**Theory of Production Processes**
**Dr. Pradeep Kumar Jha**
**Department of Mechanical Engineering**
**Indian Institute of Technology, Roorkee**

**Lecture - 52**
**Methods of controlling residual stresses in welding**

Welcome to the lecture on Methods of Controlling Residual Stresses in Welding. So, in the last lecture we discussed about the different you know types of residual stresses, which occur in the welding and we also discussed that residual stresses may be beneficial in certain situations and may not be also.

So, especially normally it is seen that, if it is in compressive in nature it may be more beneficial in certain aspect; but normally when they are tensile in nature and of having larger value then that is detrimental for the performance of the component. So, we are going to be you know knowing methods of controlling these residual stresses in the welding process.

Now, the so first of all as we see that you have either the positive or the negative effect on the strength of component based on their type sign distribution and direction.

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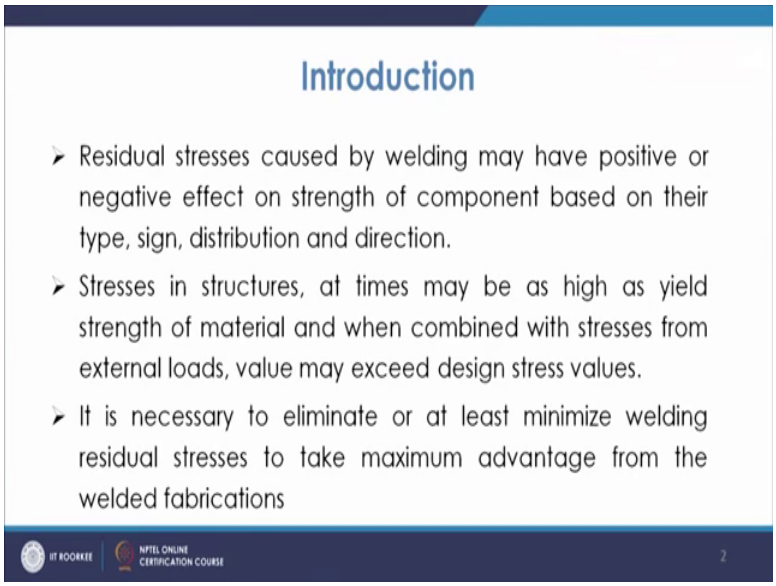

So, what type of residual stress is there whether it is compressive or tensile, whether it is you know the external stress or thermal stress or mechanical or you know the metallurgical stress

So, that is that then how it is distributed where it is uniformly distributed or at certain point it is the value is quite high and a certain point it is quite low whether it is in that type of distribution and the direction of the these stresses.

So, all these things are basically important to know when we talk about the residual stresses and it is seen that normally when you have the tri axial tensile type of stresses and when you have it is combination with crack like defects, then they are promoting the brittle type of fracture.

So, that way they are not desirable, in those cases or if you have the uniaxial or biaxial type of you know residual stresses tensile stresses then that may improve basically the fatigue resistance. So, that may sorry dim diminish the corrosion resistance fatigue resistance improved, because of the compressive type of stresses. So, that may lead to the increase in the fatigue strength of the material.

Now, if we also have discussed that many a times when even during the machining process also, the specimen are subjected to certain kind of distortion. So, this way you know there are pros and cons of the residual stresses and most of the times, you your motive is to control the residual stresses or minimize the residual stress.

So, you would like to have not residual stress, but which is very difficult to achieve. So, your motive is to basically you know decrease that value because, when the value of these stresses are high such as the yield as high as the yield strength of the material and when it is there is the combination of stresses from external loads, then that may exceed the design stress value and the material may fail.

So, that is why we need to know the residual stresses, I mean how they can be minimized. So, you have to decrease, so you can decrease in many ways. So, like you can decrease the maximum of the tensile stress level. So, that is one way you know then, you can also decrease the zones of high residual stresses you can have the different techniques by which you can see that those zones; where the there are high residual

stresses that zones may be free of the residual stresses or also you can try to see that there is decrease in the degree of multiaxiality of the residual tensile stresses.

As we discussed that when you when you have for multi axial tensile stress and that basically when in they interact with certain defect type of structure then that leads to material type of fracture.

So, you can have such kind of ways by which you can see that how your you can reduce the level of the residual stresses or now or how you can have the ways to so that the jobs or a specimen behaves better while working.

Now, we also should know that we need to be wary of these residual stresses, because if there are residual stresses inside the material the material is subjected to they are more prone to go towards the brittle type of fracture. So, brittle type of fracture why we are emphasizing because having the brittle type of brittle mode of fracture is not desirable, in the sense that they do not give proper warning you know.

So, that is why we try to see that residual stresses values are unless, similarly the stress corrosion cracking in there I mean it is chances become more. So, when the you know then similarly the dimensional stability becomes less as we know that when the stress there will be more there will be distortion and that may lead to the distortion of the body. So, you may have the changing the dimension of the material.

So, these are the disadvantages and that needs to be looked into and for that you have different methods to reduce these you know welding stresses. Now the different methods which are normally practiced to reduce these, you know welding stresses are penning vibratory stress relief thermal treatment thermo mechanical treatment welding procedure and sequence materials and design considerations.

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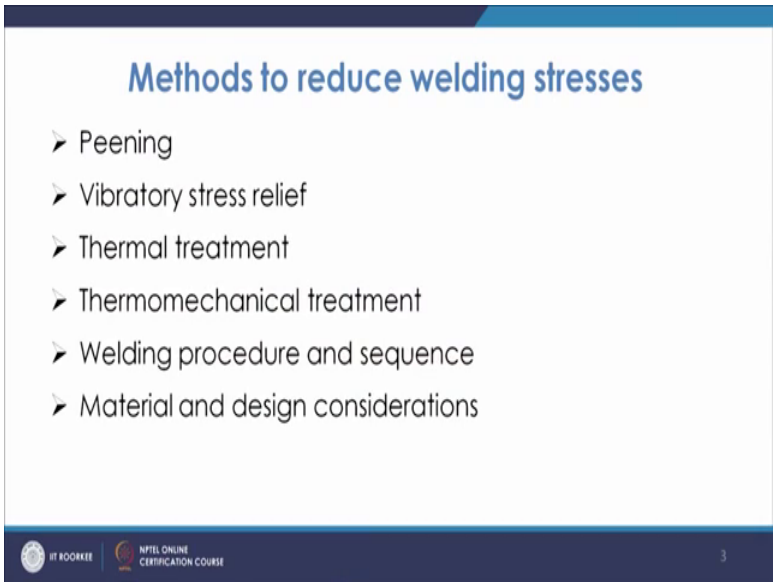


So, these are the methods which are basically used for removing or for reducing the residual stresses in the welding. Now Peening, what is Peening? So, Peening means as we know that Peening means you are having the repeated blow with some hammer or mechanical hammer type of equip with mechanical hammer you are putting the blows on that.

So, in the Peening we are what we do is we are our purpose is to have the elongation of the outer fibers of the weld. So, when we are doing the welding at that time we do the Peening. So, there will be small deformation add at the top portion, so elongating the outer fibers of the weld with the help of the mechanical hammer blows and that basically redistributes the stresses.

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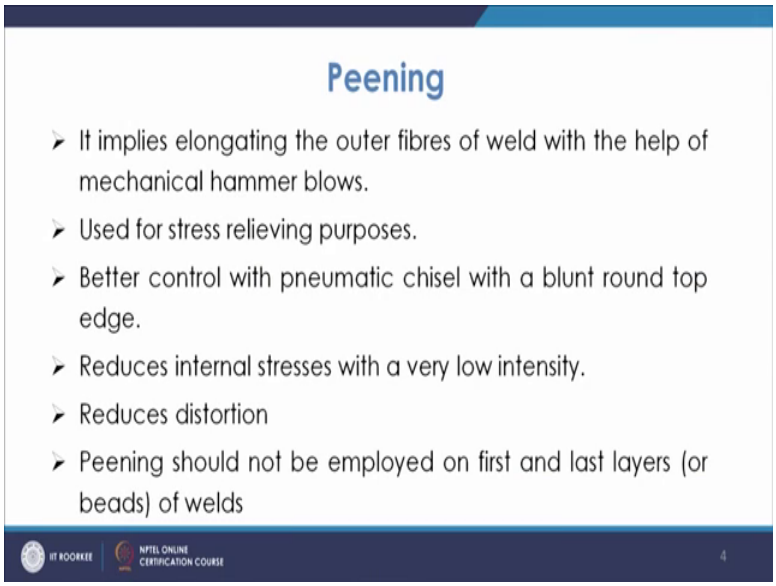


So, this stress level is basically you know you know relieved. So, the stresses are this is used for relieving the stresses you know and then if you can do it with the mechanical you can do mechanically, you can do manually, so you will have the hammers by that.

So, this is a very common practice in the case of welding when you do the welding of thick specimen and you do many passes then except for the first and last pass what you do is every time you do the welding some Peening is done. So, that is done with either manually or many a times you have better control with the pneumatic chisel with a blunt round top edge. So, you should have that kind of pneumatic type of chisel, and then you can do even better way this Peening process.

The Peening process basically it reduces the internal stresses of very low intensity. So, you know the internal stresses will be reduced of a very low intensity and it will be far below you know any affected by heating below the critical point.

So, in that case at this low temperature, so basically the main advantage of this Peening because, it is reducing the internal stress of very low intensity. So, normally it will be eliminating the need for the successive heat treatment when you are welding a very thicker section.

So, you know that way it is advantageous in such cases, it will also reduce the distortion you know because, here what we do is you are redistributing the stresses; so the

distortion which is achieved because of the larger value of the stress which is reached during the welding process. So, this way the distortion will be reduced by the Peening operation

Now, the 1 of the precaution which is to be applied during the Peening is that, the Peening should not be employed on the first and the last layers or beads of the welds because, when you do basically the Peening on the first layer then that may actually pierce the weld so because, you are you are having a thick specimen you are putting the first layer and at that time if you do the Peening or hammering, then in that case it may pierce this. So, it will pierce the weld and it may displace the weld sideways. So, this there will be not proper you know accumulation of the weld metal at the proper place.

So, normally we avoid at the first layer and also we are normally avoiding the Peening on the last layer and it is a top layer. So, that we are avoiding because, you know that may injure the weld metal. So, because if you do they are being very hot and so that may you know affect that weld metal. So, so there is because there is no subsequent application of heat to anneal that last year last layer. So, we do not do this Peening of the first as well as the last layer.

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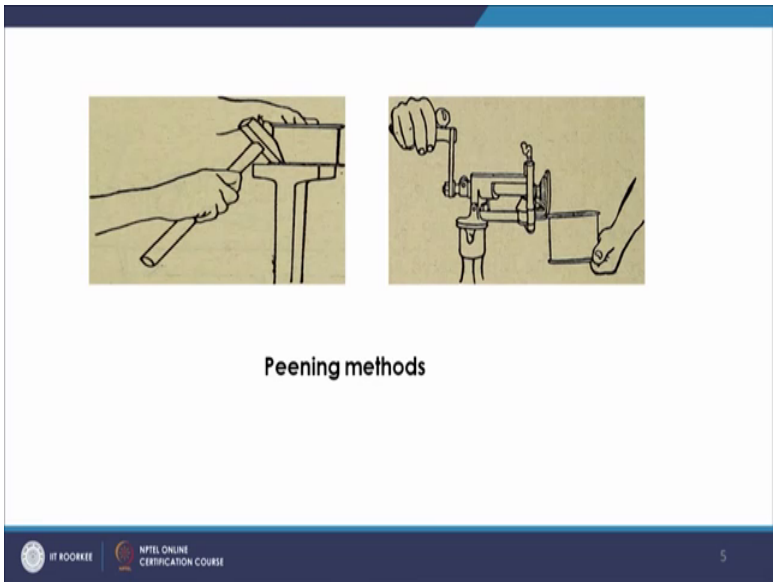


Now, we try to avoid this Peening this is the example of Peening as you see, you have you see that this is we can do with this mechanically you can do this Peening with hand

and you can have the mechanism by which you can have the pressure which is or blow which is created. So, this way the Peening methods are there.

Now, we should try to see that you do not do the excessive Peening because, excessive of the Peening if you do that may lead to the cold working of the material because, the material cools very fast and once you do the cooling that may lead to the cold working and in that case there may be strain hardening of the weld metal.

So, the excessive Peening of the material should be avoided, apart from that if you do the excessive Peening in that case there may be bending also so because, if you are doing that because being in the hot state that may lead to the bending of the you know weld or it may that may lead to even the cracking of the weld.

So, these things are there, so you must also know that when you do doing the Peening you know the material must have the sufficient ductility. So, that because every time you do the Peening there will be some deformation they are going on, so you are basically controlling that outer most 5 hours or so.

So, the material must be ductile if it is brittle and if you are draw doing the Peening that may lead to getting further the formation of cracks, that is there are more chances or having cracks in that situation. So, you have to see you have to ensure that there must be you know proper ductility of the material.

Now, coming to the next type of method, the next type of method which is used for the relieving of the residual stresses are the vibratory self relief.

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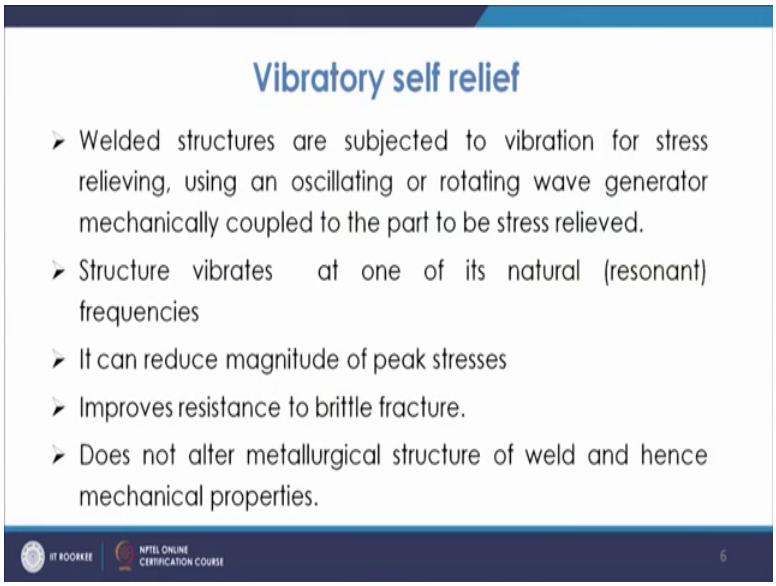


So, in this method basically the welded structures are subjected to vibration for stress relieving, using an oscillating or rotating wave generator mechanically coupled to the part to be stress relief. So, by the use of this vibration the self relief you know the stresses are relieved.

Now, structure vibrates at 1 of it is natural frequencies and this way the level of the stress which is, there that is basically reduced in such cases. So, they can basically reduce the magnitude of the peak stresses normally they are not the once which altered the metallurgical properties because, there is we are not going to the larger temperature or so.

So, in that case it does not affect the metallurgical structure of the weld and that is why the mechanical properties are also not basically you know altered. So, basically by using this process that as we discussed that many a times we need to see that the peak stress especially the tensile in magnitude or so we also are thinking of lowering down that peak value of stress.

So, this method is helpful in reducing the magnitude of the peak stresses, it will also reduce the distortion in parts that is you know which is machined after welding. So, that is another application of this vibratory stress relief for those parts which are machined after welding and you have some distortion. So, that can reduce this that distortion also, it improves the resistance to the brittle fracture.

So, as you know that this brittle fracture that is another challenge which we face. So, it will be improving the resistance to this brittle fracture. So, vibratory self relief that way is one of the methods, which is considered to be important for controlling the residual stress values.

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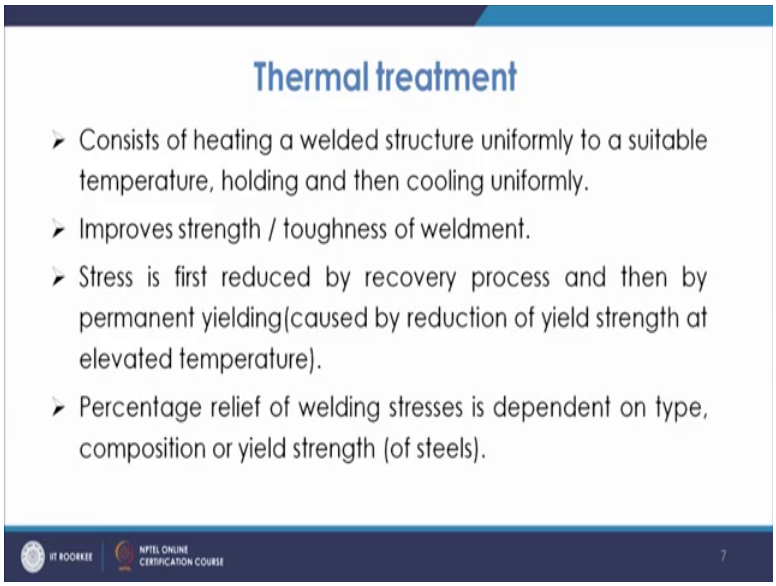


The next method which is used for the reduction of these residual stresses is the thermal treatment. So, in this thermal treatment basically we are heating the weld structure uniformly to a suitable temperature holding and then cooling uniformly. So, in this case the strength is improved as well as the toughness of the weldment.

Now, in this case as we discussed that as a predetermined temperature up to which we are heating, we are holding at that temperature and then further we are cooling. So, just in that process the stress is relieved, now the stress is first reduced by the recovery process and then also by the permanent yielding process.

So, I mean because you know you have the reduction of the yield strength at elevated temperature, so then percentage relief of the welding stress is dependent on the type and composition or the yield strength of the steel. So, basically when we talk about the thermal treatment there are many factors like what is the temperature which you are using for heating, then how much you are holding and then further the cooling is basically uniformly.

So, we have to see that how you are going to cool. So, you have to cool slowly in the furnace normally and normally you are going to cool up to 125 degree or. So, so that the steel structure for steel structure, if you talk about we are heating to about maybe 600 to 650 degree centigrade and then holding at that temperature for depending upon the section thickness.

So, we are holding for about around 2 hour for every 25 mm thickness of the casting or the welded specimen and then we are cooling that in the furnace slowly to 125 degree c or even lower. So, that way and then further we are removing that from the furnace and then cool to the loom room temperature.

So, that is how typically we do this you know process and when we are heating to 595 or 600 to 650 degree centigrade, then that basically reduces the residual stresses rapidly and also that will remove the undue distortion of the weldment.

So, that way it has the advantages in such sense, now the temperature which we choose. So, that may be different for different materials, like you have for the you know plain carbon steel you may go from about 500 to about 750 degree centigrade. So, that is there and also that is true for even low alloy steels.

So, then for suppose other type of materials like suppose, if you are going to the carbon manganese steels where the carbon is about0.2 percent and manganese is about 1.4 or 1.5 percent, in those cases it has been found that if you are going to heat up to a temperature of lower order, then you have to hold for larger duration and normally when you are heating to larger temperature of the order of 500 or 600 in that case holding time may be about 2 to 3 hours and then the residual stress levels are normally smaller.

So, if you are heating to only 200 or 300 degree centigrade in that case the residual stress level may be as high as thirt 33 percent or so, where I it comes down to about 10 percent or even smaller when you are heating to suppose 500 or 600 degree centigrade and about 6 3 to 4 or 5 degree hours of holding. So, depending upon that you know temperature of heating and then holding time you will have the presence of the residual stresses or level of the residual stresses inside the material at different levels.

So, that is how you know as we discussed that and when you are heating to a that temperature at or at the higher temperature, then in that case the recovery you know will

be taking place because, of the movement of dislocation. So, that is because of the vacancy diffusion. So, you have the other mechanism of dislocation climb out or so.

So, that way the material is coming free of the stress. So, that is how the mechanism of. So, as we know that in the case of that temperature you will have the removal of these stresses in those cases and then you have also the permanent deformation that at the higher temperatures. So, this way this thermal treatment is you know practiced for the removal of the stresses. Another practice to remove these residual stresses are the thermo mechanical treatment.

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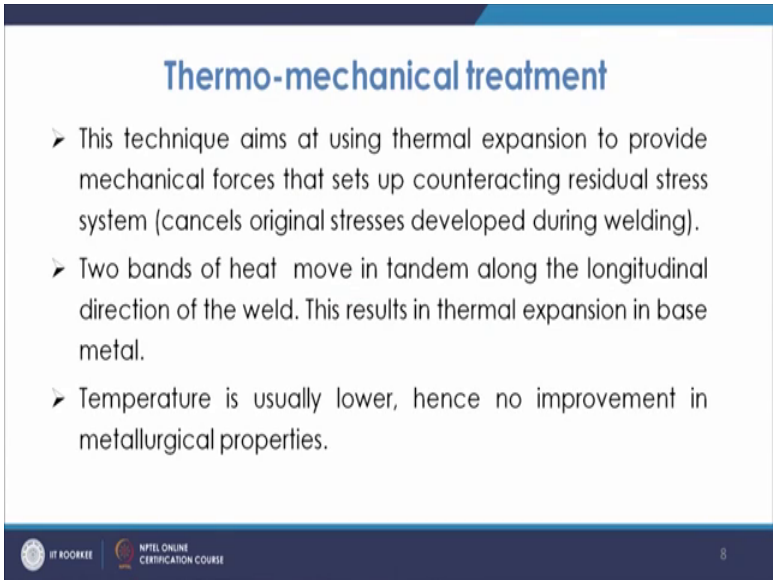


So, in this case what we do is here we use the thermal expansion to provide mechanical forces, that sets of sets of contracting residual stresses system and cancels original stresses developed during the welding

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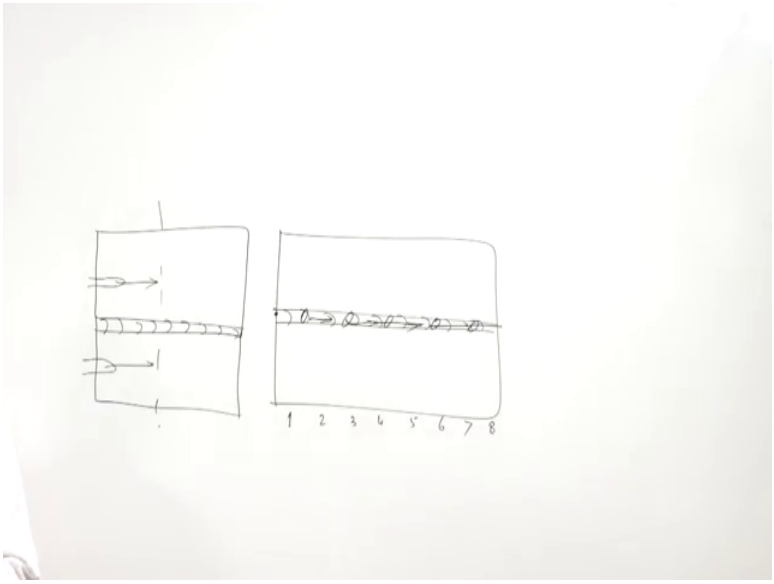


So, as we discussed that we have seen that when we you are welding 2 plates. So, you have this is the welded these 2, now what we do is we know that you have the if you take at this section you will have the tensile stress here and in this case you have in this region you have it compressive stresses. What we do is normally you try to do this thermo mechanical treatment in such a manner that the stresses are developed, so that you will have the tensile stresses developed in this region and the compressive stresses are developed in this region.

So, the compressive stresses which is they are already in that it will be having some canceling effect. So, so that is why what we do is we are basically he moving 2 bands of heat. So, you will have 2 flames so you will have 2 flames and they will be moving in the direction here from on both the sides of the weld bead, what we do is we are moving these flames. So, we have 2 bands of heat they are moving in tandem along the longitudinal direction of the weld.

So, what happens that there will be tensile stresses developed in this case there will be expansion. So, there will be tensile stresses developed and the compressive stress which is there already in this portion that is somewhat neutralized; similarly you will have the compressive stresses developed in this zone and the tensile stress which is already there, that will be you know lowered to certain extent. So, that way you try to reduce the value

of the stresses up to certain extent. So, this is the example of the thermo mechanical treatment which is normally practiced.

Now, the temperature which is kept in such treatment is normally lower in the lower side and it will be normally from about 170 to 200 degree centigrade. So, it is normally smaller and does not cause and any change in the metallurgical properties or improvement in the metallurgical properties, because the temperature is normally smaller and this is one of the you know the practiced method which is used for lowering the stresses values. Now, we look to the other processes like welding procedures and the welding sequence.

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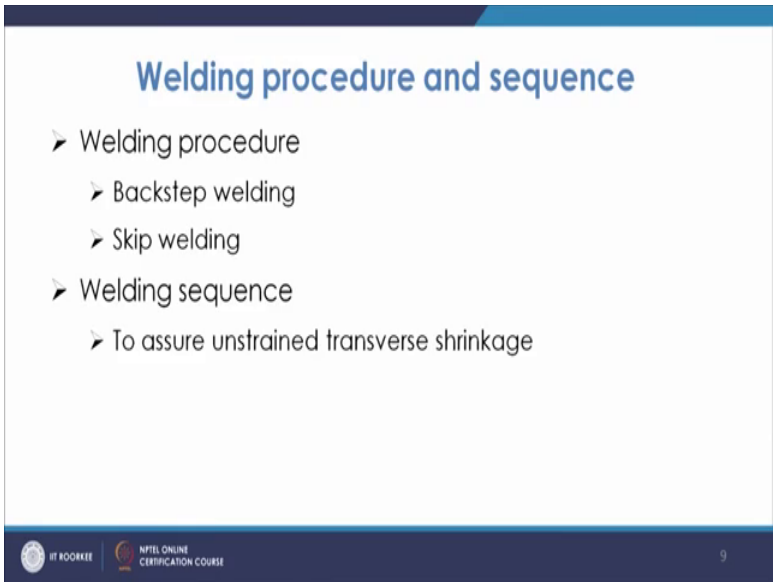


Now, what is welding procedure what should be the welding procedure, which will try to give you the lower value of the residual stresses or it will lower the residual stress.

So, normally what is seen is that you use the back step welding and skip welding, so we know that when we have studied about these welding processes. So, in this case what we do is that, if you have to do the welding of the specimen then back step welding and skip welding.

So, what we do is normally you are having the tack, so you do the tack at different places so you will have different zones where. So, depending upon the thickness of the seat you

will have the tack length and then you will have the different zones where you will be doing the welding.

Now, the thing is that in the back step welding, if you if you this is your and this is how you have to do the welding. So, what you do is you do the welding in the in the back step direction. So, what you do is you do if you have to go like this you go to like this, so this way you do the welding. So, suppose you have to do the welding. So, you do not start from here and finish here.

Now, what you do is you will be doing welding here from or here from like this. So, you will be able to going welding like this. So, this way your welding will go on that is back step welding and then skip welding, now skip welding is used because what we do is once you have the zones defined suppose 1 2 3 4 5 6 7 and suppose 8 zones are there, in that case it is not that we are doing from 1, then 2 and then 3 or knows not so.

So, we may do the first one here we may do secondone here third one here then fourth one here fifth one here and 6th and 7 like that. So, that is the concept of a skip welding technique. So, these techniques basically reduce the value of the residual stresses.

Similarly, you have the use of the welding sequence. So, how you are taking the sequence of the welding operation, suppose you have the transverse welds you have the longitudinal welds. So, in what sequence you will do the welding

So, in that welding sequence you have to know that how you have to proceed which type of whether transverse welding is to be done first or the longitudinal welding is to be done first. So, depending upon the type of component or shape of the component we do the welding and here the important principle which is applied is that we want to assure that under strained transfer shrinkage or large straining length for butt welds.

So, for that what we do is in case of when you have the plate panels, then what we do is and we have the transverse you know welds which are arranged in a staggered pattern, then you know to avoid the weld intersection. What we do is we the discontinuous transverse welds are basically first welded and then you know we weld the longitudinal welds. So, first of all we will be welding the discontinuous transverse welds and then we will go for that longitudinal welds.

So, similarly is the practice for the other case in some cases we are doing for the transverse 1 you know in this case we are doing the transverse one first and for certain cylindrical vessels in that case you have the longitudinal welds will first welded and then you will have this or longer circumferential welds that is welded later. So, this way the sequence which is followed for welding the different type of specimen that is to be you know taken care of, then the other consideration which is to be kept in mind is that the material and design consideration.

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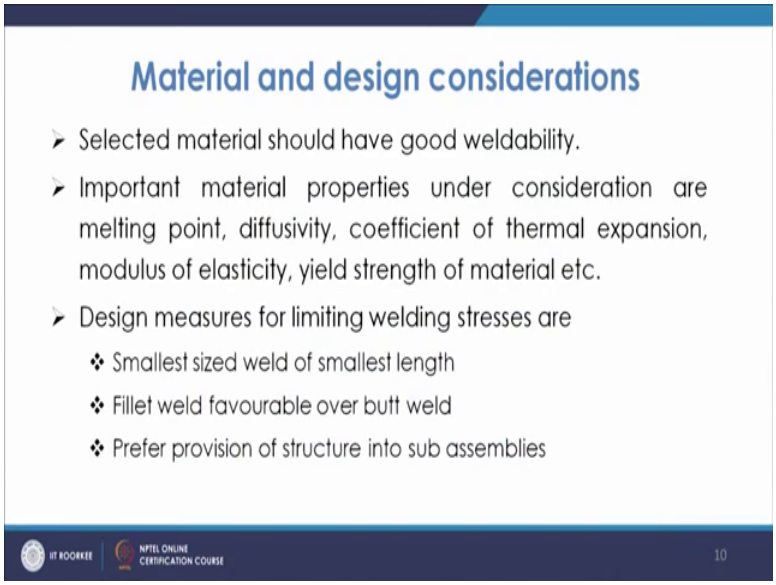


So, in that we must see that the selected material must have a good weld ability. So, so that if it has a good weld ability then the chances of the stresses and distortion will be the smaller. So, anyway weld ability defines that then important materials which properties, which are under consideration or melting point diffusivity coefficient of thermal expansion modulus of elasticity yield point of material all these.

You know properties the effect the you know residual stresses of formation in some sense like, if you have the suppose coefficient of thermal expansion is higher in that case the chances of distortion will be more residual stresses will may be formed to be more, similarly rigidity is more than the distortion may be less or so this way you will have the different you know attributes of the different these proper a meters and the effect the you know formation of these stresses and lowering the stresses in that case. As far as the

design measures are concerned then these points are important like you must go for a smallest size weld of smallest length.

So, if you I have the largest larger sizes then there are more chances of having the you know more value of residual stresses. So, that is why you go for the smallest size weld of smallest length. Similarly you can go for filler to weld which will be favorable over the butt weld and then also prefer the provision of structure into subassemblies.

So, that way you can have you can see that they will be move more chances of having less residual stresses and you will have a satisfactory structure. So, thank you very much for this lecture.

Thank you.