Welding Processes

Professor Murugaiyan Amirthalingam
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras

Resistance spot welding Part 03

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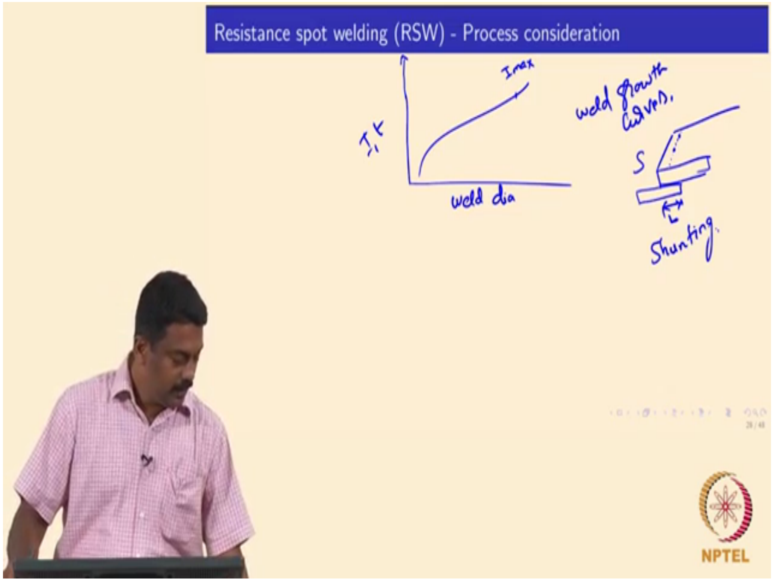

Good, so we will continue from last class. So last class we looked at the weld growth curves, so what is weld growth curve? So we plot weld nugget diameter as a function of current or time and then we can identify the I max and then the critical diameter required for the engineering applications. So we looked at I t as a function of weld nugget diameter, so generally the curve goes like this a typical application, so we can identify the maximum current for a given time so that is I max, so I max determines the (())(0:53) condition for (())(0:54) of splashing and then guidelines for automotive industries generally says that weld nugget diameter should be 4 times the square root of thickness that is the ideal weld nugget diameter I mean you can expect.

So you can identify from the weld growth curves, so what is the critical current and then time needed to achieve the required weld nugget diameter. So why is it important? Because the mass effect M, so the mass effect determines the heat energy needed to form a given weld nugget diameter, so the M is related to CP and then again so M is related to the mass and the density and volume, so we can identify by identifying the Q then you can also calculate I and t so that is the relationship.

And we also looked at some geometrical advantages, disadvantages of the resistance spot welding, so what is the minimum distance needed between two welds? So the S is the distance between two welds now overlap joint, so generally even you have an overlap distance of L, so if this is L the overlap distance so what is the distance at which you will have to place the weld? So generally that is an L by 2, so you will have to place the welds of a distance between the overlap total overlap distance and distance between two welds is S that is also very critical because so if you keep it too close then you may also shunting, so shunting we will see in this class what is shunting and then why it is you know problematic and why it is important to analyse that is minimum distance so that you do not have a shunting effect.

So the distance between two welds is also critical in terms of structural stability. So when the design is considered for an automotive industry so they also look at detail structure analysis to see how the member is behaving under load static and dynamic load and they do an (()) (3:09) analysis to identify where exactly they can place the weld, so by considering the shunting effect.

So the S and L we can get it for varying thicknesses, varying materials and then I showed you a table which can be referred for a common engineering alloys. So for detailed case, for example if you want to identify what is the L and S you will have to do a complete structure analysis using an FEM. So generally it is done for automotive component when they conceive the design, they do and elaborate structure analysis, so they think about the design, so when they also conceive the design and they keep in mind that which welding process they are going to use because in the resistance spot welding the disadvantage is the accessibility, both electrodes should be reaching to same spot.

Suppose if we have a complicated geometry, some set of a curvy geometry then you cannot reach this part from top and bottom. So design consideration involves what welding process they are going to use it for the component, for a spot welding you need to always have an access in top and bottom otherwise you cannot make a spot welding. So the design analysis when they are conceiving for a component fabrication automotive industry so they consider all the aspects, not only the stress analysis they also look at the accessibility for the electrodes to reach the same spot.

So this is what we looked at in last class, so we look at in this class some of the testing methods they use for spot welding, resistance spot welding, and then we will see some of the definitions of some parameters which is used to define the quality of the weld, the mechanical property of the weld and then we will move on to the some of the problems you may face in resistance spot welding, is it clear? So any questions so far in last class, okay good so we will move on.

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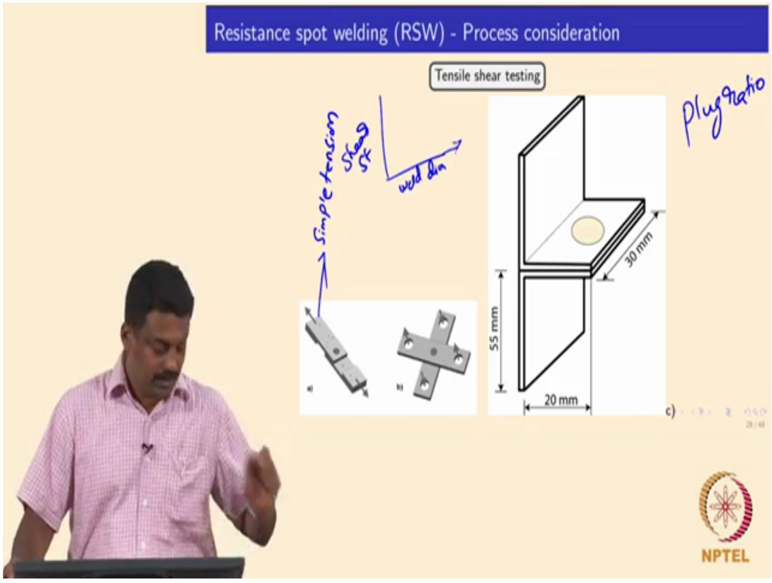

So the common testing methods we follow to qualify resistance spot weld is these three. So if you look at the sample geometry is what I have placed here. So this is a simple tension so this is in a simple tension test, so what do we do in this case? So there is a spot weld, so we make a spot weld of two plates in overlap configuration the same configuration I have been talking about, so this is the most common configuration we use in spot weld overlap.

And then so upon making samples we fix that in a tensile testing machine and then pull it in tension and identify load required to break this bond apart. And in this process we identify what is the maximum strength this interface the weld can withstand, so in this case so generally it is a shear strength because even if you are pulling it up, so interface will undergo on a shear loading.

So we identify shear strength generally as a function of weld nugget diameter, weld diameter and this follow the similar strength as a current R so shear strength can also be replaced with the elongation as well. So generally we plot the shear strength as (())(6:50) diameter and identify the what weld diameter obviously gives the best strength. And apart from strength we also look at some other important parameters in spot weld because when you are deforming such a member, you are applying load in almost in all the parts of the (())(7:11) component.

For example (())(7:13) your sample when you are applying a load, the load is applied in all the places. So when you are measuring ductility you are not measuring ductility of the weld, you are measuring ductility of the entire sample. So in order to identify what is the actual property of the weld apart from the strength and the ductility we also look at the plug ratio, so what is the plug ratio? So plug ratio we measure after the failure whether the weld nugget is intact or not.

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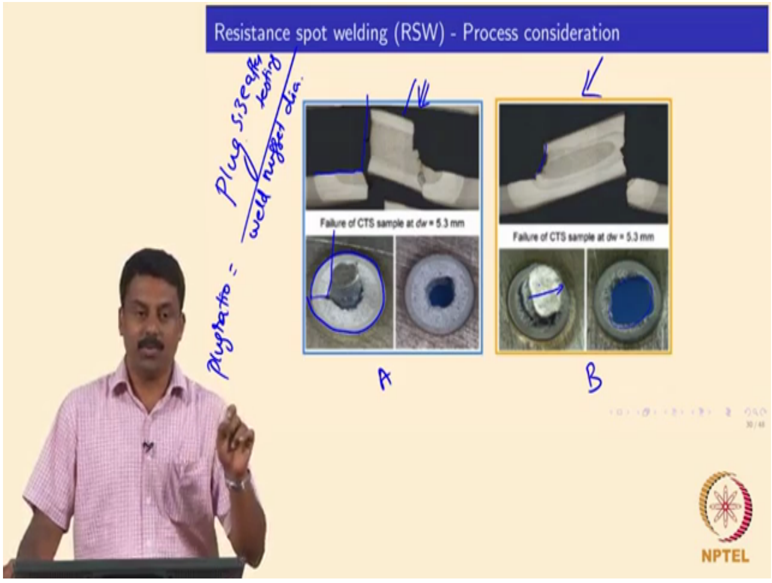

Suppose if we look at two samples after failure in this case, sample A and then sample B so what it show here is the samples after subjecting them into tensile testing, it is not pure tensile but the cross tension test, but anyway so not explain the plug ratio you can refer this figure. So what you see over here, is this the cross section and this is the top view of the weld and if you look at the cross section in this case the top image this image so you see that so this is the weld nugget after failure you see the failure has happened from the interface and then once the crack reached the middle of the weld nugget and then it deviate and then fail vertically.

So if you look at the plug so this is the fusion boundary of the weld prior fusion boundary of the weld, so when you are testing it up so crack nucleated and then the interface opened up and then ultimately the crack deflected and then it cracked like that. So in this case some amount of weld is still intact some fraction of weld is intact and we call that as a plug.

So we measure the plug size, so the plug size can be measured, plug size after testing over the initial weld nugget diameter and that is known as plug ratio, so plug ratio we measure by measuring the plug size after welding, so it is like your button you pull it apart, if button is intact what is the plug size? It is 1 because the plug size is same as the weld nugget diameter, see the image over here in this case, in this case the failure has happened from the fusion boundaries deflected, you see that plug is more or less intact, yes or no?

So the entire plug is opened up, you see the bottom plate it is a hole, entire weld actually it is intact sticking to the one of the plates. So plug ratio here is the (weld nugget diameter divided by the plug size) plug size divided by the weld nugget diameter that means that in this case 1. So obviously doing this test if the plug is intact what is that mean? The weld did not fail, the failure has happened elsewhere on the base material (())(10:59) its own.

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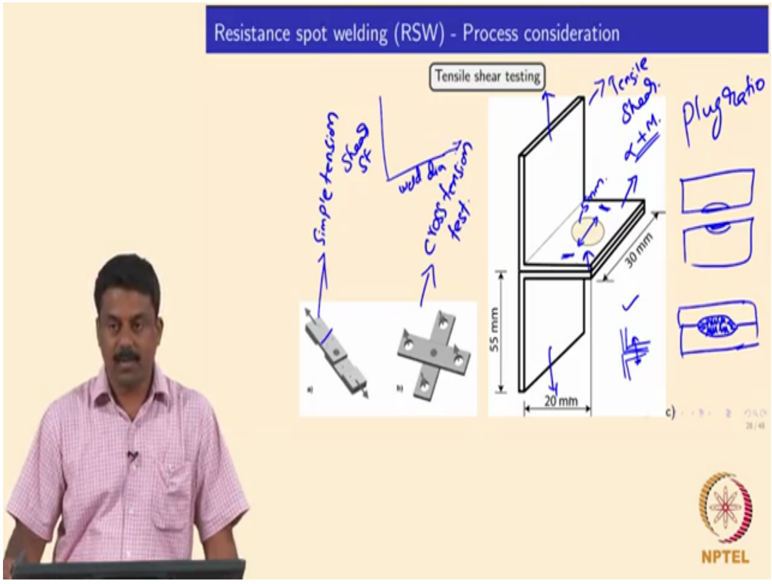

So apart from the strength it is also important to understand the plug ratio, so when you are measuring the mechanical properties of the resistance spot weld it is important to understand not only the strength of the weld because strength of the weld if you look at in this test it is a function of even base material, so base material is also contributing to the actual the strength, so that is not the clear indication about the weld property.

So in order to (identify the) quantify the weld properties clearly, so we also measure the strength required to break the joint but this break can also happen in elsewhere in the base material, but then that is not real identification weld material property. So we identify the strength required to break anywhere plus the plug size, so both combined would give us the mechanical properties, if plug ratio is 0 what does that mean? So that means that the interface has completely failed okay that means that you have situation what you had before welding complete interface failure.

So if both the plates comes apart after testing what does that mean? That means that complete interface failure, your plug ratio is 0 means your weld is completely failed at the interface, so you will have a complete interface failure so you will just take apart or the interface, so it means that you have an interface failure, is it clear? So apart from the strength the guidelines should also specify what is the minimum plug ratio you should have in order to qualify the weld.

So generally the weld qualification dictates that atleast 80 percent plug ratio you should have or 0.8 that means that the weld is not that brittle, the interface is not really segregated, it has brittleness at the weld centre line, so if weld centre is completely embrittle what happens when you are applying load? It will open, complete interface failure will happen, is it clear? So we will have to identify the strength plus the failure mechanism in order to quantify the weld metal properties or the resistance spot weld.

So we do it in generally in three ways, one is simple tension test there are some problems because you know the load applied it is not applied directly on to the weld so people have device some other methodology for example in this case it is known as the cross tension test. So in this case we make sure that some majority of the load you are applying it is applied to the weld, so you make cross samples there are some standards you can there are control so you make weld in such a setup and then you apply tensile load for example you pull the top in tension and similarly bottom in tension.

So in that case you also make sure that the load is concentrated majority at the weld and you identify the strength required to pull this interface apart and then you also can calculate because this will be slightly more accurate than and this in order to quantify the weld because whatever load you apply because from the load only you are going to measure the strength. So you can identify the strength of the weld, is it clear?

So plus the strength you also identify the plug ratio, is it clear? So if both are matching then the weld can be qualified, is it clear? So the cross tension test is very commonly used (()) (15:09) to test the mechanical property of the weld and apart from cross tension test we can also do on a tensile shear L tensile shear and this is simple to do because in this case you will have to make such a geometry sample and machine it and then you will have to do and this is very simple so you bend it, you make an L flange and then attach, make a spot weld at the middle of this L and then you pull in the tensile testing machine pull it apart and then identify the load required to break the either interface or elsewhere, so the failure happens somewhere over here that is best, so the weld is better than the base material then the welders will be happy.

So if a failure happens at the interface obviously the weld is in brittle and it is not acceptable, so same way in this test also we will identify the strength required to cause of failure and identify the plug size after the failure, your flux size is same as the weld nugget diameter that means that plug ratio is 1 that is the ideal case you can achieve because the failure did not happen at the weld, if failure happen elsewhere, is it clear?

So these three are the common testing methodologies used for quantifying the mechanical properties of the welds so in simple tension the cross tension test tensile shear in tension, is it clear?

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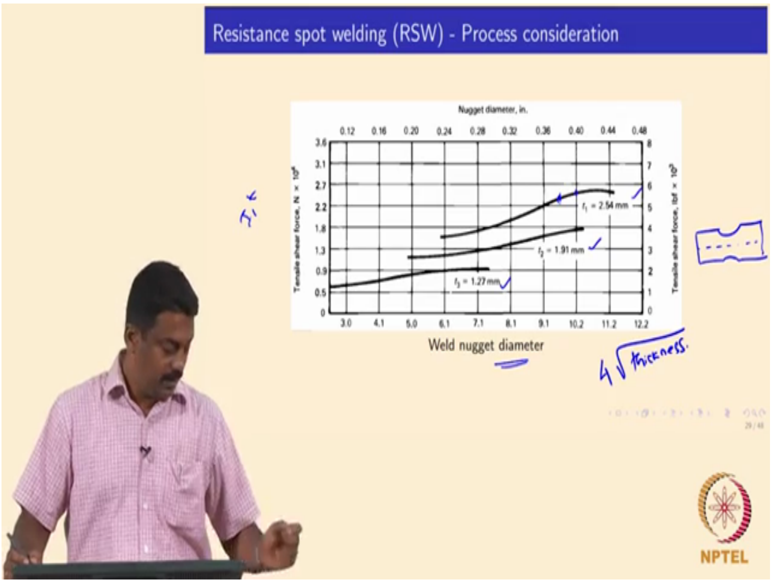

So then we plot graphs like this again if you change the thickness obviously the weld nugget size can also change for a given current, so we will not have to quantify the mechanical properties, we will have to measure it varying thicknesses. So in this graph I plotted three thicknesses 2.54, 1.91, 1.21 and then weld nugget diameter, so obviously when the weld nugget size change it change the tensile shear force also changes because if you are making in larger weld diameter so obviously you need to give more load to failure, so obvious.

But if you are keep on increasing weld diameter then after critical diameter you may not change, of course you will also have an I max and then you will have failure by the splashing then the properties may be cannot form in a weld nugget. So ideally so that is why so for example in this case 2.5 of 4 mm and you have one diameter that gives the maximum strength, so after that now you may also have severe cavity formation or (())(18:06) formation because of the more amount of liquid is there and you may also have a surface repression, if you look at in the weld case so you may also have a repression, so because material becomes really softened if you have a large amount of liquid.

So there is a critical diameter upon which you know you may not really increase the strength so that is why generally that diameter is 4 by square root of thickness, is it clear? So we identifies from these curves plus the weld growth curve, so weld growth curve will give us so what current and time we may get the required diameter and then we measure the strength as a function of weld nugget diameter and you may identify so what is the precise current and time you may have to use to identify the maximum strength containing weld and then simultaneously we will also measure the plug ratio.

So you may also have very good strength at it point if the plug ratio is lower here than here, so then we may still consider this. So we can have a compensation for loss in strength with the good better mechanical properties with the very high plug ratio, is it clear? Yes or no? Good, so these kind of curves the measurements are carried out for each thickness for a given composition because if you change the thickness so obviously the mass effect would influence the weld nugget diameter that will influence the current and time, so that is how we generate the properties.

So we identify weld nugget diameter, the idea weld nugget diameter which gives the maximum strength and acceptable plug ratio, is it clear? Yes or no? So this is how we qualify the spot weld, good.

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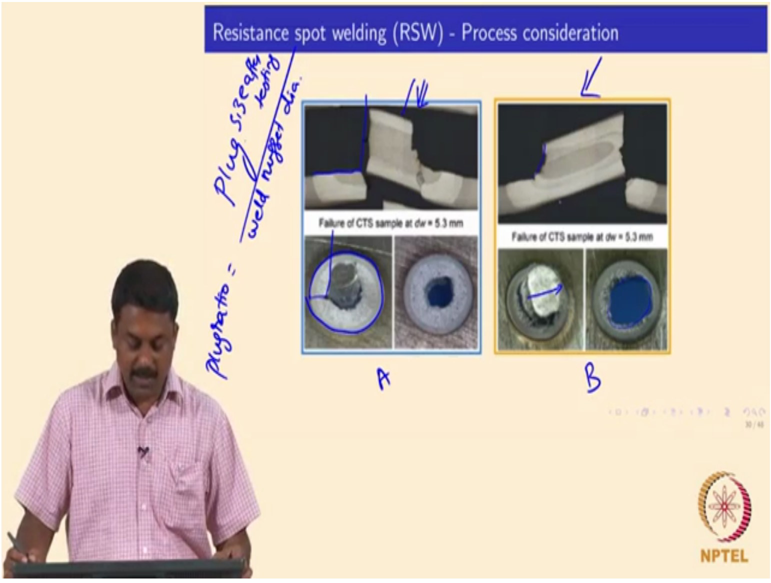

So this is already explained, so how do you measure the plug ratio?

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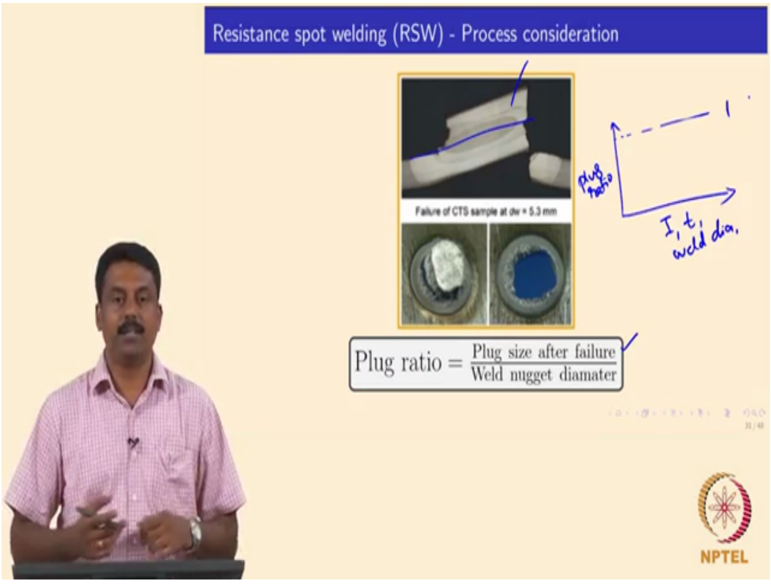

So plug ratio is measured, so while measuring the plug size after the failure and then taking the ratio between the weld nugget diameter over the plug ratio at the plug size after welding we measure the plug ratio, is it clear? And then we can plot plug ratio as a function of weld nugget diameter or even current, so current or time or weld nugget diameter and then identify if a plug ratio is always 100 percent so times 100 or 1 according to this equation.

So then that means that it is the best condition you can explain and then you can identify which diameter gives the maximum strength period and then identify what current and time you will have to use to achieve that weld nugget diameter and that you can identify from the weld growth curves, weld growth curves are plotted as a function of current, time as a function of weld nugget diameter, is it clear? So this is how we measure the mechanical properties of the resistance spot weld, so plug ratio is important so it is plug size after failure divided by the weld nugget diameter.

So, if the interface failure, so how did they know interface failure look? For example in this case if there is a complete interface failure then you will have failure here and this would have been gone, the cross section that means that the interface has become the same as it was before and this could happen when you have a very brittle alloying elements segregating at the weld centre line.

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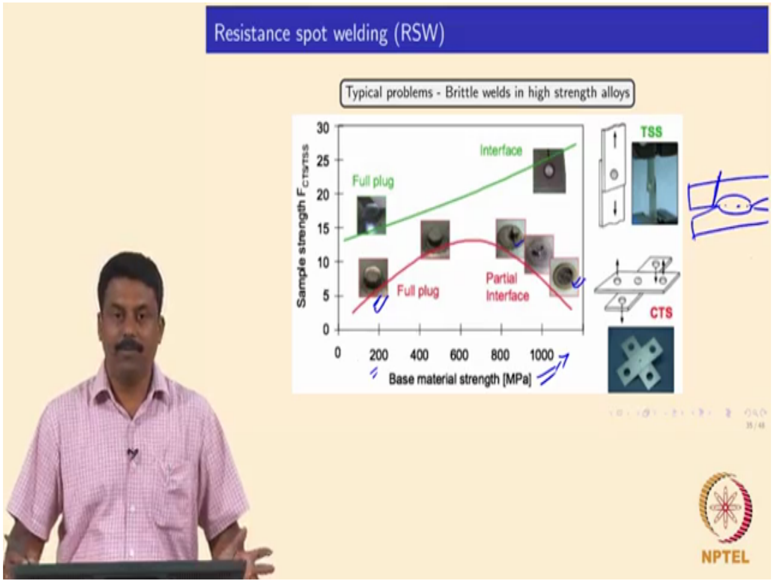

For example say case like this so we have material strength at the base material strength as plot of the function of strength and if we have a high strength material obviously to increase the strength you add alloying elements carbon is increased, you also add silicon, aluminium and phosphorus for material becomes very brittle, so obviously when you add more amount of carbon, carbon segregates to the solidifying liquid and then weld centre line becomes an enrich in alloying elements silicon carbon, then you may end up having interface failure, so interface failure means there is no plug at all, you see this in this case the complete interface failure.

Whereas material with low strength you do not have much amount of alloying elements. For example ion with 0.01 percent carbon pure ion, so its segregation is not that severe compared to the high strength alloys which has a lot of alloying elements phosphorus and carbon and you see this plug, plug is intact. So this is a full plug failure where the (())(23:28) ratio is 1 and if you increase the strength so obviously the plug ratio decreases you see that becomes a partial (())(23:36) and then we have a full interface failure, is it clear?

And why is it changing? Because in conventional steels and if you want to increase the strength of the steel obviously you will have to add alloying elements, so alloying elements can segregate and then make the welds centre line brittle and then (if you are failing) if you are pulling it obviously so already showed you right the notch of it, so if you have segregation on the weld centre line because that is the region which only faces the end, if your (())(24:12) propagates and then completes then you will have a interface failure, is it clear?

So for ideal case if you want to have a plug ratio is 1, so you will have to have a failure somewhere over here, so the cracks would propagate and then fail somewhere here that means that you have plug intact something like this. So in this case the failure has happened far away from the fusion boundary, so that is why you have a plug intact a full plug and then you can also identify the strength from the test, is it clear? How is it working? How do you qualify? Good.