will end up effecting the weld nugget size here because whatever current you sent it is not used to generate the weld nugget, it is bypassed so this effect is significant if the weld spacing is not controlled properly, if the welds are placed close to each other, so then you have a shunt effect, is it clear? And this is commonly observed so that is why the weld spacing is very critical in order to avoid the shunting, then you will end up reducing the weld nugget size where you are welding and you will heat it the weld which is already made.

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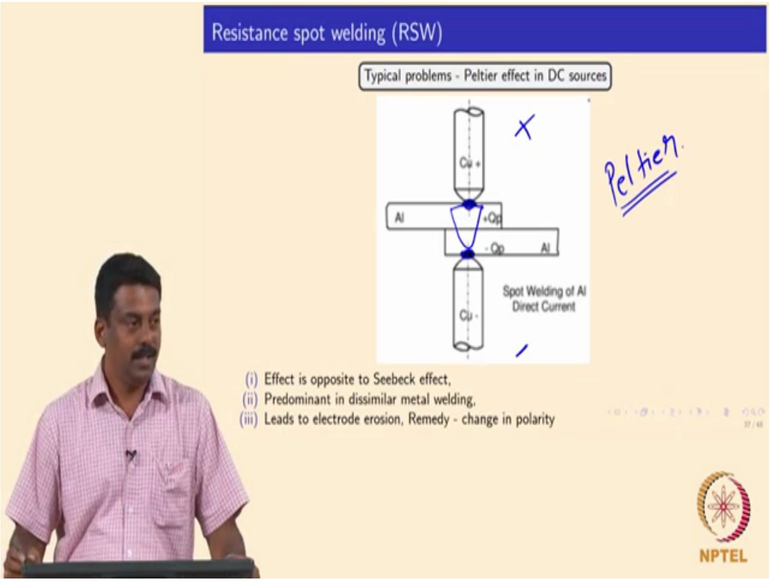

The other problem which is observed specially when DC current is used for welding, so that effect is known as Peltier effect (it is not peltier it is peltier French spelling), so it is Peltier so this effect the Peltier effect is opposite to Seebeck effect, so what is Seebeck effect? Not just junctions, dissimilar junctions, so what is the Seebeck effect? So when two dissimilar junctions are kept at two different temperatures there is (())(23:50) generated, what is (application of) common application of Seebeck effect? Thermocouple temperature measurements, okay so now we have opposite effect, so when you have DC current so you have plus, minus.

So imagine in this case we have already dissimilar junctions so for example here copper aluminium, so you have one dissimilar junction and other dissimilar junction. So when the known amount of EMF is passed it is impossible to generate same temperature in these two dissimilar junctions, it is always one hot end, one cold end.

So same as Seebeck effect, Seebeck effect the EMF is generated by two different temperatures, so now we have a dissimilar junction two of them you pass an EMF, these two temperature can never be same, so that is the opposite of Seebeck effect, not opposite it is reverse inverse of Seebeck effect, Seebeck effect you keep the dissimilar junctions in different temperature there is one EMF, now you have two dissimilar junctions you pass one EMF and these two junction can never be in same temperature, it will always be hot and cold.

And during welding resistance spot welding, especially this happens when we use a DC current direct current because one EMF there is a flow of current from negative to positive that is EMF you have and you have a dissimilar junctions, you have here and here. So in this case when you have EMF you have dissimilar junction and these two junctions can never be in same temperature that is the Peltier effect.

So you always make the weld if you are doing it in a DC current the weld in the hard junction will be wider and in the cold junction will be smaller, so the weld nugget will not be uniformed that is possible, but which one will be hot end and which one will be cold end that depends on the polarity, but this effect if you are using dissimilar joints the hot end would always have an erosion of the electrodes because the temperature will always be higher and then the electrode life will be always be very bad at the hot end.

The complexities involving in doing a DC current it is possible to use a DC current by carefully then controlling the electrode erosion that is possible, the best (())(26:31) is you can also switch the polarity so do not maintain the same polarity we can also continuous switch the polarity, how do you switch the polarity? By alternating current, so that is why resistance spot welding is advisable to use alternating current to avoid this Peltier effect and if someone uses DC current it is advisable to switch the polarity with some frequencies, okay.

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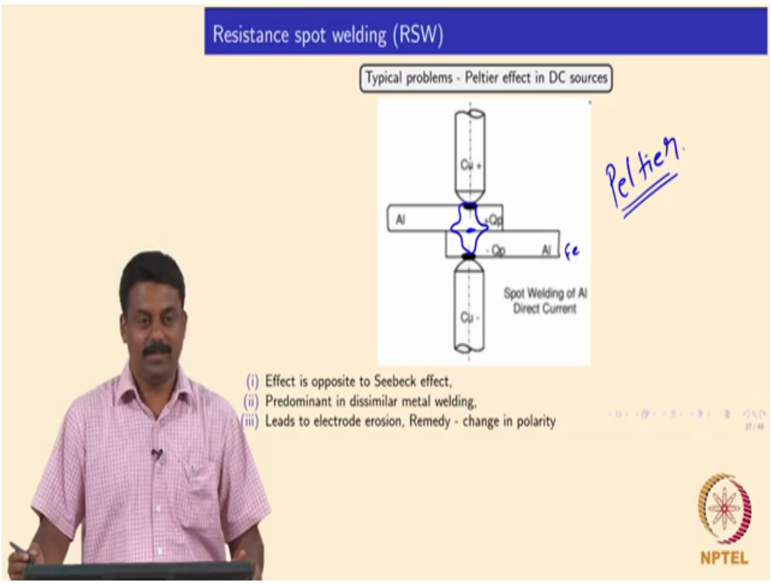

And this happens predominantly if you have dissimilar material. So then if you are using say aluminium here ion which is very difficult anyway then you also have another dissimilar junction, so the problem will be more complicated. So you will end up making a weld say for example something like this, so this could also happen.

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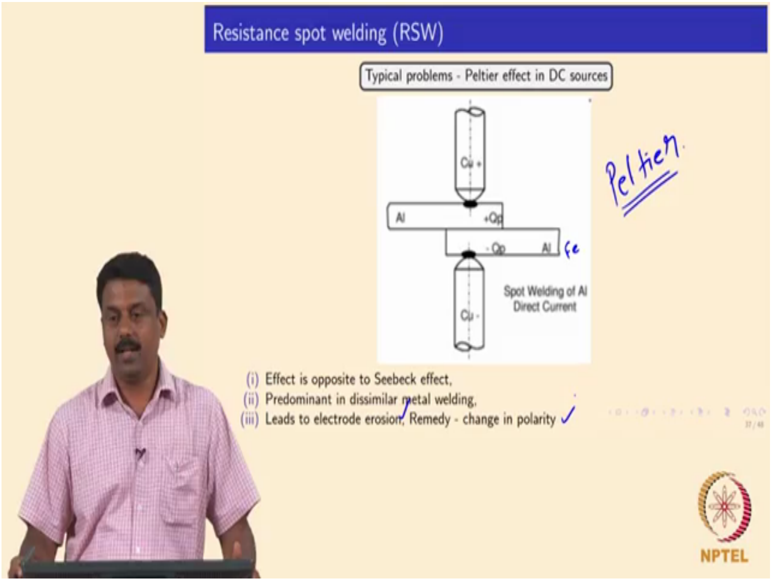

And this can lead to electrode erosion specially in hot end so that is why you know the resistance spot welds generally done with alternating current, okay so only remedy is to change the polarity better to use the alternating current.