Marine Construction & Welding

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Module No. # 01
Lecture No. # 24
Line Heating

Well, today, we will start with the, I mean in continuation with plate and plate forming as well as forming of sections. In continuation with that we will talk about line heating. The basic, the basics of this or the mechanism of this, we have talked about in the last class. It is basically the part of that thermal forming of plates and sections.

So, we have seen how, because of certain heating, how the things, I mean there is a dimensional change that takes place. We have seen in that simple experiment of a small cube being heated uniformly. In one case, it was clamped; in another case, it was lying free. So, we have seen the clamped one showed some dimensional change, so, that principle, that mechanism is used to basically deform plates to our requirement to deform frames to our requirement; that means in other words, for the purpose of forming, bending of the plates.

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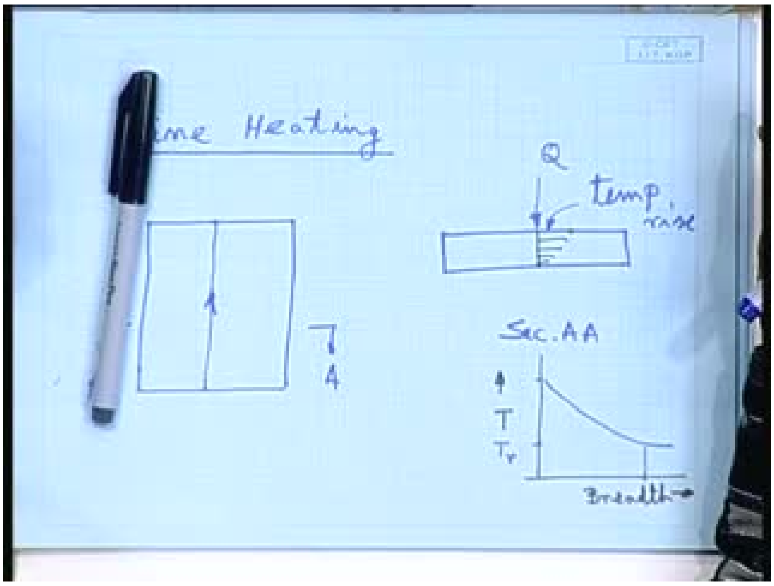

So, what happens is the technique is referred to as line heating, means heating along a line. That is how this thing has come line heating. Let us see how, that by this technique we achieve plate bending, say this is one plate, and if you see the cross section here, along this, let me draw it here. So, this is the section A A of any plate, and now, if I heat along this line, let us assume along the central line I am heating it, heating it means what? I am basically passing a moving, I am passing a heat source, say a oxide still inflamed, a torch having oxyacetylene flame or a laser beam or some induction heating, sort of induction heating head keeping it here and moving it. So, what I will attain, that means here I am putting in some heat Q; as I am putting in heat here, what this will result in? This will result in some temperature rise on the surface. There will be a temperature rise will take place, and along the thickness, there will be a temperature gradient.

If I assume the temperature on the surface is up to this much, temperature little below will be here and so on. It will be somewhat like this. At different level, you will have different temperature; that means temperature will eventually will come down. So, what we will obtain is a temperature gradient on the plate.

Now, I have shown that this much temperature means what I am showing? What I am trying to tell you is that over the entire surface, there will be a temperature distribution. So, if I plot that, this is my breadth, breadth of the plate, and this is my temperature. So, at the centerline just below the heat source I will have the maximum temperature and it will gradually - it will be less, it will gradually come down, and beyond a certain point, it will be the room temperature, say temperature, room temperature, or in other words, a part of the plate, a part of the plate only will be affected by that heat source; that means there will be feasible temperature rise only on a part of the plate; the rest part of the plate will remain as if cold.

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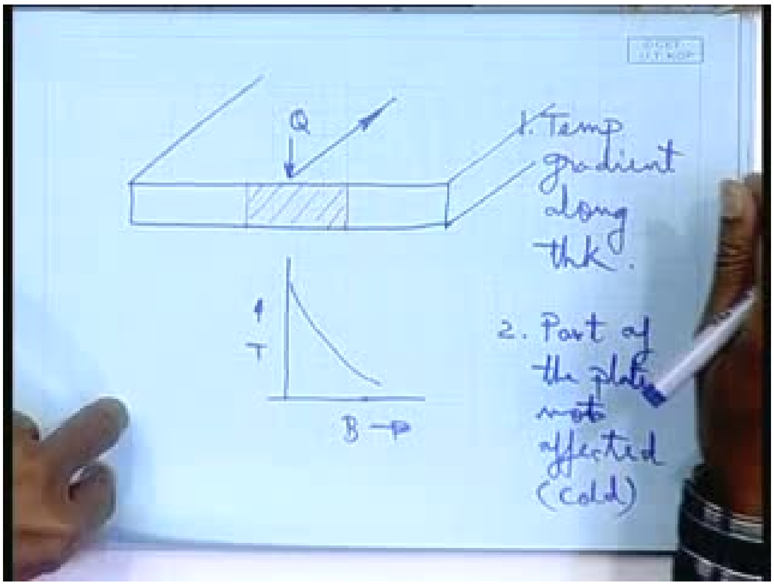

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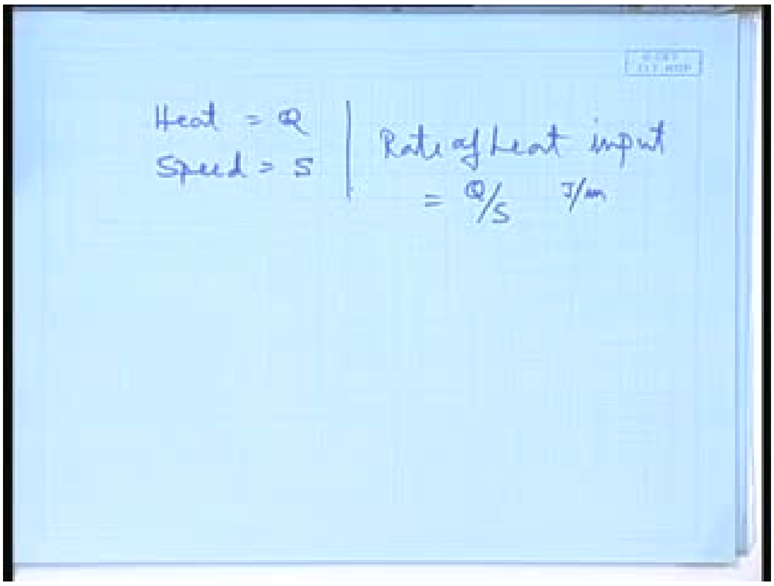

So, if we look at it once again in a little enlarged form, I am giving heat here. So, as if a part of the plate is only getting affected; that means there is a visible temperature rise only in this part and that too that temperature rise is changing from here to, it is coming down, as I am going along this. As well as, as well as in the thickness direction also, it will be decreasing.

So, from this we are getting one aspect, that is, there will be a temperature gradient along thickness. 2. What we are getting? Part of the plate is remaining cold, part of the plate not affected, or in other words, remaining cold, because depending on the amount of heat we have put, depending upon the speed of movement, because this heat source will move along the, it will move. So, depending on the, that means that the parameters here we are having is the heat, that is Q, and speed, say that is S.

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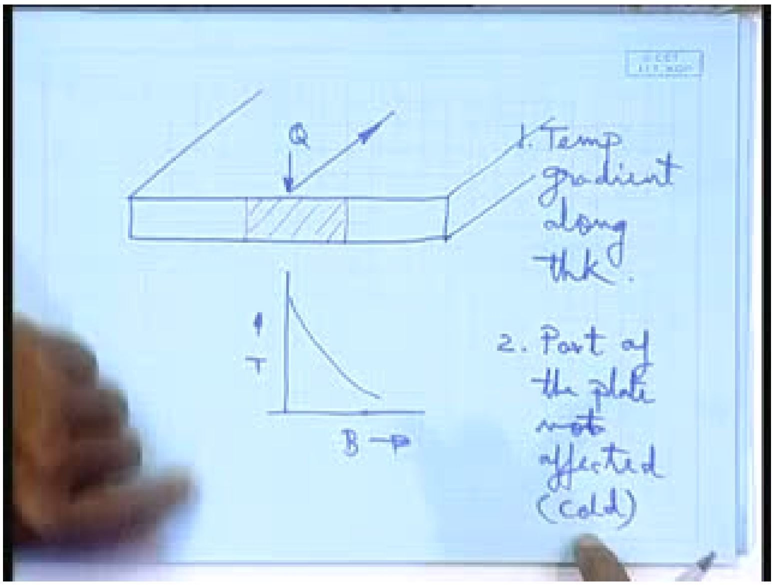

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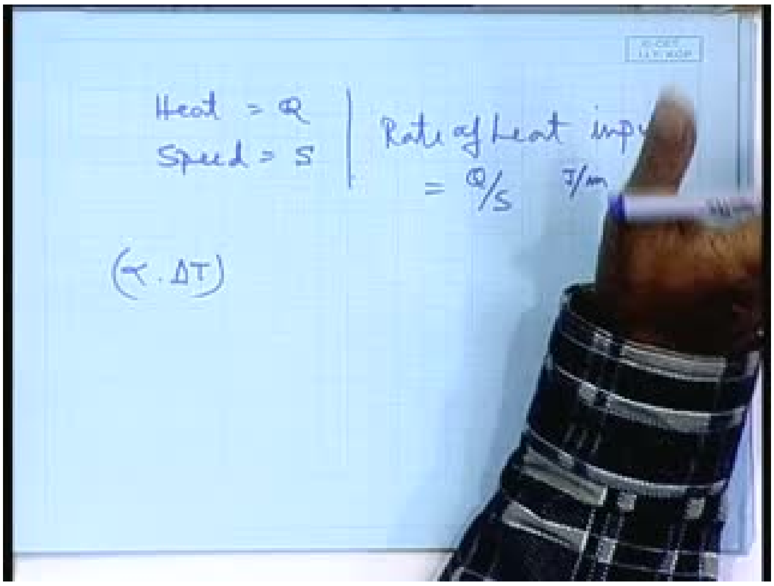

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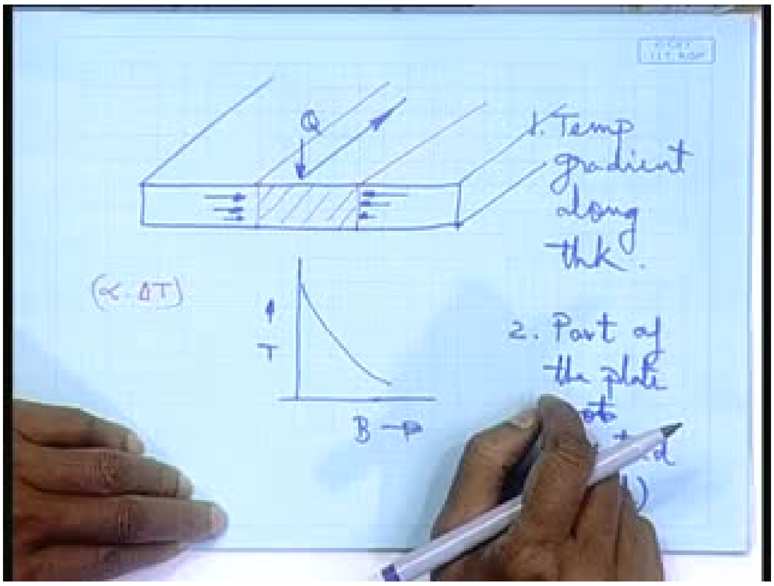

So, we have a rate of heat input as Q by S, so many joule per, say meter. So, depending on the amount of Q and the speed, it is moving. We will have a part of the plate only is getting affected; means there is a rest part of the plate is remaining cold, remaining cold. So, what is happening? The part of the plate which is getting heated up, there we will have the so called effect of alpha into delta T, is not it? What is that? That is what is the thermal expansion; rest of the plate is remaining cold; so, that is not expanding.

If I assume that only this red part as we have drawn here is affected by the heat; means is contributing towards this alpha delta T; that means it is undergoing some expansion because of heating, and rest is not affected, not only that because there the temperature rise is very insignificant, delta T is very small, if not 0, because further away it will be 0, because it will remain at room temperature. As you go closer to this red zone, there might be some temperature rise you may feel but delta T is very negligible

So, we may conclude that a part of the plate along which the heating is being done. A neighboring part of the plate along in the heating zone is subjected to kind some kind of thermal expansion. Whereas, the rest part is remaining cold, not expanding. So, what it is doing? Rest part of the plate is acting like a vice that analogy is coming; that means the cold part of the plate is not allowing, the, this part to expand. So, in the process, your compressive thermal forces are generated, compressive thermal forces are generated.

And then again you may recall, we talked that there will be thermal forces will be generated the plate is hot, so, there is a less, what you call, the elastic limit has got lowered, yield point stress is reduced, and then, your, it will be a undergoing automatic, it will be also undergoing so called contraction. So, all these things will be happening to this zone which is sort of getting affected due to the heat.

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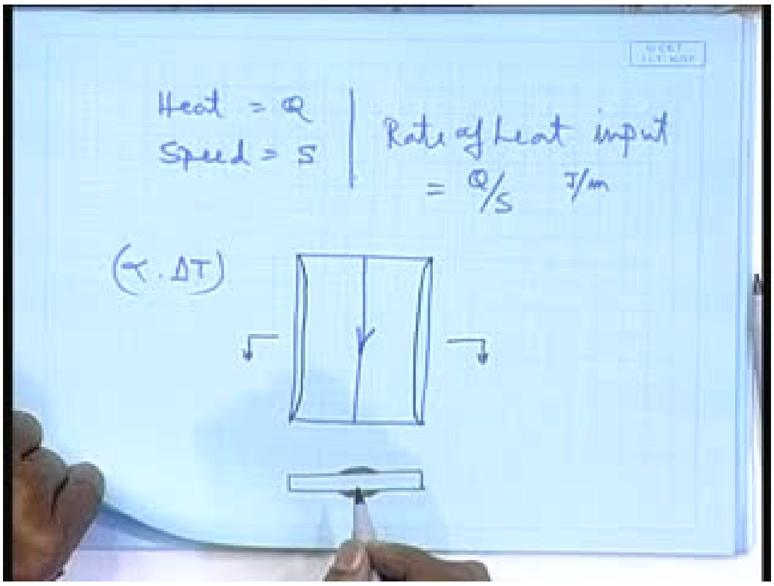

So, what will happen? One of the aspect will happen is it will be shrunk; that means if the plate was like this, so, once I heat it along a centerline direction, so, there is a possibility that after it is done, I measure the dimensions of the plate. I may find that the plate boundary has become like this, it was shrunk. If it has shrunk, where is the material has gone in that heated zone? The heated zone has become fatter; that means if I look a take a cross section here, we will find that the plate thickness has increased, plate thickness has increased.

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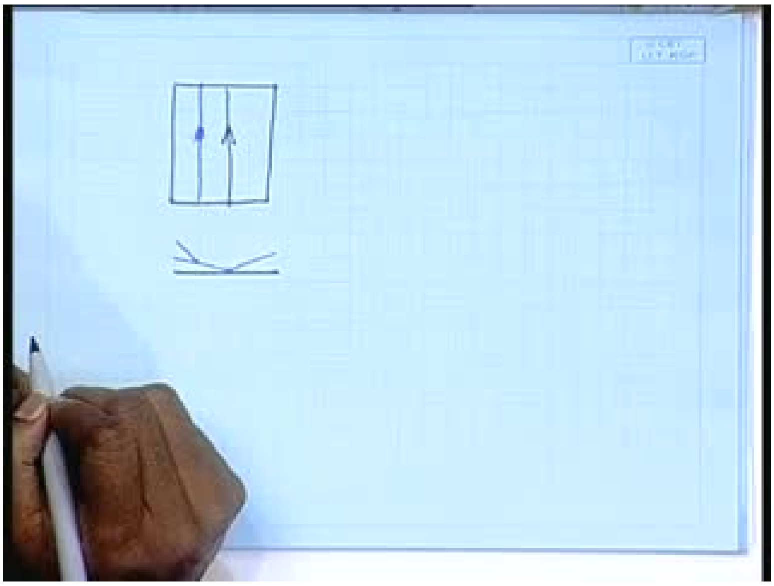

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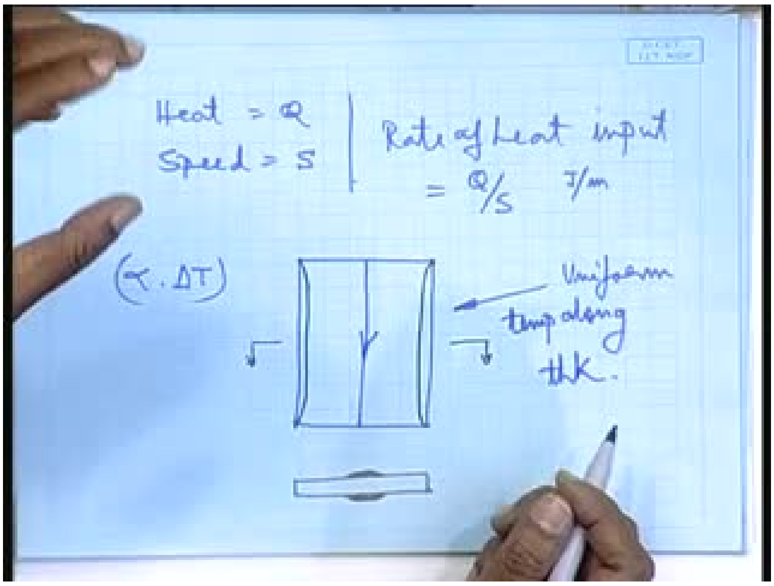

So, this is one possibility we may observe. What is the another possibility you may observe? That is, if we heat the plate along, say centerline, I am now drawing with a single line. The originally the plate was like this, flat, and now, after heating, it has become like this; it is bent, it is bent. Now, you can well imagine, if I heat along this line, it may further bent .

So, we will come to that. So, first we said that we may observe that it has shrunk. Why it is shrinking that is well understood. That is shrinkage forces are developed, so, it is getting that offsetting effect. As if I am forging it along the breadth, so, it has become narrow.

Now, why I have drawn like this? It is demeaning at 0 somewhat, because the shrinkage forces were nominal there at the starting point, were much less. Then gradually it increased to maximum, then it continued to be the uniform, again it has tapered down to 0; that is why I have drawn like this.

Well, this will happen provided, this will be the case when there is no temperature gradient along the thickness. This will happen when there is a uniform temperature, uniform temperature along thickness; that means there is no temperature gradient, then only this situation will takes place, but for all practical purpose, whenever we are talking about plates having certain thickness 6 millimeter, 10 millimeter, 20 millimeter.

So, there, what will happen? If I take really a thin plate 2 millimeter and heat it, possibly the temperature at the surface and the below, we can attain very quickly same temperature depending with the speed of movement. If I limit my speed of movement, if I reduce my speed of moment, give sufficient time for the heat to conduct.

So, the temperature rise will be there both at the surface as well as at the bottom and you will have a uniform temperature distribution along the thickness. If that happens, then it will shrink only, but if I move it very fast, do not allow enough time to heat for the heat to penetrate, or if the thickness is more and the speed of movement is such that heat penetration is there, but still there is a temperature gradient along the thickness. Then, you will have this effect; it will bend, why it will bend? Because what will happen in that case, when there is a temperature gradient along the thickness?

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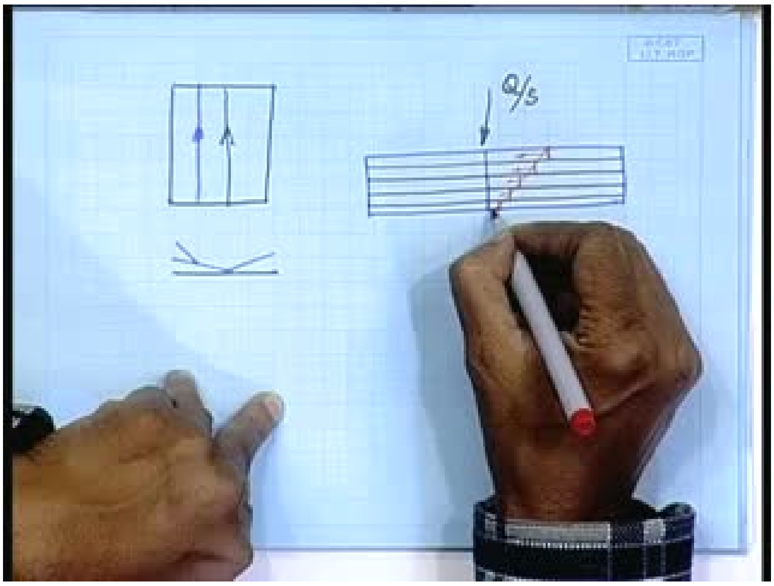

I am drawing it little thicker along the thickness there is a temperature gradient. If it is there, let us assume that the plate is made up of various, I mean made up of various thin layers, or in other words, we consider the plate, we discretize the plate thickness in several thin layers, and we said that if the plate was thin, I could have attained the same temperature both of the surface and the bottom.

So, now, again, the, this I apply my heat at a certain rate, the heat is moving continuously. So, what will happen? I can presume the thickness is sufficiently small to presume that is certainly, I mean the maximum temperature, the each layer attaining is represented in this way; that means this is attained this much; the next one is attaining this much, and so forth .

Or in other words, I am simply assuming that the topmost layer, the top of the layer and the bottom of the topmost layer having the same temperature. Just below that, this top and bottom having same temperature, there is a fallacy, this cannot happen. It will be actually a continuous phenomena, but for our understanding, let us assume, if I assume that this and this are they are delinked, so, it may take some such situation, that means top layer has this much of temperature this and so and so forth. So, this dimension you can see they are faring.

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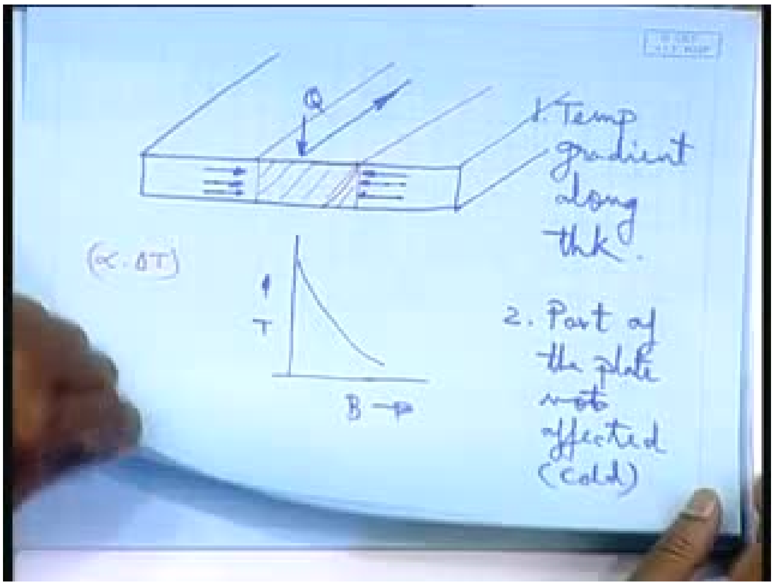

So, the component of that alpha delta T in all these, this thing will be different. Alpha delta T into the length, that length is changing, that is number 1, and because of that, what will happen? The compressive stresses that, that will develop will also be of varying magnitude. Compressive stresses will be of varying magnitude. As you go down from the top surface to the bottom, because at the surface, the heat flow was maximum, bottom it was gradually decreasing.

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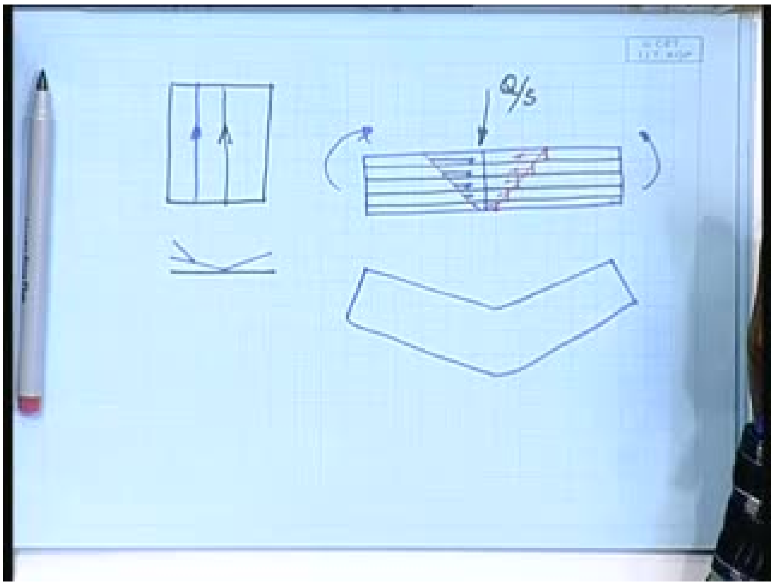

Here we draw a uniform. If it is uniform, then obviously the compressive stresses also will be uniform. Now, when we have a, when the heated zone is varying, then the compressive stresses also will be, you will have maximum at the top and gradually decreasing. If that happens, then again if we assume they are individually working. So, this kind of stress distribution or the compressive force distribution cumulatively will generate a couple, is not it?

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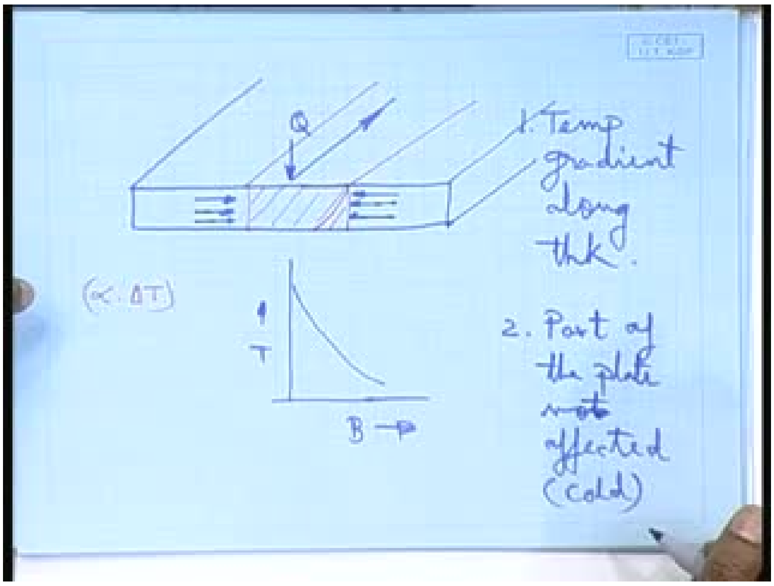

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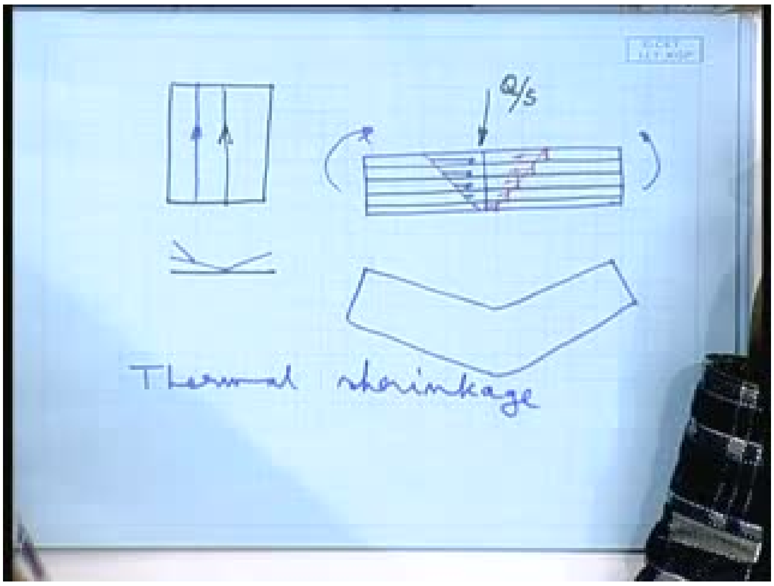

If a plate is subjected to this kind of loading, a couple is formed; so, it will bend, so, it will bend. That is how it bends; when you heat it, it bends, because we will have to achieve these two conditions; that means there should be a temperature gradient along the thickness which automatically forms, and also part of the plate should not get affected by the heat; that means should remain cold, should give that so called clamping effect, then only the compressive stresses will develop.

So, this is referred to as shrinkage, thermal shrinkage is taking place, and once thermal shrinkage, there is a differential thermal shrink is taking place; more at the top, less at the bottom.

So, once there is more at the top and less at the bottom, then automatically a couple forms a bending movement comes in to picture and that leads to bending of the plate. So, that is how the plate is bent.

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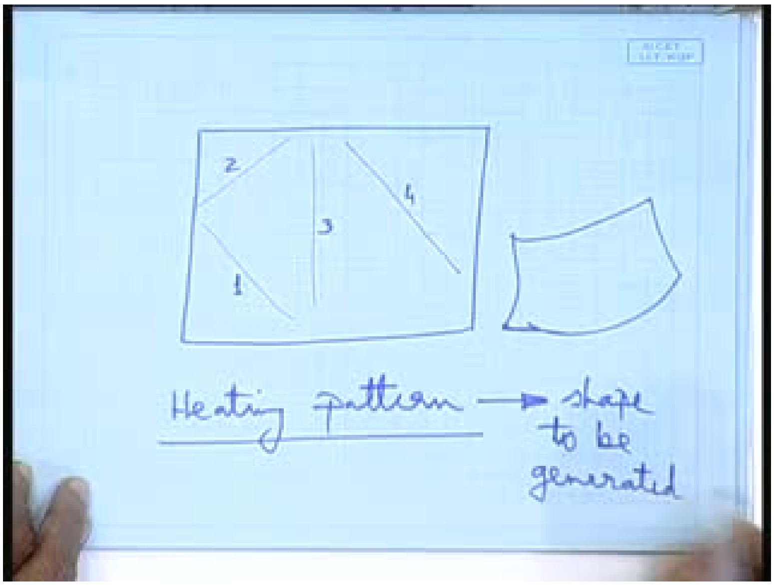

So, now you have a plate and apply this heating, say along this line I heat. So, what will happen? This corner part will come up. Then, suppose, I apply along this, this corner will up; this will come up, this part will not come up because this is heavier, this will come up and so and so forth. (Refer Slide Time: 21:27) Then, suppose I heat this way, then these two have bent like this and the whole thing bends; that means the way I want to, if I do this, then this much bends and so forth.

So, the point is that means if I can correlate that what shape is needed, I mean correlate the pattern of heating lines to the desired shape, then I can generate that shape means, here I have just arbitrarily shown that this this was my first heating line, this was my second, third, fourth, so, it has generated a arbitrary shape.

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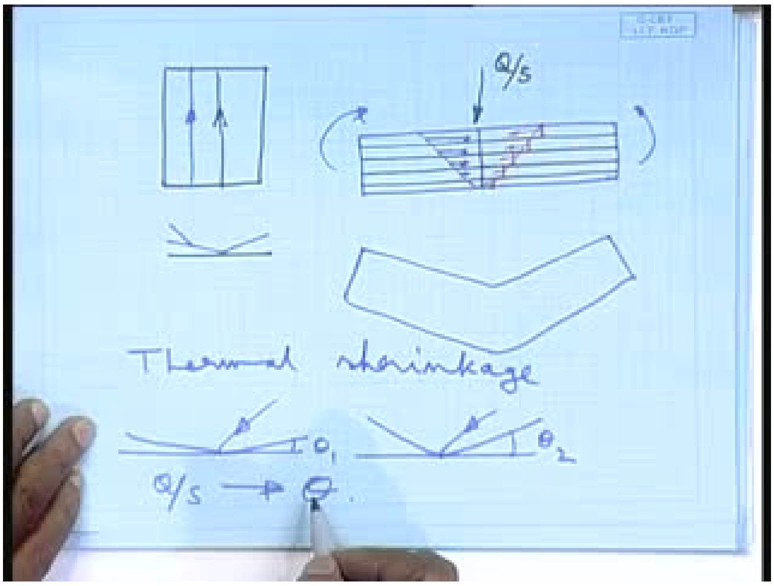

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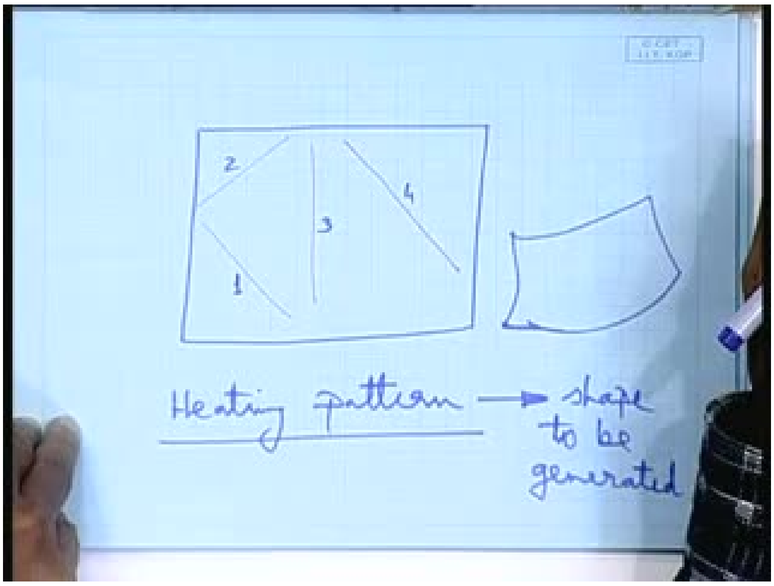

But now if I would have had a mechanism of estimating, I mean mechanism of correlating the heating pattern, heating pattern to the shape to be generated; means we have to do two things - one is each heating line what kind of deformation it gives because here we are saying that I have heated through this, it has bent like this.

Now, this bending whether, well, let us draw once again. If it is this much or if it is this much, these two are different, say, the same plate. Here I have done some heating, here I have done some other heating or whatever; that means I should know that how much is this angle theta; that means some correlation of Q by S to this angle of deformation that has to be established. That, that, that, that actually has to be seen whether more Q by S will lead to more theta or not? That may lead to more theta but how much magnitude has to be known and where is the limiting condition? If I go on increasing Q by S, whether it will go on increasing theta, all those things are to be seen, because go on increasing Q by S also we will have effect of I will have, those are the limiting things we will talk little later.

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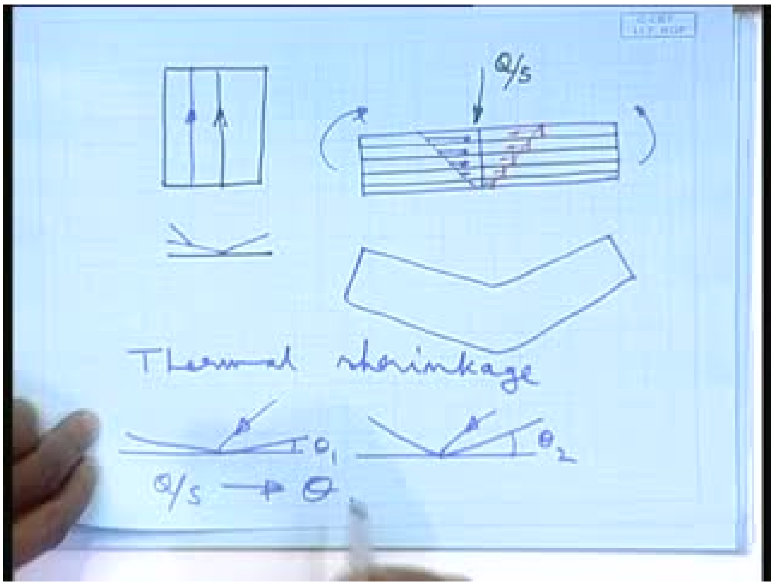

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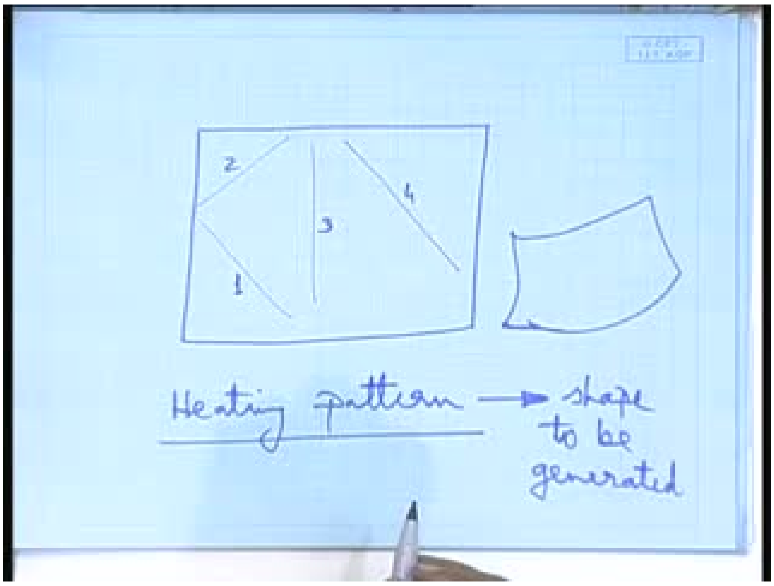

So, heating pattern, so, essentially what we need is that, that we will have to correlate that how much heat is to be, how much heat generates what kind of deformation? Second - what should be the pattern of heating, such that, I get the desired shape? In the first case, it was simple that I have just applied heat and the plate bent like this, a v kind of shape came.

Now, if I again heat here, heat there and so on, then a cylindrical kind of shape will come, but no point making a cylindrical shape through line heating that I can do much easier in a rolling machine. So, here, we will talk about only those shapes which are difficult to generate means, double curved shapes, those patches which are having double curvature all.

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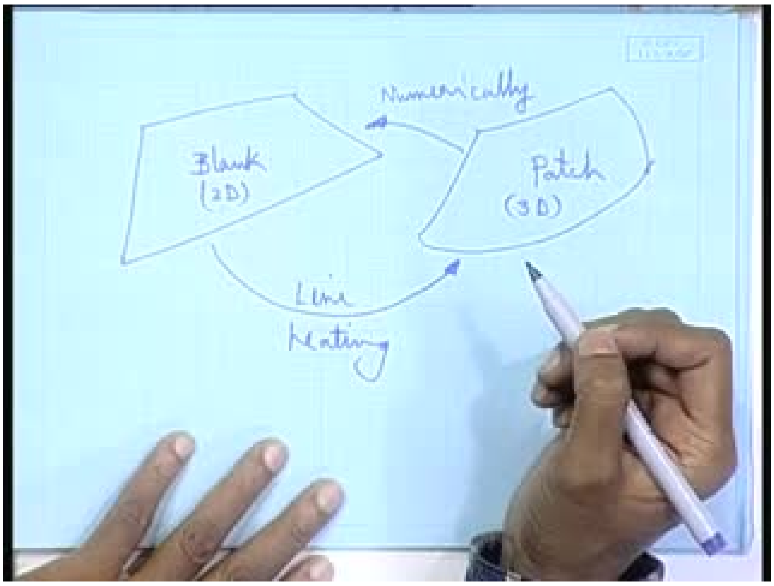

So, there we need to essentially establish the heating pattern such that it conforms to the desired patch. So, how it is done? Once again the same thing like, suppose, well, I mean some arbitrarily I am drawing, say this is my blank, this is the patch.

So, from the patch, I have generated the blank. Again from the blank, this patch is to be generated. This has been done numerically means patch is there already generated by the hull designer. Whoever has generated the hull form, he has given me this information. He generate the hull form, he has described the welding lines, so, one particular patch suppose, I will have to develop it.

So, I have the all x y z co-ordinates of this patch. So, have a numerical way of doing it to get to the 2 D shape. This is my 3 D and this is 2 D, 2 dimensional flat shape. So, I have got this, I got a cut from the steel plate. Now, to this, I am applying line heating. This technique is referred to as line heating, why? Because the heating is done along the line, certain pre-determined lines, that pre-determined line is the pattern of heating.

So, that to get to this patch, I have to find out this heating pattern. Once I know the heating pattern, I apply that heating pattern there can be 10 lines of heating or 40 lines of heating, depending on what shape.

Sir these lines can be curves also

It can be anything, but generally we try keep in straight line heating. A straight line heating wherever we can find out. So, so, important is to get to the heating pattern; so, this line heating I will apply, I will get that patch. So, how do we get that? Essentially, from the patch when you are coming to the blank, what we are doing? We are taking out the strain which has been imparted in this blank, because I told you when it is a doubly curved plate, so, from a flat plate, when you want to make a doubly curved plate, you have to apply strain in it, plate has to be stretched. So, there will be a strength distribution was given to this where we got this patch.

So, when from the patch I am going back to blank, as if I am extracting the strengths. So, I am finding out the strength distribution. What was there in this? If we can find that out, this distribution of the strength, so then I know that how to generate that strength distribution. So, I know I will find out the principles, I mean out of the strength distribution, the line of the principle strengths.

So, where ever you have the maximum strength, a line perpendicular to that will be the heating, heating line, because when I heat it perpendicular to that, it bends. So, if can find out the strength distribution, from that I will be able to find out the heating pattern. It is, I mean there is a philosophy, it is not very easy but that is how you will have to work on.

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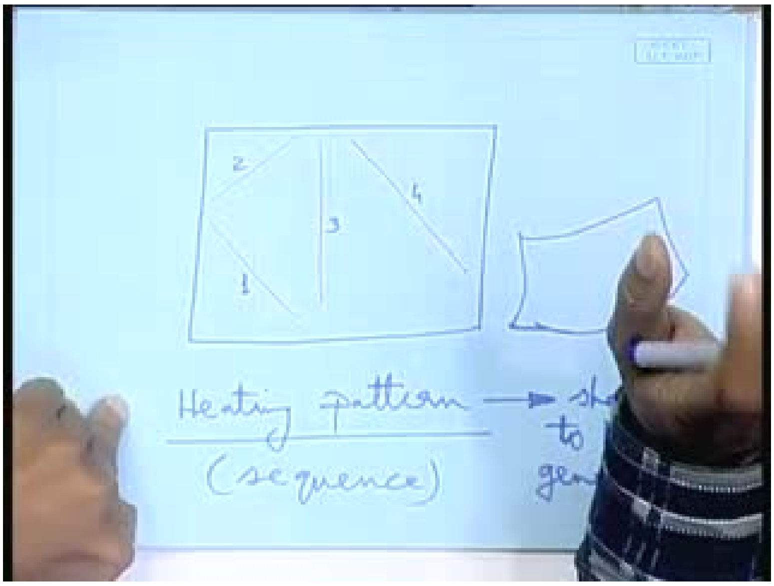

So, from the strength distribution, we will get to the heating pattern. How that we will identify the maximum strengths, distribution of the maximum strengths? And we will fit a line perpendicular to those maximum strengths. So, there will be several lines because strength, it will have a very peculiar distribution, because the shape is quite, I mean a doubly curved shape and it can have any shape right. So, once we do that, then I know the actual distribution of my heating lines or in other words the heating pattern.

So, once I know that heating pattern, then job becomes absolutely easy means, I will have to only move a heating torch as per the sequence given. It is not only important to know the heating pattern but also that heating pattern also involves this sequence of heating, not only the magnitude of heating, speed of heating but also sequence of heating. Whether I will first heat at the position 3 or we first heat at the position 1, all these are to be worked out.

Sir if accidently more bending was done then

It tends to reverse

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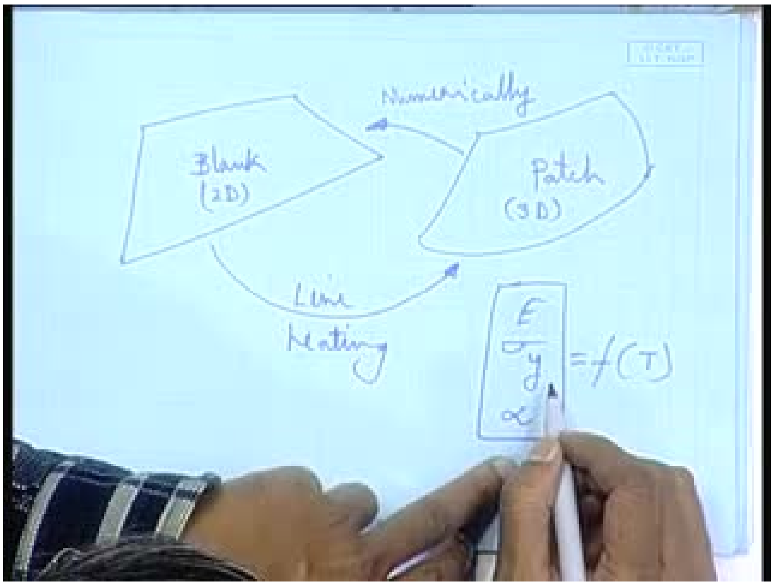

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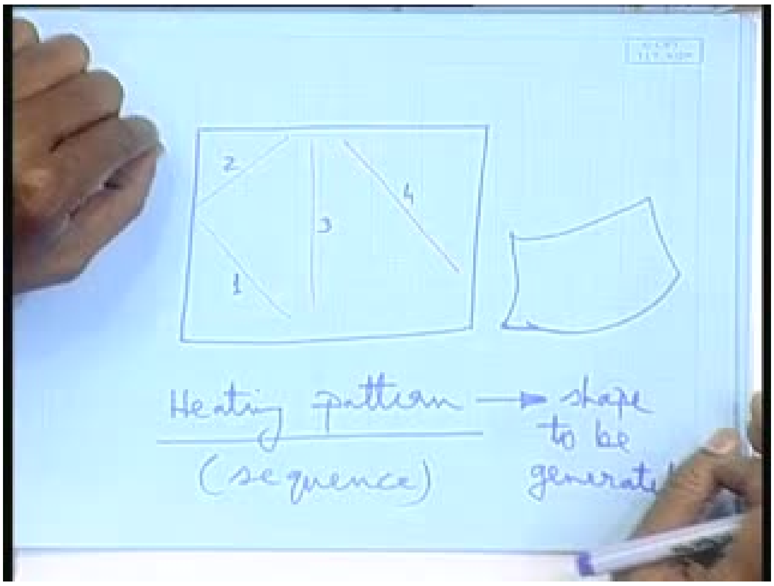

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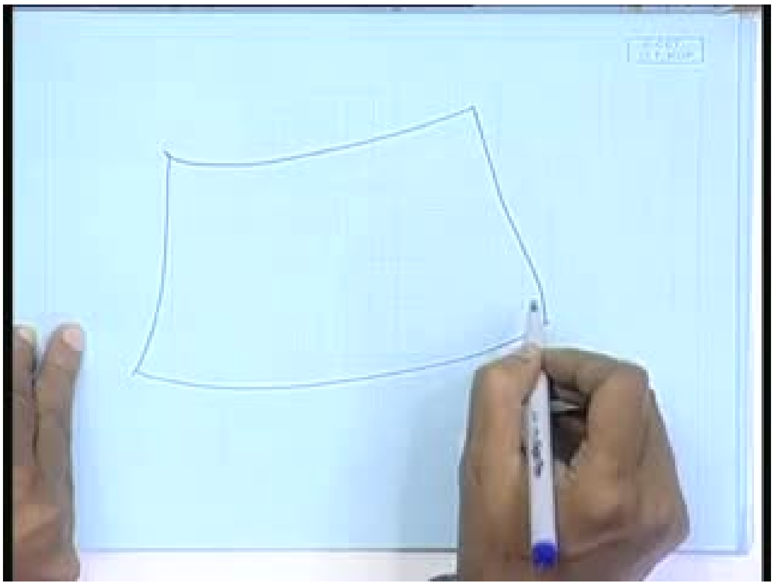

So, well, we will come to that, so, what is happening here that I know that if I can generate the necessary strength distribution within this through heating, I get this patch. Again all those calculations are based on, again all those parameters of modulus of elasticity, yield stress, coefficient of thermal expansion, all these things, again all these things are function of temperature.

They are function of temperature, not only that, they are also, I mean plate dependent, I mean they are not unique values. They are as we talked about that spring back, spring back action; they are within a range. So, which value you take will again have a effect on the entire calculation or the strength distribution.

So, once we got the heating pattern, we implement the heating by well moving the heating torch like we move the cutting torch in the same fashion and you get the bent ship. Now, the question comes of monitoring, how do you check? Whether it has really matched that desired surface? Whether it is matched a desired patch?

Now, again if you go back to template, that will not be worthwhile. So, here the checking would be well again scanning by laser beam. Here checking is little easier, in, in that sense, because I have the entire plate visible.

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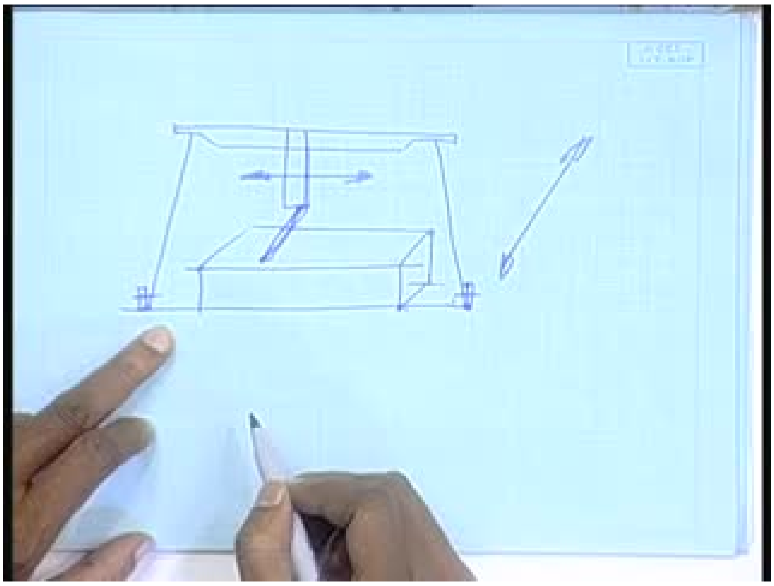

Once that heating device that could be a gantry mounted heating torch like in plate cutting, the plate cutting machine is what, it is somewhat like this schematically, and say, I mean here, here you have the cutting table. This is moving on wheels; this is whole gantry is moving on wheels along this axis and this can move along this axis, say this is my cutting torch. So, it can move the cover the entire this cubic space, entire this square space the cutting table, is not it? Over this table, it can move.

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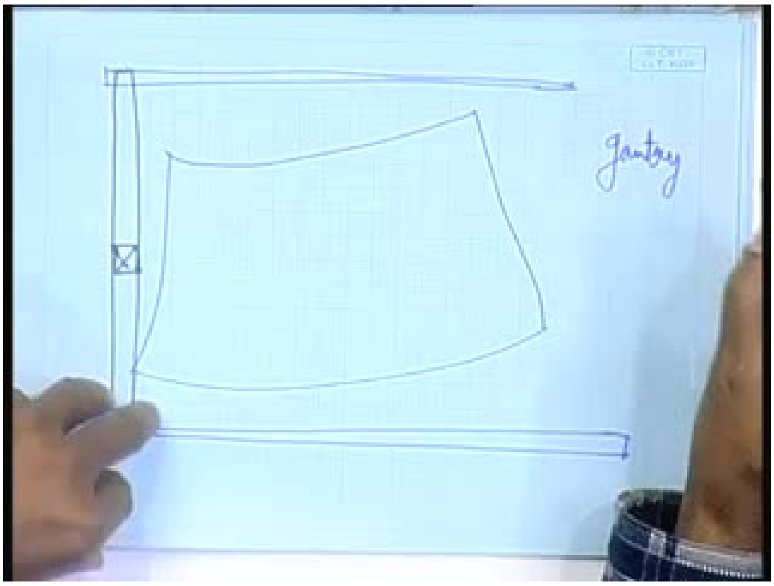

So, same thing, in this gantry, I hang a heating torch which can move in whatever direction you describe to move, it will go on moving and go on heating it. So, thereby I can generate there shape. Now, once that is generated, you move the thing away, move it out; means here you have the along the rails, suppose this is moving, this have the both side rails are there and you have moved it out. This is my heating gantry.

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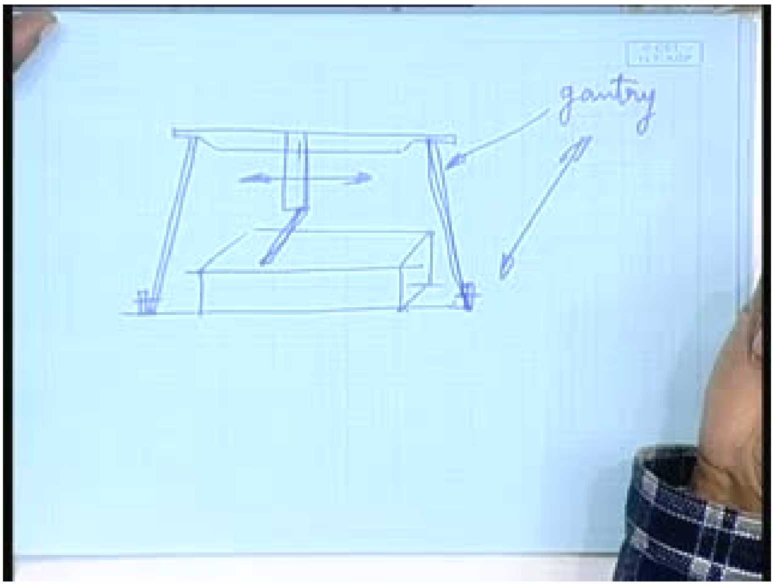

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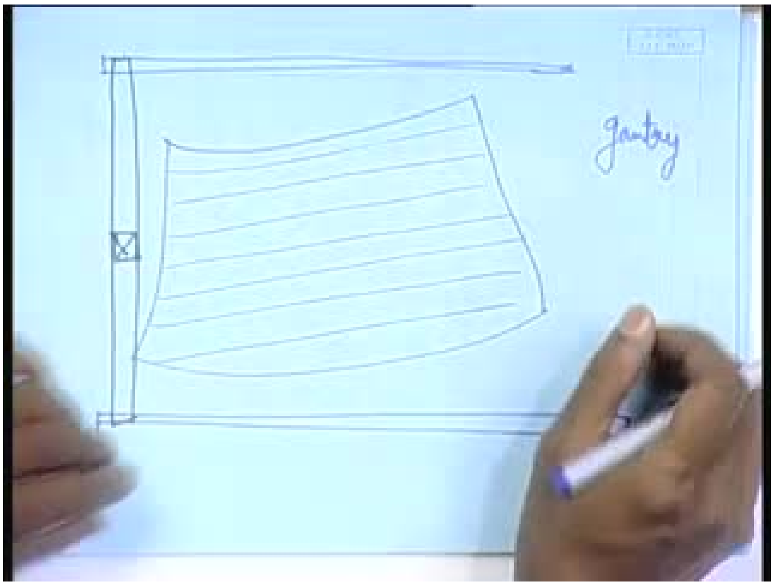

They are called gantry. This kind of structure, this kind of structure is refer to as gang tree. If there is lifting head, we call it gantry crane, we call it gantry crane. So, the, I take the gantry out, you have the entire plate visible. So, on top, I can have a camera located, or a laser source located which can very comfortably which can scan the entire plate. It can do the scanning of the entire plate and thereby capture the necessary coordinates. If it is, if the x y co-ordinates are well defined, it only tells the z co-ordinates. So, you correlate with that, you generate the 3 D surface correlate with the given surface.

That is how one can here the checking. In the case of frame bending, we had been talking about checking was difficult because the frame is getting covered by the machine. Otherwise, I will have to take it out from the machine, scan it, again put it back. The work is becomes complicated, but here, once the whole runs off this heating is given, so, it comes out the entire plate is visible, it scan it, or sort of, anyway, whatever monitoring device, through that you can observe it and compare with the, numerically compare with the given surface the patch.

So, there we will see whether it has been over bent or has remained under bent. Whatever it has happened, we will check and one can find out what needs to be done. If it is has to be straightened, then it is little difficult. You will have to probably turn the plate, but if it is under bent, further bending is to be given. So, new set of heating lines are to be again generated. So, based on that comparison, a new set of heating line, if required will be generated, again you apply that heating.

So, eventually get the bent ship that is how it is done. So, here, what you see, this method is quite sort of seems to be quite promising from that point of view. because we had been all through looking for methods, by which you can automate the process, specially plate banding because say otherwise a very tedious and skill dependent.

Now, the skill has been transfer to a machine; that means the whole skill has been converted to a some computer code through each which generate the heating pattern, and based on that, the heating torch is moved. So, we need just a operator. Who did not understand all these? You can only operate switch on, switch off the thing. So, it has becomes skill independent.

And the moment it becomes skill independent, well, then not only you depend on a skilled employee but also one can probably improve productivity and improve the consistency of the quality. The same quality product will be produced, whatever level that same level can be maintained because what is important is consistency of quality. Since it is becoming impendent of a human skill, it can achieve a constant consistency.

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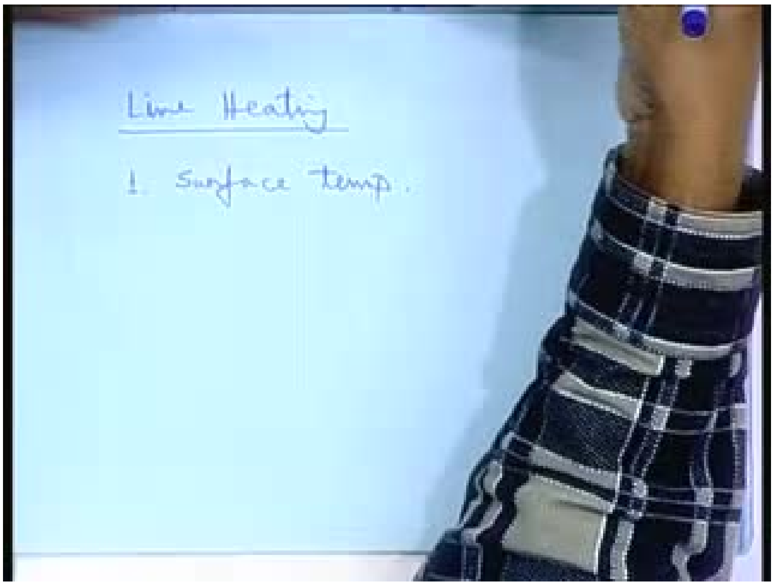

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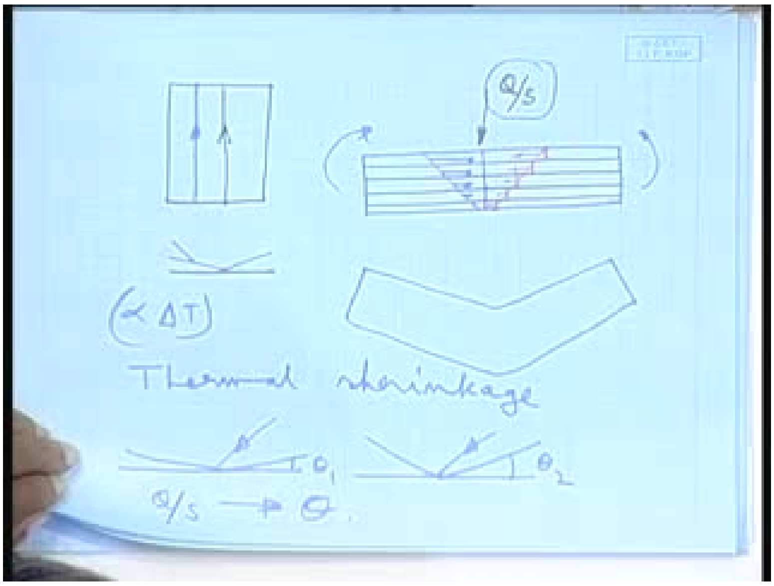

So, so, in this process, what are the then so called perceval aspects coming in this, that is, one would be the surface temperature, because depending on what surface temperature your attaining, in fact, that will lead to what temperature you are attaining at the bottom means, how much heat you are putting? If you want a certain level of temperature at the bottom or whatever certain level of temperature distribution in depth, it is understood if I can increase this parameter or we can give more heat. My alpha delta T component increases; means I can generate more bending stress; I can generate more bending movement, more effective the method may become.

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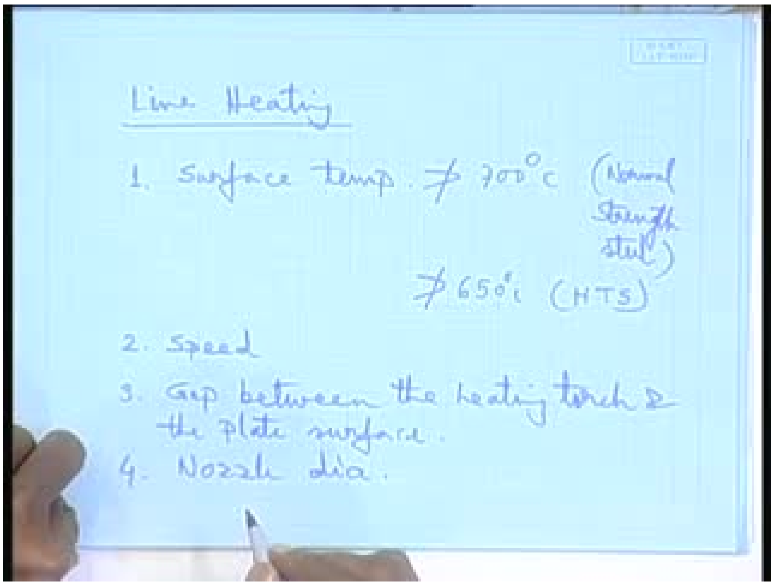

But the limiting factor is that I have to leave it the amount of heat going in here, such that the maximum temperature attaining at the surface does not exceed around 700 degree centigrade in case of normal strength steel. It should not exceed around 650 degree centigrade in case of high tensile steels.

If I could have increase the temperature, my process of bending would have been more effective probably, but if I increase this, there is other side effect means because 723 degree is the re-crystallization temperature means; the micro structural change would have taken place. So, the plate property would have got adversely affected; so, there is a limit on this temperature of the surface.

Next parameter is the speed of movement. Now, surface temperature, how do you control? I mean this this temperature such that it does not exceed this. It will be controlled by the speed that is one of the parameter by the speed.

If you increase the speed, you do not allow enough time for the heat to so called penetrate. So, temperature will not rise. So, you will have to the find out the optimum speed which will lead to this temperature at the surface not beyond.

Another aspect will be the gap between the heating torch and the plate. So called gap between the heating torch and the plate surface, why? Suppose, we are doing it by oxyacetylene flame, heating it by oxyacetylene flame, the plate is here if I keep that flame tip here and move it at a certain speed, I attain certain temperature. If I bring it down and do the same thing, I attain some other temperature. Obviously bring down I will have higher temperature, but I bring it very close, again it will not work. It depends on the flame characteristic.

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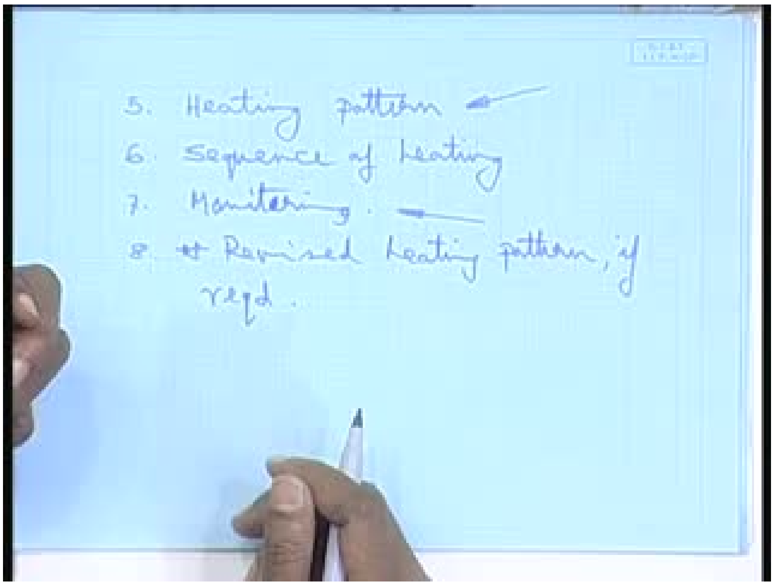

So, it is important that this gap is also important depending on what on what kind of heating source we are using. So, one of the source cheap or easier source could be flame heating, gas flame heating. So, if that is used, this gap is important, with what gap? On the aspect would be for oxyacetylene heating, the nozzle diameter because nozzle dia will generate the heating surface. How big surface is being heated? So, based on that also the heating distribution, heat floor that Q by S is quantity will vary will depend. So, nozzle dia is also another aspect which will come in to which will be important.

And then obviously comes the heating pattern. By heating pattern I mean, that distribution of these heating lines, the distribution of the heating lines, obviously the sequence of heating. In what sequence these heating lines are to be, these lines are to be heated? So, these are the aspects of line heating, and after the six tapes, I achieve the bend surface.

So then comes monitoring. Now, in this monitoring, again the same issues, well, when I am finding at the fifth step the heating pattern, now, I have to bend a plate that geometry everything is given. So, the heating pattern I should be able to generate online means immediately, not that I run the computer for 4 hours, 10 hours and I get a pattern of heating, then again the whole purpose is lost, because within the 10 hours, I could have manually bent it, provided I had a manual skill with me. So, if we, if that finding this out through computation, if it takes a huge computation time, then again the process purpose is lost, it become expensive.

Similarly, monitoring, if the image processing time becomes too long; that means the plate has been bent, it has been scanned by laser beam or any other method and I am trying to figure out whether the bent shape has conformed to my desired shape or not. If that process, computational process image processing filtering, etcetera, takes say 5 hours, then again the process becomes not liable, because by that time, if I had two skill worker, they could have produced it in that time. So, this has to be again online that means it monitors, again generates the new revised heating pattern if required.

So, it has to be done online; that means one will have to develop a code through which it can be done, also should develop the algorithm and the code should be such that it is feasible. Feasible in the sense not only computation time point of view but from the computational capacity point of view, the kind of memory required, etcetera. So, those are some of the aspects which are difficult to tackle if one goes by the conventional method of computation, conventional method of thermoelastoplastic analysis. If anyone does, it will be difficult, so, one will have to implement probably some kind of artificial neural network, some kind of genetic algorithm, through that only, it becomes feasible. So, that is what these are the aspects of line heating. So, that is how we do the bending of plates. What about the bending of beams then or the frames?

Sir in case of thin plate is still line heating not applicable

Also applicable but we have for the time being restricting ourselves to shipbuilding activities, where, in fact, thin plate application is very minimal. As far as the, by thin plate means, well, that is again a very vague word, well, in concrete terms, plates starting from say 3 to 4 millimeter onwards are used.

So, for plate bending, **w**e will not require any plates less than probably 6 millimeter, why? Because the hull when we make, there only plate bending is needed. Superstructure is generally all straight plates. Both hull and superstructure the plate thickness will never be as such less than 6 millimeter from corrosion point of view and all that. Three millimeter and below, thickness plates will be used for some very specific applications like ventilation ducting, big ventilation ducting where may be 2 millimeter sheet metal is used but they are all rectangular shapes.

So, there bending we are not doing but even thin plates also can be bent by very precise laser heating, those techniques are there, but we are not dealing with that. That is very precision things.

Sir, what is the effect of line heating if the like the least temperature gradient is 0?

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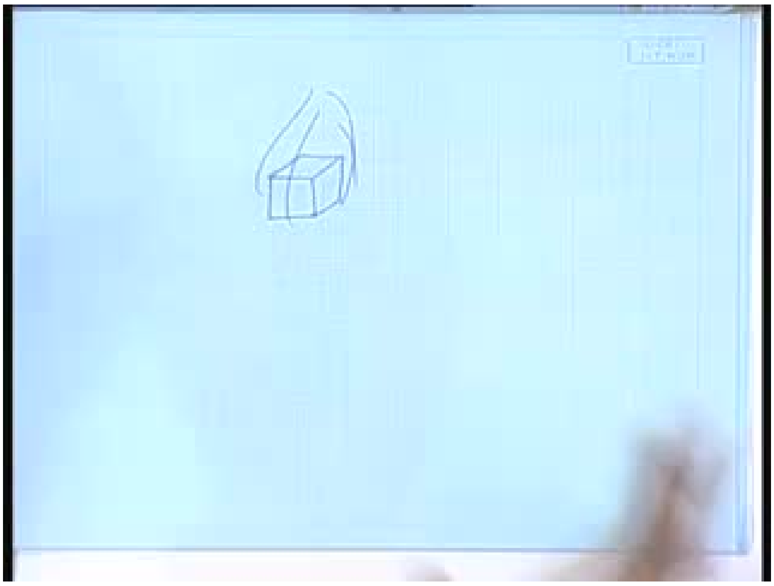

No, if the temperature gradient is 0, then there will be shrinking effect only. That is what the effect we found when we talked about that experiment of one small cube being heated and keeping clamped in a vice, there what happened, I used a kind of heating such that it is uniformly heated all around, it is uniformly heated. So, there it will transverse shrinkage will takes place, a transverse shrinkage will takes place. That is what you said in the first this thing.

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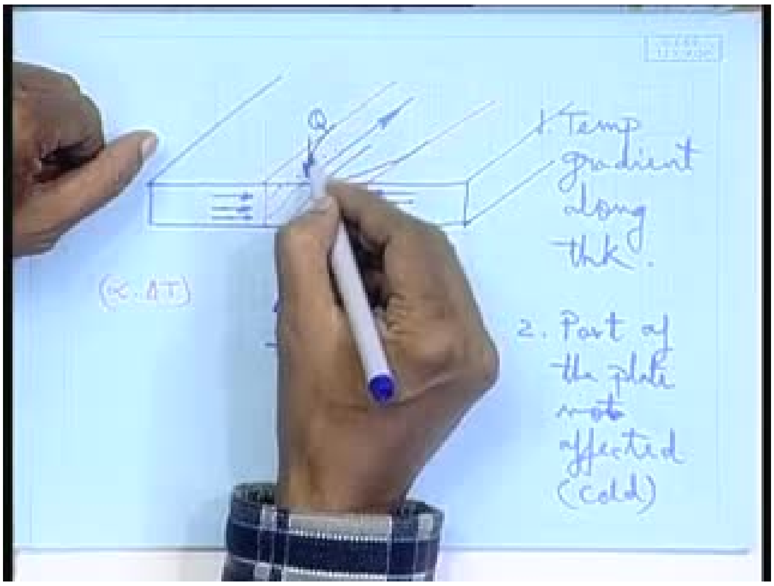

That if this is my case, that means there is no temperature gradient across the thickness, then it transverse shrinkage only will take place.

Then sir when shrinkage is 0 and its…

At the ends because it is a transient phenomena is taking place at the here. When I start the heating, the maximum temperature it is not reaching here. If I can monitor the temperature at different places, I will find beyond a certain place this whole width is coming. Bbefore that it is it will be somewhat like this, because there will be a some transient level till I attain a something like a steady state.

Here the steady state is a is refer to a quasi-steady state means same thing will keep on repeating over the time, but actually at every point of time, the temperature is changing at all points of the plate, but that changing pattern is continuing. That is what quasi steady state will attain.

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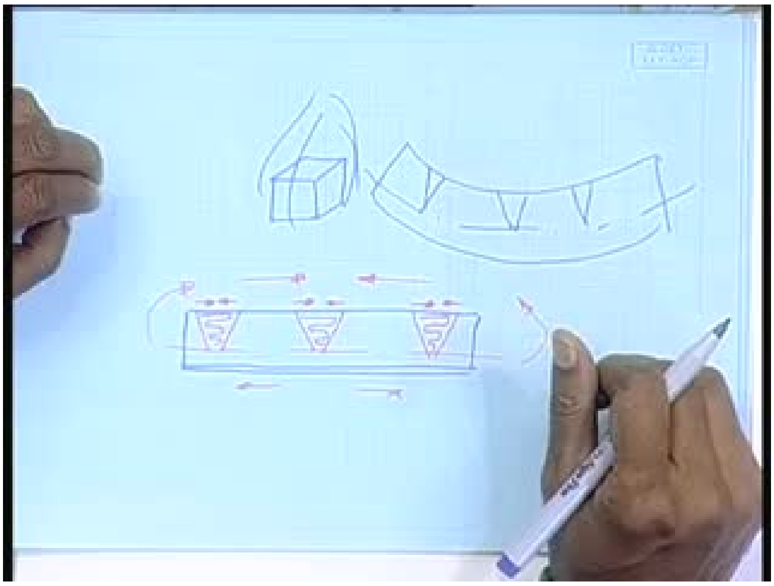

In case of frame bending, what is done is - you have the, suppose the frame, a longitudinal, this is my neutral axis, so, take a v shaped zone and heat it along this, say in this beam three such zones along these lines, they are heated means, these are, this I am drawing as the heating lines.

So, what will happen, shrinkage here will take plate. It will shrink because of that same mechanism of shrinkage, it will shrink. If shrinking, then cumulative a shrinkage force is developing. If that is happening, below the neutral axis a tensile force will develop will give rise to a couple and it will bend. So, that is how one can do the bending of frames.

So, now, again it becomes a skill dependent. You will have to see for a given bent shape, I have to find out the first neutral axis. That is pretty easy, one can find out. Draw the neutral axis, then I will have to work out how many such heating zones are to be implemented. So, it is to get this bent shape. So, that is a frame bending can be done by line heating but, well, frame bending is much easily done by frame bending machines. So, that is not very much implemented as such, but for plate bending, this is the only probably option through which one can do a automated bending using line heating.

So, we conclude here. Next we will go for fabrication; that means we will start with welding.