Advances in Welding and Joining Technologies

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Lecture – 20
Welding Metallurgy Part IV

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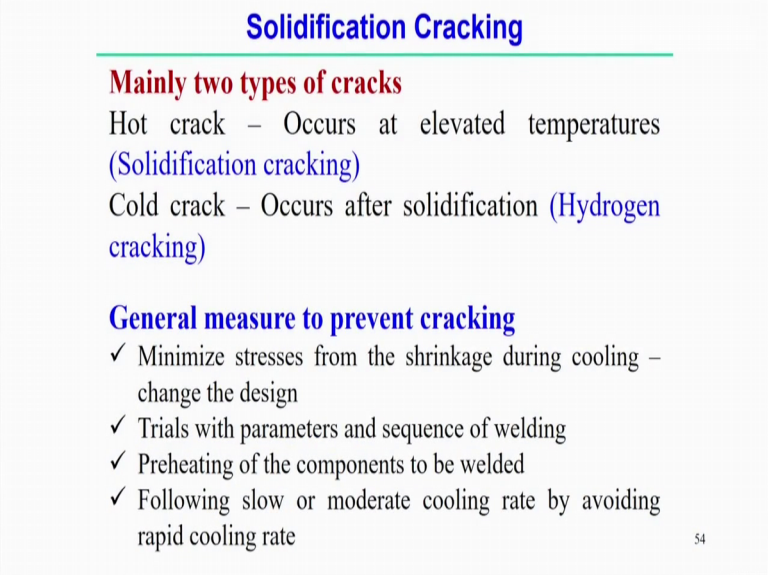

So, in solidification cracking mainly there are two types of cracking we generally observed during the welding process. So, one is the hot cracking process that actually occurs at very high temperature and that is also known as solidification cracking. Another is the cold cracking or cold crack that actually occurs after solidification sometimes it is also known as hydrogen cracking.

So, these two types of hot cracking or solidification cracking, and cold cracking or hydrogen cracking generally observed during the fusion welding process. But of course, these two cracking phenomena is entirely depend on the several parameters; but most it is link with a metallurgical or transformation that actually occurs during the solidification period or throughout a solidification period.

But what is the general measure or what are the situation is basically necessary to prevent the cracking phenomena in welding process. So, if you look into that points first all are tries to minimize the stresses for the shrinkage during the cooling period. And of course, to do that there maybe it depends on the change in the design during the solidification process.

So, what it is not always possible to avoid the completely the development of the stress during the cooling phases because maybe there is a phase transformation happens that actually into some most of the cases the some amount of the residual stresses. So, changing design in the sense that if it is possible to control on the rate of the cooling or maybe with the aid of some other external heat or maybe cooling process to control mainly the cooling rate can be done onto minimise the stress during the shrinkage, shrinkage process in solidification.

So, there may be another significant point that we need to do to capture or to prevent to avoid the solidification cracking. Several trials with the parameters are required. And then you can find out the opposite of the parameters that actually try to avoid in practically the solidification cracking or that is called solidification cracking or maybe you can say the cold cracking also; so in that case the sequence of welding maybe important.

Then sometimes preheating of the weld components; that means, before doing the welding maybe we can raise the temperature so that during the cooling period or maybe during the welding process, the temperature generated temperature gradient can be reduced that mean there may not be too drastic change in the temperature can be avoided if you do the preheating of the sample.

This is a one kind of very general technology that in that sense we can avoid the cracking phenomena in welding process. And finally, how to avoid to prevent the solid cracking that can be that following very slow cooling rate very slow cooling rate or even it is in moderate cooling rate by avoiding rapid cooling that during the solidification process. So, that can be one of the measure we can do to prevent the solidification cracking or in general the cracking phenomena observed in the during the solidification process.

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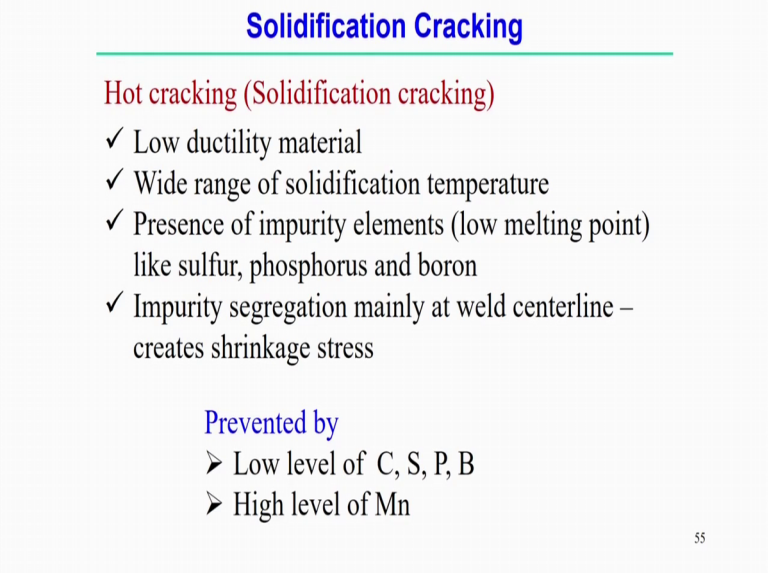

Hot cracking or solidification cracking normally occurs the in presence of low ductility material that means, if brittleness of the metal is high so in that case the development of the solidification cracking is more obvious. And apart from that there may be the wide range of the if material have wide range of the solidification temperature that actually promotes the solidification cracking.

And of course, from the metallurgical point of view, if the material content impurity elements that means, impurity elements it is having the low melting point elements like sulphur, phosphorus and boron and sometimes carbon presents within the hour that actually promotes the solidification cracking or that promotes the hot cracking phenomena.

So, also the impurity segregation that actually occurs at the weld centerline and that segregation sometimes create the solidification shrinkage stress that actually induces some amount of the shrinkage stress and that shrinkage stress basically induced the hot cracking phenomena in welding process.

So, to prevent that solidification cracking in general we can follow the low level of carbon, sulphur, boron and phosphorus these are the typically low melting point material elements. And if we try to control the low level of these elements in during in welding or maybe in the parent materials, we can to some extent avoid the solidification cracking.

At the same time that if high level of manganese that also helps to prevent the solidification cracking because presence of high amount of the manganese that actually neutralize the effect of the low melting point like carbon, sulphur, boron, they react with the manganese. And they basically reduce the effect of these individual elements like carbon, sulphur, boron and phosphorus.

So, in that way high amount of the manganese is basically is reduce the amount of the solidification cracking during the welding process.

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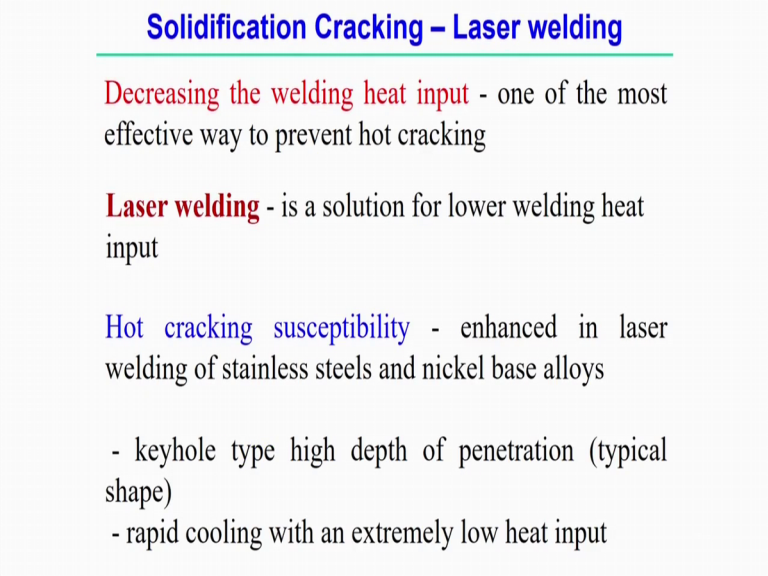

Of course the solidification cracking can also be reduced that by the in by during welding process if it is possible to reduce the welding heat input during the welding process. So, definitely the welding heat input can be depend on the welding speed also because high power if we use or high concentration in case of laser welding we generally use the high powered high concentrated heat, but part laser welding can be used at very high welding speed also. So, in that sense, if we use a high welding speed that also reduce the amount of the heat input to the sub state material.

So, in that sense laser welding may be a solution for lowering the welding heat input heat input in the sense that use the laser welding process at very high speed. So, hot cracking susceptibility can be enhanced in the laser welding process also in case of materials like stainless steel and the nickel based alloy. So, even lowering the heat input, but for a

specific material, the stainless steel and the nickel based alloy during the laser welding process can also be susceptible for the hot cracking phenomena.

In laser welding, sometimes it produce the mode of the laser welding maybe keyhole type of. So, in that keyhole type of depth of penetration is very high. So, typical safe of this also promotes the solidification cracking or hot cracking phenomena in laser welding process. And is there if we do not use any equation that means, in the equation so in that case rapid cooling with an extremely low heat input; So, normally very rapid cooling, but even at very low heat input that actually sometimes it is a promote the hot cracking phenomena in laser welding processes.

So, if we look into that mechanism of the solidification cracking, and it very specific to laser welding process. So, in that case the solidification cracking, if we look into the temperature and strain if we link it in the sense the thermal stand access the critical amount of the strain then that amount of the strain actually induces the cracking phenomena in case of the solidification during the laser welding process.

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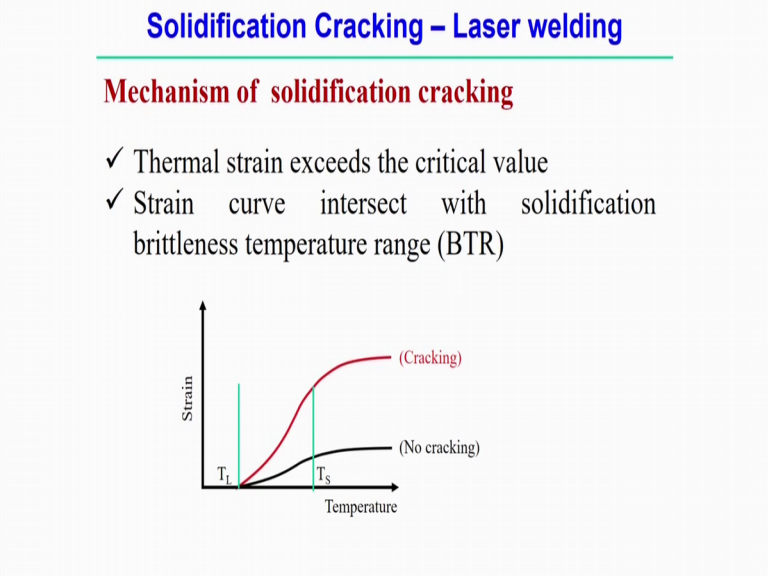

So, if you look into the figure also that the black line of course the strain induced the amount of the strain induce very low that actually may not create any amount of the any amount of the cracking between the temperature and the solidus and liquidus temperature. But if the amount of the strain thermal strain develop between the temperature and solidification solidus and liquidus temperature that amount of the strain

is thermal strain is very high and often it cross the critical value of the thermal strain and that actually induce some amount of the solidification cracking.

So, it is a by looking into the amount of the thermal strain generated during this process, and if you compare with respect to the critical amount of the strain, and we can predict the whether there is any solidification cracking happens in the laser welding process or not. If you look into this figure also the strain curves intersect the with the solidification brittleness temperature range that is called BTR; If strain curve intersect with the solidification brittleness temperature range that actually predicts that generation of the solidification cracking in laser welding process.

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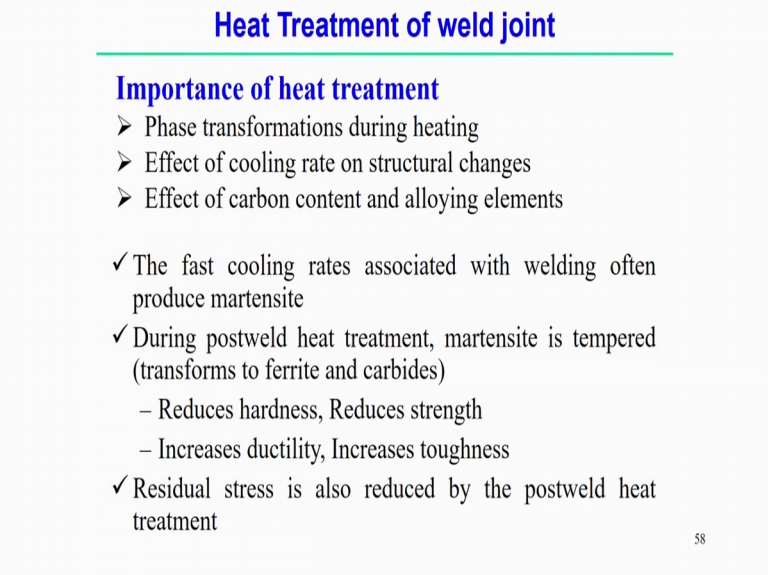

So, in this case, we are not be in much details about the solid cracking phenomena, but just try to give some overview of the solidification cracking phenomena this module. Now, we look into the heat treatment of the weld joint, because it is sometimes we use the heat treatment of the welded joint to get the to improve the weld joint strength. And that actually the heat treatment actually modify the structure microstructure basically and that microstructure impact of the strength of the weld joint strength, strength as well as ductility also.

So, heat treatments is open associated with the post weld treatment to find out the good amount of the weld joint or to recover some amount of the ductility of the welded joint the heat treatment is required. So, what the importance of the heat treatment can be

summarised like that during the heat treatment is a controlled heating or cooling and of course, over with respect to time that is the heat treatment process and during that process the phase transformation also happens during the heating process.

So, therefore, effect of cooling rate differently impact on the structural changes. And sometimes in presence of the carbon as alloying elements content or any other alloying elements that actually redistribute their structure redistribute in the microstructure of the weld joint.

So, in that sense it is try to input the weld joint properties. But the fast pulling rates associated with welding often produces the martensitic structure that we have seen if the cooling rate is very high in welding process. So, in that case there is a chances of production of the martensitic structure, but martensitic structure and the distribution may not be beneficial for this weld join.

So, that therefore during the post weld heat treatment, if you follow any kind of heat treatment process after the welding, martensite is basically tempered and that means, martensitic structure may transform to the ferrite and the carbides.

So, during the transformation its overall impact of the weld joint properties like that reduce the hotness, reduce the strength, but increases the ductility, increases the toughness, so that is the benefit of the heat treatment process in any case of the weld joint. Of course, residual stress is also reduced by the post weld heat treatment process, therefore, it is very important that looking into the structural changes whether there is a need for the heat treatment of the weld joint is required or not.

Normally, is if material contact is the high alloying elements or still contents the high amount of the carbon content. So, in that case heat treatment is very much essential to improve the weld joint strength.

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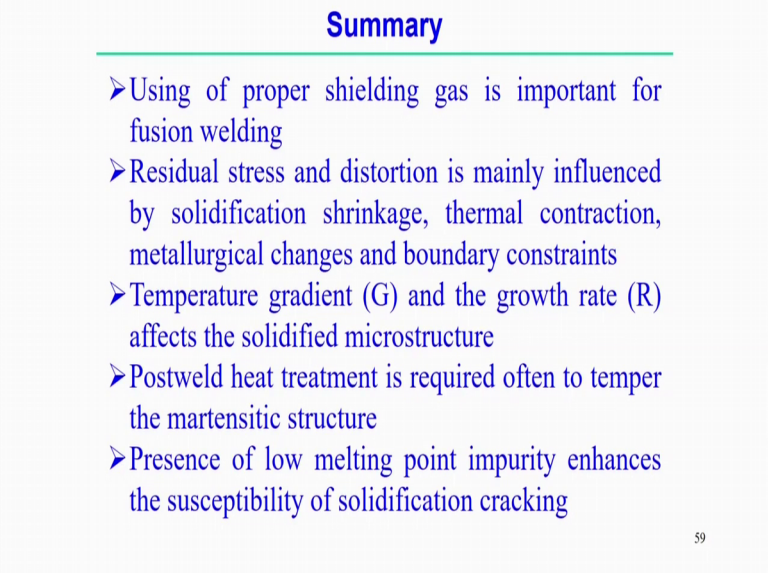

In summary of the solidification process, we can say that using of the proper shielding gas is basically important for the fusion welding, because the presence of the shielding gas is actually protect the molten pool from the outside atmosphere. But of course, the shielding gas also having the several characteristic different type their properties whether they are reactive nature with a molten pool or not accordingly we can select the shielding gas, but mostly fusion welding process. The inert gas is mostly select as a shielding gas because the reactivity of the inert gas at very high temperature or it is less with the molten pool.

Second, the residual stress and distortion is mainly influence by the solidification shrinkage, any kind of thermal contraction, metallurgical changes during the solidification with respect to the base material and any boundary constants all actually affects the amount of the residual stress and the distortion generated in the welding process.

Of course, we cannot avoid the amount of the at least some amount of the residual stress and distortion generates in the weld joint, but we can control or we can minimise the amount of the residual stress and distortion if we know the which factors is basically responsible for the generation of this distortion residual stresses in a while return.

In terms of the solid analysis of the solidification process in welding, the temperature gradient and the growth rate G and R is the main two parameters that actually influence

the solidified microstructure. And that quantitatively explain the solidification behaviour during the welding process using these two parameter combination of these two parameters that means, G by R that actually controls the solidification mode. And G into R that represents the rate of the pulling that means, whether the fine structure or course structure can be produced that is better describe quantitatively the by the multipitle multiply of the G and R these two parameters.

Next postal recruitment is open required to tempering the martensitic structure and that actually improves the weld joint properties. Of course, presence of low melting point impurity elements like sulphur, phosphorous, boron, they actually enhance the susceptibility of the solidification cracking. So, it is always use that presence of this impurity the low level that actually helps to prevent the solidification cracking or presence of the other alloying elements such as manganese that actually neutralize the effect of this low melting point impurity in an alloy during the solidification process. So, in that sense the presence of the large amount of the manganese is helps or to prevent the solidification cracking.

So, with this I just end of this module six that was related to the welding metallurgy. If necessary, there may be the related any kind of mathematical problems related to this module, welding metallurgy we can discuss and the short term basis.

Thank you very much for your kind attention.