Welding of Advanced High Strength Steels for Automotive Applications

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Lecture - 10
Process Characteristics of Resistance Spot Welding - Part – II

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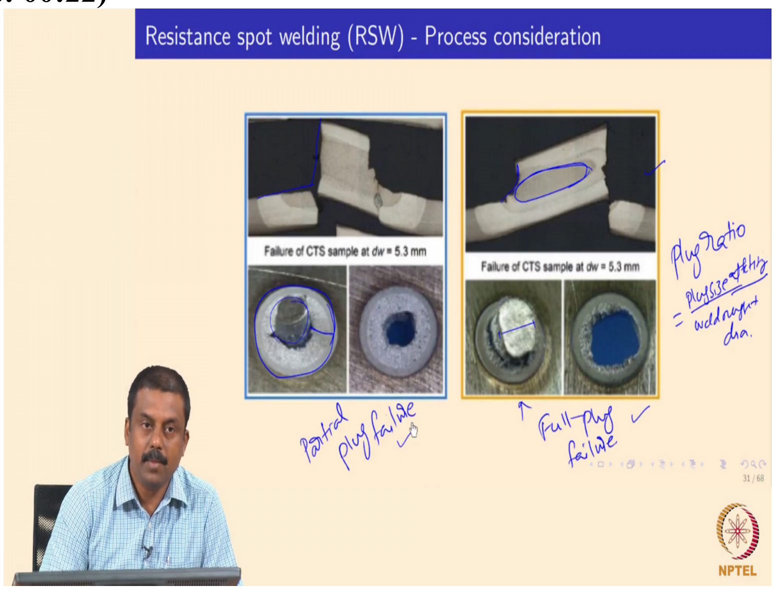

So we look at in detail about the plug ratio explained in previous slide so there are two images that are showed over here and this is the cross-sectional image and this is the top view or after the cross section cross tension test. If you look at in this case below you see that we have a weld nugget that formed somewhere around here. And this failure mode weld nugget diameter intact ok weld nugget the entire weld nugget is intact to the plate that means you are plug size is same as the weld nugget diameter.

So, then this is the most acceptable failure mode because failure has happened not in the weld zone but at the heat affected zone compare to this and if you look at the failure mode over here in the left side of the slide. In this case the crack actually propagated in some distance towards the weld Centre line along the middle of prior interface and then it cracked in the weld nugget. That means that you see here the plug diameter is decreased consider compared to this case. And here the initial weld nugget was here and you have a crack towards the centre of the weld.
You are remaining weld area reduced significantly and this kind of failure mode what is called as partial plug failure ok. This is full plug failure and calculating the size of the plug we can also

calculate the plug ratio. So, the plug ratio is plug size after testing over initial weld nugget diameter ok. So in these two cases you can say so the plug ratio is higher in this case and your plug ratio is lower in this case right.

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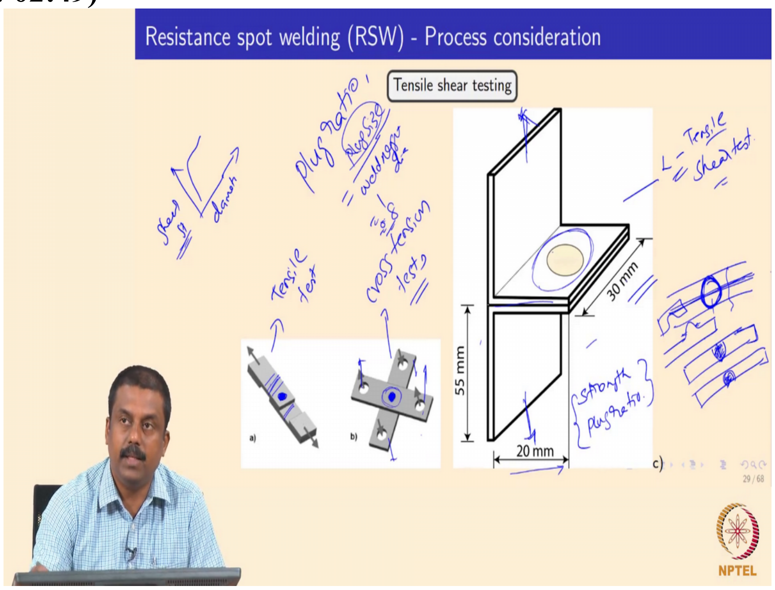

So, we will move on today 3rd testing methodology we used to identify the spot welding characteristics is the tensile strength the L tensile testing so instead of using cross tension test because the sample preparation geometry machining of this test is bit complex. So, we may also used modified geometry where we have an L shaped samples or spot welded typical dimension of the 55 mm length and 20 mm in this direction and 30 mm in the width direction. And we will do one spot welding at the centre of this sheet.

And then apply tensile stress along this axis again to identify this, the load required to have a failure plus the plug ratio because the load required to cause a failure it is also a function of deformation that is happening in adjoining regions. So, it is by itself may not give you the actual properties of the weld. So, we also use the plug ratio to identify the actual characteristics of the weld which you make, so, by combining and by looking at the values of the shear strength or the shear load to cause of failure plus to the plug ratio.

They both would give acceptable welding characteristics so this is very simple to carry out so it is actually preferred in various industries. In tensile strength in the L configuration so we will identify the strength the required or the load required to pull the plates apart after the spot welding and the plug ratio and both combined will give you the characteristics and the mechanical properties of the welds we make in the sheets.

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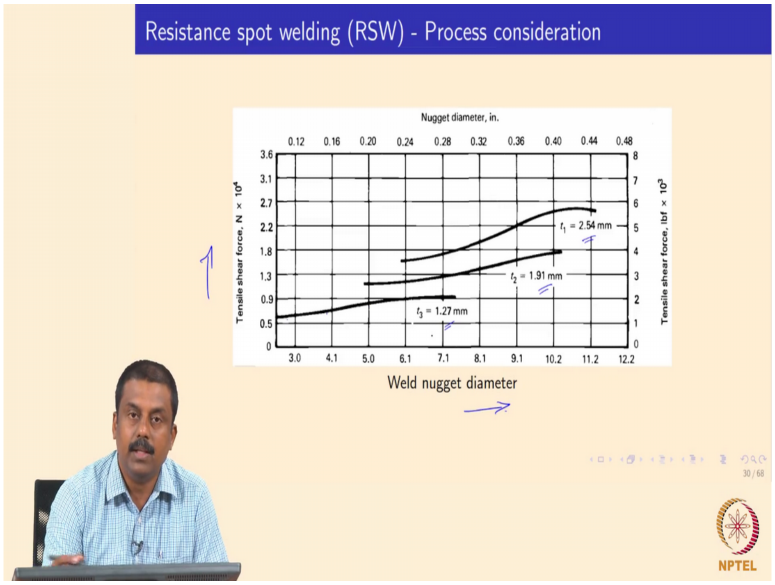

So, in this graph show such an experiment so what we see over here is the weld nugget diameter as the function of tensile shear stress for three different thicknesses. So for a thickness of 1.27 mm, 1.91 mm, 2.54 mm sheet thickness we can identify the tensile shear stress if you look at it because of the sheet thicknesses the acceptable diameter decreases obviously we look at the relationship right generally it is 4 square of thickness. So we identify the tensile shear force required to cause a failure of the joints and we will get such graphs with varying thickness and varying completions.

Along with this graph we will also look at the plug ratio if for example in this case all these failure case the plug ratio is 1 this is ideal case we may say and if plug ratio is acceptable generally it is about 80% or 0.8 if that is the value so then it is also acceptable based on the guidelines what we use. So this is already explained we calculate the plug ratio and in full plug failure and partial plug failure. So we measure the nugget diameter before test the cross tension tensile test or the L shaped tensile shear test. And upon failure we will identify the plug size and take a ratio and that will give you the plug ratio.

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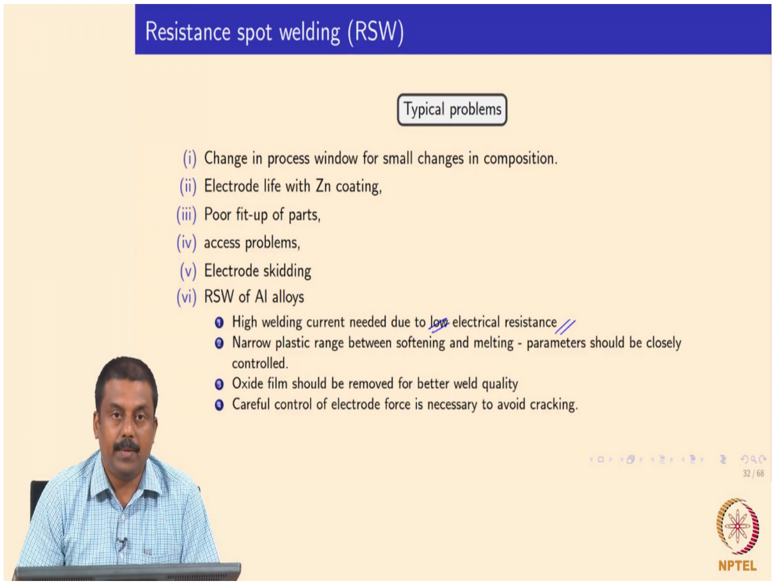

So, we move on to the; whatever typical problem we have in resistance spot welding. As I already explained process window of resistance spot weld can change significantly even small change in composition because if you look at weld growth curve as I explained if you change the carbon concentration and also change the resistivity and material and if you change the surface chemistry and changing the coating characteristics. If you move from galvanizing to other galvaniled material for example iron electroplated material.

And you also change the contact resistance ok because you change the surface morphology of the coating you use that will also lead to change in contact resistance. And if you change that obviously it will also change with your weld growth curve. So far even given thicknesses and surface chemistry and the material composition we need to generate this process window the weld growth curve that I explained. So, if you change even the small composition or thickness changes from 1 to 1.1 mm to 1.2 mm again this curves will change.

So, that is a big problem in this spot welding to identify the process window where you can get stable weld metal property. So, the other typical problem is industry is the electrode life. So, especially you are welding galvanized sheet in most of automotive steels they are galvanised zinc coated and then zinc diffusing to the electrode which is copper and copper and Zinc will from brass ok.

So, in case moments you form the brass layer you also change R2, the resistance between the interface of the electrode and material and because of that you also change your weld nugget characteristics ok. You may see in your real life for example if you are doing say 1000 weld a day over a period of time in a day weld nugget size may increase significantly because you also increase resistance by forming the brass layer on the electrode tape.

And you need to machine of the electrode machine of the electrode is also changed the electrode diameter then you will also they weld nugget weld size. So the electrode life is in big problem lot of research went into their electrode life for example using carbon layer or some sort of an extra material in between the electrode and the sheet. But still has a huge problem the electrode life need to be monitoring if you do not do that weld nugget size will change over a period of time with the number of welds you make.

And the third is poor fit up of parts I already explained that if you do not consider the minimum distance required for the overlap configuration the L the distance between two welds and those are all you know should be taking care of to get the ideal stiffness. So, the stiffness analysis is extremely critical to identify the location at which you need to do the spot weld. And the fourth one is access problem that is again so because of the nature of the process we need to have two electrodes reaching at the same spot of your component.

If that is not possible you cannot make the spot well so that design criteria the design of component should also in such a way that you have and clear access to the two electrodes at the given location where you want to make the spot welds. And you may also have a problems like this skidding if you have excessive load or if you have a misalignment in terms of the electrode placement. There are some inherited problems during the resistance spot welding of aluminium alloys because we all know that aluminium as a very low resistance.

So, we need a resistance current because of the oxide layers what we have in the aluminium alloys and the aluminium also exhibit very narrow plastic range between the softening and melting. So, even if you change the small amount of current you may also end up expulsion end of the expulsion and the oxide filling what you have in aluminium sheets. It should always be machined of but it is very difficult to remove the oxide layers. And the all the aluminium alloys most of the aluminium alloys used in the automotive industries all aluminium alloys they all have issue during solidification in terms of hard cracking.

So, the electrodes force what you apply it also aids the cracking So you may end up having hot cracking during welding so, the careful control of it is very important so due to these problems the aluminium alloys are all considered not suitable for this resistance spot welding.

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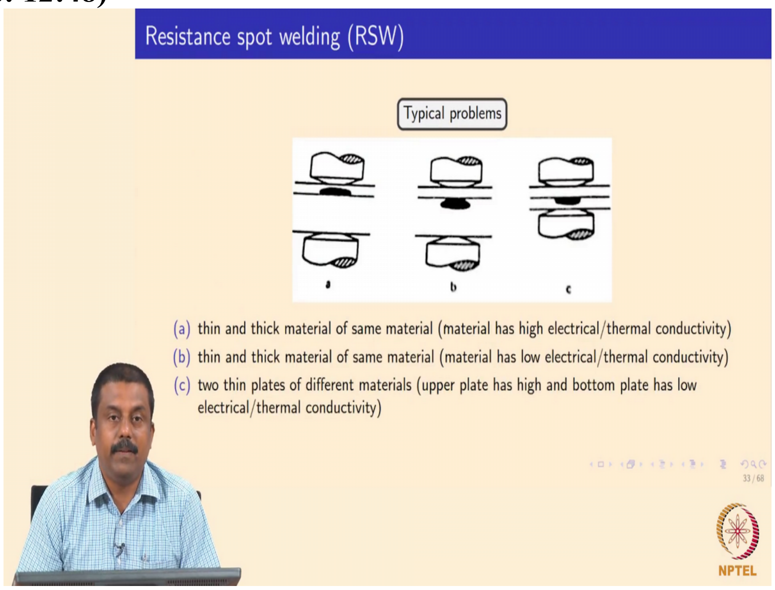

So, there are some other typical problems you may face if you have a dissimilar materials either in composition or thicknesses again the problems can be case to case based on the composition of the materials used for example I put 3cases here a, b, c ok. In case a, we have material two materials, the bottom one is thicker than the top one and if the, both of them are made from the same compositions, the composition are the same the bottom material the bottom sheet as large thickness than the top ok and if this material as high electrical thermal conductivity ok.

What will happen the bottom sheet thickness can conduct the heat much more effectively then top sheet ok because of the mass effect and you may end up forming weld only at the top sheet ok. And if the condition is reversed the material has low thermal conductivity ok and uses the same material in both top and bottom sheets. If that material has low thermal conductivity and you end up containing heat only at the thicker sections. So you end up making a weld only at the bottom sheet.

And if you have a same thickness and upper weld as an high thermal conductivity and bottom as a low thermal conductivity and obviously the low thermal conductivity material contain the heat, you end up forming welds at only the bottom ok. And the; you can overcome this problem in various ways so the most common ways to overcome the problem is increasing the contact area in one of the electrodes ok for example if you see that material is welding in one area only in one sheet and you can increase the contact area another sheet so that you may form uniform weld size.

Are you can also have material with thermally low conductivity instead of using copper you can also use copper alloys where are you decrease the thermal conductivity ok so that you know you can also from welds in both region ok.

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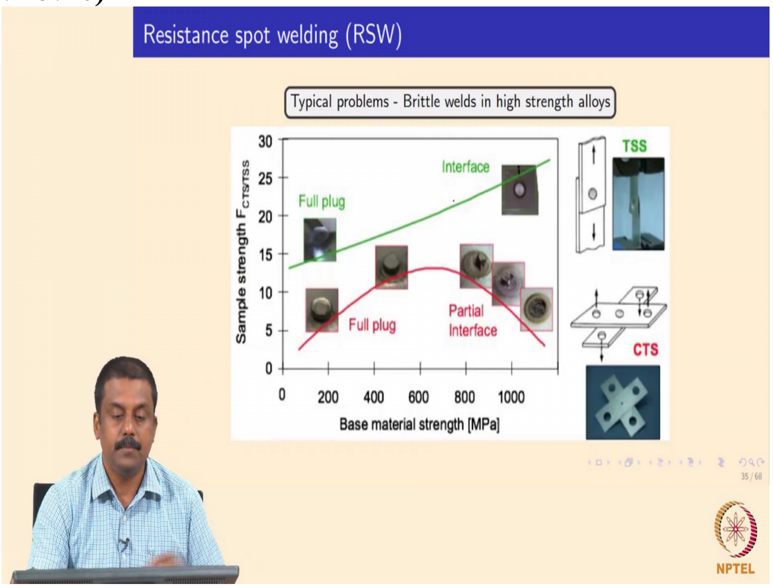

The most common problem other than this while welding the dissimilar thicknesses is the brittle welds that what we generate especially if you have a high alloying composition all of our advanced high strength steel they have high amount of alloying element then converting conventional steels and cooling rates what we use what you obtain in the resistance spot welding as I have explained you can go and 100 killing per second. So invariably you end up having martensitic microstructure.

And apart from that your columnar grain development or grain growth during solidification can also lead to very severe segregation at the weld centre line ok. Both the brittle microstructure and the segregation arising from the columnar grain solidification so your weld metal develops very brittle characteristics, for example if you look at this graph I showed you the sample shear strength after the cross tension tensile test.

This graph is actually plotted from CTS also you can get it from tensile shear strength the only problem. So if you are a low best metal strength obviously you may have low alloying element and simple chemistry and you end up getting very good weld metal properties the full plug failure the plug ratio becomes 1 in this case. And if we increase the strength that mean you are moving more slightly along the alloying elements.

In advance high strength steel is obviously if you have a strength level 600 to 1000 ma Pascal and you may also cause severe segregation because of increase amount of alloying elements which are needed for example trip steel you may also have phosphorus, the role of phosphorus as I explained in previous classes. So that may cause and segregation at the solidifying grain boundaries as well as the weld centre line.

Weld center lines unfortunately in this spot welds happens at the middle of the prior faying interface so that is the most brittle region in this resistance spot weld when you apply a tensile stress your interface completely breaks up apart causing interface failure but sure here plug ratio becomes zero. Based on the segregation behaviour you may also have partial plug failure. And these brittle welds that are actually you know no commonly observed in advanced high strength Steel that is not accepted.

Therefore we need to come up with an alternative wealth among cycle 1 for resistance spot welding that is what you are going to look at it in subsequent classes ok. And this kind of the brittle weld issues are perennial in advanced high strength Steels because of the alloying elements that are present in the composition.

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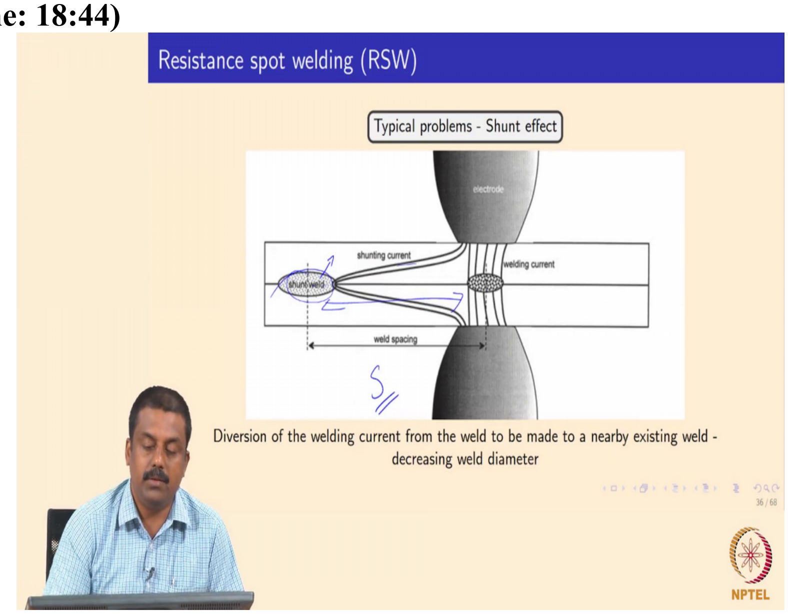

There are some other typical problems couple of them I will explain now the other problem you need to actually address while designing your weld configuration. So I would have explained the minimum distance between two welds right that is very critical because if you are placing the weld's too close each other. And you may also have a shunt effect ok. The shunt effect what is actually it is very clear electrons basically when you are passing the current obviously you have a moment of electron between one electrode and other electrode the electron obviously finds the easy way to one electrode to other electrode.

And if you are placing the welds to welds close to each other then we end up passing the current from the welds which you made already to the electrode and causing re-heating the weld's that already you made. So your welds that are already made is used to pass the electrons from one electrode to the other electrode in this process the welds that already you are made it is also to be reheated sometimes you may also have re-molten in this case. And this happens especially if you place the two welds very close to each other not taking care of the BS that we have explained in the previous slide the distance between two welds leading to change in the micro structure or properties of the welds that already been made.

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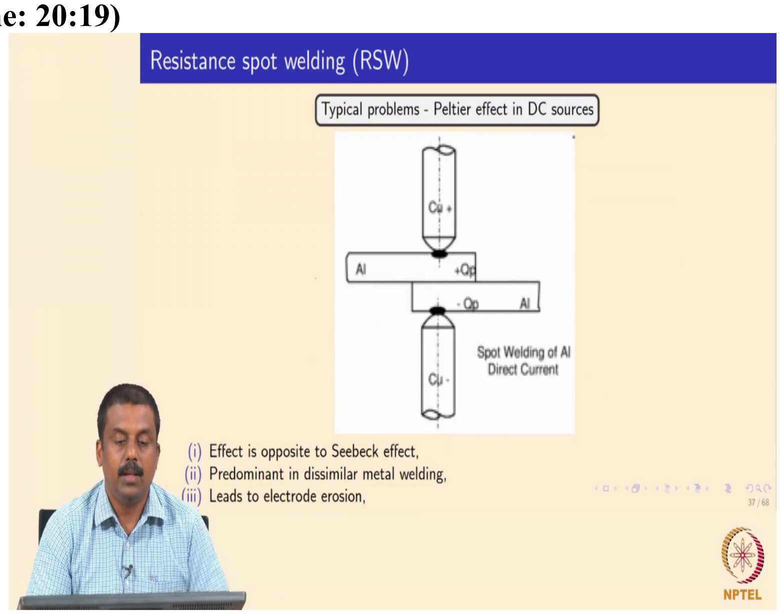

So, other problem especially if you use DC direct current for welding is the Peltier effect this is the Peltier by the scientist name and it is opposite to Seebeck effect. Seebeck effect you must have already been heard the principle behind thermocouples temperature, measurement systems what is Seebeck effect? When you have dissimilar junction and these two dissimilar junctions are kept at two different temperatures and EMF of generators and Peltier effect is opposite to that so when you have DC current EMF and pass through two different junctions.

And you have hot and cold junctions ok. So, for example in this case we have an example aluminium, aluminium welded with a copper electrode this if you pass an EMF or if you pass and current so what will happen you will always have hot and cold junctions ok and the exact exactly opposite Seebeck effect. Seebeck effect because of difference in temperatures you generate EMF and here because of dissimilar junctions you generate hot and cold junctions. And due to that you never get the uniform nugget formation.

You always have a problem with hot and cold Junction leading to irregular shape of nuggets. And rebuild nuggets forming only in one end which is hot end, weld nuggets absent in the other end. So, that is the reason direct current is not really used for welding resistance spot welding. And if it is a direct current we should also make sure that you have an repulsing which change the polarity during welding such way you get a the form of hot and cold Junction generation. This is really happening more predominant in terms of dissimilar welding then you will have even more dissembler junctions lead to hot and cold junction formation.

And due this you have how much rapid electro erosion happening and because of hot and cold junction at the two electrodes to the sheet plates. The so we will summarise again in this class so we looked at the mechinical properties of weld. The plug ratios and we moved on to the various problems that are associated with the resistance spot welds the problem leads to the dissimilar thicknesses, problem due to dissimilar materials.

How we can overcome and we will also moved on to the design aspects what is the minimum distance between two electrodes what we need to keep so that we can avoid shunt effect. And then we move on to the use of direct current, why it should be avoided if possible while welding of dissimilar materials or even with similar materials it is advisable to use the alternative current due to the Peltier effect thank you.