Welding Metallurgy
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Lecture No. 44
Bowing, Buckling and Twisting in Welds

Welcome to the lecture on bowing, buckling, and twisting in welds. So, we are talking about the distortion in welds and, in that process, we are going to have the discussion about the other types of distortion, that is, one is bowing or that is also known as longitudinal bending, then apart from that you have buckling as well as twisting which is observed in the welds. So, in this lecture, we are going to have some discussion over those phenomena.

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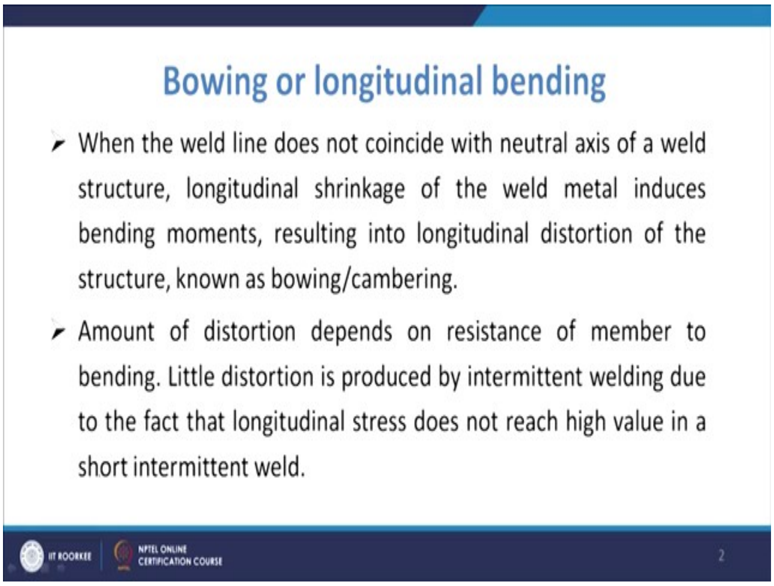

So, coming to bowing or it is also known as longitudinal bending, so this is basically when the weld line does not coincide with neutral axis of a weld structure. So, longitudinal shrinkage of the weld matter induces bending movements. So, in that case, you will have the longitudinal stress which is there that will be inducing the bending moment and that results into the longitudinal distortion of the structure and that is also known as cambering or bowing.

So, in that case, the amount of distortion basically that will be depending upon the resistance of the member to bending. So, how much resistance it is offering, based on that your amount of distortion will be depending upon. And as we know that there are certain properties of the material or structure also that tells about what will be the resistance to bending. So, in those cases, those properties are taken into account while calculating this bowing or bending.

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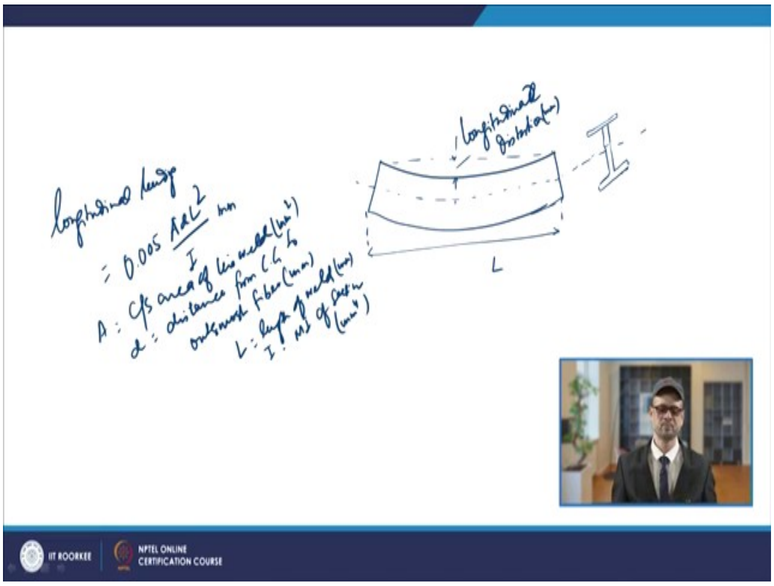

So, basically you can understand what happens is that your structure becomes like this. So, that way, any section is there, so you can have a section and for this section, suppose you have a section, so you will have this as the neutral axis and this basically will be termed as the span length. So, this is the amount. This basically amount is known as the longitudinal distortion.

So, that is in terms of mm. So, this is your neutral axis which is passing and the longitudinal bending can be calculated using a formula. So, that amount is being calculated as 0.005 $\frac{ad\,L^2}{I}$. So, that is your longitudinal bending which is being calculated. So, here, you have all these terminologies, that is, a is the cross sectional area of the weld. Similarly, you have d as the distance from center of gravity, i.e. CG, to outermost fibre. So, that is in terms of mm.

Then, you have other standard terminologies that is your L, that is your length of weld, and I as we know that is moment of inertia of section. So, this will be in terms of mm^4. This will be in terms of mm. Similarly, all these, you know, d will be also in mm. Area of cross section of the weld will be in mm^2. So, that way, you can have the calculation of the longitudinal bending in the different kind of the welded structure.

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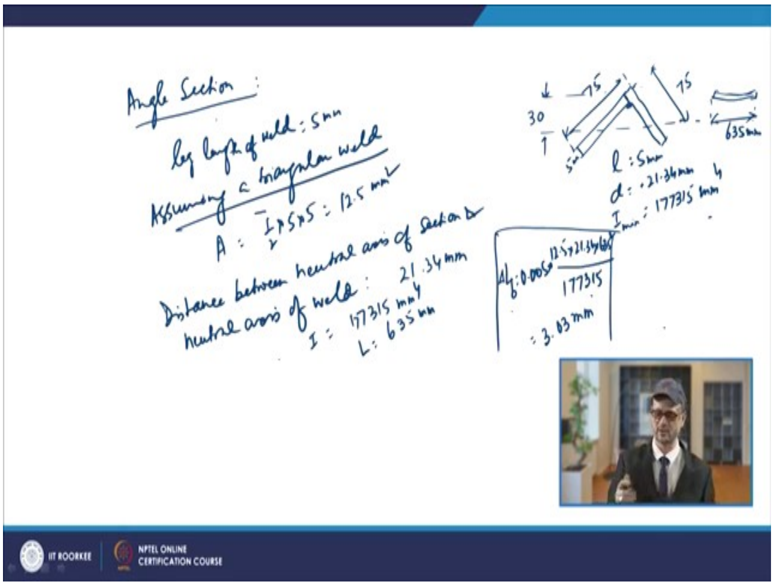

Angle Section :
leg length of weld = 5 mm
Assuming a triangular weld
A = 1/2 × 5 × 5 = 12.5 mm²
Distance between neutral axis of section & neutral axis of weld = 21.34 mm
I = 177315 mm⁴
L = 635 mm
30
75
75
5 mm
635 mm
l = 5 mm
d = 21.34 mm
I min = 177315 mm⁴
Δl/l = 0.0050 × 12.5 × 21.34 × 635 / 177315
= 3.03 mm
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So, suppose, you have different cases and you want to calculate the longitudinal bending in all the cases. So, suppose you have one section where your welding is for this section, so you have two sections which is welded. And in this case, for these two sections, the dimension is given. This dimension is given as 75, and similarly, these dimension also is given as 75. Then, this is your 5 mm in that case. So, this is your axis. So, now, this length becomes 30.

Now, if you talk about this angle sections, if you are taking first section is the angle section, now for this angle section if you want to find these longitudinal bending, so what we see is that you have the leg length of the weld. So, leg length of the weld is shown to be 5 mm. So, this l is given as 5 mm here in this case. Now, you have to calculate in these cases. So, your d is calculated and d is shown to be + 21.34 mm and your I mean, that is 177315 mm^4.

You have to calculate the moment of inertia of the structure and based on that you can have. So, once you know the neutral axis, those you can measure, the value of d, and we know the l, so how you calculate that. Suppose, in this case, you assume that there is a triangular weld. So, assuming a triangular weld, so in this case, as you know that we calculate the area of the weld. So, area of the weld will be half into weld length. So, that will be 5 and 5 both sides. So, it will be 12.5 mm^2.

Now, you have the distance of the neutral axis of the section and neutral axis of the weld. So, that d, that will be indicated as the plus value and that plus value indicates that distance d is above the neutral axis of the section. So, basically this distance between neutral axis of section and neutral axis of weld that is being calculated as the plus value of 21.34 mm as we indicated that the plus value indicates that the neutral axis of the section it is above the weld, that is above the neutral axis of the section.

So, that is why this value is 21.34. Your I that is section that is given as 177315 that is mm^4. Now, length of the section, if you look at, this length of the section is 635 mm because that is your section which is given, this section's length is given as 635 mm. So, this is again one of the input value. So, once you know all these values, in that case, the thing is that once you have these sections for that you have to find the neutral axes you have to find the moment of inertia, you must know the neutral axis of the weld.

So, accordingly, that d will be calculated and all that once calculated then you will be finding these longitudinal bending values. So, that value, as we know, you have the formula 0.005 $\times ad\,L^2$. So, $\frac{12.5 \times 21.34 \times 635^2}{177315}$ So, if you try to calculate the longitudinal bending of this triangular section, so that comes out to be something like 3.03 mm. So, this is the way of calculation for the longitudinal bending in the case of angle section, it is there in the angle section. This is for the angle section.

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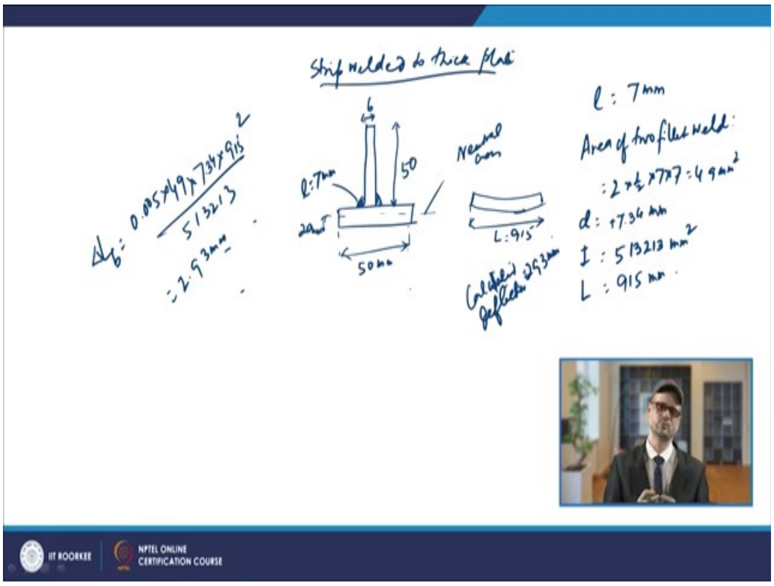

Next, if suppose, you have another case where the strip is welded to a thick plate, so the situation can be represented by, you have a strip and this trip is welded to a thick plate. So, in this case, this is the weld which is here. So, in this case, this dimension that is L, L is given as 915. Now, in this case, what we calculate. You have in this case your leg length, so l, l is taken as 7 mm and this is your axis, so this length is 20 mm.

So, this is 20 mm and this dimension is 50 mm. Now, this is your neutral axis and this length is also given as 50. Here it is 6. So, how do calculate the longitudinal bending value for such cases. So, in this case, we have to calculate the deflection. Now, what we see in this case is that your l is given 7 mm, that is given, that is leg length is given as a 7 mm. Now, again, weld section if you take as the triangular one, so area of two fillets, so you have two fillet welds here, so if you take it as the triangular one, so it will be 2 * (1 / 2) * 7 * 7.

So, your 7 is here and 7 is like this. So, ultimately it becomes 49 mm^2. Now, the d, d basically which is calculated to be + 7.34 mm. So, that is the distance between the neutral axis of the section and neutral axis of the weld, and neutral axis of the weld basically being positive value indicates that your neutral axis of the weld is above the neutral axis of the section. So, accordingly, this value of d is 7.34 mm. If you calculate the moment of inertia of the section, so, that is computed out to be 513213 mm^2.

So, this is your moment of inertia of the section and then l comes out to be 915 mm. So, for such strip welded to the thick seat, thick base, now you can again find the value of the longitudinal bending and that again you will put it like 0.005 * 49. Similarly, after area term you have the d term. d is coming as 7.34 and then you have the term that is your L^2, so L is your 915^2 and then 513213. $\left(\frac{0.005 \times 49 \times 7.34 \times 915^2}{513213}\right)$. So, that comes out to be 2.93 mm.

So, this way, in this case, your deflection which you calculate that is coming out to be 2.93 mm. So, that way, you may have different cases. Suppose, there are some cases like you have the I section and I section with a plate which is welded to the top plane.

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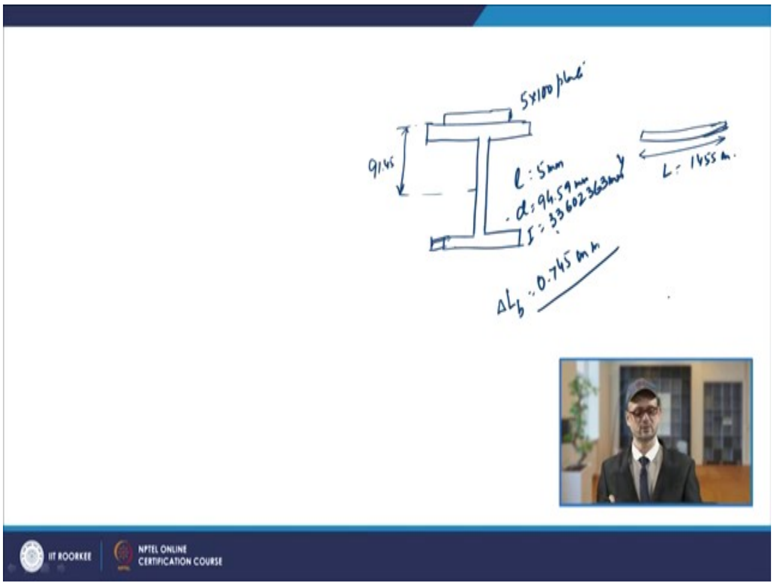

So, in those cases, if suppose in this case you have one I section is there, so you will have there is one I section and then this is also same dimension, and here you have a plate which is welded. So, for the I section with a plate welded to this top flange we are welding this plate and this plate has, suppose 5 * 100, that is your plate dimension, and this, if you look at the distances, so you will have the neutral axis and the distance is computed out again to be 91.45.

So, this is your I beam and in this case your l becomes 5 mm and d is computed out to be 94.59 mm. And then, you have I, so I is computed out to be 33602363 mm^4. So, in that case, basically this L dimension which is calculated, this is 1455 mm. So, again, you can have the values and you can calculate the delta value. So, if you find the longitudinal bending values, in that case, it comes out, again you are putting, so it will be coming as 0.745 mm.

So, accordingly in this fashion you can find the values of the longitudinal bending for all the cases. In all the cases you have to find this moment of inertia, you have to find the neutral axis of the weld, finding the difference between these values, and then accordingly you can have the value of the ΔL_b calculation for the different cases. So, that is how you can have the calculation of such values. Now, coming to another case of distortion, that is your rotational distortion.

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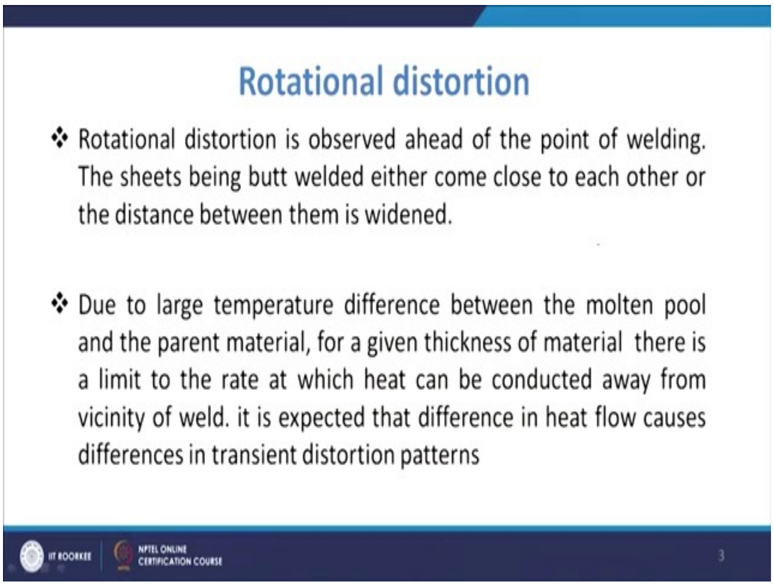

Now, rotational distortion that is observed ahead of the point of welding, and in this case the seats being butt welded either they come close to each other or the distance between them widens. So, many a times, what happens is that you have the two seats which you are trying to weld. Now, these seats either they try to come close to each other or they are trying to separate when you are doing the welding.

So, depending upon many parameters, especially you may go for slow welding or you may go for fast welding, so when you go for fast welding in that case normally what happens is that it tries to separate out, so the distance between their ends which is free that this moment that becomes more.

And when you normally go for the slow welding it is likely that when you are moving towards the end the distance between the two ends, I mean, which should be there, which should be at one point, so basically that comes down, so they overlap each other. So, that kind of thing is seen.

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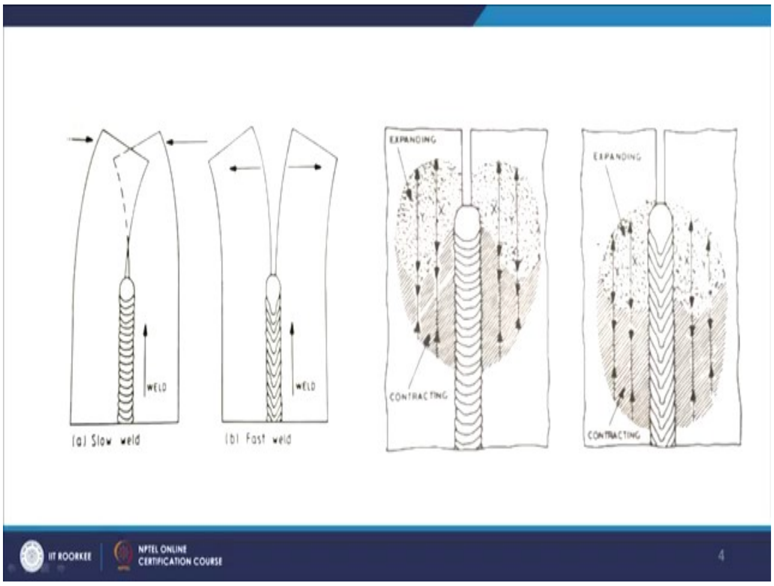

That can be understood by referring to these figures where we see that, this is the case of the slow weld, so when you have the slow welding going on, in that case, their distance is basically reduced, whereas when you go for the fast welding, in that case, the distance between them basically increases. So, basically, what is happening in this case as you see here, for a given thickness of the material and we see that there will be large temperature difference between the molten weld pool and the unheated parent material on these two sides.

So, basically, there is a limit at which the heat can be extracted out. So, heat can be conducted away in the vicinity of this weld pool. So, if the heat input is basically more than the limit, then the isothermal lines will take form. So, basically, this difference in that heat flow for any particular case for a given thickness of the material, you know, so that limit has to be maintained. And if that exceeds, in that case, there may these problems.

So, these are the two cases in this case, and what you see is that in one case it is coming closer and in another case it is going away from them, and that is what can be understood, by knowing that expanding and the contracting zones in these figures. So, you have the slow weld here and you have the fast weld here. So, what you see is that in this case you can look at, so this is C, this is your slow weld, and this is your expansion and this is your contraction.

And similarly, this is your fast weld, and in this case this zone as you see, this expanded zone, is up to this place, whereas in this case you are going fast, so this region basically cool down whereas very near to this place what do you see, this is your expanded zone. So, in this case, basically because of this they are giving restraint to either retaining its position or so. So, in one case they will be prevented by returning to their original position or mean pollution, and in that case, basically, their distortion results into.

So, this is a case of the slow and fast weld and that results into these rotational distortion in such cases. So, you have regions X and region Y which are the zones. So, you have the contracting zones, you have the expanding zones. So, based on that, you can understand how these results into either moving closer to each other or moving away from each other. So, accordingly that can be justified.

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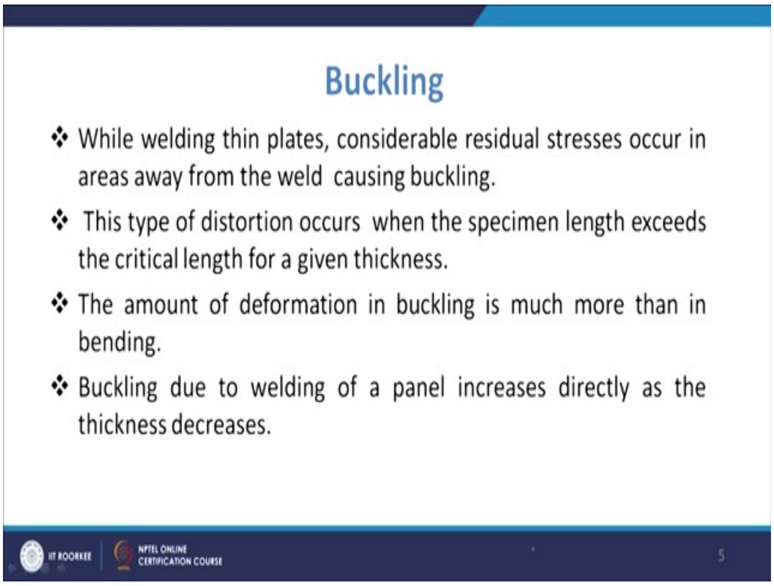

Next kind of distortion which is also observed, that is your buckling as well as twisting. Now, in the case of buckling, while welding thin plates we see that considerable residual stresses occur in areas away from the weld that will cause the buckling. So, this type of distortion will occur when the specimen length exceeds the critical length for a given thickness. So, what happens is that you have some critical length for a given thickness, there are values given for that, and based on that you can have, so what happens in such cases.

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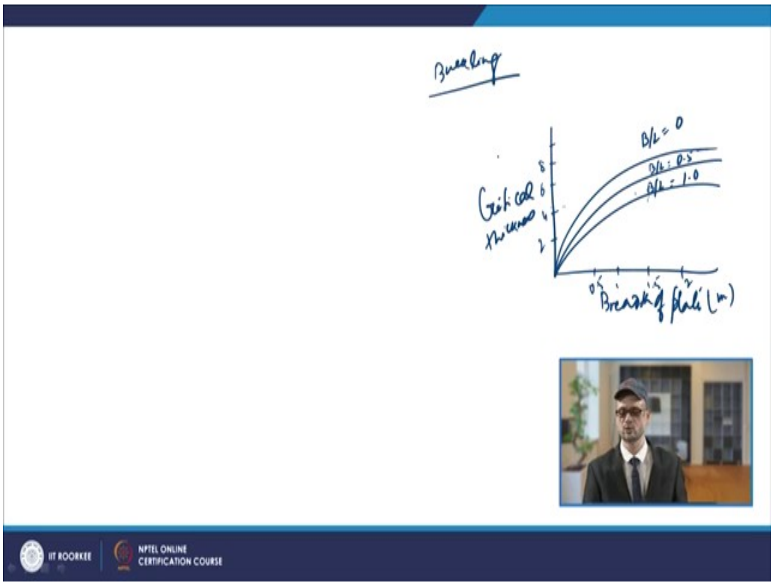

When we talk about the buckling, so you have the calculation of the critical thickness. So, you will have the supposed critical thickness is there, so that is in mm and this side you will have the breadth of plate. So, the ratio goes like this. This way it goes. So, this is your aspect ratio and aspect ratio is B/L, that will be 0. Similarly, this will be B/L and is 0.5, and this will be B/L that will be 1.

So, critical thickness values can be found from here and from this point. Suppose, B is 2 metre and for L length of the plate is 1 metre, so B/L that becomes 1. Now, in that case, by looking at this point, if you look at the breadth of the plate, suppose you are taking breadth, so breadth will be here suppose 0.5, then you have 1, then 1.5, then you have 2. This is in terms of metre. And this is your critical thickness.

So, for a particular breadth you go there and you look at the B/L value and based on this B/L value, your critical thickness, so it will be suppose, say, 2, 4, 6, 8 like that, it will move. So, based on that you can have the value of the critical thickness. So, the plate will be going to buckle if the thickness is less than that value. So, depending upon this value, suppose, you are coming here, so it will be something like more than 4.

So, the thickness is less than this value, suppose, if you take 1.5 or so, in that case wherever it falls. If the thickness is less than that, then the material is going to buckle. So, that way this buckling is defined.

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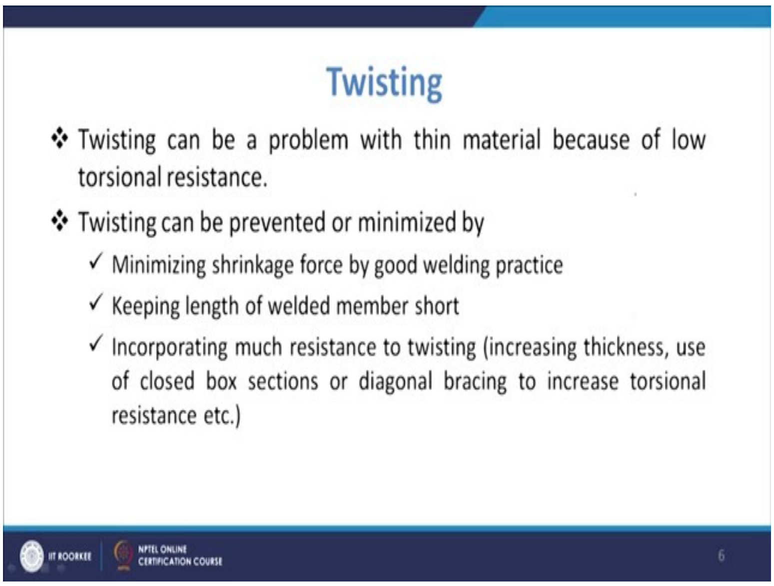

Now, we also have seen that in the case of buckling the amount of deformation is much more than that is found in the case of bending because there is more than one stable shape in the case of buckling, so more than one stable deformed shape is there in buckling and then you have the amount of deformation which is there in buckling which is quite larger than that in the case of bending.

Then, we have the case of twisting. Now twisting is basically observed in the case of problem when you have thin material and it has low torsional resistance. In that case, it gets twisted and twisting can be prevented or minimised by minimizing the shrinkage force by good welding practice, keeping length of welded member short, and incorporating much resistance to the twisting.

So, that way, if you increase the thickness or you have increased rigidity or so, in those cases the twisting can also be avoided or prevented. So, these are the normal kinds of distortion which we come across in the welds and because of that basically they are out of the shape. So, we will have in our next lecture talking about the methods to prevent or minimise the distortion in the wends. Thank you very much.