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

Lecture – 53
Welding Distortion

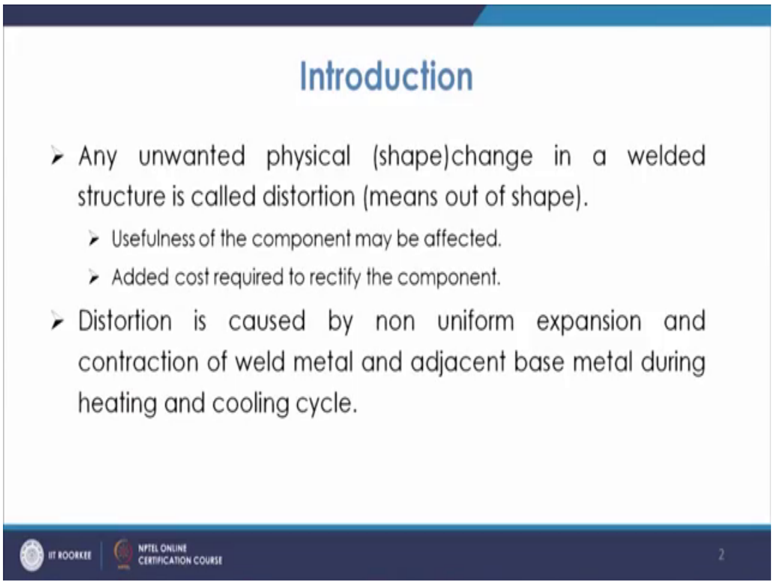
Welcome to the lecture on Welding Distortion. So, in this lecture we are going to discuss about the different type of distortions which take place in welding. So, we know that there are formations of residual stresses development of residual stresses during the welding process. And if the residual stresses values are more than a limit, more than the instant of the material or you have the restraint on the size and formation residual stresses and there is hindered expansion and contraction then that may lead to the distortion of the welded specimen.

So, depending upon the structure or depending upon the type of specimen we where welding you will have different types of you know distortion in the welded specimen when we are welding in a certain direction there may be welded there may be distortion in that direction or it may be in the transverse direction depending upon even the seats if it is thinner or thicker.

So, or it may sometimes go down or it may be a rotational type of distortion it may come closer or to be go apart. So, depending upon that you will have different types of distortions that we will discuss in this lecture.

So, what is distortion basically? Any unwanted physical change in a welded.

(Refer Slide Time: 01:47)



Structure is called distortions means anything which is going out of shape which is not in the shape which for which it is meant to be then it is said to be distorted. So, you know usefulness of the component may be affected.

So, when any material becomes distorted when anything will be out of shape then it is usefulness will be affected. The purpose for which it is going to be used it will be affected suppose you have so, directional changes will be occurring and then the purpose for which it has to be used or it has to use in a proper place or in a proper shape that is basically gone.

So, that way it is usefulness may be gone either is will be devalued or it has to be rejected. So, if it is devalued you know it is a loss of the productivity. Maybe many a times you are trying to rectify that component so, you will have the added cost required to rectify the component.

So, that how you are going to you know suffer in economic terms and maybe that it is rejected. So, in that case you have to further go for the fabrication process. So, that is a again a loss so, that way this is going to reduce the productivity of the organization.

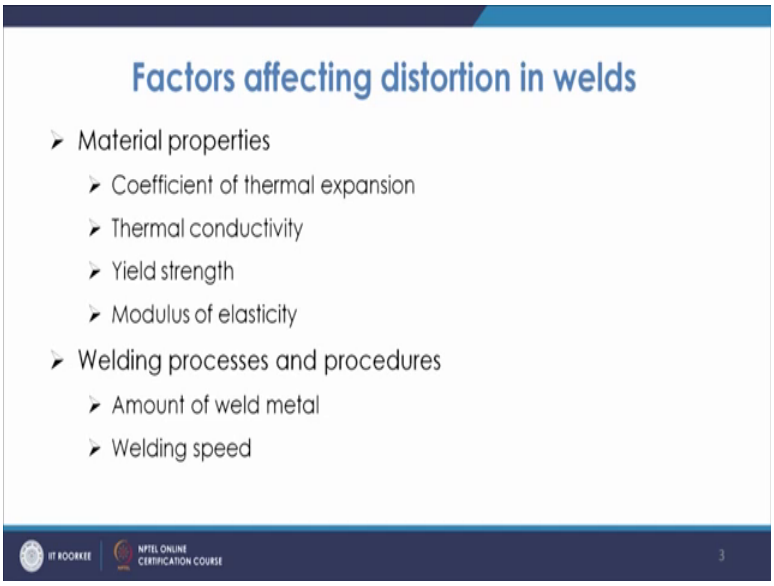
Distortion is caused by non uniform expansion and contraction of the weld metal and adjacent base metal during heating and cooling cycle. So, we have already studied about it that when you have uneven cooling and heating so, the have the cycle to which this material is subjected to.

So, during that the stresses will be generated and then because of that there may be the distortion because of this non uniform expansion and contraction of the weld metal and the adjacent base metal. We have already studied that how in the adjacent metal when you are welding in the middle portion then this tries to expand and the adjacent portion will try to contract it.

Similarly, while cooling it will try to contract and the adjacent metal will try to further let it be expanded. So, this way you have the cycle under which it is subjected to the either compressive or tensile stresses and then ultimately you have the formation of certain type of stresses in the material. So, that way because of this heating and cooling cycle you have the formation of stresses at the different points at any section and that leads to the distortion of the specimen.

Now, we have to understand that; what are the different factors which affect the distortion in the welds. So, you have the factors that can be categorized under either the material properties or the welding processes and procedures

(Refer Slide Time: 05:25)



So, the materials which we are basically using for welding process they have it is own specific properties and as this properties vary from material to material. So, the expansion characteristics or the distortion characteristic will also be changing.

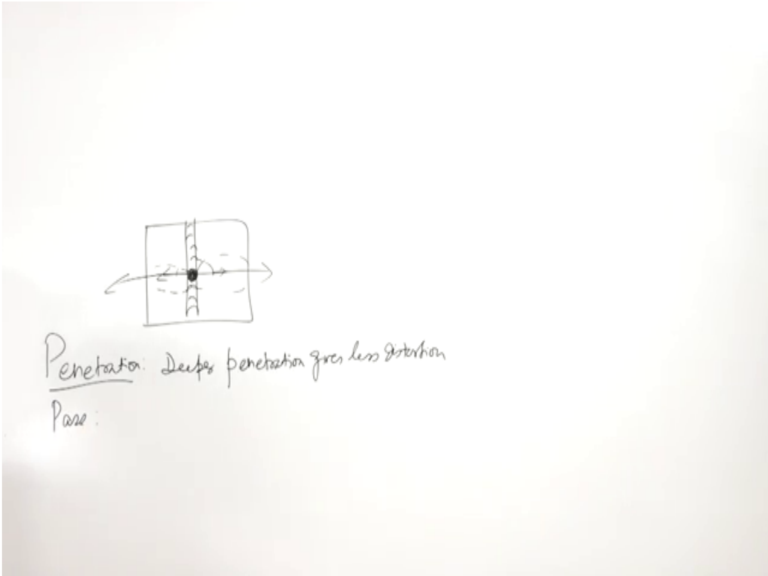
So, the property which are primarily important for deciding this, such kind of distortion is one is the a coefficient of thermal expansion. So, if the coefficient of thermal expansion is more in that case the as the temperature changes, in that case the expansion or contraction will be more. So, in that case once that is more then it means the distortion will be more.

So, the material with lower value of thermal expansion will be more prone to getting distorted. Then as compared to those materials which have very high coefficient of thermal expansion so, that is basically you know a function of the change in temperature. So, so, that is why this coefficient of thermal expansion is one of the important you know property of the material because of which this distortion is affected thermal conductivity.

Now, you know that because of the thermal conductivity the heat which is you know pointed at one point that heat has to dissipate. Now, the heat which has to dissipate how quickly that is dissipated so, whether it is dissipated quickly or whether it is dissipated slowly. Now the thing is that when the heat will be dissipated quickly means you have high thermal conductivity.

So, if the thermal conductivity is higher in that case you will have temperature gradient lower and if the thermal conductivity is lower you will have high thermal conductive thermal gradient because what happens that if so, you have this.

(Refer Slide Time: 07:54)



this is the welding. So, here once you are heating at this point now the heat has to extract from here and from here, now if the thermal conductivity is high it will quickly pass through it and then it will go to the surroundings.

So, and otherwise the heat will be contained more for more number of more time in into this zone or into this zone or even in this zone. Now, if that is there in that case you will have more likely more chances of the distortion. So, so, for basically higher thermal conductivity we will have lower distortion and for lower conductivity you will have high thermal gradient and you will have high chances of distortion. Then comes the yield strength.

Now, if the yield strength value is higher in that case the residual stresses values are higher and in that case the distortion is also likely to be higher. Similarly, the modulus of elasticity or which is the property that is rigidity so, if that is more in that case it will resist any kind of deformation. So, for a material with large value of modulus of elasticity will be likely to undergo less distortion so that is how these you know properties affect you know the distortion in the welds, coming to the welding processes and procedures.

So, for a given design you have the deformation which will be determined by the order of assembly of the component. So, how you are doing the assembly then you will have the welding current and voltage and similarly you have welding sequence and you have the a clamping methods all these things are you know important. Now, the amount of weld metal so, when we talk about the amount of weld metal you know amount of the distortion will be depending upon the volume of the weld metal.

So, now again the volume of the weld metal which is heated it will be depending upon the welding processes like you have what is the welding speed, what will be you know heat input rate and all that. So, if the amount of weld metal will be larger certainly it will be giving you more and more distortion. And then welding speed is there so, welding speed is there, edge preparation, fit up and then and the welding procedure all these things are basically important factors in distortion.

So, when we talk about the welding process in that case we have to be sure that I mean of certain concepts like either we can have a source which is giving the concentrated heat source or it is not concentrated heat source. So, it may have a very very dispersed type of heat source.

So, whenever you are using the concentrated heat source it is going to create less amount of distortion because as we have studied the welding metallurgy part. So, when we use the concentrated heat sources in those cases the zone which is affected because of the heat also is smaller.

So, when we use the concentrated heat sources they give lesser you know distortion than the those type of processes which have the spread heat sources like if you take the example of electron beam welding or TIG welding or so, or even TIG welding if you take and as compared to the flame welding.

So, in the case of flame welding oxy flame welding or so, you will have large amount of spread, if you take the electron beam welding which is just like in a beam shape it goes and does the welding operation.

So, in that case in the case of EBW electron beam welding you will have lesser amount of distortion as compared to the flame welding. So, that is why the concentrated heat source is preferred then the spread type of heat source. Similarly, the welding speed welding speed is also very important welding speeds if it is higher than it will be giving the lesser distortion because if the speed is higher than the spread will be smaller and in that case when the spread is smaller than the distortion will be smaller.

So, this way the distortion is affected. Then the penetration so, if you talk about the penetration, then the penetration be if is the penetration is deep. So, deeper penetration will give you less distortion, deeper penetration gives less distortion. Maybe because of the fact that it will hold the plates with more you know strength and then so, the distortion chances of distortion will be lesser in the case of you know distortion. So, you have deeper penetration that will be leading to the less distortion.

Similarly, pass so; the single pass will give you less distortion then multiple pass. So, as you increase the number of passes the chances of distortion will be more. So, the single pass will give you less distortion than the multiple pass. As we discussed that the weld metal also should be minimum because amount of weld metal being higher that will lead to the larger you know value of stresses and then so, the larger you know distortion chances in that case.

We also talked about the edge preparation and fit up so, we must have a proper edge preparation. So, as we discussed that we should ensure that there should be minimum amount of weld metal and you must have the edge preparation while we do it should be as uniform you know as possible. So, that you have consistency as far as the shrinkage is concerned.

So, along the joint if there is shrinkage occurring then if this is uniform then there will be consistent shrinkage so, that will lead to lesser amount of accumulation of these stresses. Now, also that when you have closed fit up of the joint in that case also it will reduce the a stresses..

So, it will be reducing the if you have the fit up close fit up is not there then the more amount of weld pool melt metal will be there in that zone. So, that will further lead to the increase in the stress value. So, this closed fit up also is necessary for decreasing the value of the residual stresses.

Now, talking about the procedures so, we talked about the welding processes and parameters and other procedures if you talk about. So, you know we should try to go for mechanize type of welding so, that will give you the less you know distortion as compared to non mechanized ones.

And you go for single speed single you know pass, high speed type of you know welding should be preferred where which will be likely to giving you I mean give you the less distortion as compared to the other type of joints where you have multi pass, low speed kind of you know welding processes. Also as we discussed in our last lecture that we should also used processes like skip welding and you know back step type of welding process to reduce that distortion. So, that is another way by which we see that the stresses are smaller.

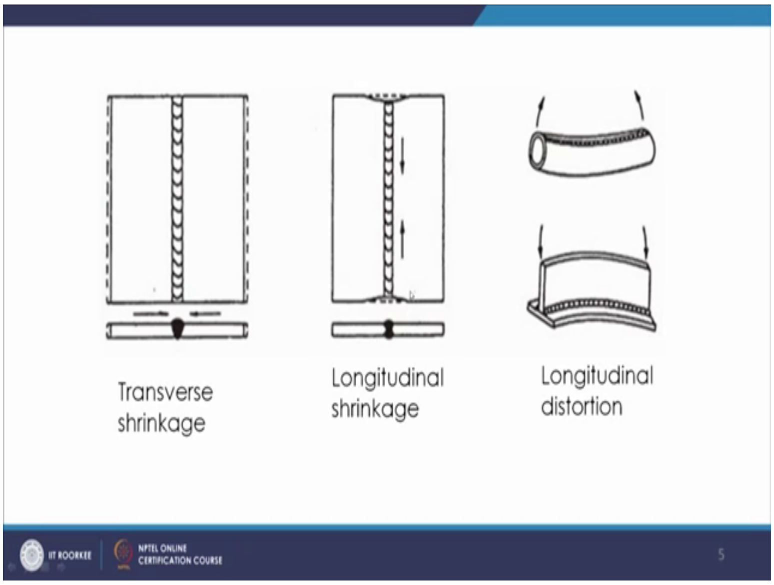
Now, coming to the longitudinal you know types of distortion. So, when we talk about the distortions then we must know that.

(Refer Slide Time: 17:10)

What are the types of distortion, how the distortion looks like ok. So, distortion is normally of these types like you have longitudinal shrinkage, you have transverse shrinkage, you have angular distortion, you have longitudinal distortion, you have rotational distortion and buckling and twisting.

So, we will discuss one by one about all these type of distortions which take place in the case of welding. So, coming to the longitudinal shrinkage you see this is the.

(Refer Slide Time: 17:46)



Example of longitudinal shrinkage so, as you see that this is the longitudinal direction. So, in this case the material shrinks and you see that there is a void which is formed at this point. So, this shrinkage which is occurring in the longitudinal direction that is known as the longitudinal shrinkage and that basically makes the shape you know at this place this shape becomes like this. It would have been flat in ideal case, but because of the shrinkage it shrinks in this direction in the longitudinal direction and that is why this is known as the longitudinal shrinkage.

So, normally about 1000 of the weld length is the normal value of this longitudinal shrinkage and it is quite less very less as compared to the transverse shrinkage and there are certain formulas. So, basically depending upon the current and the length of the weld this longitudinal shrinkage varies also the thickness of the plate. So, if the thickness of the plate will be more in that case the longitudinal shrinkage will be smaller and current and the length of the plate you know being a length of the weld being more the longitudinal shrinkage will be more.

So, there is a correlation between this longitudinal shrinkage and these operating parameters for a certain type of you know butt weld. So, for butt welds as we see here for that normally that is how it varies. Similarly, you will have certain fillet welds also, in the case of fillet wells you will have the areas you know that is straining cross section and then you have the weld metal cross section based on that this longitudinal shrinkage will vary.

So, that way you know it varies. So, it will be transversely this is a longitudinal shrinkage for fillet weld it will be a directly proportional to the weld metal cross section. So, if it is more in that case the longitudinal shrinkage will be more and the restraining area if it is 16 cross section is if it is more in that case the longitudinal shrinkage will be less in the case of fillet welds. So, that is how you calculate the longitudinal shrinkage in the case of butt and fillet welds.

Now, coming to the transverse shrinkage so, as we discussed that when the shrinkage is in the direction of the welding. In the longitudinal direction then it is the longitudinal shrinkage and when the shrinkage is in a transverse direction. So, because you have the solidified metal here so, there will be shrinkage also in this direction and that so, as you see this is the what weld and you have the shrinkage in this direction. So, because of that the actual size should have been here the dotted line about the actual size you know after the shrinkage this is the line appears like this one which is the bold line.

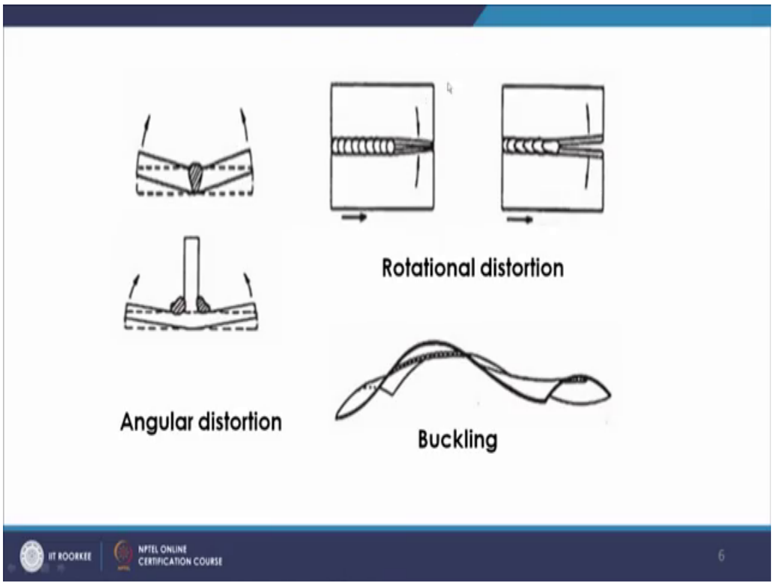
So, this appears this is the example of the transverse shrinkage. Now, the transverse shrinkage as we know that you know again it depends upon the cross sectional area of the weld. So, if it is more in that case the transverse shrinkage will be more and if the weld thickness is more than transverse thickness will be shrinkage will be less. So, the major factors which are causing this non uniform transverse shrinkage they are the rotational distortion and the constraint. So, because of that this transverse shrinkage are affected.

So, these are the longitudinal as well as the transverse shrinkages. Next is the longitudinal distortion so, in the longitudinal distortion as you see this is how the material will look like, this is the example of longitudinal distortion. So, that is also so, as we see this is your longitudinal distortion which is nothing, but bowing or and bending also. So, now in this case what we see is that the weld line which will be not coinciding with the neutral axis of the welded structure.

So, if it does not coincide with this a neutral axis of the welded structure then we say that it is a case of longitudinal bending so, it may be you know bowing or twisting. So, you can see it is a bowing or bending, then again you have here what happens that you can calculate the amount of this longitudinal bending. And normally it will be depending upon the cross sectional area of the weld, then you know distance from the cg to uttermost fiber. So, that is another parameter then you have the length of the weld and also the moment of inertia of the structure.

So, based on these parameters we normally calculate this longitudinal distortion of the welded structure and we calculate these values in terms of some numeric values. So, this way longitudinal distortion is calculated next type of distortion you have the rotational distortion as you see here.

(Refer Slide Time: 24:01)



This is the example of rotational distortion, now this is observed at the at ahead of the point of the welding and when you are welding the seats then you many a times you see that these seats when you are doing the butt welding of the seats then they come either closer to each other or they are basically in the distance between them is widened. So, in this case what you see is these 2 edges either they are coming closer or in this case they are going away.

So, this is the example of rotational distortion and you know in this case because what happens that you have there is a limit you know of the rate at which the heat has to be conducted. So, because of that you know either the seat in some cases either it comes closer or it comes you know depending upon the welding speed also it matters.

So, the way you go you may go fast or you may go slow so, based on that and depending upon the heat input also that way you have the either these 2 sides. So, many a times when you are doing the larger you know sections, larger plate which you are welding and if you are not putting the tack weld you can see that if you are doing welding maybe that when you reach towards the end either they are separated part or they may go like this. So, you have to and pull it and then do the welding.

So, that is the example of the rotational a distortion so, this is about the rotational distortion. Then comes the angular distortion so, this is what you see; this is the kind of angular distortion. So, this occurs at butt lap or T joint on even on a uniform joint or cruciform joints and this is above because of the symmetrical double sided welding, this type of distortion occurs. You see that you have the symmetrical double sided welding that creates such kind of angular distortion as you see it comes in that shape like this.

Now, how much this angular distortion will take place? that will be depending upon the width and depth of the fusion joint fusion zone and relative to the plate thickness. So, as compared to the plate thickness how much is the width and depth of the fusion zone and then which type of joint it is and what is the weld path sequence.

So, then thermo mechanical properties of the material and you know welding processes all these are the processing parameters which affect the amount of angular distortion that the material will be subjected to like the parameters of welding process then again comes like heat input you know per unit length of weld and distribution of the heat source density.

So, these are the parameters which affect this extent of this angular distortion or the amount of the angular distortion to which it will be subjected to. Then comes the buckling and twisting as you see here this is the defect which is known as the buckling and twisting. So, in this kind of you know this is when the when you are welding the thin plates then this kind of defects are likely to occurred. Now what happens that there will be considerable amount of residual stresses which will be developed in the areas away from weld and then that causes welding.

So, in the case of when we are doing the welding of thin sheets and we have seen that we if you recall when we use the seats welding using the dc welding and if you use the electrode with you know reverse polarity that is or straight polarity in that case your work is positive, reverse polarity the work is negative.

So, when you use a straight polarity for thin plates in that case that will be heated in that case when you do the welding so, these more likely these plates are subjected these thin sheets are subjected to that distort distortion.

So, in those cases they cause these buckling of these seats. So, buckling occurs basically buckling or twisting you can say. So, buckling occurs when you know specimen length will be exceeding the critical length for a given thickness.

So, in those cases when you do the welding that time distortion which occurs that is known as the buckling. So, with related to this bending now if you talk you try to compare to the bending distortion, you will have more than one you know stable deform shape in that case and amount of deformation in buckling distortion is much more you know as compared to the bending. So, that is the basic difference between these buckling and bending distortion.

So, these are typically the different kinds of the distortion which occur in the case of you know welded structures, they are the normally 6 types of distortion which occur in the case of welded structures. And you know you can compute the values of these distortions using the standard formulas which are available.

And the purpose is that once you know the a different kinds of distortion and once you are knowing that what are the root cause of having these distortions then you can have the accordingly the proper you know ways to tackle these distortions and lowering the value of the distortions.

So, we will study about those methods how to control the distortions in weldments in the in the coming lectures.

Thank you very much.