Welding Metallurgy
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Lecture – 40
Controlling Residual Stresses in Weldments

Welcome to the lecture on controlling residual stresses in weldments. So we will talk you know in more detail about the methods by which we normally control or eliminate the residual stresses in the weldments. So residual stresses which are caused by welding may have positive or negative effect on strength of component based on their type, sign, distribution and directions. so in some cases the residual stresses as we had discussed that they may be also advantageous for the product.

So but in most of the cases it has the negative effect on the strength of the component so and also you have the you know that may be the type of you know that is it may be compressive or tensile type of stress you may have that weight as positive or negative and how it is distributed in what direction it is distributed all these things are you know important to know and basically based on that sometimes they cancel each other or sometimes they are detrimental more.

So like that it effects and many at times the stresses in the structure will be as high as the inner strength of the material and when combined with stresses from external loads.

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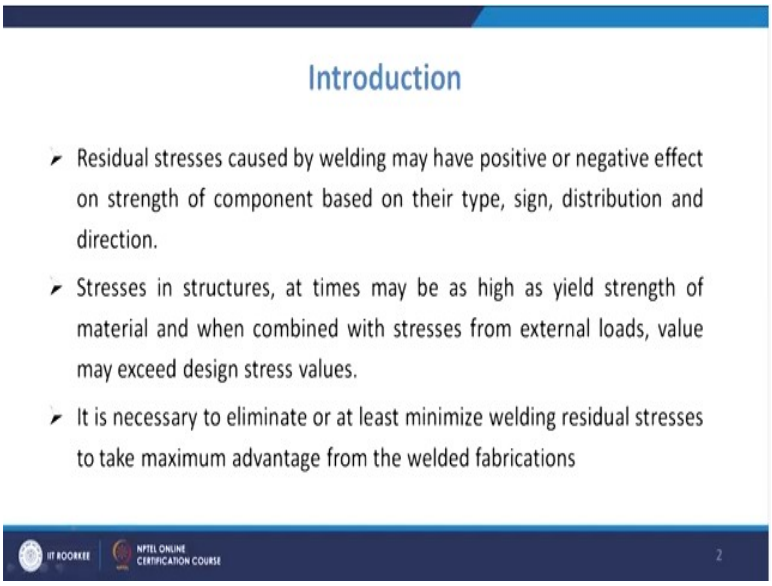

So then in that case it will be going beyond your designed value. So basically you know you have to have the ways for the elimination of these stresses and you must will be discussing about the different methods of you know eliminating you know the stresses you know so though the different methods which are you know used for the elimination of the stresses are like peening then you have vibration, stress relief, you have thermal treatment, thermal mechanical treatment.

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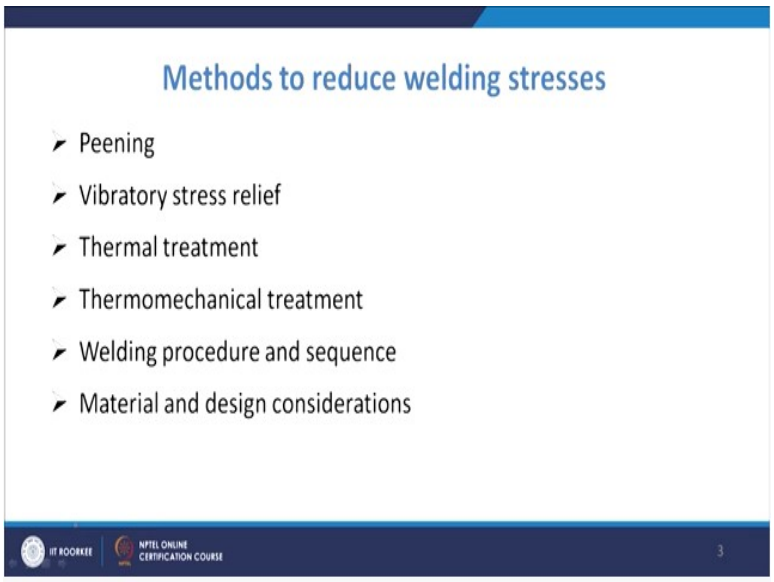

You have a melding welding procedure and then you have you talked also about the material and design considerations. So basically there are you know large scale it affects the residual stresses on large scale it affects the properties of the material because you know they will be you know in

giving you the material tendency to fracture in the brittle manner. There may be effect on the stress corrosion cracking of the material.

It will be affecting the dimensional stability of the you know material. Then also you will have you know when it is under the dynamic loads so you have many times you have the failure because of those loads the materials. So accordingly you know based on that you know these so for taking into account you know those effects those ill effects of the residual stresses these methods are being you know used for you know for removing these or eliminating or maybe controlling that residual stresses.

So first among these methods is the you know peening method. So as you know that this peening is normally done with hammer. So you have you know what you do is in this case you are in the purpose is to elongate the outer fibre of the weld with the help of the mechanical hammer blows.

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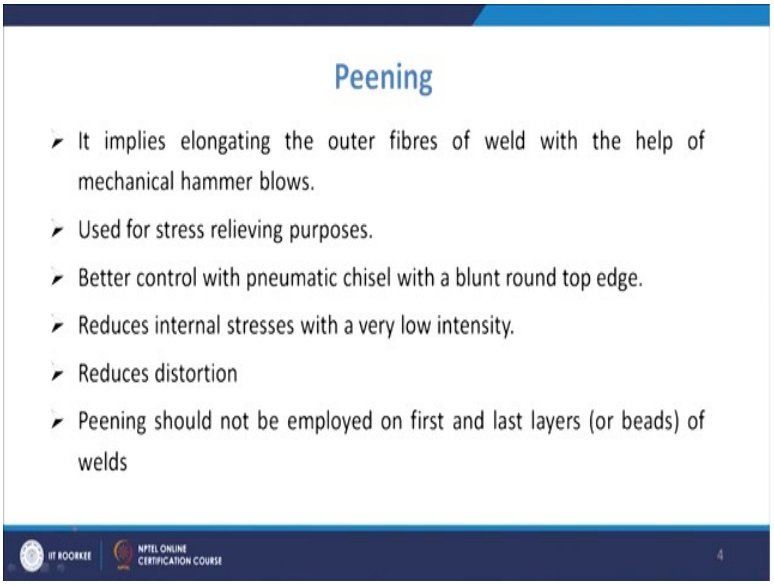

So you know you have you give the hamming action when you do the welding. So mainly especially in the multirun welds what we had discussed in those cases we follow this practice of pinning. So this is normally for the you know stress relieving purpose it is used so you know when it is properly applied it will be causing the plastic flow you know. So when we apply the layers and if you do the pinning.

So that basically you know does the plastic flow you know in the welded zone and you know it will be subsequently relieving that restraint which is you know that is a set up you know so which is producing the residual stresses. So basically that is how you know it will be trying to decrease the you know stresses.

So you can do by hand also but you have if you use the pneumatic you know chisel with a blunt or on the top edge in that case you can have a better control of the pinning process. Now you know what it does is that the pinning process basically reduces the internal stresses of the low intensity.

So that internal stresses are very low intensity you know you know stresses they are reduced because of the pinning you know process and it will also reduce the distortion in the in the material. So many what happens that if you do that so it will be also you know avoid any further heat treatment you know of successive heat treatment when normally you do the welding of thick sections. So that way you know that is normally you know the practice in the case of welding.

Now there is one you know in this pinning process one care you have to take that when we do the pinning. So this is basically the you know this is how the pinning is pinning methods are there with chisel and you have this way also. So what is suggested that when you are doing the multi run welds in the first and the last weld you don't do the pinning. So you know the because of the when you if you do the pinning in the first layer. So that so what happens that when you have the.

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So if you have the if you have multi run welds and if you know you know so you are doing it. So you will go for many times now in the first time when you do the pinning so on the first layer so that will be basically that PSD weld. So since because it is delicate that time so it will be piercing that weld or it will displace the member sideways.

So that may happen you know if you pin for the first time and then if you go further and when you are coming towards the last layer which is applied now at that time also we avoid this pinning because that may you know that may do the see cold working and that also may injure the at that time it there may be injury so that may be plus splashing or so that may be there may be injuring injury also to the worker.

So that you know precaution you have to apply in the case of pinning. Now we also don't do the excessive pinning because of you know certain factors like if you do the excessive pinning then there may be cold working with strain hardening taking place. So that way you will have your hardness will increase and that will be affecting the other properties of the material the work material may bend also because of the excessive pinning.

There may be you know crack also in the weld that may also you know happen. So another and one more thing that you have to do pinning only when you are ensured that there is sufficient ductility in the material at that temperature. So if the ductility will be less and if you do the

pinning in that case you know there may be ill effects or undesirable effect on the material properties. So the so that is the pinning.

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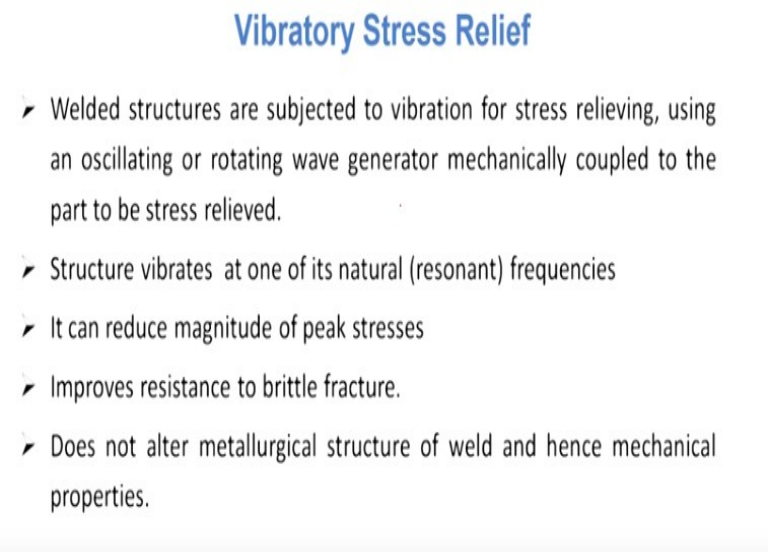

Then next method is the vibratory stress relief. Now in this case the welded structures basically are subjected to vibration for stress relieving using an oscillating or rotating wave generator mechanically coupled to the part of the stress relieved. So basically this is here we use those vibration basically to relieve the material of the stresses. So the structure will be vibrating at you know one of its you know natural or resonant frequency.

So that is normally you know seen and it can reduce the magnitude of the peak stress it improves resistance to the brittle fracture. So these are the traits so what we do in this case the you know will the structure basically be all will be vibrated and at its natural you know frequency. So you know so plastic yielding in the reason of the plastic deformation so in that reason you know so that will be doing that you know purpose of stress relieving.

Now you know this vibratory stress relief it does not affect the you know metallurgical structure of the welds or the heat affected zone. So it will not affect the mechanical properties also so you know like strength or toughness so they are unaffected so that way it is you know good in that sense. You have another method that is the thermal treatment.

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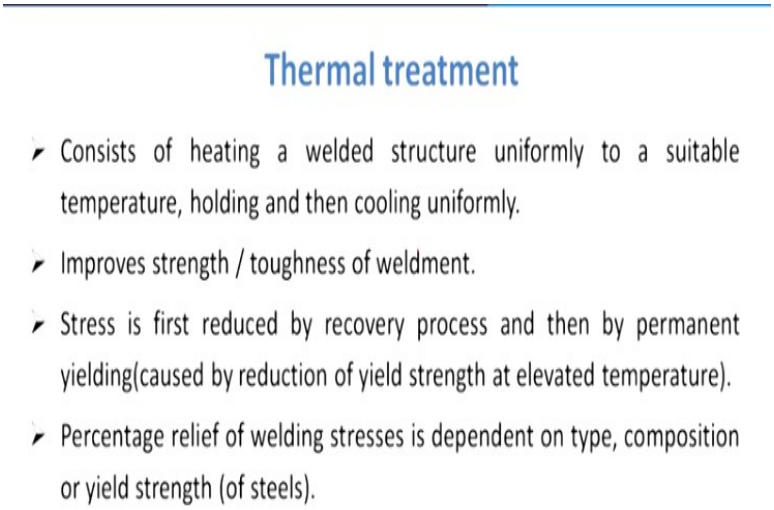

So by thermal treatment means you are basically subjecting the material under some thermal treatment you are heating and cooling in a certain fashion so that the stress is relieved. So it will be heating of a welded structure uniformly to a suitable temperature then you are holding there and then further you are cooling that uniformly. So that you know basically will be relieving that result into this relieving of the residual stresses.

So that will be improving the strength and the toughness of the weldments. So what happens that in this case the stress will be first reduced you know by the recovery process and then by the permanent yielding. So that is caused by the reduction of yield strength at you know elevated temperatures so because you are increasing the temperature. So you have the deduction in the yield strength.

So because of the you know recovery process stress will be reduced and you have the permanent yielding also you know taking place. So you will have the you know selection of the temperature also appropriately you will have to have you know in this case because that also the temperature to which it is heated then the time for which it is you know hold.

So that basically results into the percentage relief of the welding stress and it will be depending upon the type of you know composition then it will be how much is the time of holding so and what is that temperature so on those things it will be you know you know it will be deciding so in

a very rough manner it has been seen that you know for a desirable you know this thermal treatment stress relieving treatment.

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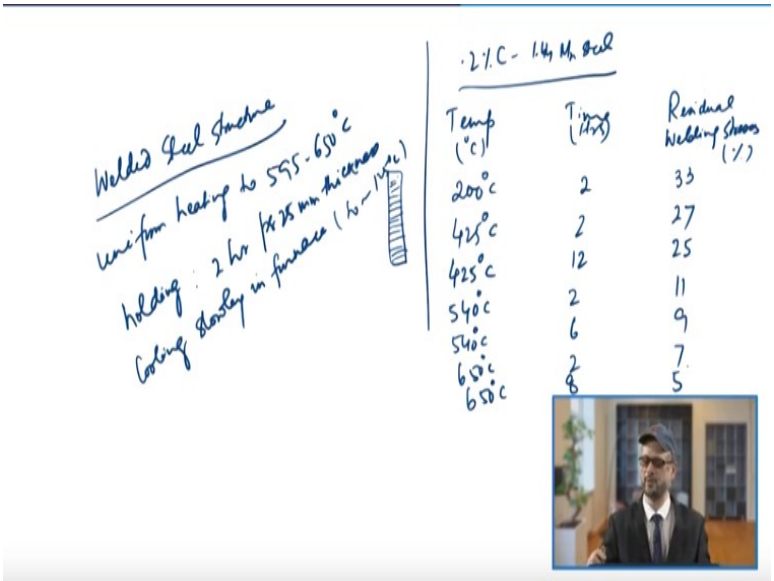

What is happening is that you have the suppose welded steel structure. So you normally you know uniformly heat so you need you do the uniform heating to about 595 or 650 °C and then their you are holding. Now for holding also there are you know certain guidelines so the holding will be based on the section thickness. So holding will be about you know 2 hour per 25 mm thickness and then once you hold for some time then you are basically cooling.

So the cooling will be there is slowly in the furnace you will be cooling slowly in the furnace maybe to about 125 °C or even lower and then it will be allowed to cool once you take it outside to the furnace and allowed to you know cool to the room temperature. So that way normally that is the normal you know stress relief cycle which is practiced. Now it also depends upon you know so if you give that time you know if you know change the timing of holding in that case the percentage relief will be changing.

So you know for suppose you know for a 0.2% carbon and 1.44 you know manganese steel it has been seen that if you have the different temperature and if you have the holding time which is there in the hours and this is in °C. So you will have some you know residual welding stresses which is there remaining. So what is seen that if you do at 200 degree C and if you do for

suppose 2 hours then it is about 33% still residual welding stress is there but if you do at 425 °C and if you do for 2 hours then it is 27%.

So that is basically as you see there is a decrease in that residual welding stress when the temperature is increased and the time is kept constant. Now if you increase the time at this temperature if you do it for 12 hours it will be reducing somewhat 25. Further so there is only a small decrease in that you know residual welding stress value but if you increase the temperature to 540 and if you do only for 2 hours it comes to 11%.

So it is considerably so if you go to that higher you know temperature and if you go to suppose say you know 540 for 6 hours then it comes to 9%. So that way you know if you go to suppose 650 then and keep it for 2 hours it will be 7% and if you do for 650 °C for 8 hours it will be about 5%. So the renewal stresses can be minimized by holding for different time you know and maintaining the different temperature.

So that way you know the stress relief treatment can be given and based on the timings you will have the different values of the residual rebuilding stresses which is there inside the material. So accordingly you have to take the you know different temperature and you have to have the different holding time. So that you know you can have the relief of the residual stresses also you have the permanent yielding which is caused at the high temperature.

So this is because of the reduction in you know of the instant that I elevated temperature so you will have other phenomena also may you know be you know active in those cases. So but that is not to be discussed here.

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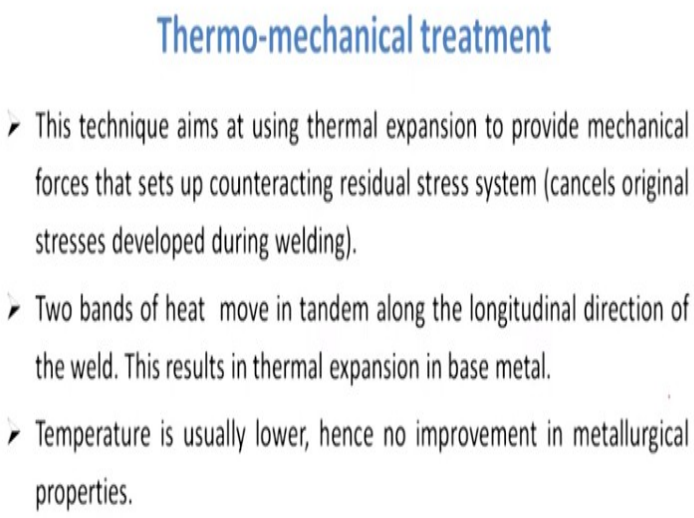

Now coming to the you know different other you know method is the you know the thermo mechanical you know treatment. Now thermo mechanical treatment is basically aimed at using the thermal expansion to provide the mechanical forces that set up contracting these residual you know stress system. So there will be cancelling of the original stresses which are developed in the material.

So many a times what you do is you use some heating means so you have some you know thermal means and also the mechanical thermo mechanical treatment is given to see that the stress system which is there which is actually you know we know that we have studied the residual stress pattern in the welded specimen and if you do some you know some heating or so. So what we can ensure is that there may be you know a contour type of stress pattern that maybe you know generated inside the specimen and that will cancel the existing stress which is there.

So which is originally there in the material. So what you do in this case is that you have two bands of heat move in tandem along the longitudinal direction of the weld. So that results in the thermal expansion of the base metal so what we do you know in this case.

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So suppose you have you know a weld so this is your weld bead so this is you know done and you know that when we if you try to have you know in the longitudinal direction if you try to see the you know the stress pattern. So you will have positive here and on this side you have negative. So now for that what you do you are doing the heating on these sides. So the on these sides you do the heating.

So what will happen because of the heating now see now you had the earlier what you see you might have you know seen earlier recall that this was the you know type of you know residual stress pattern in the case of you know weld. Now if you are heating now in that case you will have the you know development of you know the stresses and that will go like this so because of the heating on both the sides.

So you are heating you know so you have two bands of heat so your here and here so you use the oxy fuel gas you know torch is on the both this side you know along the longitudinal weld and they will be moving to a parallel to that bead. So this way they will be generating a type of this type of another residual stress you know because of the heating. So that will be basically cancelling so what you see from here, here it will be you know it will be neglected.

So you have negative on this side so that will be positive so that will cancel. Similarly you that will also be minimized so this way now the position of the heat source is also in such a way it is

chosen that you know the residual stresses which are there and the residual stresses which you are basically generating this would be cancelling each other or their effects should be you know in in opposite directions.

So that there is decrease or the cancellation of the residual stresses so you know in this case you have considerable reduction of the residual stress levels that can be you know obtained in these methods and it has been found that may be of the order of more than 50% you know the reduction in that stresses can be you know can be seen in in such cases of the you know removal of or the elimination of or decrease of the residual stresses.

Now they do not improve the mechanical properties so that way now you know so this is not going to have the you know substitute for the stress relief treatment. So that is one another trait of this you know process. So next we have to see the other methods by which we can have the you know control of the residual stresses are the welding procedure and the sequence. So in the welding procedure normally what we do is we go for the back step welding.

So what we do that in these back step building we take the you know short tack wheels so you have the length which is normally the tack weld length is normally taken as the 2.5 times the thickness.

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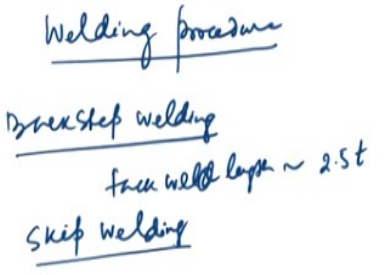

So what we do in those cases you know where we talk about the welding procedures. So in that we take that so the important point which is to be seen is the back step building and the skip welding. So in the in the back step building what we do is you are doing this welding in the back direction.

So you know to the longitudinal direction so in this case what you do is you have the tack weld length you which you take. So it will be taking somewhere close to 2.5 times the thickness of you know the sheet which we are taking and we are you know so we are and depending upon the welding speed also you will have the wheel length spacing between the tacks so if it is you know slower so that will be closer also.

Now the first weld it will be deposited it will be using that you know back step method. So from one tack to other in the opposite direction of the you know overall welding direction. So welding direction is such so welding should be done in the in the back you know in the back direction. So in the back side so that's your back step welding. So this is normally you know found to provide you know more uniform type of residual stress distribution in the case of you know the welding.

Similarly you have another thing is your skip welding. So what happens that you know it is another method of reducing the residual stresses. So what we do is we are skipping you know the portions so what we do is we do for one tack length and then we skip and then go to the next one. So we next is skipped and then we go to so that way you know you know so we are.

So this way is also very much this proves to be very much effective in you know reducing that you know residual stresses localization or increase in that localization and it is normally very much you know seen or practiced in the case of welding of cast iron. So this these two methods normally are you know adopted for controlling that residual stresses and welding sequence is that you have to you have to have the proper you know welding sequence.

So that your transverse shrinkage is basically you know reduced then you also have to focus on the material and the design considerations.

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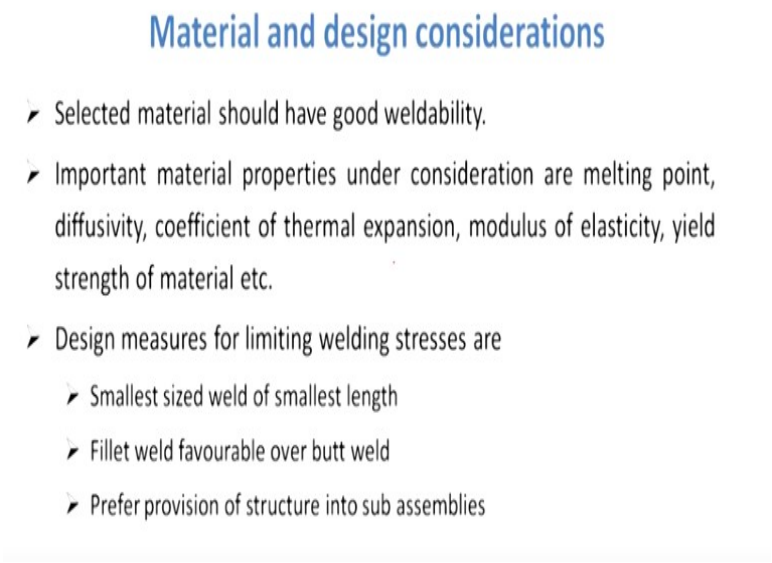

So you have to see that the material which has been selected they have the good weldability properties then the important material properties which has to be considered are the melting point diffusivity coefficient of thermal expansion modulus of elasticity yield strength of you know material.

So these are the you know material properties which needs to be understood and its effect on you know having the generation of the residual stresses should be you know should be known to you so the design measures for limiting the welding stresses are that so these are that smallest size weld of you know smallest length then fillet weld will be you know preferred over the butt weld. So you know these are normally the may know material and design considerations.

So then you have the you normally prefer the division of you know structure into sub-assemblies. So that is also you know another you know point which is worth looking into for understanding the you know the distribution of the residual stresses in the material. So and properties you know it is required to know.

Because you know some of the properties you know allow the crack to you know to propagate more and some may less and you know depending upon the thermal properties you have the you know development of temperature gradient that will basically inducing the stress values and so. So that way you know these properties also will be affecting the residual stress pattern of the

material and accordingly the measures should be taken to reduce the you know welding stress or residual stress values. Thank you very much.