Theory of Production Processes
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Lecture – 55
Preheat and Postweld Heat Treatment of Weldments

Welcome to the lecture on Preheat and Postweld Heat Treatment of Weldments. So, we discussed about the different welding processes and we also have seen that how the there is chances of deformation of residual stresses and then there are the possibilities of a deformation distortion in the weldments. So, one of the very important process which are employed in most of the cases to avoid these distortion or to relieve the welding a weldment of the residual stresses, preheat and post weld heat treatment of weldments you know they play an important role.

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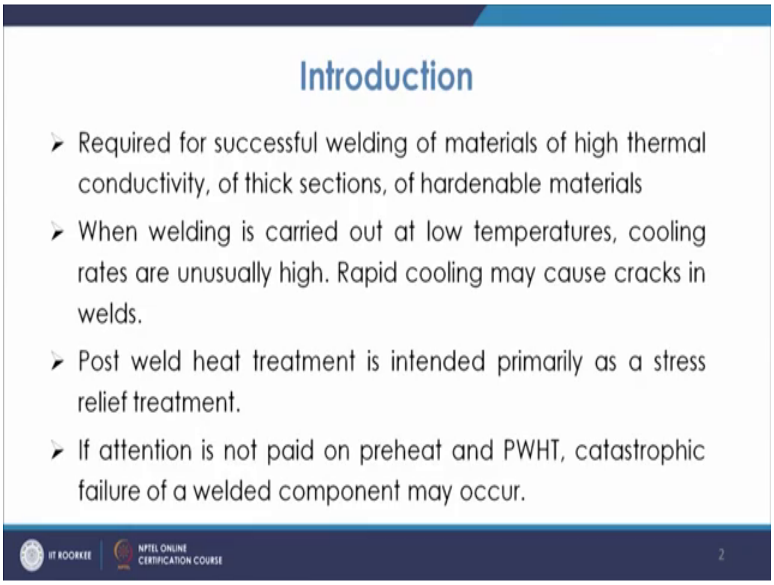

So, this is a preheating we are talking about or post weld heat treatment they are required for successful welding of materials of high thermal conductivity of thick sections or hardenable materials. So, basically the challenge comes when we have these materials of suppose high thermal conductivity, now in those cases the heat transfer from the weld specimen goes very fast. So, if even if you are having in normal cases when you are using the heat source and if the conductivity of the plates is quite high, in those cases it is very difficult to contain the heat at that point and do the proper fusion of the material.

So, in the case of that you have the challenge similarly in the case of thicker sections and also among the hardenable materials where there is quite a big chance of a formation of martensite phase, which is normally brittle. So, there also you know that is the challenge because, even in the normal cooling rate you have the chances of formation of martensite which is undesirable or martensite deformation which is completely brittle. So, which is undesirable in those cases you try to slow down the cooling rate even then the normal. So, that way you will have to have the special type of treatment given, so that that leads to formation of the phases which are not so undesirable, when welding is carried at low temperatures cooling rates are usually high.

Now, again another situation may come when we are welding at lower temperature below 0 degree CE ntigrade. So, in those cases what happens that a once you do the welding and as the ambient condition is you know at very low temperature ambient temperature is quite low. So, the cooling rate itself which is developed is quite high and when the cooling rate is quite high in those cases because, of the stresses generated there may be formation of cracks in the welds. So, when we are doing the welding under those conditions of lower temperature again there is a challenge and in those cases you need to have this special provision of the pre or post weld heat treatment. So, that you get the satisfactory results.

This is about primarily about the preheating and then we talk about the post weld heat treatment. Now in the case of post weld heat treatment the primary aim is for the stress relief heat treatment. So, what happens in many cases the stresses generated are quite high. So, for relieving the weldment of the stresses we do this post weld heat treatment and in the in that case normally what we do is we are heating to a temperature of somewhat higher degree then that is required in the case of preheating and then there we are holding for some time and then cooling. So, that is required for so that the stresses are you know relieved and this is necessitate the need is that much fail to only because, if you are not paying the proper attention on this preheat or post weld heat treatment, then undesirable phases may occur there may be you know brittle phases there may be a cases where there may be stress corrosion or so.

So, in those cases if the brittle phases are present or brittleness occurs, then there is a chance that there is catastrophic failure of the welded component. So, that is the you know a challenge with these a preheat and post weld a heat treatment processes that is their importance lies behind these concepts, now what are the aims of a preheating.

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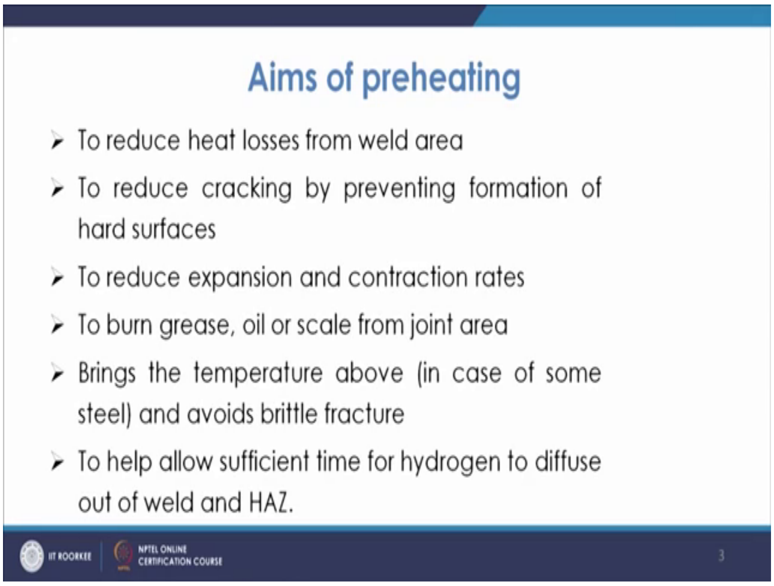

So, as we discussed that the aim of preheating is to reduce the heat loss from the weld area, to reduce the cracking by preventing the formation of hard surfaces or a hard phases many a times hard faces like martensite or so to reduce the expansion and contraction rate.

So, in many cases what we see is that if the expansion coefficient is a coefficient of linear expansion is larger, in those cases the chances of deformation is more and the stresses generated and that may lead to deformation. So, in those cases if you are doing the preheating, in that case the a rate of heat transfer will be smaller and the expansion.

So, expansion basically will be depending upon the change in the temperatures. So, if your temperature is you know a small temperature difference basically, so it is a temperature difference is smaller in that case an expansion will be smaller or contraction will be smaller. So, that way it helps in reducing that then it is also important you know aim is to burn the grease oil or a scale from the joint area.

So, many a times when you are going for welding, then the specimen which is to be welded which was kept priorly. So, that may have the grease oil or a scale or a sometimes maybe painted or maybe you have a some other substances which are actually volatile, so if you preheat then they are basically gone. So, they will be you know going off of the surface, otherwise they are going to create you know the problems in the joint there may be inclusion of the impurities and other type of defects if they remain on the surface.

Bring the temperature above and avoids the brittle fracture, many a times when the temperature goes quite low and we do some thermal treatment in that case there are some brittle phase formation. So, in this case if you are having that temperature, then that temperature difference not being that much the chances of the brittle phase formation is less and.

So, the brittle fracture chances become less to help allow sufficient time for hydrogen to diffuse out of weld and as a. So, if you are preheating then that give that way you are allowing the hydrogen to come out and we are giving the proper time. So, hydrogen induce defects it is chances become less. So, these are the aims of basically preheating.

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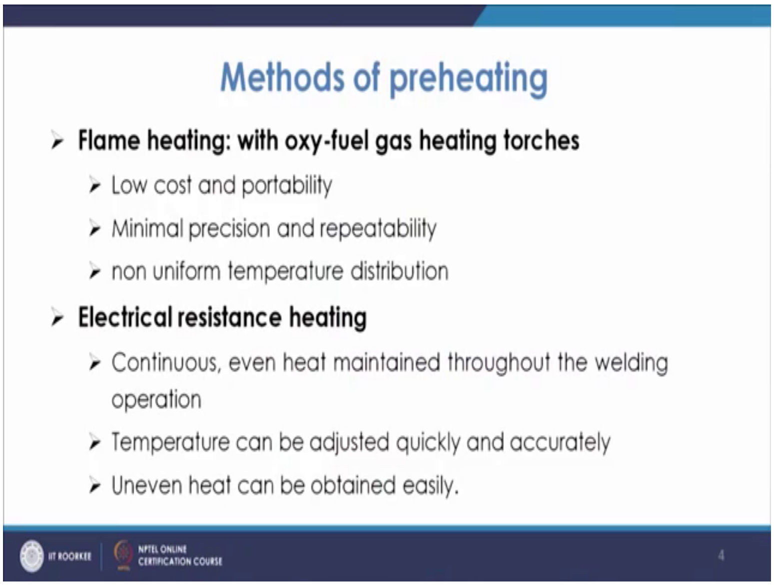

Now method of a preheating, so when we talk about the method of a preheating, how we can do preheating like you may do with the flame. So, you have you can use the oxy fuel gas heating torches, so you have a torches of diameter then you have you have from there you can if you are with the supply of the gas, you can generate a flame of a different type like maybe like you we know that we have they have 3 types of flames.

So, then with that flame you can do the preheating like oxy oxidizing or reducing or the neutral type of flame may be generated and then you can do the preheating. So, the attributes of such flame heating you know with oxy fuel gas heating or like they are a low cost and a portable. So, that is the advantage of that type of a flame heating mechanism because, you can take them to any place you need the cylinders of oxygen and a acetylene and you can generate the flame and you can heat it.

But then the disadvantages are like you have a minimum of the precision and repeatability because, they are done normally manually. So, precision is also because and also the flame has spread. So, the precision is also less then you have a non uniform temperature distribution also. So, that is the disadvantages, then you have electrical resistance heating you have the resistance coils which are there and because, of the electrical resistance mechanism you do the heating and it is advantages are that they are continuous. And even a heat maintained throughout the welding operation.

So, you can be assured that there is even heat which is maintained throughout the welding operation, temperature can be adjusted quickly and accurately. So, that is further you know an advantage and many a times we see that there are also disadvantages like uneven heat also you know can be obtained in the these cases.

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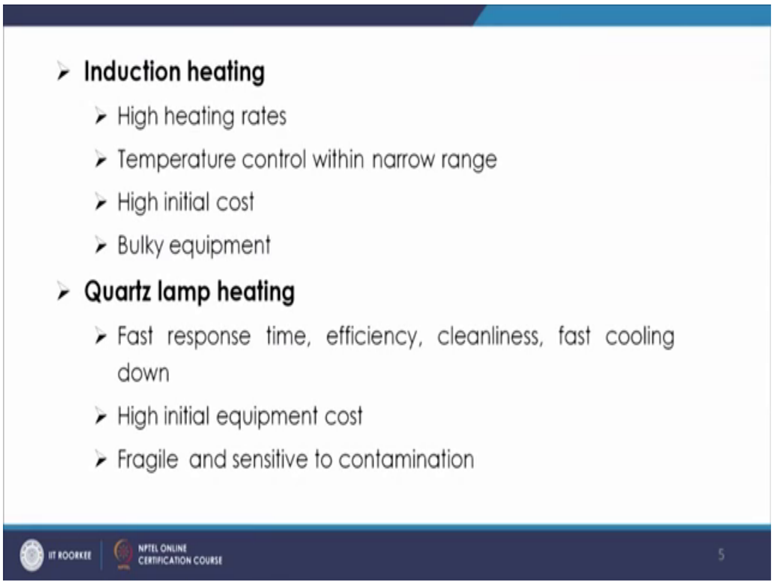

So, then you have the induction heating, a induction heating is further the another you know mechanism by which you can do the heating. So, it has the advantage of like you have a high heating rates and also temperature is controlled within the narrow range. So, this way you can maintain that, but the disadvantage is that you have a high initial cost and also the equipment is bulky, so that is the disadvantage.

Then you have the quads lamp heating which has the advantages of a fast response time efficiency cleanliness fast cooling down these are the advantages; whereas, the disadvantages are like you have a high initial cost fragile and sensitive to contamination. So, this way you have the different type of a heating mechanism and you can do the heating and depending upon the situation where you are welding or depending upon the case to case, you can use the different any kind of a heating mechanism and do the preheating.

Now, we will discuss about the preheat temperature of a different materials. So, among the materials we have suppose we discuss about the carbon steel. So, in the case of a carbon steel, the preheating is a necessary for the heavy sections.

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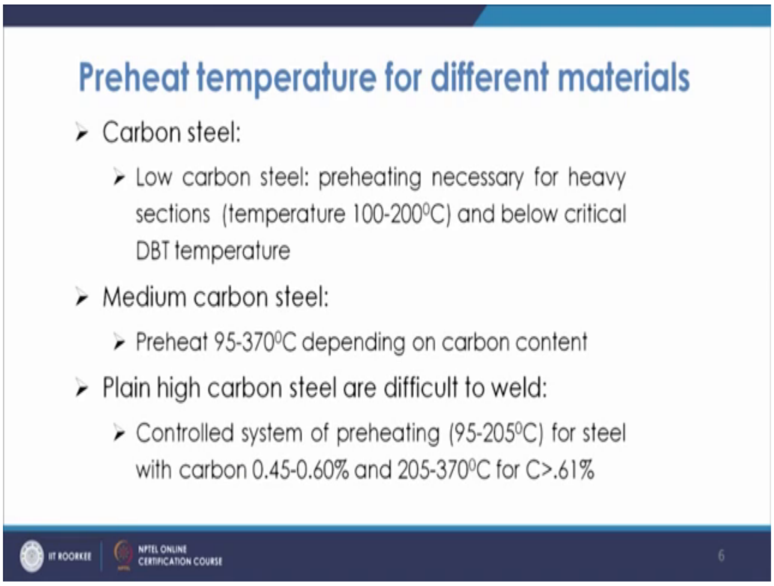

Because when the carbon content is smaller than you do not require that much of a preheating, but so a when you have a carbon content to lower side then you do not require the preheating because, the harden ability is less in that case harden ability increases with the carbon content.

So, if the carbon content becomes larger, in those cases you have the more chance of formation of martensitic phases and in those cases there will be chances of having the more stresses and all that. But as the carbon content increases or even the alloying elements increase. So, that also have the effect on harden ability that we will see and in those cases you need the preheating. So, preheating basically when you have a less than 0.2 percent of a carbon then you do not need that much of preheating requirements.

But when the preheating is more than point you know 0.27 percent or 0.25 percent in those cases you need the preheating that becomes necessary, also preheating becomes necessary for a heavy sections and when you have a such heavy sections in those cases even if the current content is less in those cases, because you have a large heat content into the zones.

So, in those cases you need the preheating temperature of about 100 to 200 degree CE ntigrade and because you know in the case of heavy sections the weld pool being basically surrounded by or being in adjacent to the thicker you know parent metal on both the sides, the heat extraction rate will be quite faster in those cases you require the preheating and preheating temperature which is normally suggested is about 100 to 200 degree CE ntigrade.

But it should be also seen that this should be below the critical at a tile to brittle transition temperature they are especially, if you are doing the welding in the case of a winter. So, the then you have to be careful that the temperature should not be below that. Now also it is seen that if the material has not the impact value of about 8 to 10 joule, in that case also the considerable danger is there for the cracking under the stresses. So, te that value of you know toughness, so that is required to be having that.

Now in the case of a medium carbon steel, as we discussed that when we the carbon component carbon percentage becomes more, in those cases the chances of you know I mean a harden ability increases the chances of formation of martensite with ease will be more. So, in those cases you require to have preheat and preheat temperature is suggested to be close to I mean in the range of 95 to 370 degree C. So, depending upon the carbon content means if the carbon content is more, in those cases you require to have more of the preheat temperature and if it is less in that case you can think of having a lesser of the preheat temperature.

If you talk about the plain high carbon steels, when you talk about the high carbon steel and it is plane means there is not one much of the alloying elements, in those cases as the carbon percentage becomes more, so in that case it will be difficult to weld. So, weld ability or difficult difficulty in welding basically increases with the carbon percentage. So, in this cases you require to go for the preheat temperature of about a 205 to 370 degree C, if the carbon is more than 0.6 and if it is 0.45 to 0.6, in that case we go from 95 to 205 degrees C a control system of preheating is maintained for such materials.

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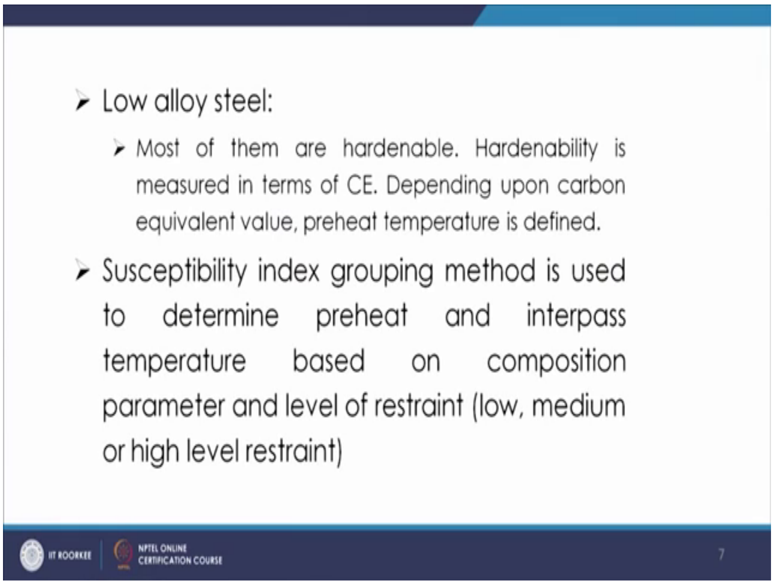

Now, if we talk about the low alloy steels, now in the case of a low alloy steels most of them are hardenable. So, harden ability is basically measured in terms of a CE, CE means when we talk about low alloy steel you have allowing element which is around 5 percent or less. Now in those cases the role of the alloying elements also is towards the harden ability. So, harden ability is not only because of a carbon when we have the plain carbon steel, then in that case you have a mainly alloying element is carbon, but then otherwise when we go about the low alloy steels.

In those cases what we do is we have to find the value of the carbon equivalent, depending upon the percentage of alloying elements we find the value of the carbon equivalent and this carbon equivalent value is function of the alloying elements. So, as the alloying elements increase then the carbon equivalent value increases and if the carbon equivalent value is more, in that case the preheat requirement will be more and more. So, that way you go for the finding of these preheat temperatures, like many a times what we see that for normal steels you have a percentage of a carbon plus percentage of manganese by 20 then percentage of nickel by 15.

Similarly, chromium a molybdenum bang or vanadium and their percentage is added by 10. So, this way you get like the carbon equivalent value and then depending upon the carbon equivalent value, if the carbon equivalent value suppose increases more than CE retain value, in that case you have to go for the preheat. So, it has been seen that if you are suppose dealing with a plane or low alloy steel and if you have the carbon equivalent above of about 0.4, then you go for the preheat of about 50 degree centigrade, then if you have the you know 0.45 then it will go to 100.

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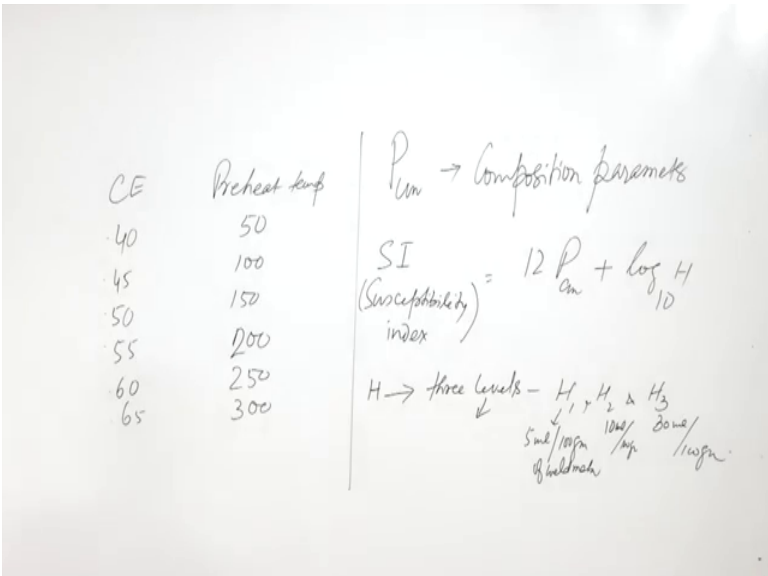

So, like that so that way the carbon equivalent changes, like you have a carbon equivalent and then preheat temperature. So, it will be for 0.4 it will be 50 like it will be 0.45 it will be 100 then it will be 0.5, then it will be 150 then 0.55. So, it will be 200 0.6 it will be 250. And similarly it will be 0.65 in that case 300. So, this way these there has been a suggestions that you can have the value of the preheat for the plane and low alloy steels, we find first the carbon equivalent depending upon the allowing elements and then we try to see that how much should be the preheat temperature so that way we can have it.

Another method which is suggested for this a low alloy steel is the susceptibility index, in that method of susceptibility index grouping we find the susceptibility index value and this susceptibility index value will be depending upon the a composition parameter.

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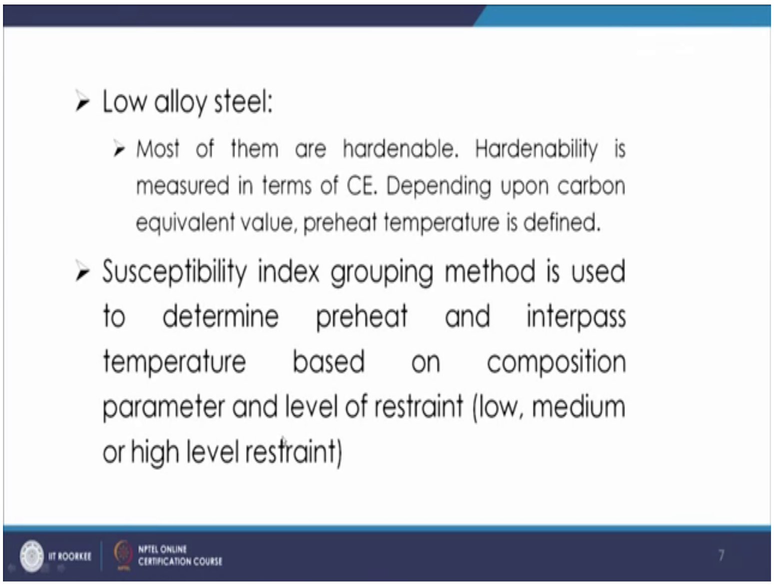

So, that is a PCM also or it will be effect it will be simply a function of the similar to that carbon equivalent and once we get that value then basically what we do is, we determine the preheat and inter pass temperature based on the level of restraint.

So, like we find a composition parameter and again composition parameter is a function of the percentages of the alloying elements. So, percentage of carbon plus you have other alloying elements so they so for silicon if suppose divided by thirty then for a manganese divided by twenty like that. So, you have a these values of susceptibility, so this way you get the composition parameter PCM. So, in those cases we first find the PCM and then from that you get the depending upon the hydrogen level we also get the you know a susceptibility index.

So, basically first of all we find the PCM. So, this is composition parameter composition parameter is basically a function of the percentage of carbon plus the you know the contribution by the other alloying elements like, you have a silicon manganese molybdenum vanadium all that you have or you have other elements. So, you have a standard formula that formula is used to have the composition parameter. So, percentage of carbon plus all that once you get the composition parameter, then you get the value of susceptibility index depending upon the hydrogen level in that you know melt, so based on that you have the value of a susceptibility index that is twelve times PCM plus log 10 h.

. So, susceptibility index SI that is susceptibility index. So, that will be 12 times PCM, PCM plus log 10 of H now this H is basically the level of hydrogen and you have a levels of hydrogen like H 1 or H 2 or H 3. So, H 1 means you have 5 milliliter per 500 gram of weld metal. So, this H has a 5 milliliter per gram of weld metal per 100 gram of weld metal or 10 or 30. So, this H will have the level, so this is H has 3 levels and that is H 1 H 2 and H 3.

So, the in that case and this level basically level is nothing, but suppose in H 1 5 ml per hundred gram of weld metal, then here you have a 10 ml per 100 gram and here you have 30 ml per 100 gram. So, this way once you have a you know that H and once you know the you know susceptibility PCM in that case you have a you can find the susceptibility index. Now after finding the susceptibility index a values you can have you have a depending upon that you give the susceptibility index value and then based on that you define a preheat and inter pass temperature for different materials.

So, that temperature will be basically maintained for a different type of materials and that is how we say that how can you control these you know preheat or inter pass temperatures or how can you define or set the preheat or inter pass temperatures.

Now, in that also you have the different type of a restraint is there, like you have low medium and you have a high level of restraint. So, how much freedom you are supplying how much the structure is having the freedom, based on that you have the restraint values and on that also you have the value of a preheat that is determined. So, basically normally we define like when we talk about the you know a load strength means it is like about common filet or a group welded joint and where the a freedom is there for the movement of the member.

So, similarly if you have the medium in restraint in that case it is stretch attached to a structural network already. So, that way you get it you give that and when there is no at all movement and so in those cases you have you say that it is the completely un you know a high restraint of a type of a weldment is there and in those cases the accordingly you will have to define the preheat temperature.

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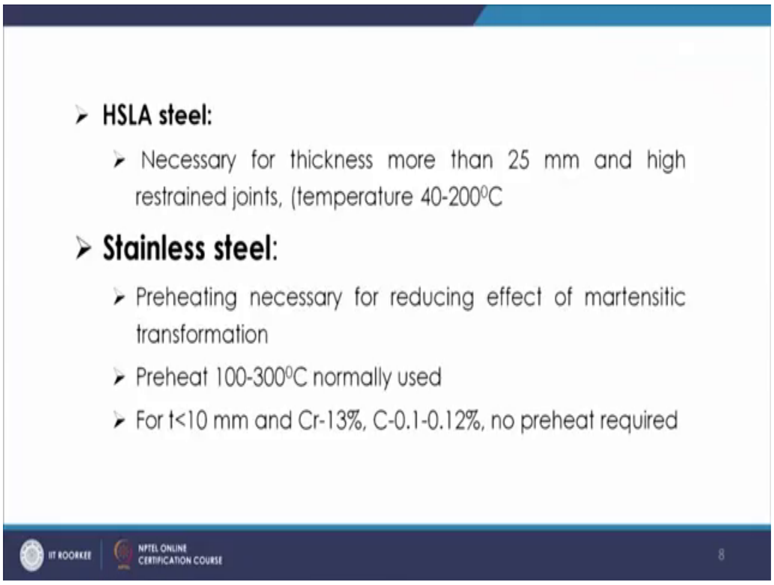

Now, we will go to the other kind of a steels like a for HSLA that is high strength low alloy steels, in those cases when you have the thickness of more than 25 mm and you have the high restraint joints then temperature is about 4 at 10 to 200 degree centigrade is taken.

Similarly, for stainless steels you have the preheating necessary for reducing the effect of martensitic transformation. So, that is another requirement in the case of stainless steel where the preheating of 100 to 300 degree c is used and for a normally for thickness of less than 10 mm and when the chromium percentage is about 13 percent and a carbon 0.12, 0.12 percent in that case there is no requirement of preheat in those cases, preheating is very much important in the case of aluminum alloys also.

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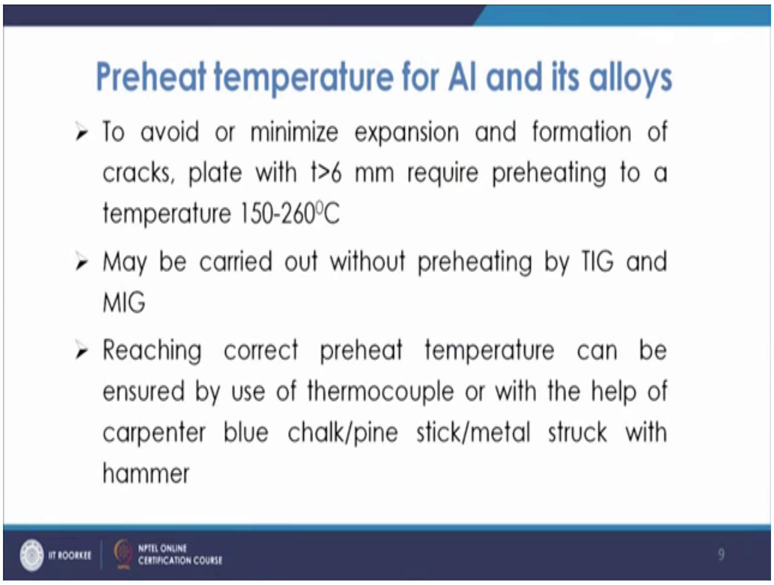

Aluminums and it is alloys as we have discussed that in the case of aluminum or we have discussed in general for other materials which have a very good conductivity or the or in those cases you have a good thermal expansion coefficient. So, in those cases to avoid that or minimize the expansion and formation of cracks because, when you have the more expansion or contraction coefficient; then if you do not do the preheat then the temperature differential will be high and the chances of pre I mean expansion or a contraction will be more and with some strength there can be the distortion or so.

So, in those cases when the plate is having a thickness of more than t or in 6 mm then you will require preheating to a temperature of about 150 to 260 degree centigrade. So, that is the requirement in the case of this aluminum now when we talk about the MIG or a TIG welding, in those cases we have the concentrated heat source. So, that can go and in that case we do not require the use of basically preheat. So, without preheat also if you have you are using the TIG or MIG then you can do it, but otherwise in a normal other arc welding processes you require the preheating.

Now, as we discussed that in the case of aluminum deciding that what is the temperature, so that now preheat actual temperature has reached for that because aluminum does not show any change in color, so it is very difficult. So, further there are certain you know experienced welders you know judge by experience, either you can use the thermocouple or there are users of a some like you have the carpenter blue chalk which will turn white at that temperature of preheat. Similarly you have pine stick which will have a mark on left on that specimen or you may have the use of a hammer to stuck and you would not find the metallic ring in those cases.

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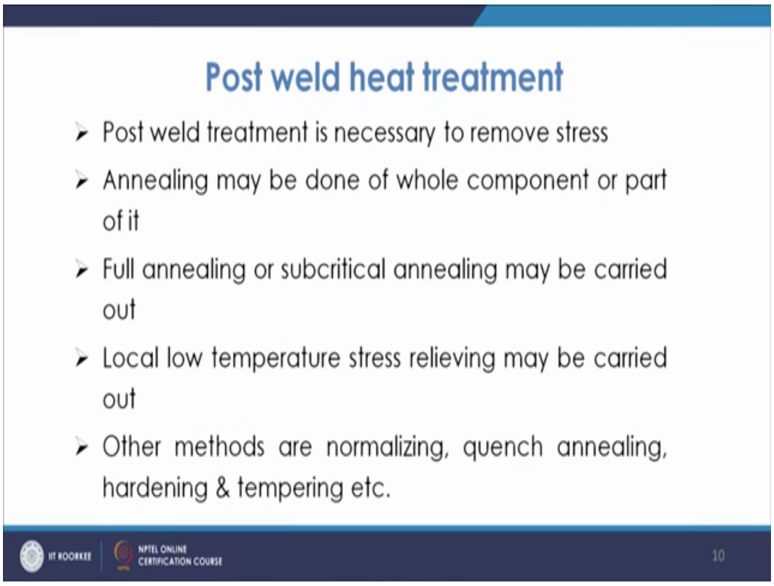

So, you assume that now the preheat temperature has already been reached, a is similar to preheat new you are requirements also for the post weld heat treatment and normally in the post weld heat treatment what we do is that is required for removing the stresses. So, the annealing is the best way to go for the post weld heat treatment. Now annealing can be done either for the only the component which is welded of that part of weldment or for the whole component, then annealing may also be done like full annealing or sub critical annealing. So, that may be also carried out depending upon what is the requirement.

Then local lowest temperature stress relieving also is carried out, basically the purpose is to relieve that from the stresses. So, the local a low temperature stress relieving is also carried out, other methods which are there in the post weld heat treatment is that you have the quench annealing normalizing hardening and tempering.

Now in the case of a annealing you will have to have a certain precautions and what we do is normally when we do finish the welding and then we are coming then in the case of suppose you take the steels, in those cases you will are you are further coming you do not go to the room temperature rather you further heat and go to a temperature larger than the martensitic finish temperature and for the hetero table basically low alloy steels and then there you are holding for some time and then further cooling.

Similarly when we talk about the martensitic steels, in those cases you are cooling down below the mf then further you are holding there for some time and then further you are heating and going to about 750 degree centigrade then you are you know staying there for certain time. So, in normally you have 600 to 700 degree centigrade of a preheat temperature is there and that also is there for different value for different types of a steels and if there you have to maintain some time and then you have to cool in a control atmosphere, so that the stresses are relieved.

So, you have the different pre post weld also heat treatment cycle for different components which can and we the main thing which is to be kept in mind that they are for the stress relieving purposes. So, that is to be kept in mind. So, that is about preheat and post weld heat treatment cycles.

Thank you very much.