# Welding Metallurgy

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## Lecture - 38
## Causes of Residual Stress Development in Welding

Welcome to the lecture on causes of residual stress development in welding. So we talked about you know the different types of residual stresses and you know how they are going to affect the you know service life of the component. So and then how can we get rid of them also I mean in short we discussed about few steps by which we can minimize those residual stresses, but then we will talk about the causes or mechanism of these residual stress development which is there in the case of welding.

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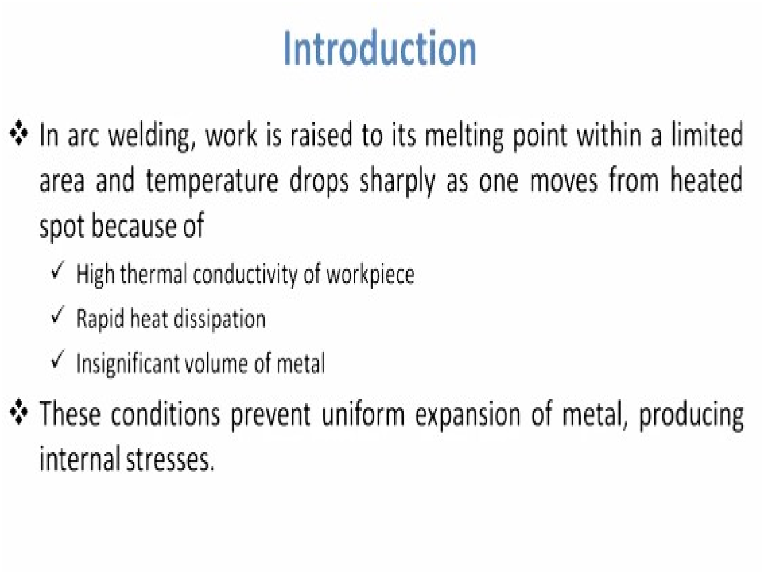


So what happens that you know when we have so first of all in arc welding the work will be raised to it is melting point within a limited area. So in a very limited area you are increasing the temperature to a large value and then temperature will drop sharply as we move from the heated spot. So the reason for the sharp decrease of the temperature is because of the high thermal conductivity of the workpiece.

Then you have rapid heat dissipation. So you know because you know on all the sides you have the metal and which has normally very high conductivity values. So the heat dissipation rate will be quite high and also the volume of the metal is quite high, I mean small, you know so if you talk about the casting where you have large volume of metal and in this case you have a very small you know metal pool which is you know getting cooled.

So that volume is also smaller than you have rapid heat dissipation and also the heat is conductivity on the sides is higher. So all these things basically they prevent this uniform expansion of the metal and that basically will be the responsible you know factor for the development of the you know internal stresses.

So that we have already you know talked about. Now so you know in that case we can understand by referring to one example say. If you have you know if you have a steel plate. So if you take example of a steel plate.

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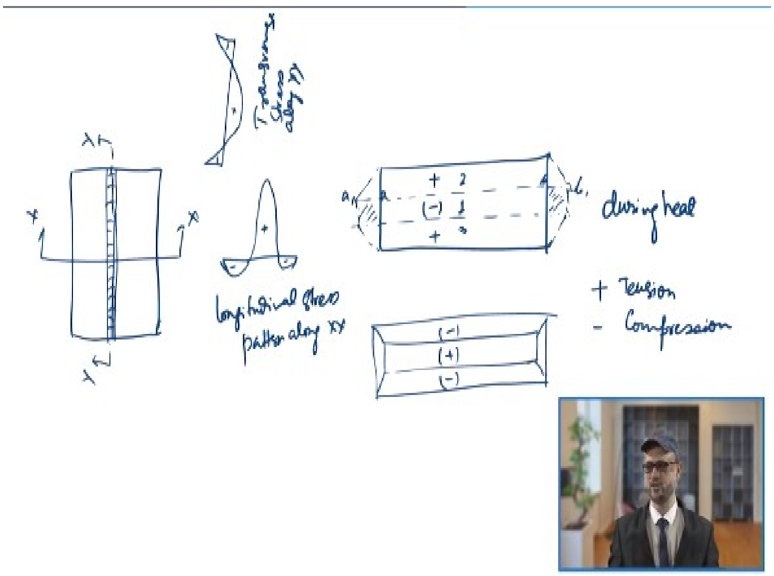


Say you have this way a steel plate and it has 3 zones. So basically we talk about these 3 zones in this steel plate. Now what happens that if suppose we take this as you know 1, 2 and 3, so if suppose it is subjected to heating. So we will talk about the internal stresses which are developed in this plate and what happens that you know as the zone 1. So this is your zone 1, zone 2 and zone 3.

So as the zone 1 will be heated in the temperature then it will try to expand. So it will try to you know go like this and it will try to expand. So this zone once it is heated it will try to expand. Now so it will be expanding you know longitudinally and you know the length which is suppose here ab so that length will become a1 b1. So this way your length of this zone will increase to from ab to a1 b1.

Now the zone 2 and this zone 3, so they will be providing a restraint to the expansion of you know this zone. So this zone will try to expand whereas the zone 2 and zone 3, this zone 2 and zone 3, they will be restraining to the longitudinal expansion of you know of zone 1. So what happens that now that will develop you know the stresses on these zones. So 1 is you know expanding and 2 is basically you know trying to stop it because they are in you know contact.

So you know because they are not so hot, so 2 and 3 since they are not hot, so they will be providing that restraint on that zone. Now it will be you know so accordingly so that since it will be restraining it. So zone 1 will be under the you know, it will be under the compressive stress. So zone 1 will be you know it will be developing a stress which is compressive that is why we denote it as the you know negative sign.

Then zone 2 and zone 3 because it has expanded so it will try to expand the zone 2 and 3. So zone 2 and 3 basically will be subjected to the you know tensile type of stresses. So this is the you know type of stress which is developed in the case of you know heating. So this stress development is during the heating process. So this is during the heating process. Now if so while we are supplying the heat and when the temperature is increased at that time this will be the type of stress which will be developed inside the material.

So then if you go further and if you talk about the cooling. So when it starts cooling at that time again you know this will be cooled. So it will try to contract whereas the zone 2 and 3. So zone 1 will try to contract and zone 2 and 3, will try to you know restrain that from contracting because of velocity and temperature is decreasing. So in that case what will happen.

Now zone 1 will be experiencing a you know tensile type of stress. So it will be stressed basically it will try to contract but then it is not able to say type of tensile stress is developed in the case of zone 1. So zone 1 you know if you see, zone 1 will you know be under the positive you know stress, it will be under the tensile you know stress and zone 2 and 3 so you will have you know zone 2 and zone 3 on these sites.

So zone 2 and zone 3 will be under the you know negative stress that is your compressive stress. So that basically you know so what you see that the sign of the stress which is generated inside which is basically either pulling or pushing. So that is basically changing in both these cases. So that way you know by this you can understand that you know how your different type of stresses that is tension or compression.

Where tension is signified by the positive sign and the compression is by the negative sign. So you know that will be this way your stresses will be changing you know in the case of you know the joint. So if you have the different zones this way your you know the stresses will be varying. Now if you try to see the you know the stresses and strains in the you know butt welded plates.

So suppose if you have a butt welded plate if you talk about you know a butt welded plate you know and in this you have the welding you know going you know along this line, so this is your weld bead. So if you take this section as the you know XX and if you, you know take this section as the YY, so what happens that you have the development of the longitudinal stresses as well as the you know transverse stresses in those cases.

So the development of you know the longitudinal stresses which is developed is normally you know what happens that you know this way you have the you know this positive which is there in the middle and on the sides you have the negative stresses. What you see finally that you have the you know positive stress which you see in the person here and you have the negative stresses you know on this side.

So that way you have the longitudinal you know stress longitudinal stress pattern along XX and you can have also you know you can draw the transverse stress also along the YY and along YY if you try to draw the you know along YY you will have the you know you will be getting this way that will be your type of pattern which you see in the case of the transverse direction.

So this is your transverse stress pattern, YY, so this will be your positive and this is your negative. So that way your stresses are basically changing. So we can further understand it you know by looking at you know this that if suppose you have the plate.

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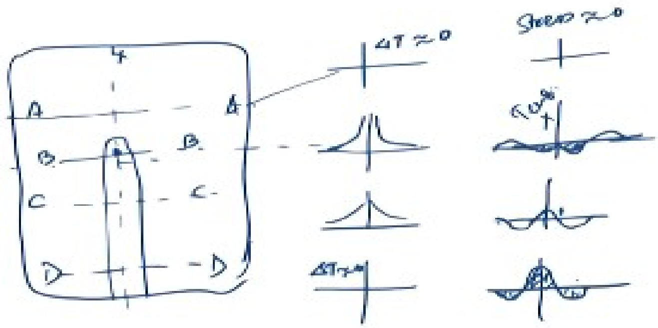

So and if you know you are doing the welding so suppose you are, if you are taking about at this point you know this is your melted region and you will have you know different zones. So this is your you know this point, so if suppose this is you know x and we are talking about the you know different points. So suppose if you talk about this zone that is your AA. So you know in the you know melted zone.

So just it has been melted and your torch is here. So in the melted zone if you talk about the change in temperature and the longitudinal stress value. So just ahead of this you know if you see you know in this case you have the ΔT so if you talk about this point you have a ΔT as 0. So your stress is also will be 0.

Now if you look at this section which is basically BB, now in this case what is happening that if you talk about the temperature. So what you see that on this side you have the temperature which is the lesser one. So the temperature value you know is increasing you know to a very large value here and then it is you know the decreasing towards this side.

So that way this is your you know thermal you know line that is your temperature you know change which is occurring and this is resulting to your you know the tension and compression stresses which is being provided. So that will be given like you know so this way your so this is your compression and this is your tension. So that way this is your in this case you have tension and in the bottom you have compression.

So that way you have in the middle part you will have the compression and in the top on the sides you have it is under the tension. If you go to you know this section. So if you are coming to you know the some point here that is your CC. Now in this case you know your temperature profile will be you know like this and that will lead to the stress values. So you will have the stress value like this.

And on this side on the middle you will have the positive and on the sides you will have negative and finally if you talk about this point. So in that case which you see after cooling. So here again what you see is you have the $\Delta T$ as 0 and the pattern which you see, so you will have this way your pattern comes, that is what we have seen earlier. So this is what you see while after cooling.

You see this you know temperature stress distribution like this. So this is how the development of the stress goes in that case. So basically now what we wanted to know that when we talk about the mechanical stresses. Now in those cases you have basically the expansion as well as contraction going on. So in those cases this way your stress pattern will be changing and that will be development of the residual stresses.

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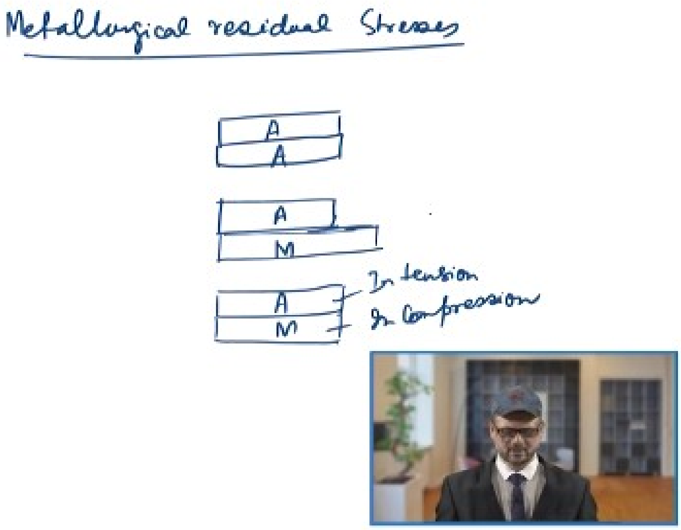


If you talk about you know the other you know residual stress that is your you know metallurgical residual stresses. So in the metallurgical residual stresses as we talked about that is because of the phase transformation which is taking place. So we know that you have you know the austenite which is you know changing to martensite when we are cooling. So you know, so if you have you know.

So if you suppose have the austenite in austenite together now when you know the austenite will be changing to martensite. So that you know this will be your austenite and then this will be the martensite. So volumetric change will be there. Now because of that you know, so this will try to drag it you know towards the back and this will try to pull it. So because of that you know so this austenite in the equilibrium case what we find the structure.

So this is your austenite and this is austenite and after transformation this austenite becomes martensite and then in the final case if you have austenite and martensite like this. So this austenite will be in tension and this will be in compression. So what happens that this is because when the austenite is converted to martensite then that occupies more volume.

So that will be expanding and then the austenite which is you know near to it so that will be trying to give the restrain to it, so that way there will be stresses which are you know developed high compressive stresses are you know and the surrounding constituents having you know lesser volume.

So you will have these you know development of these stresses which are there and that is why the stresses which are generated in these cases they are under the you know category of the metallurgical stresses. Now the other type of stress which we also discussed was the reaction stress.

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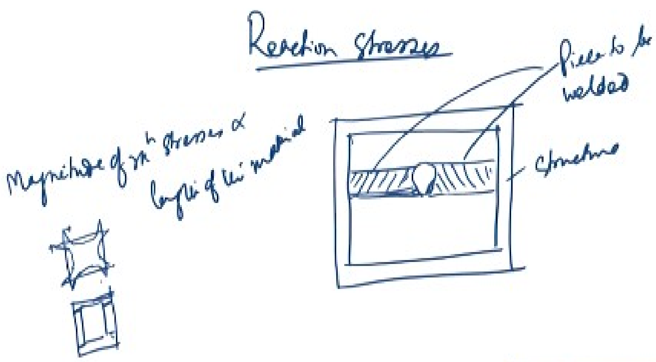


Now if you talk about the reaction stresses. So in the case of reaction stresses as we discussed it is because of the constraint which is provided or the restraint to the thermal expansion and contraction which is offered when we do the you know welding. So it is not by the work piece, but it is because of the other part of the you know structure to which the you know parties you know or the pieces to be of the welding is attached.

So this is because of that you know that restraint during the welding process. So that happens suppose you have 2 pieces to be welded so and they are already so when you have 2 pieces to be welded and they are already attached with certain structure you know in that case these happens. So suppose you have 2 you know pieces which are to be welded and so these are you know these are the 2 pieces.

And they are basically on the sides, they are you know fixed to certain structure. So you know so in such cases when there will be heating, so they will try to you know so these are the you know 2 pieces. So you have these 2 pieces and this is your weld metal zone. So in that case when there will be heating going on. So it will you know try to you know expand and so that way the stresses will be generated.

So what happens that in these cases the magnitude of the reaction stress which is you know generated they are the inverse function of the length of the material. So the length of the material is larger then the stress which is generated will be smaller. So magnitude of reaction stress so that will be you know inversely proportional to the length of the you know specimen, so the length of the you know material.

Okay so you know it will never exceed the yield strength of the material and if it is very tight you know then it may you know so it will be exceeding so it is value will be exceeding many a times, but normally it does not go beyond that middle point. So it will be you know normally occurring in the plate structures or it may be in the girders or in the ships also.

So that way in those cases where we do the welding because you have to do the welding and bond both the sides you have the constraint. So when you do the welding in that case the stresses will be developed and these you know, so this is your structure and this is your you know piece to be welded. So that way you know these stresses are developed and these are known as the reaction stresses.

So normally you have the stresses which occur in the case of different types of joints and that varies from joint to joint. So we have talked about the you know pattern of the residual stresses which occur in you know the normal butt welds but you know in terms of suppose box welds, so if suppose you have a you know box weld which is there. So in those cases the pattern will be suppose you have the welding here.

Then you have the welding here you have the welding here and you have the welding here. So in those cases you will have the different kind of you know residual stress distribution and normally what happens that you have if you look at this value of the residual stresses so you will have you know, so it goes like this and you will have the value here in this case similarly it will go to on this side.

So you will have the value of going like this, so you will have positive as well as negative. So this side it is positive and this side it is negative. So this side is positive. So that way you will have the development of the stresses in the case of you know box shape, you know, so that way you can have the prediction of these stresses in the case of box shape. So similarly in the case of H shape also you have some stress distribution.

So that is the type of stress distribution. So what we have the studied because the residual stresses are not so desirable, so they may result into the you know weld cracking or the stress corrosion cracking, they result into the brittle fracture of the material and they result in to the lower value of ductility.

They will be affecting the surface you know fatigue properties of the material so that way we have and that affects the performance of the material. So we have to see that you must have the means or you must have the ways to decrease or to minimize the value of the welding you know stresses or residual stresses to the minimum. Thank you very much.