Marine Construction & Welding

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Lecture No. # 40
Distortion Control & Mitigation

So, we have already talked about different types of distortions and we have initiated also discussions regarding distortion control. So, we shall becontinuing with distortion control today, and subsequently, we will look into the distortion mitigation techniques. Actually, distortion control and distortion mitigation, they are somewhat close, by the whole idea is, I mean both they have the same objective of minimizing weld-induced distortions. Here, when you talk about distortions, obviously we are referring to weld-induced distortions or distortions due to the thermal application because of the welding.

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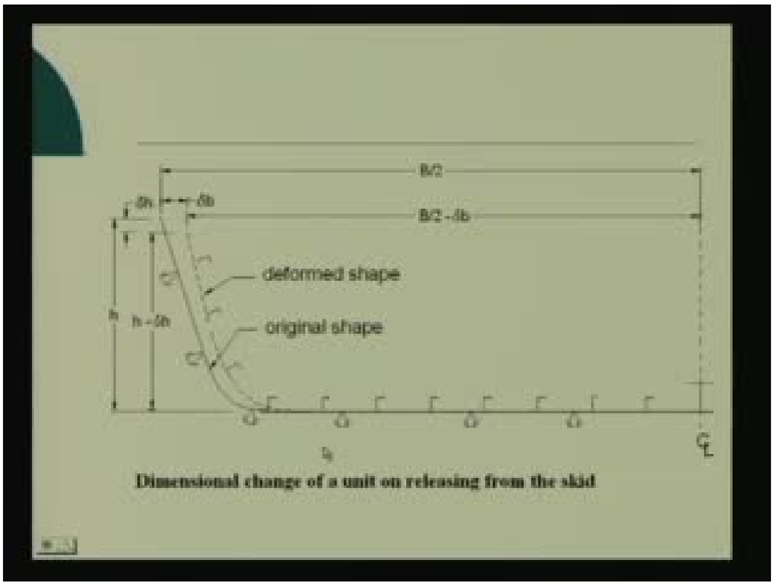

So, we have seen, say here, I mean how the distortion, they effect. Here, it is a sketch of a, say a bottom shell, a bottom part of the of a ship structure, just the double bottom unit. A section if we look into, here you have the bottom shell which is stiffened by longitudinals and the part of the bilge plate, and well, a part of the side shell if I say so, but you can consider it to be a small unit, one part of the double bottom, and here. you have the side shell longitudinal. Of course, we have not shown the floors, etcetera here; just a shell structure.

So, what we have tried to show here is the dimensional change of a unit on releasing from skid. What we had been discussing in the last class that generally these structures are erected on a skid; it is not erected on just plane floor; that means, some structure is erected over which the plates are laid and they are connected together.

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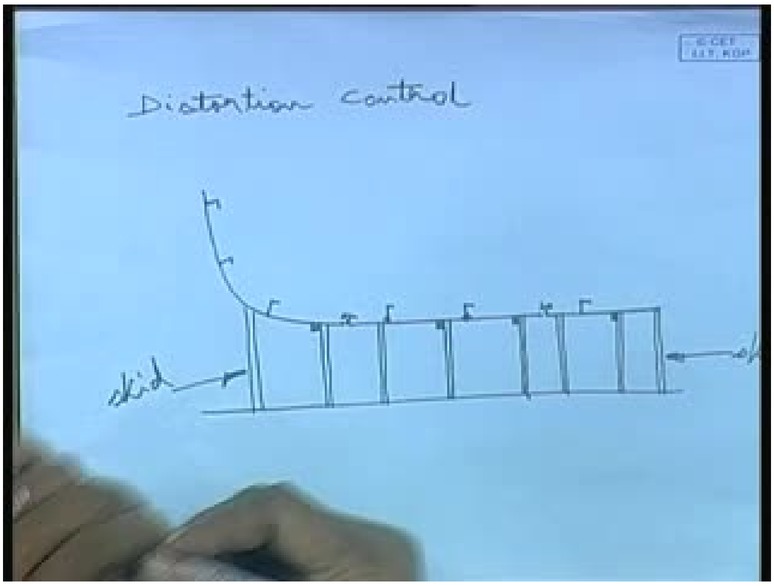

So, such that the plates they remain in position, such that, because of welding or any other operation, the plate, they do not move, because when two plates are to be welded, as you know, say this is one part of the plate, here you have another part of the plate, and let us assume this is another part of the plate. They are all sitting on the skid, and now, skid, this what I am putting here, these two lines, they are representative of a structure which provides a support over which the entire units are erected. This is what is skid, this is going out, skid.

Now, as you can see, here, I have given a small gap. It is nothing but to signify the root gap between these two panels. When this, I have shown here the plates, it can be just flat plates or it can be prefabricated stiffen panels also that means, you already have the longitudinals welded over it, whatever is the case, so, these are the gaps root gaps. Now, as to do proper welding, you will have to maintain that root gap uniformly. So, to, for maintaining that means, after alignment, when the welding process starts, such that the plates, they do not move. What is the general tactics is you put some lugs here and fix them to the skid. These small squares I have drawn, they are representing small small lugs. What is a lug? Lug is nothing but a small piece of plates which you have welded to the bottom shell or the or the shell plate, not necessarily bottom shell, it can be any structure what is being fabricated. So, to the shell plate and to the structure, that means they are restrained, restrained for movement.

So, once this is all, this welding's where completed, also the welding of the stiffeners are completed, everything is done. Then, there might be a situation that you will have to remove this, release this from the skid that means, this all these lugs which we are welded their cut and take it to some other fabrication station, wherein, possibly you will at the side shells and other components, whatever it is.

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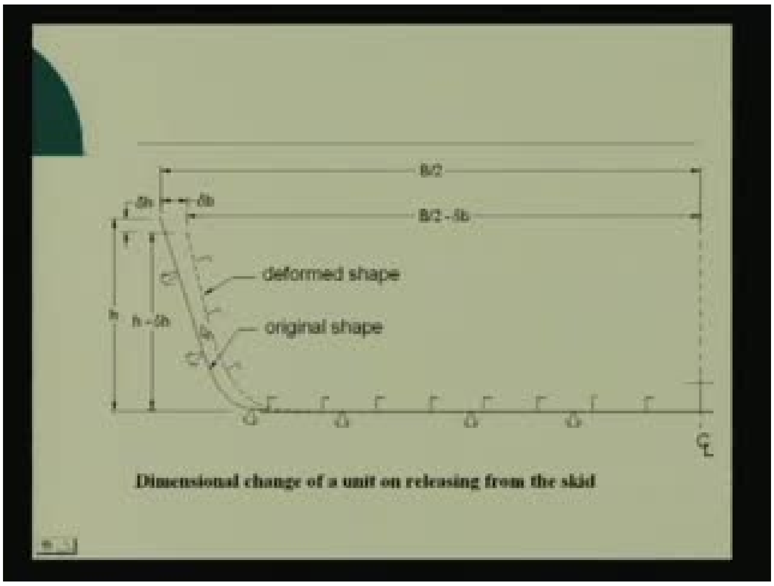

So, what, one may observe the phenomena is this, what is been shown here. When it was in the skid, this was the original shape, this was the original shape. Now, when it has been released, the deformed shape could be like this. So, what has happened, it has shrunk. Basically, it has shrunk in this direction that means, it was instead of this breadth would have been b by 2; it is following short by some amount delta B as well as the height would have been h this following short by delta h, because it has shrunk in this direction as well as shrunk in this direction. So, they are observed.

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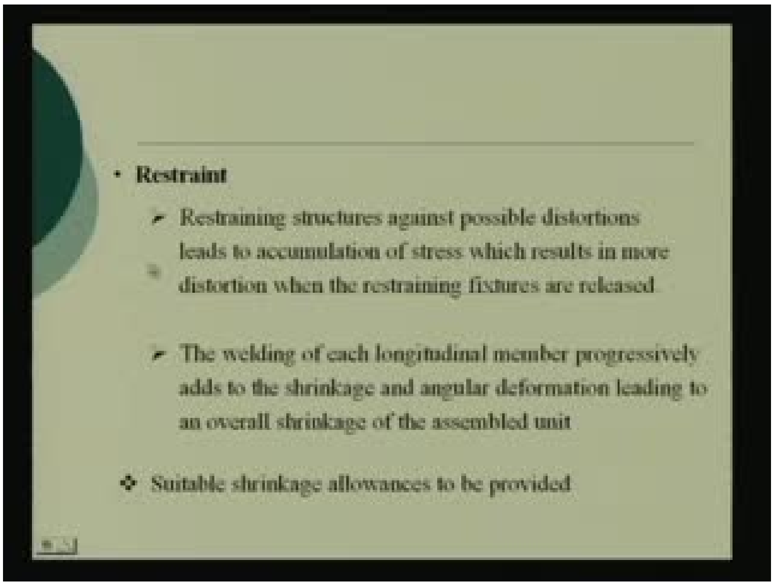

So, that means just restraining, we have talked about restraining a structure to prevent distortion, to control distortion, not always works, not always works. So, you may result in such a situation. That is why a suitable shrinkage allowances, what is that the solution? The solution is not restraining, not restraining that means, what it was mentioned the restraining structures against possible distortions leads to accumulations of stress which results in more distortion when restraining fixtures are released.

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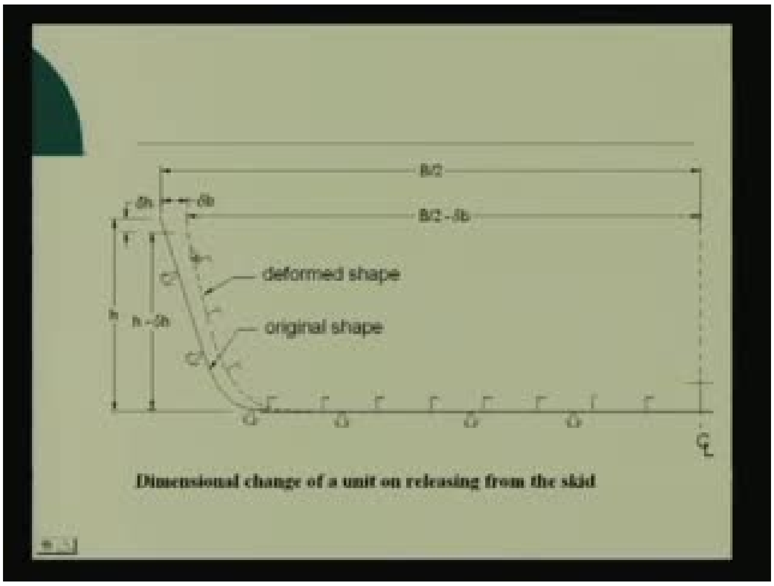

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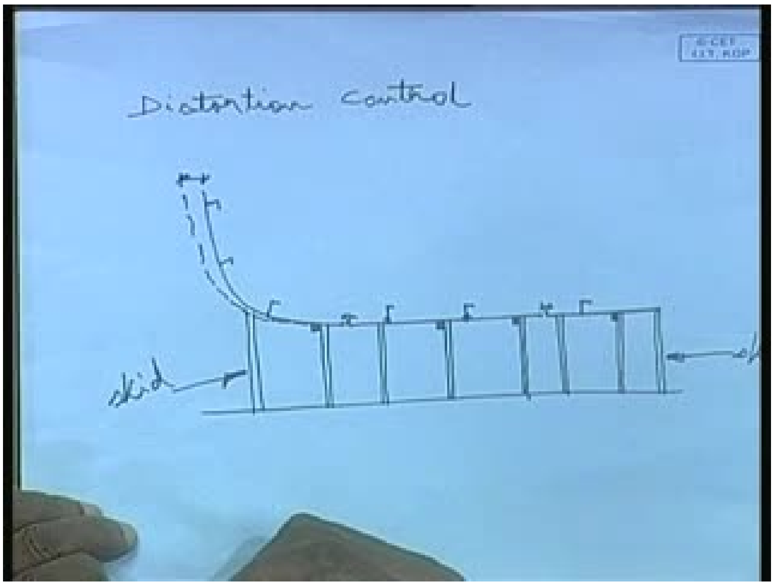

So, essentially, solution is suitable shrinkage allowance that means, here, you provide suitable shrinkage allowance. Whatever shrinkage is taking place, such that, this height short fall in height is taken care of. As well as this sinking whatever is taking place, that has to be, that means, you will have to provide the allowance, such that, it is actually done like this such that, after shrinkage, it will shrink back to the design designed dimension.

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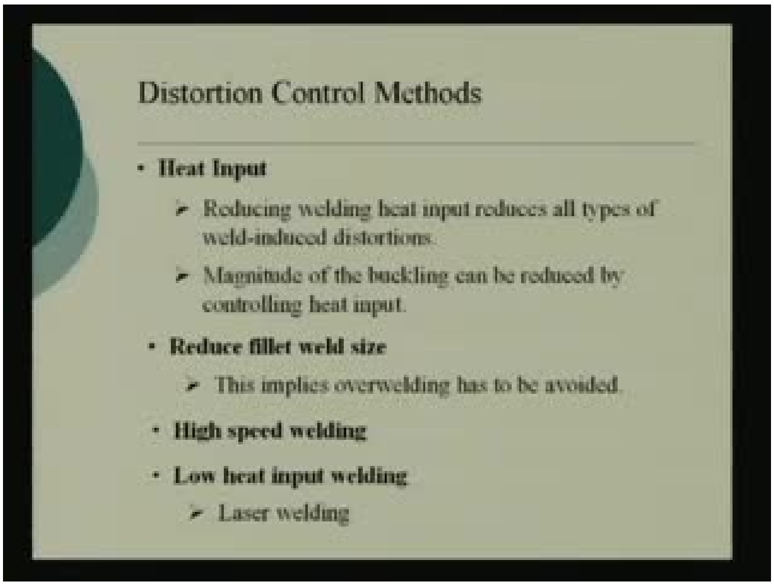

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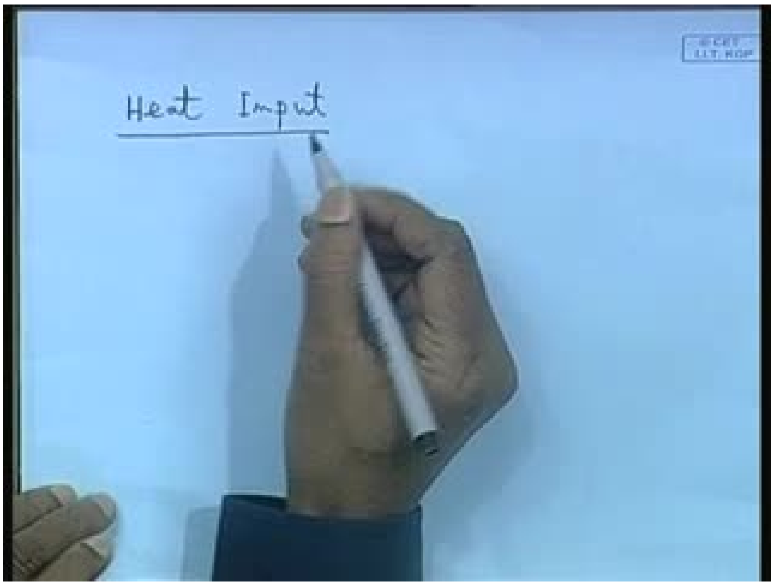

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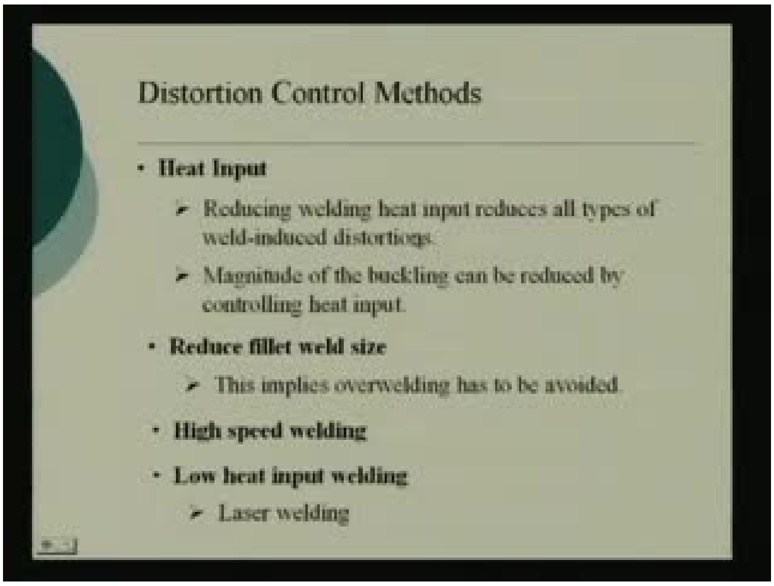

So or in other words, one or two properly estimate this shrinkage allowance, and then, continuing with the distortion control methods next is heat input, because as we have seen that the primary aspect of the entire distortion is because of heat input, because it is a thermal process, heat is going in, so, it is causing expansion, causing thermal stresses, and eventually resulting in structural deformation. So, best way would be to reducing welding heat input which reduces all types of weld induced distortions. What about distortion we have talked about? We can reduce the heat input.

Now, the problem is, also let us see that the magnitude of the buckling can be reduced by controlling heat input. So, in other words, if you can control the heat input, if you can reduced, it is fine, but truly speaking reduction means what, primary purpose is to achieve necessary fusion, melting of the electrode as well as fusion of the parent metal, these two are to be achieve. So, if I reduce the heat input to such an extent that adequate fusion is not taking place, my purpose is not served.

So, so, it do not have other options other than to put heat into the structure and stresses will form. So, the next concept comes is how to control that heat input, how to control that heat input. Control means what? Well, essentially that will follow mitigation means, how to mitigate the effect of that heat input, because I cannot reduce it, I can advise control it, and then, subsequently I can mitigate the effect. Mitigation means basically mitigate the effect of the heat input. We will see that.

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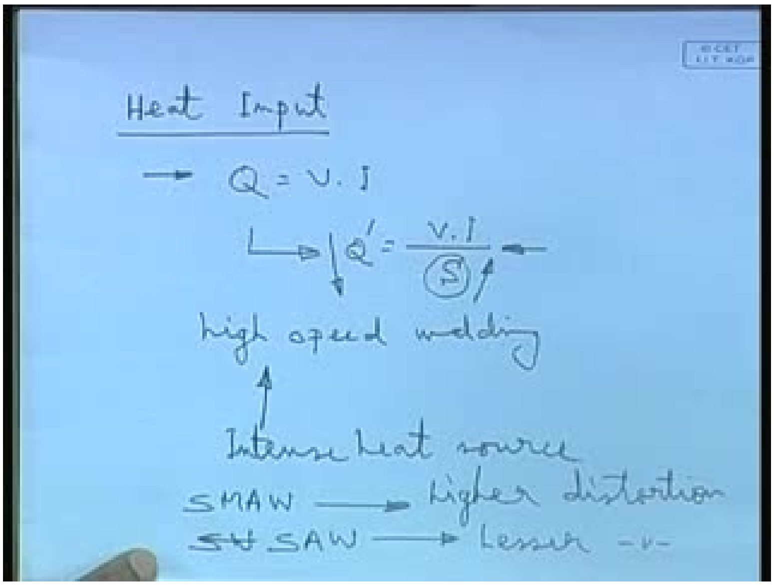

So, this gives us one clue that if we can reduce the heat input control the heat input, so, that way one of the solution of this reduction of heat input. As we have seen, the distortion is not actually dependent on the absolute value of the heat input, that is, V into I; it is actually dependent on the rate of heat input, that is, V I into divided by the speed that means, this gives us the clue that if I use welding speed very high, then the heat input rate can be brought down that means, high speed welding simple as simple. To reduce distortion, one should choose high speed welding process. Now, high speed welding process means what? It means the welding speed is high. Now, welding speed is high means what? It means that it should have sufficient heat input, sufficient heat generation rather sufficient heat generation which will enable me to melt, deposit, melt, and deposit the filler metal as well as melt the required amount of the parent metal in that lesser period of time, because if I take the heat away very fast, then it may not achieve necessary melting.

So, this can be achieved through welding with intense source of heat. It should have a intense heat source. That is how we see one of the analogy with the flame cutting process. When we do flame cutting, oxy acetylene cut cutting or any other similar equivalent thermal cutting, we see also deformation take place.

Now, instead of oxy acetylene if I use plasma jet, then deformations are less. Reason is same, because when I am using plasma cutting means, it is a much intense source of heat, so, I can move the heat source very fast. So, as I move the heat source very fast, lesser amount of heat is dissipated into the plate conducted into the plate. Lesser amount of plate is getting heated up, so, less distortion. Similarly, with case of welding, that is why a shielded metal arc welding will give higher distortion will lead to higher distortion for the obvious reason, because shielded metal arc welding is what? It is a manual welding, so, limited in the speed; you are limited in the current, because manually you would not handle very high current, so, you are limited in the heat generation, and thereby, also limited in the speed of welding. Whereas, a welding process are submerged arc welding. You have lesser distortion, why? Because in submerged arc welding, you can have much higher, the heat source is much intense.

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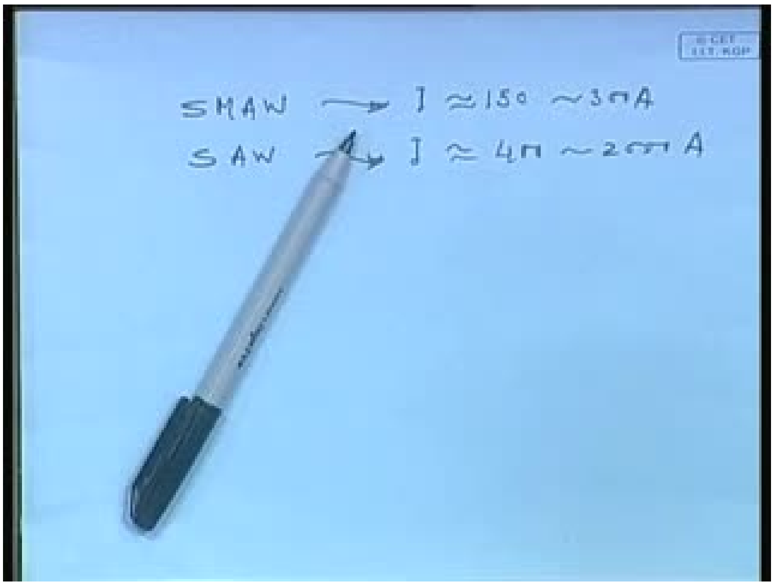

Why because if you see submerged arc welding, sorry, this shielded metal arc welding which is a manual process. Here the current level would be of the order of, say, well, around 150 to about 300 amperes. Whereas, as we have discussed in submerged arc welding, the current level could be, say around from 400 to, say 2000 ampere.

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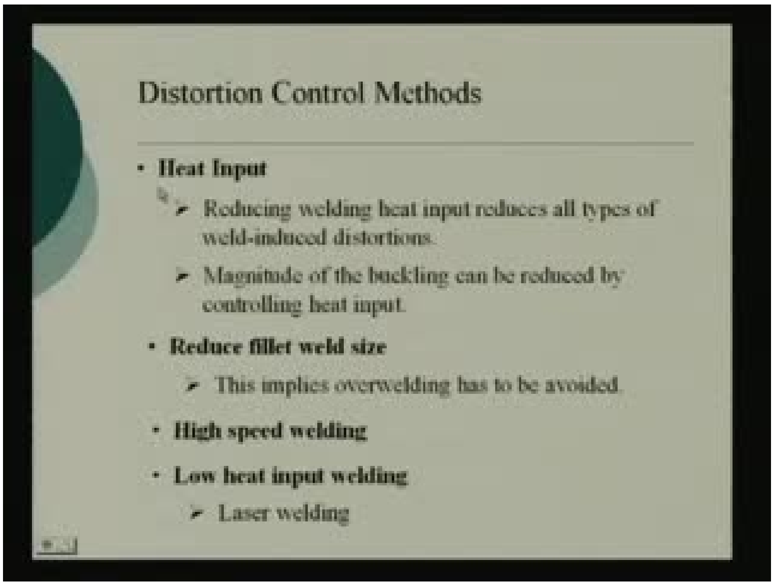

So, you can see the heat generation is much much higher. So, more heat does not mean that more distortion; it is the rate of heat input. That is what actual influences extent of distortion. So, that is how this controlling heat input, controlling distortion through controlling heat input is essentially controlling means, essentially selecting a welding process where the rate of heat input is reduced by increasing the welding speed.

So, obviously, the, I mean that leads to the thing that if you can implement laser welding for example, electron being welding, your deformations are less, why? Because in electrode beam welding, the heat source is very intrinsic source. Similarly, in laser welding also heat source is very intense, but well, also at the same time you will have to see what are the costs involved the feasibility of the process. I know electrode beam welding will give me lesser distortion, what, whether it is feasible to implemented in shipyard environment. So, all those aspects are there, laser welding, yes, it can be used but still it is expensive process. So, one will have to weigh all those factors.

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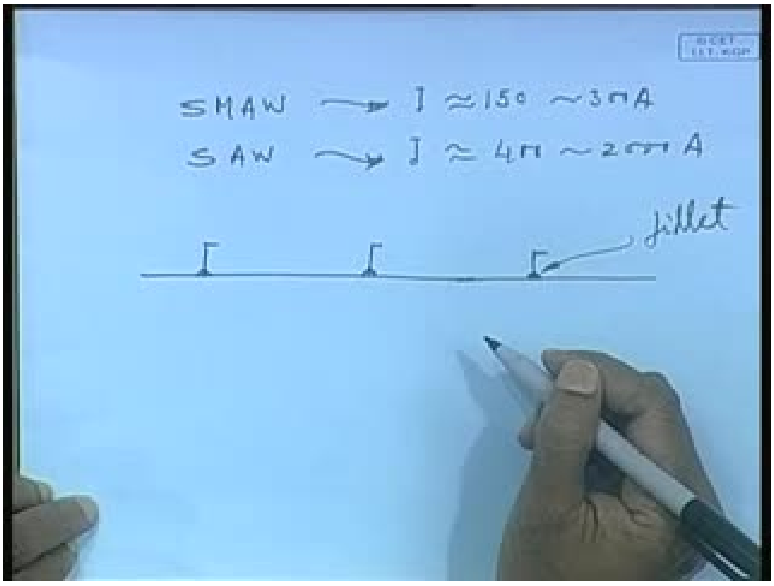

Well, next method of controlling distortion could be that reducing the fillet weld size. This is for the distortions we have talked about, wherein, say, because you see in shipbuilding, one of the fundamental building component is such stiffened panels means, flat plate with stiffeners. This is one of the building brick of the final structure. So, these are fillet welds, these are the fillets, so, there will be huge amount of such fillet welding. Now, as you can see each fillet welding is contributing heat, each is contributing towards distortion.

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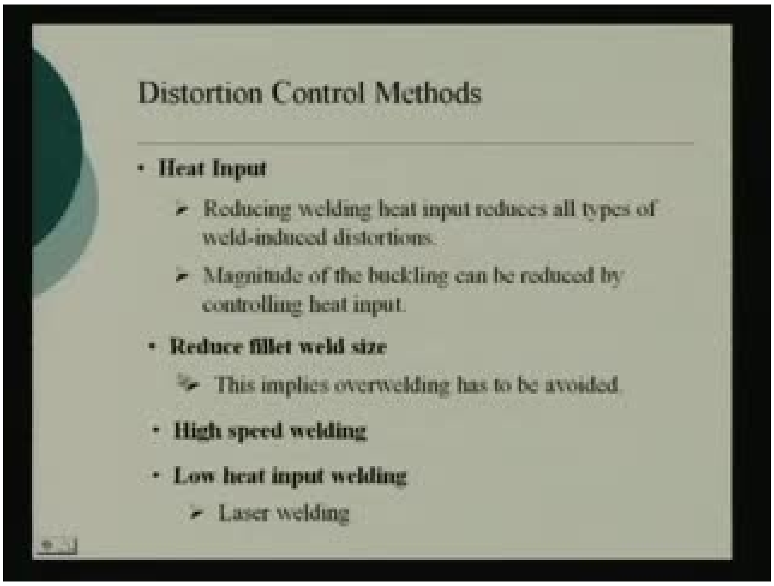

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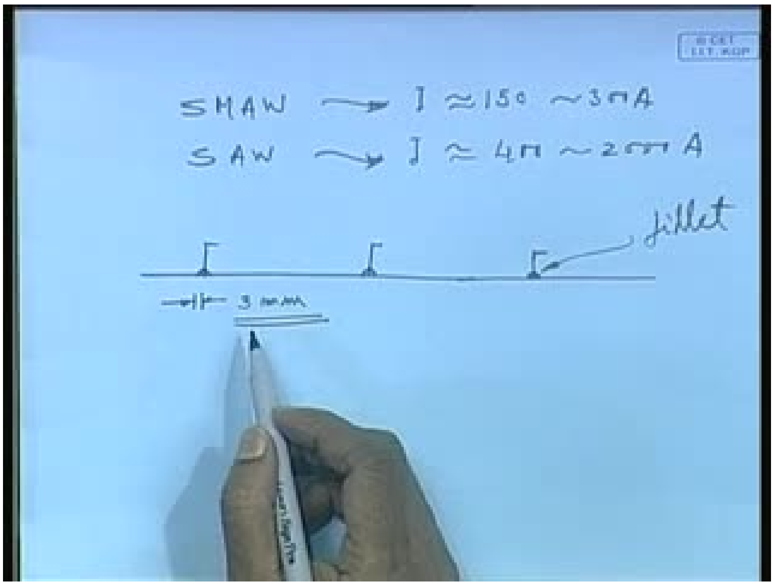

So, what we will have to do that reduce the fillet weld size. By reducing means what? You cannot go below the designed one. Whatever is required that means weld only that much as much is required. That is why we said that this implies over welding has to be avoided. Like, I was telling where a 3 millimeter leg length is needed, if the leg length needed say 3 millimeter, you will have to set the welding procedures such that, only 3 millimeter deposition is done. If you do more, not necessarily it makes the structure stronger or any other thing but definitely does harm to as for as distortion is concerned.

More heat goes into, so, more deformation, more thermal stresses, more possibility of residual stresses.

So, you will have to look for such welding process wherein, you can control it to the desired dimensions of welding, so, fundamentally, no over welding. What impact is many a times happens as I have already told you that it is easier to over deposit material. Easier means what? Means you set the current at a higher level, choose a higher geometry electrode and go on depositing, go on welding. So, it will be rather easier to deposit 5 millimeter fillet than 3 millimeter, because three millimeter, you will have to be more precise. That is how may be you will have to one will have to look for pulse more power supply. Wherein you can further control the deposition pattern.

So, that is why this is one aspect that over welding and at times there is a wrong notion that if the weld deposit is less, then it is a weaker joint, no, that is not correct, because wherever in case of fillet weld, well, it depends on the shearing load. So, whatever is required, you do that much. Over welding does not make it necessarily stronger, does not make it.

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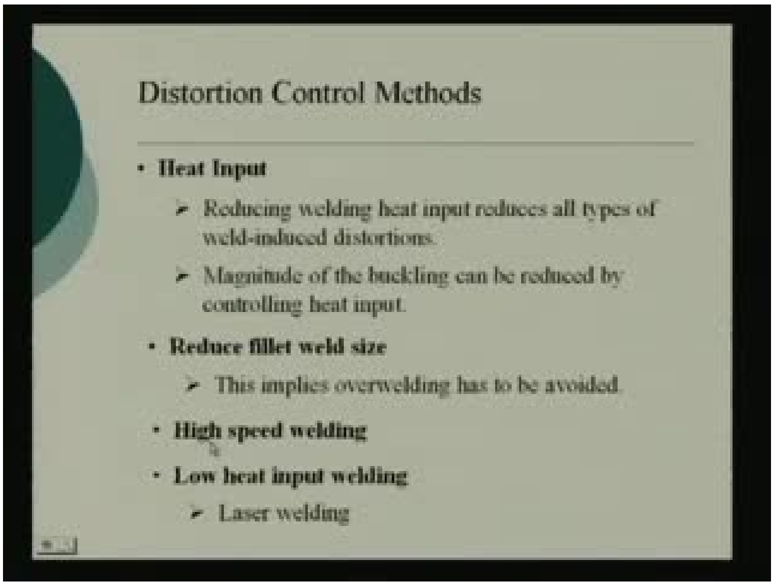

So, that is another aspect. Next is high speed welding. We have already talked about in connection with heat input because high speed welding, well, obviously, in conjunction with the heat input, this gives us mechanism for controlling the distortion. That same thing can be talked about given a name as low heat input welding. As you can see the first we have mentioned is the laser welding, but laser is not a lower heat input welding does not mean that a welding with a heat source whose heat generation capacity is less, no, it is actually low rate of heat input basically.

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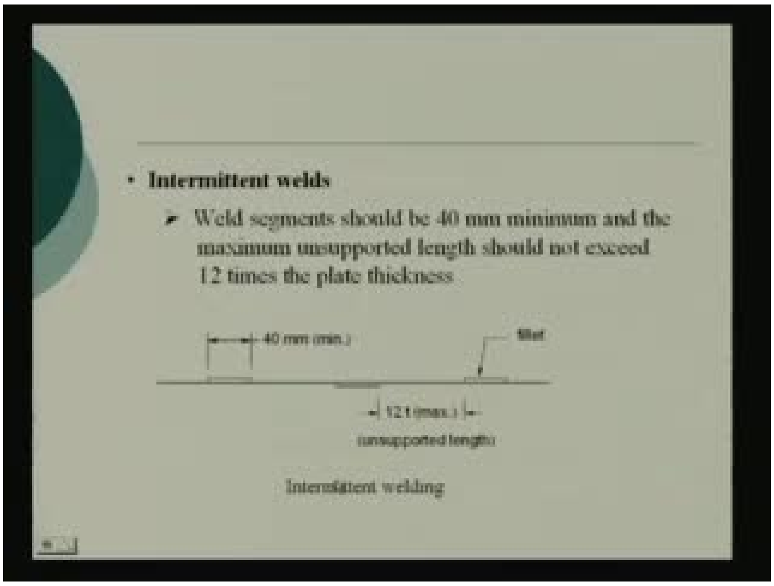

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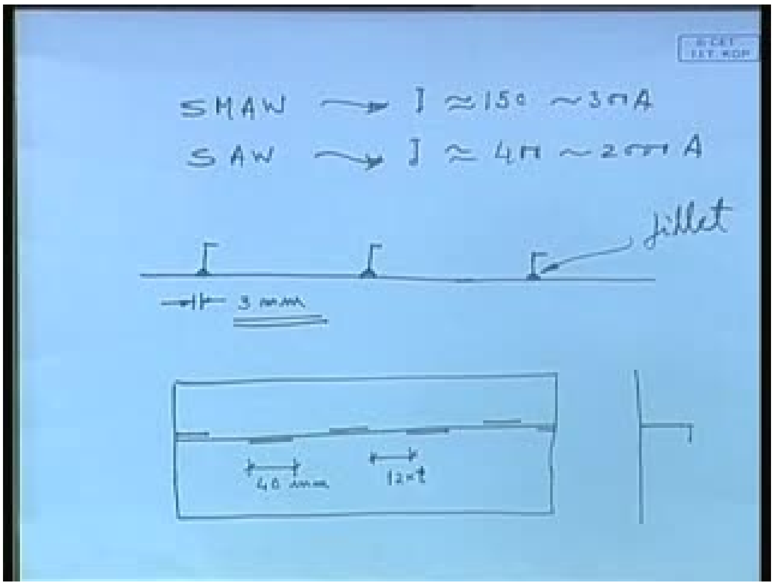

So, these are that means heat input, speed of welding, low heat input welding, these are one and the same thing connected with each other. Then there is another concept of intermitted welding. What basically is being done here is you are reducing the heat input, reducing the amount of heat going into the structure by staggering the weld that means, instead of doing a continuous welding, I give intentional gaps between the welds, I mean in the welding, that means I do not continuously weld a stiffener, like, possibly, well, say this is my say one plate, you have a stiffener to be welded along this line. So, instead of continuously welding on both sides, because as you see, the welding is done on the both sides, fillet is done on both sides. Instead of continuously welding on both sides, let us assume a situation I weld like this.

This small lines what I am drawing is showing the fillet deposition. So, what I have done. This part only one side, I have welded, then I have a given a gap; then again on the other side, I have welded again a gap. So, it is just as if the entire welding, you have staggered it.

So, what generally, wherever there is such stagger welding is done. Practice is are this is kept around 40 millimeter, I mean minimum 40 millimeter, then you provide a gap. This gap is provided is around 12 times the thickness of the plate, around 12 times the thickness of the plate. That is how it is generally done.

So, in the process, automatically what happens? You will heat, amount of heat going in the structure is reduced, because I have not done continuously deposited material, I have done some welding given a gap, again did on the other side and so and forth.

So, this is one of the very effective way of, in fact, controlling distortion, but obviously, such welding cannot be done for all the stiffeners, obviously, in butt welding, this is the never a case of butt welding, you cannot do stagger welding. When you are putting two plates together, only in fillet welding while welding a stiffener, such welding can be done, but it is not always permitted, say this side shell, main hull girder, whatever stiffener is being welded or say that deck plating, the deck longitudinal, bottom shell plating, the bottom shell longitudinal, side shell, frames, all longitudinal, that means primary stiffening members, it cannot do stagger welding, because obviously, this will, this kind of welding will lead to less distortion, but at the same time less strength. For obvious reason the less strength which is not, which cannot be afforded. So, only cases where it is not a very load varying structure. For example the partition bulk heads in accommodation region. In the deck house, the walls, the partition walls between the cabins. They are refer to as patrician bulk heads.

So, there one may go for such staggered intermittent welding but still it is not, from another point of view, it is not very preferable. Can you tell me why it is not preferable? I mean what problem? Definitely it is not preferable, because definitely in the long run or whatever it leads to some kind of problem, difficulties. Strength wise fine I mean, when the strength requirement is not high, there only I implement this, but you will land up in some other difficulty, that is why it is not to very favored one and even and spacing for defense applications means navel shapes. They simply do not permit this anywhere. The structures become more prone to corrosion in such kind of welding. For the obvious reason, the un-welded part, you see the un-welded part are depending exposed to the moisture, cruise environment, because what is happening? You imagine this central line is the line of the width this stiffener has been welded. So, wherever it is not welded, there, there is a minute gap between the stiffener edge and the plate, there is a minute gap there.

So, moisture will definitely creep in, and you cannot protect that, because, you know, all steel, the entire structure eventually is protected by means of a painting, a coating, so called protective paint is applied. Apart from that you have a well sacrificial anode, etcetera, other mechanisms of account preventing corrosion, but primarily the thing is painting, providing a insulation barrier between the corrosive environment and the metal.

Now, here, you cannot paint. The wave of the stiffener is sitting flat on the plate, so, that is my micro gap, how do you paint it? You cannot. So, the gap is enough for moisture to set inside and corrosion to start. So, that gives a very high corrosion and also what will happen? The rest part of the plate is well painted, so, only a very small part is exposed, so, the corrosion rate increases, the corrosion rate increases because the whole part is covered, that is not corroding, only small part is corroding. So, if that forms the anode, so, the corrosion rate increases.

So, that is why, well, naval shapes, I mean the defense applications, they are very stingened about this, so these are not permitted, but anyway as a mechanism of distortion control, this also needs to reduce distortion.

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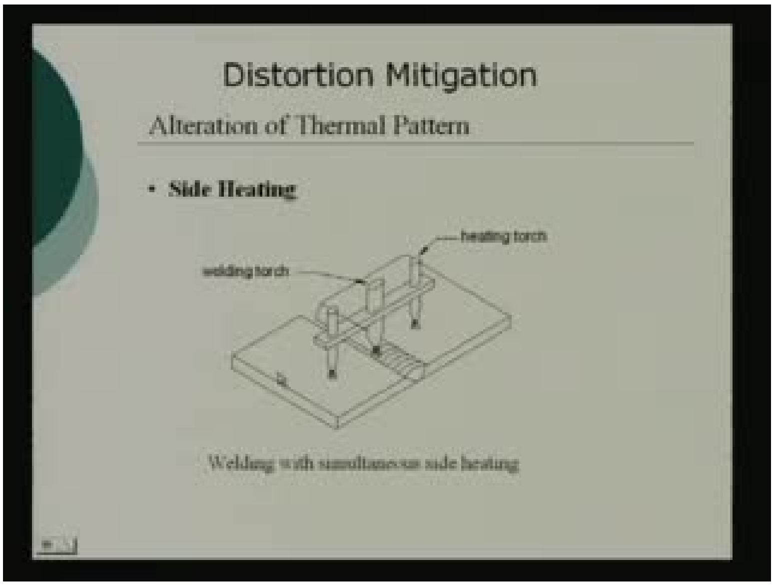

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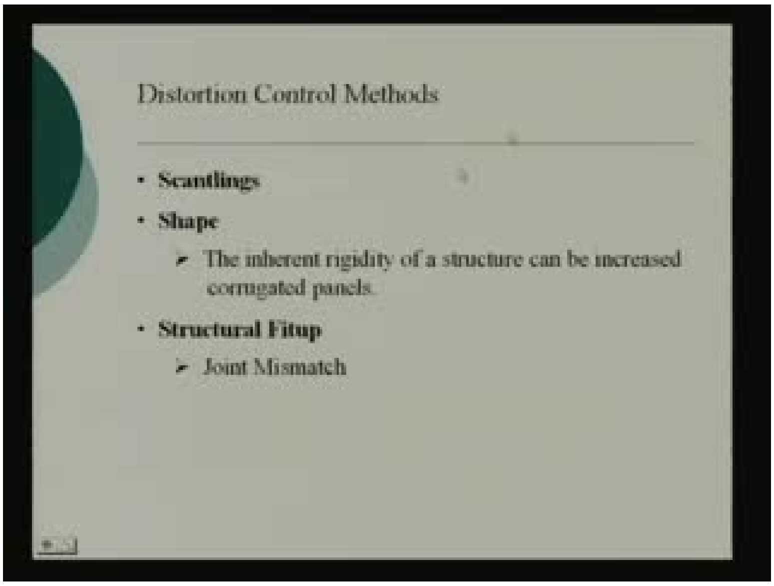

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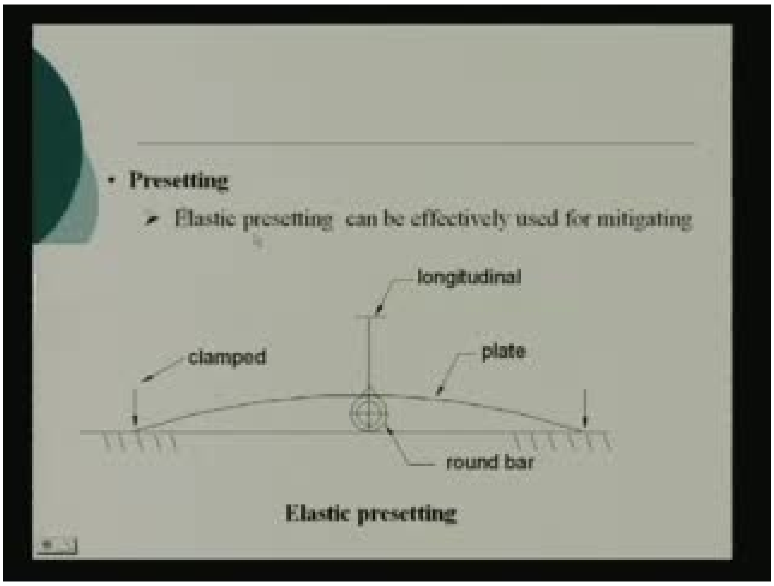

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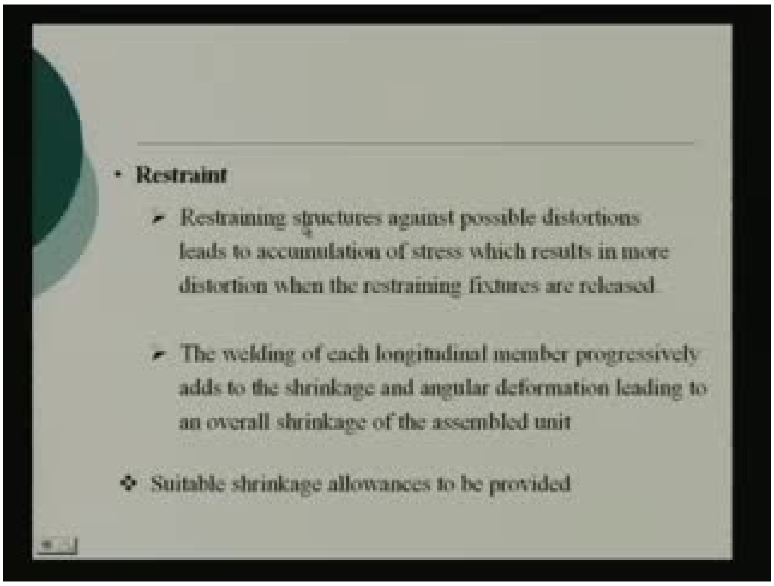

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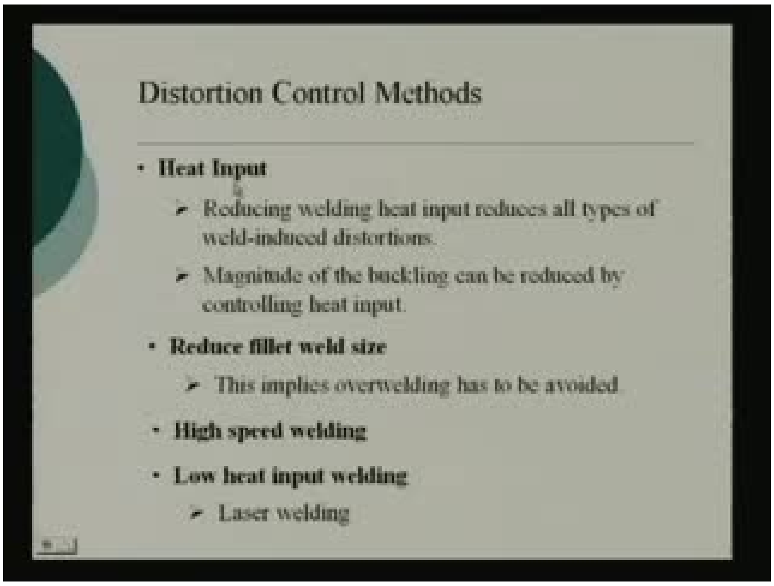

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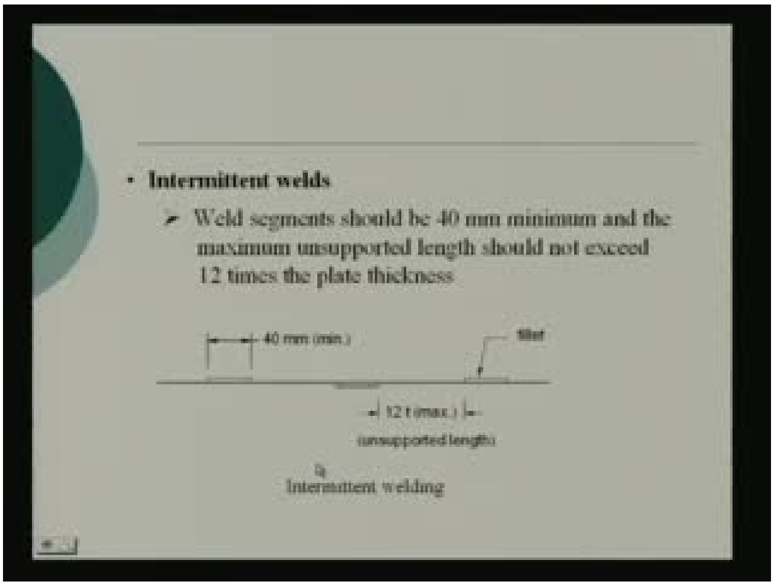

Well, then, we come to the, so, this is a some of the distortion control methods what we have talked about controlling changing the scantlings of the structures changing the shape of the structures, that is, if you just go back, there are, that means, controlling, changing scantlings of the structures, changing the shape of the structures, the structural fit up, presetting, putting restraints, and controlling the heat input, the fillet size, all these the speed of the welding and finally intermittent weld, so, these are some of the methods which can be applied to have a control, to have a check on the resulting distortion.

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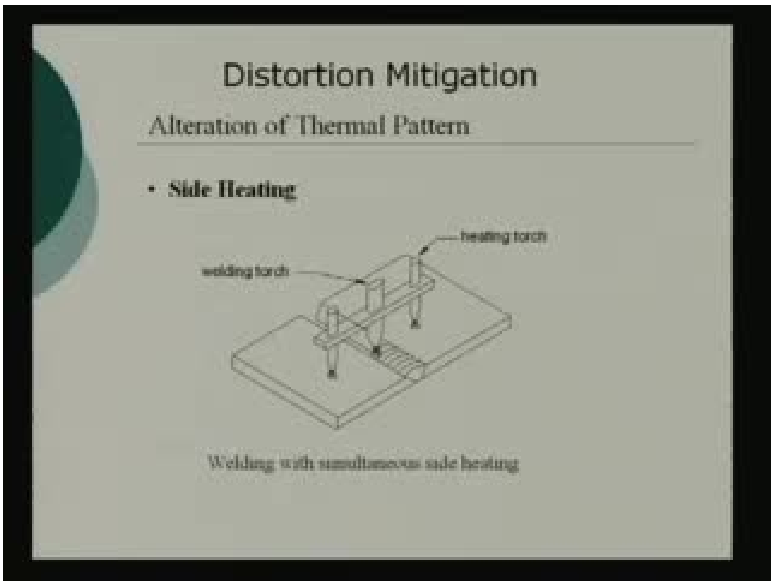

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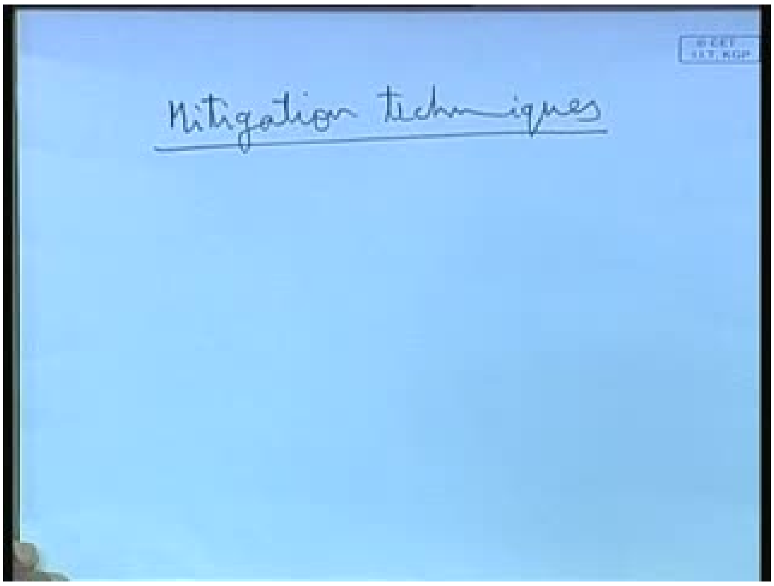

Now, we talk about some of the methods which can mitigate the effect of distortion. That is why we call them a mitigation techniques, distortion mitigation techniques, because we see that heat input is heat is needed to do the welding and it will lead to thermal stresses and the effect is finally a distortion. So, how to mitigate that?

So, what we see that entire reason behind this distortion is because of the heat, the heat flow and the resulting thermal pattern, the resulting thermal profile. When a plate is welded along a line, so, what physically you have observed? When the welding is done, if you physically, if you see, what you will find is when the welding is done and you go and touch the plate little away from the weld line. The movement the welding is just being done it is the plate, you can touch it, but go and try to touch say after 2 minutes, you would not be able to touch, means what? By that time heat has flown, it took some 2 minutes time for the heat to flow in the structure, and more heat flows in the structure, more part of the structure gets effected by the temperature. Effected means there is a temperature raise, so that, so called delta t component comes into being. The temperature differential between its original ambient temperature and the temperature now, there is a raise in temperature, it has a thermal expansion of coefficient, so, you will try to expand.

Now think of a situation, if they can alter that thermal pattern means, that altering means what? It is trying to expand in this direction, I alter the patterns such that it is now compressing it. The welding heat is trying to expand, I put some other heat it tries to compress means cancel the effect of the welding heat, or the heat was flowing, I said after 2 minutes you go and try to touch, you cannot means, heat is flown, but in between I put a heat trap, a heat sink, more appropriate term uses heat sink, I take out the heat. So, as I could touch in the beginning, I can still hold it, I do not feel the heat, why? Because heat in between has been taken out. I have provided some means of sinking of the heat provide a heat sink which is taken of the heat. So, deformations will be less.

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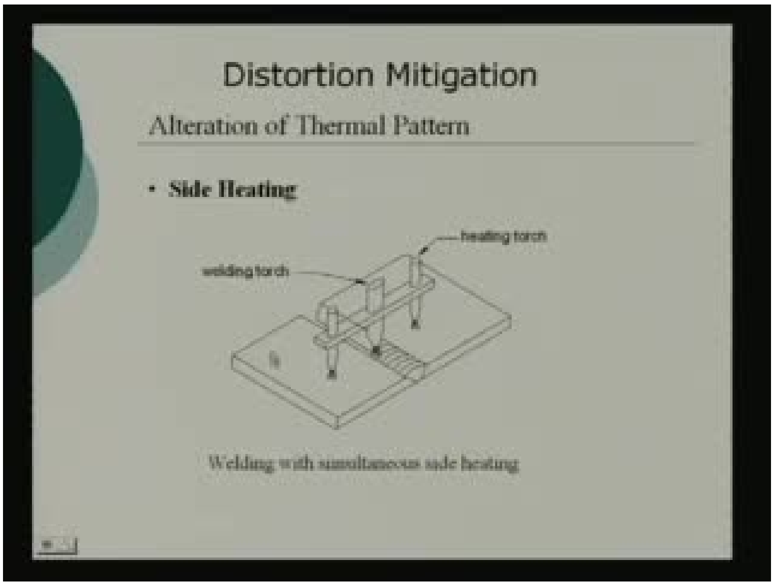

So, these are some of the methods of so called distortion mitigation. So, here, one example, so, it lies on the fact of alternation of the thermal pattern. Distortion is due to a certain thermal pattern. Now, if I alter the thermal pattern to our advantage, such that distortion is reduced, so, that becomes a method of distortion mitigation. So, one of the method is side heating.

In side heating, what is what we are doing? You can see the schematic here that is welding with simultaneous side heating. I am welding the thing, so, this, the central torch is the welding torch which is a depositing the metal and the side torch is at simple heating torches. There are nothing but say oxy acetylene torches which are little away from the welding line, and as the welding is progressing, it is metal is deposited here and simultaneous heating is being done there on the sides.

So, what basically happening here is that it is mitigating the effect of the central torch. The heat flow, what was taking place, whatever expansion it was trying to do, I am simultaneously heating on the sides, so, it will try to expand in the other direction.

This is very easy to say to do this and in real life practice also not a very difficult to implement can be done. Only aspects what are the important aspects as you can see, the distance between these torches, what should be the optimum distance?

What temperature it should attain at the side? All these are some of the aspects parameters which are to be properly estimated, because the worst case is if not properly implemented, it may end to the distortion. If the temperature control of these torches, the heating torches are not proper, then it may damage the metallurgical property of the plate. What does that mean? That means the heat going in through the heating torches should be such that it do not, it does not raise the temperature above the re-crystallization temperature. For normal strength steel, that is, the temperature should be below 700 degree centigrade, 723 degree centigrade. For, you are high tensile steels, you should be even more careful; it should be below 650 degree centigrade.

So, that will depend on the rate of gas flow; that will depend on the height of the torch nozzle from the plate; that will depend on the speed of moment, all those will influence the surface temperature. That will be attained by this side heating torches. So, the whole principle is essentially to negate the effect of this by the simultaneous side heating. When this heating is being done, so, it tries to expand in both these directions. The coal plate was trying to oppose that direction. Thermal stresses were developing. Now, I am simultaneously heating here, so, it also tries to expand in this direction and tries to expand in this these gets canceled.

So, basically, if one can do a analysis and see, because of these what was the heat flow pattern, because of the welding torch, and now, along with that these two torches, what is the heat flow pattern? And based on that, what thermal stresses are developing? From there one can estimate that what to do with the optimum distances from this which will have minimum, I mean which will have a maximizing effect on mitigating the effect of the, on mitigating the distortion, mitigating the effect of the welding torch.

So, in any case, this is one of the method. Well, as far as application, actual real life application is concerned. These methods have not found much application as such because other problems are you can very well see this edge to the hazard of the construction process. Hazard means what? Basically here what originally was you just weld it, so only the central part is heated. Now, you additionally you heat up the additional part of the plate, so, lot of heat is generated, the work environment becomes difficult, and also simultaneously, additional cost of heating, and then, final thing remains that if this is not properly calculated, properly estimated, instead of lowering deformation, we will land up with higher deformation, and analysis of these, well, they are not always that simple or that straight forward. So, but this is a good concept which is based on this basic philosophy that entire deformation is due to a particular kind of thermal pattern. So, I try to alter the thermal pattern. So, one of the method would be this.

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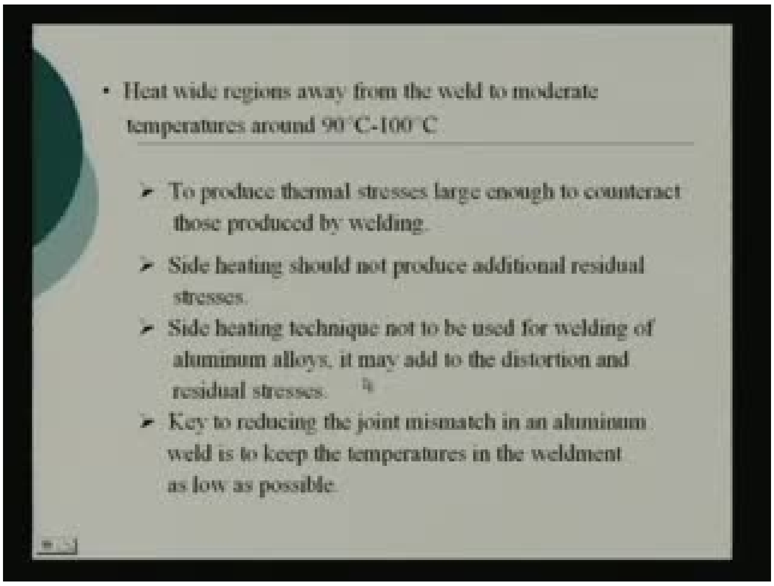

So, here, some of the details of that process is I have mentioned that the heat wide ranges away from the weld to moderate temperature of 90 to 100 degree centigrade that means, that way the heat temperature level is kept much below to produce thermal stresses large enough to contract these those produced by welding. That is the whole idea is to contract the stresses which may form by the welding.

The second point, obviously, one should be careful that it does not add to the distortions, and well, in this case, aluminum alloy such stainless better not to be used because it may add to the distortion, because that is a highly conducting material.

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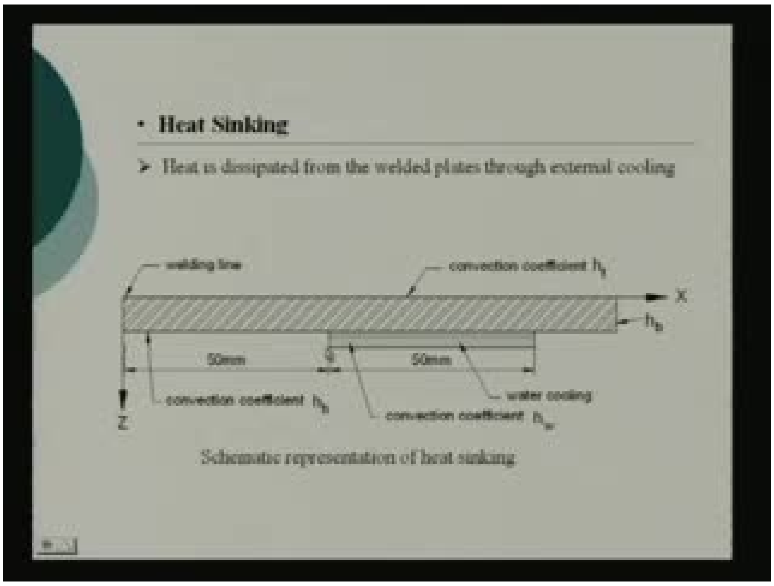

So, that is how we shift that was the simultaneous site heating, and now, here, as I was telling this is that another quite effective method heat sinking.

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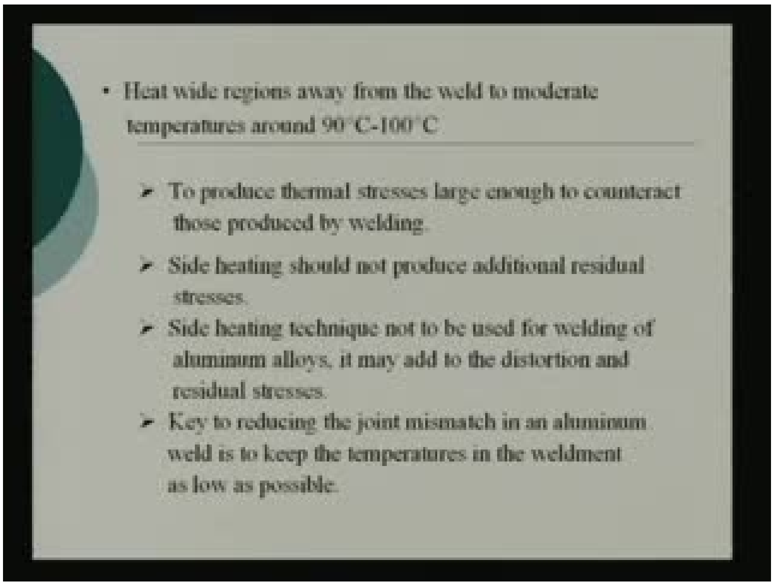

Sir, in this days, how can the stresses produced by temperature like 90 to 100 degree centigrade (( )) stresses due to bending

Yes

Yes it is like this. With higher temperature, not only the stress levels, how much stress level will come that do not directly depend on the temperature level. With higher temperature level, your, your deformation residual, deformation can be high, but at a lower temperature level, it is trying to expand, and it cannot expand, the stress level can be equally high, stress level can be equally high, stress level can be equally high, but deformation level will be low with low temperature, why? Because with high temperature, you are, well, stress level is higher, will be, can be as high as with a low temperature level also, but when the temperature is high, your yield stress is lower. So, deformation increases, but when it is only 90 to 100, then it may have a high stress level, but your yield point is also high, it has not soften, the material has not become softer, so, it cannot deform much, so, that is the thing. That is why in line heating, for example, when you are trying to really bend the plate, shed the plate, then you try to achieve as high temperature as permissible, permissible from the point of view of metallurgical concerns, that means, in fact, there is nothing but below 700.

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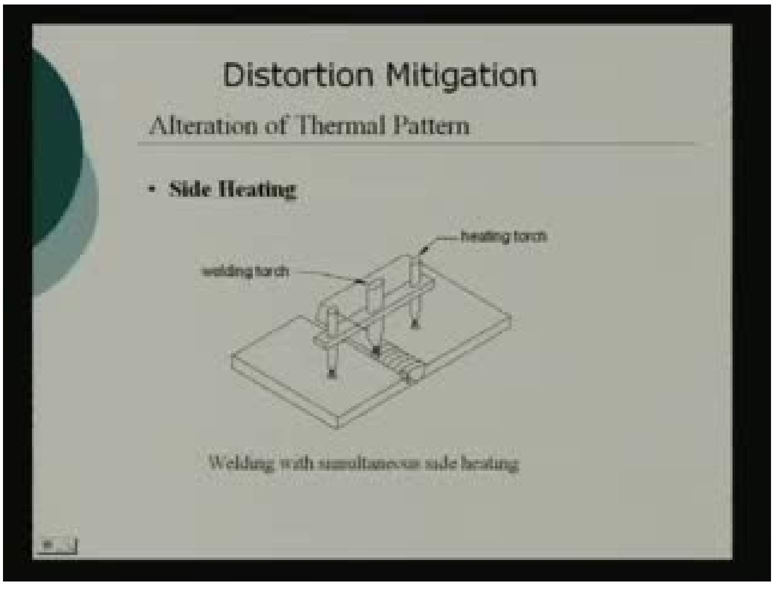

So, if I heat only up to 200 degree centigrade, then what will happen is I will have to probably 5 times I have to do the operation, every time it will bend very little, whereas, if I can attain the temperature of 600, I will get a faster bending. If I can heat up still further, say 800, possibly my effectiveness will increase but I run the risk of changing the microstructure of the plate; so, that is not permitted. So, that is how essentially, but, well, these are also not very sacrosanct by 90 to 100. All these will depend because the whole idea is altering the thermal pattern. So, you cannot, I mean, it is not recommended that just like that you start side heating, nothing is mentioned about how what should be the distance between them.

All that will depend if I heat up to 100 degree centigrade, then probably this must distance. If I heat up to 400 degree centigrade, probably distance I have to increase, I have to see which one gives me best effect.

So, for a given case, for a given plate material, plate thickness, stiffening arrangement boundary conditions means, what are the restrains, what is, whether it is a free plate, the size of the plate, all these will have to taken into account and find out which is my best solutions for side heating? Whether 100 degree centigrade or 200 or 600? What should be the distance? how far (( )) what patch of zone I will be heating? So, these are essentially not very feasible, I mean all those analysis on a case to case bases have to be done, and well, for I know that, my welding requirements are say 8 millimeter plate, 12 millimeter plate, 16 millimeter plate, and some such fixed. Stiffening arrangements are such, so, for all those I can have a analysis done and keep a table ready. So, whenever say 16 millimeter plate is coming, I implement that. So, possibly that is the only way of implementing such things in practice.

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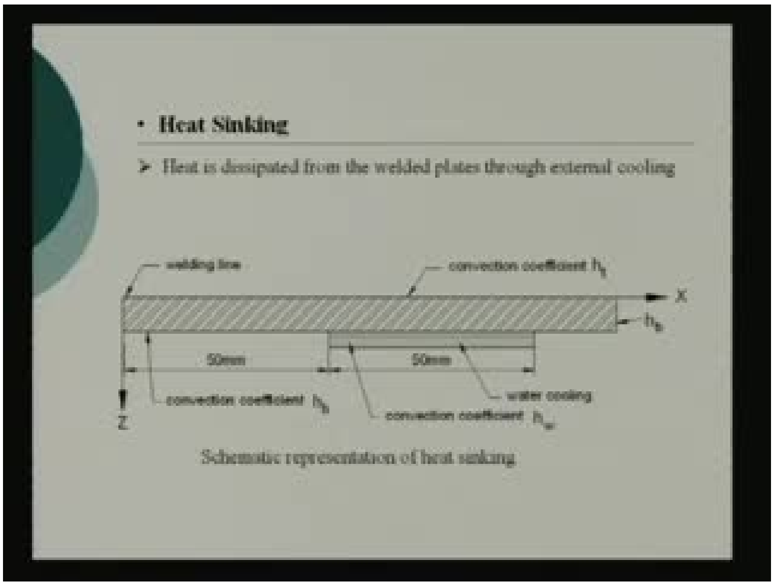

This is heat sinking; something similar situation here also. So, here it is even more straight forward. What is being done here? Heat is dissipated from the welded plates through external cooling, so, this is best, best in the sense that you do not run the risk of additional deformation. If it is, because side heating is a risky business, why? Because as the heat is going, and you are putting it extra heat. So, you put it wrongly, it differ the plate further, but here that problem is not there, here you take the heat away, take the heat away.

Suppose, this is the one of the half of the plate just a schematic representation here of heat sinking, say here is my, the other half of the plate is extended that side, say a butt welding is being done or a stiffener is being welded here. So, heat will flow along the plate. So, if I put a heat sink here, this part schematically I am showing that as if a situation of water cooling, water cooling means heat sinking means heat is flowing here and going in the water which is being flown below, the heat is taken out. So, that will take a heat and lead to lesser distortion. This is very logical.

So, now, what is to be done? That is again like in this particular case, we have studied where a 50 millimeter away from the welding zone, I am putting the cooling medium. How wide I have kept the cooling medium? Another 50 millimeter, so, well it should be 50 or 100 or 500 or whether this cooling away 50 millimeter or 100 millimeter, all these are aspects which are to be needs to be same.

Obviously, this cooling cannot be very close to the weld zone for the obvious reason, then that material will get badly hit treated, the quenching effect may come. So, that way that means from the weld zone, the cooling zone will start, not below the weld zone, but little away, but how wide the weld cooling zone? Well, again from common sense, wider the cooling zone, better it is.

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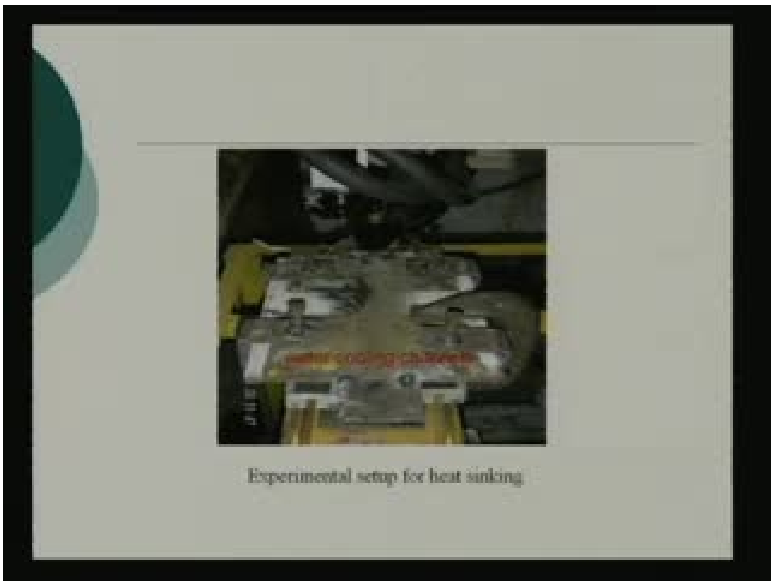

So, that is how, so, this a much of a covenant method of distortion mitigation. So, for say analysis of this kind of system, what it will be? You will have you will have to play with the convection coefficients essentially. The heat input is there, and the, it has a particular thermal conductivity this material, only the convection coefficients are changing. On the top, we have a convection coefficient; something at the bottom below, another convection coefficient. Probably, these two can be the same because there is in the normal air medium. Then, here you put a convection coefficient of whatever cooling medium you are putting. So, thereby you simulate the situation of water cooling, so, this in fact, we experimented in in all lab, not very much visible.

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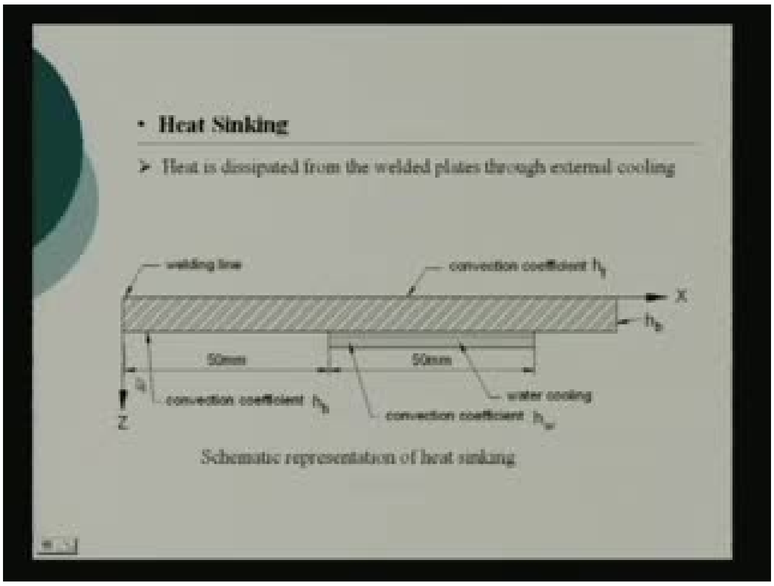

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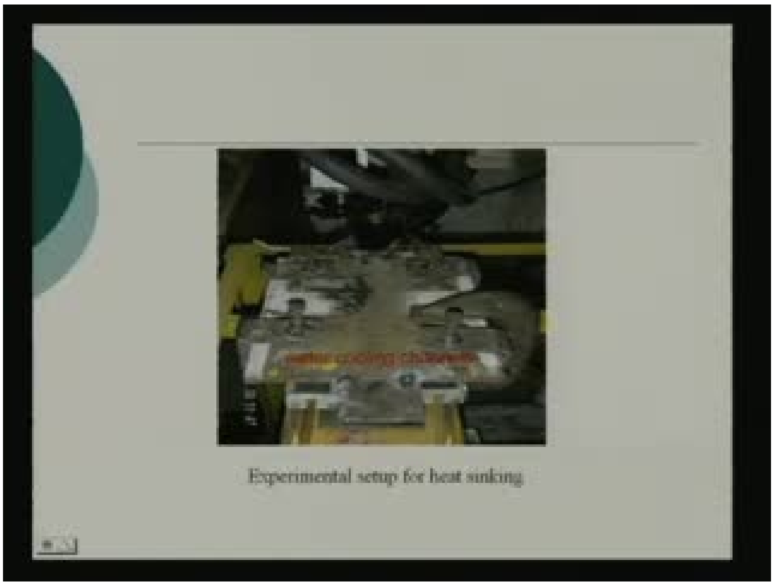

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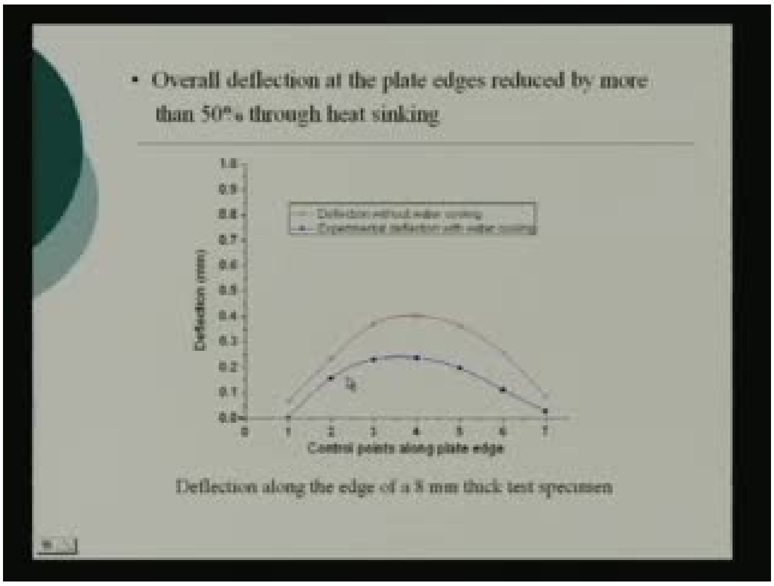

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So, these are the two plates which are being welded, and here are the two water cooling channels. You can see, this yellow, these are the pipes which are flowing water into this channel. This is the one channel here, another channel this side. There are two channels, it is actually replicating this situation, 50 millimeter away from the weld line. This is the weld central line, 50 millimeter away, and a 50 millimeter, a cooling channel. So, these are the 50 millimeter wide cooling channel. From here, this is the weld central line; from here, it is another 50 millimeter, and the welding was done. Just to physical verify, so, what was found out? Of course, to verify what exactly is happening and also you develop a theoretical model and see how much it is matching? So, here, you can see, it gives us almost 50 percent reduction of distortion, 50 percent reduction. This red line is deflection without water cooling that means, same plate geometry was welded without this cooling, and next it was welded same plate geometry another set with water cooling.

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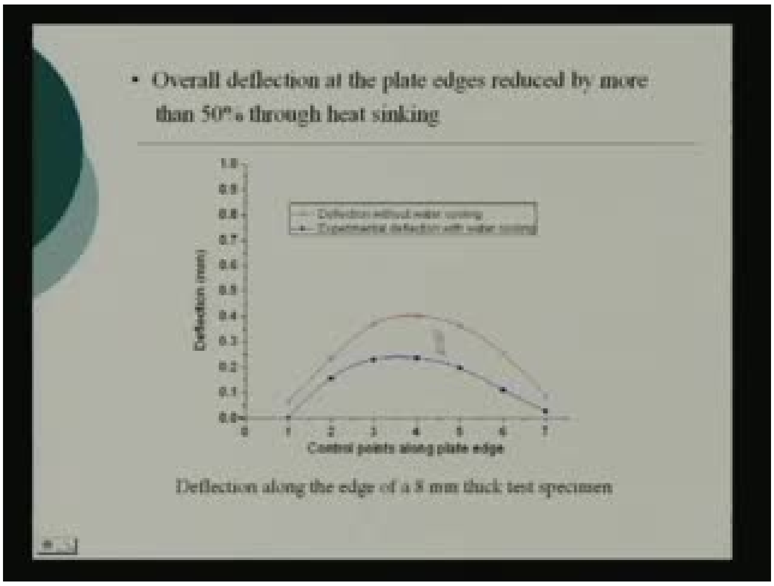

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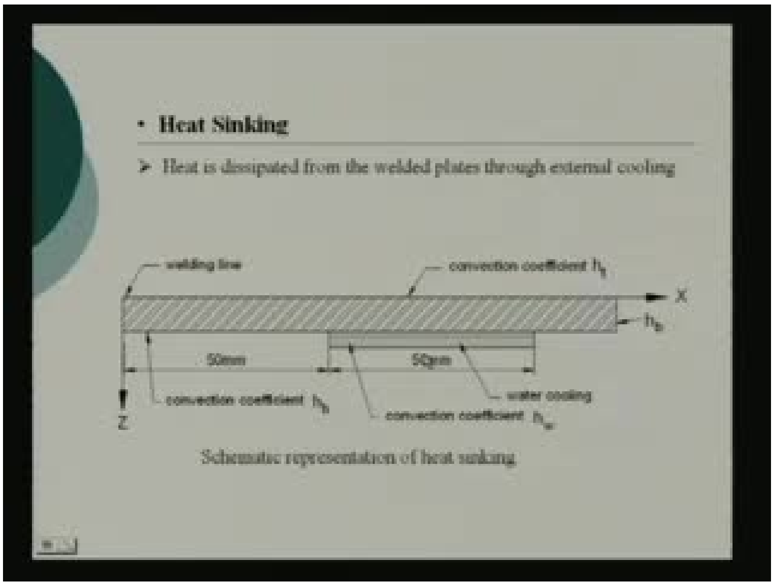

So, you can see there is a substantial drop in the distortion level. In this case, it was around 0.4 millimeter deflection. Here, it was roughly 0.2 millimeter deflection, very less, whatever, that is not important because that will depend on what thickness of plate, how much heat input. So, what is the deformation level but overall there is a 50 percent reduction in distortion. So, that way heat sinking as a method is quite effective.

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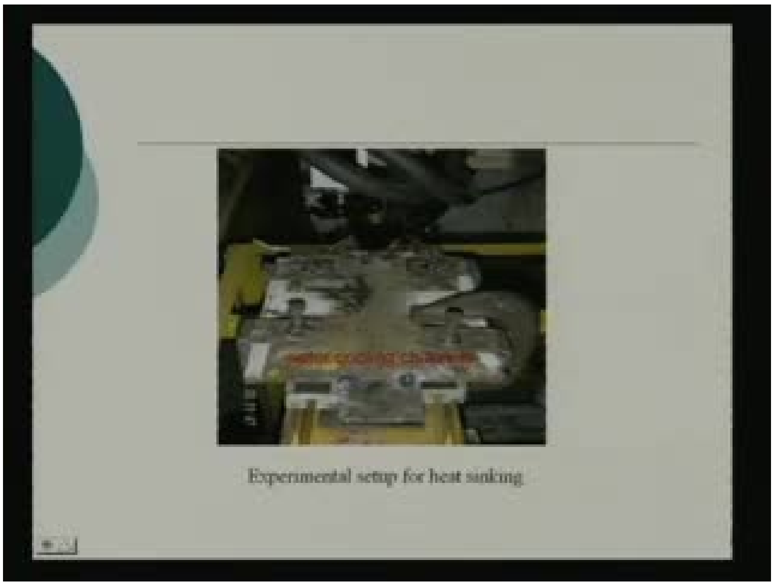

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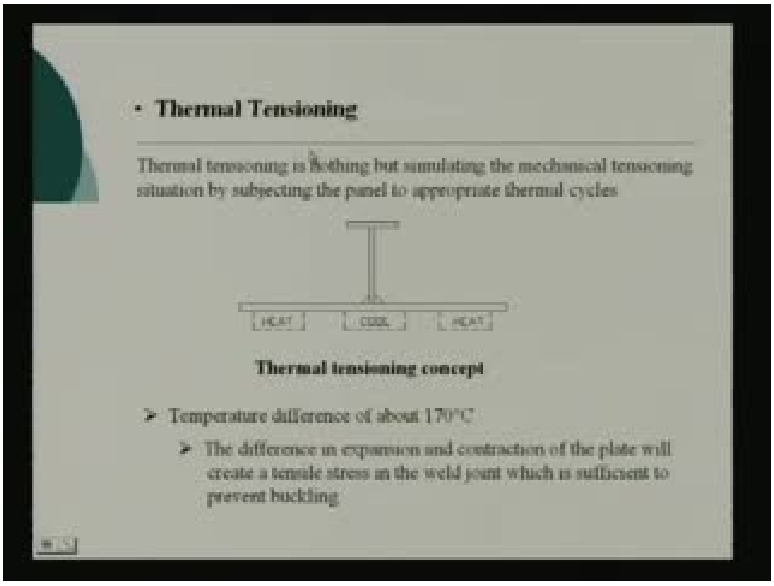

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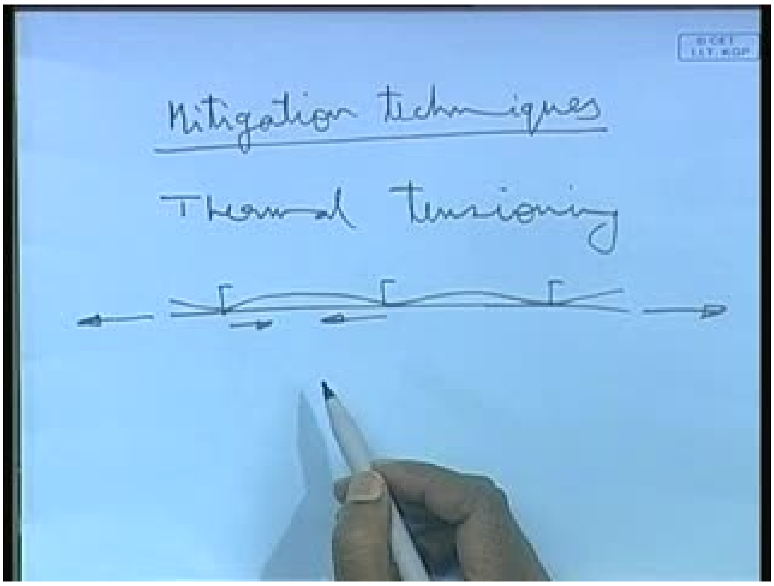

In fact in practice people, they have tried with keeping dry ice, just put dry ice on both the sides of the weld line, dry ice means solidified carbon dioxide and do that. So, what we felt because that again becomes little expensive, we will have to have dry ice, and there is a huge amount of welding will go on, so, you will have to that becomes, obviously, if one does the economics of what is the loss because of deformation and mitigating cost, etcetera, so, but oh one way similar simple arrangements can be made where in water can be channeled, put through channels below the plates. So, possibly this can be used in shipbuilding environment. Then there is another method of thermal tensioning. What is that thermal tensioning? Essentially you see, what we have seen is - when this is welded, apart from angular distortions, this is a buckling deformation, a buckling deformation is taking place.

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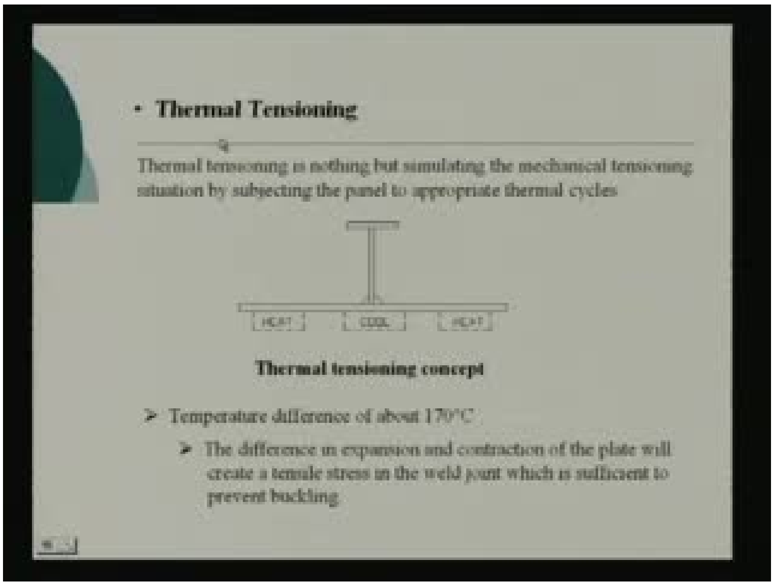

Now, buckling is because of what? Because of compressive force is developing. So, it causes buckling deformation. Now, if I could have a provided a tension, compressive forces are developing I provided tension. So, that will nullify the effect of the compression, so, deformation is reduced. Now, how to provide tension? Because, in, when the plates are being welded, or the stiffener being welded, they are huge. How you provide a tension, not very feasible. So, that is again done through thermal tensioning. Thermal tensioning means again by altering the heating pattern altering, the, rather the thermal pattern such that this effect of tensioning comes into play.

So, that is what is being done. This thermal tensioning is nothing but simulating the mechanical tensioning situation. If I could have at clamped the plates and give a put on the tension, mechanical tensioning, so, how it is done? In this way, for the fillet welding is being done on the top, s,o bottom part, you provide a cooling, and on the sides, you heat it. So, that gives a resulting effect of tension. The difference in expansion and contraction of the plate will create a tensile stress in the weld joint which is sufficient to prevent buckling, but again it has again not very, I mean these are theoretically feasible but practically it has other difficulties.

Now you have additional problem of you will have to provide some heating, again simultaneously cooling. Inside heating, it was only additional heating. In heat sinking, it was only cooling. Now, you have both, plus not only that you are cooling it, just below the weld where welding is being done. So, you run the risk of damaging, quenching this part of the plate. If it is a thinner plates and thinner plates are more prone to buckling. When you weld 6 millimeter 8 millimeter plates, they are more prone to buckling, and this thermal tension is good for preventing buckling.

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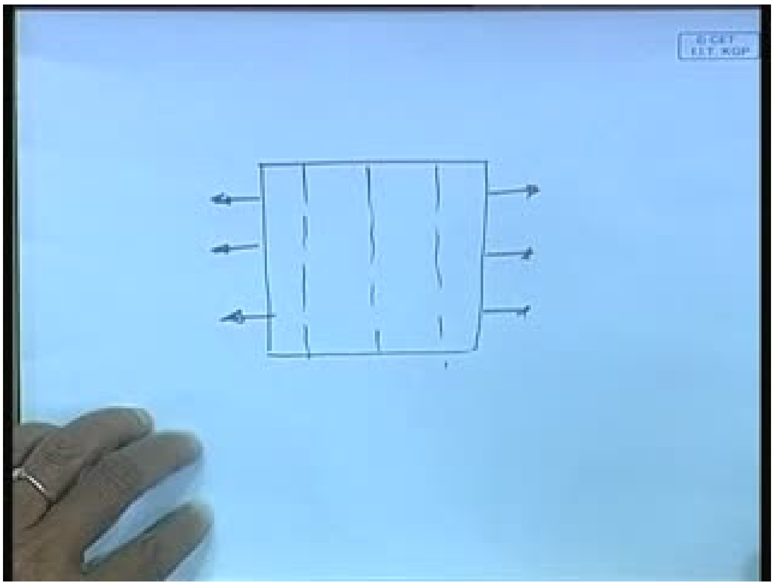

Now what will happen when it is only a 6 millimeter plate? So, it is likely that the bottom part of the plate also will have a high temperature. High temperature means beyond re-crystallization temperature, so, if you cool that, you run the risk of changing the micro structure, hardening the plate there, so, it is not a good method, and the simple method of tensioning is that is a very wise solution one can say it is like this. You have the plate; say the stiffeners are to be welded in this direction. So, what happens? If I can, so, it tends to buckle in this plane.

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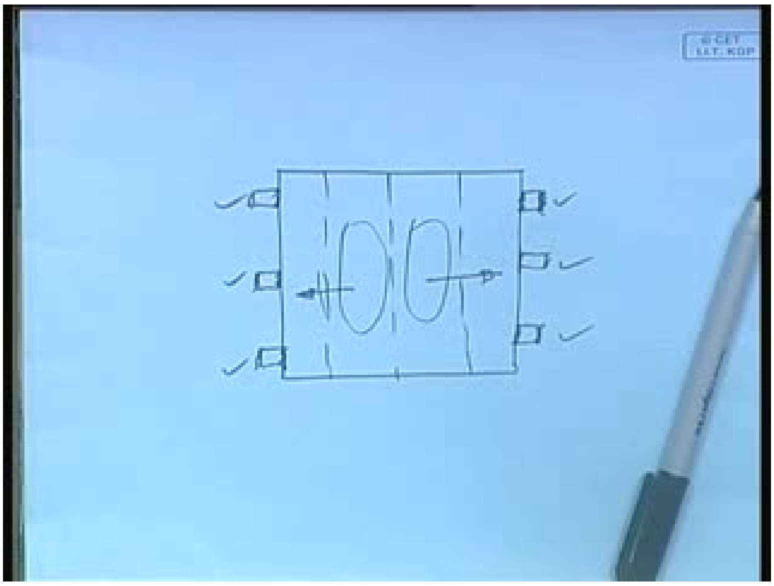

So, we can provide a tension force, then this buckling will be prevented. So, what is done is you have the plate, you make arrangements such that I can weld, let me draw another same situation. The stiffeners will be welded along these lines, say these are my markings for the stiffeners to be welded. So, I put the plate, and then, at locations, I weld certain lugs. With the skid, again it is a flat horizontal skid, over which it is placed. So, such lugs are welded. What I do just before welding? These are small lugs; before welding, I heat up the lugs. They are hot, and then I weld it. When it is still hot, I weld it.

So, what basically I am doing? It has to be done kind of in a proper sequence that means one side you have welded it to the plate. Before welding, the other side to the fixed structure, I heat it up, heat up the lug only, and then weld it. What I am basically doing? When I am heating it up, it is expanding and I am welding it. When it will cool down, it will contract, it will put the plate in tension, it will put sufficient tension force, so as to mitigate the effect of buckling here.

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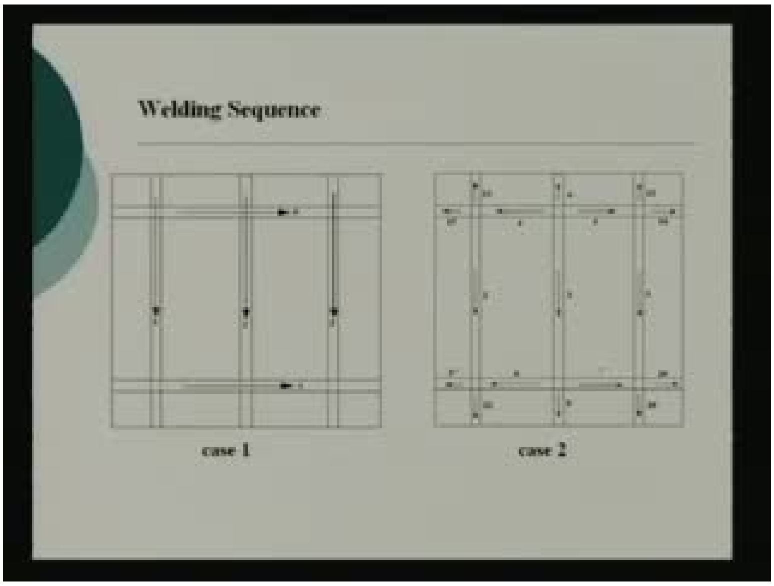

See, these are very simple technique but have to be done, I mean in a proper logical fashion. Depending on the size of the structure number of lugs, the dimension of the lugs, welded, heat it up, and then, weld it. When it is cools down, automatically it is putting in tension. So, one side first I weld it, other side only I heat up and weld. So, these are the distortion mitigation techniques. Well, in the next class, little bit we will see in the welding sequence.