Theory of Production Processes

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Lecture - 56
Weldability of metals

Welcome to the lecture on weldability of metals. So, first of all you must know what is weldability? Weldability as you know this is a composing of towards that is welding and ability. So, the ability of the metal to be welded so, how easily the metal can be welded that is basically in a very rough way we can say that, if you are able to weld the material in easy way it is way it is more weldable than those materials which can be welded with lot of difficulty.

So, that is in rough sense we talked about the weldability. So, we will talk about these weldability aspects of different materials, and this is important because welding is one of the very important process very you know keep process in manufacturing because, it is extensively used in most of the structures which you are seeing largest structures specially they are they are you have you know lot of use of welding.

So, now the thing is that when you do the welding you always feel that the quality of the joint should be better, that should be proper you know properties the property should not be you know decreased because of any other factors are. So, so for that you have to be controlling lot of things you have to have proper selection of material proper, selection of electrode, proper selection of operating parameters proper design proper you know joint design fitting and all that.

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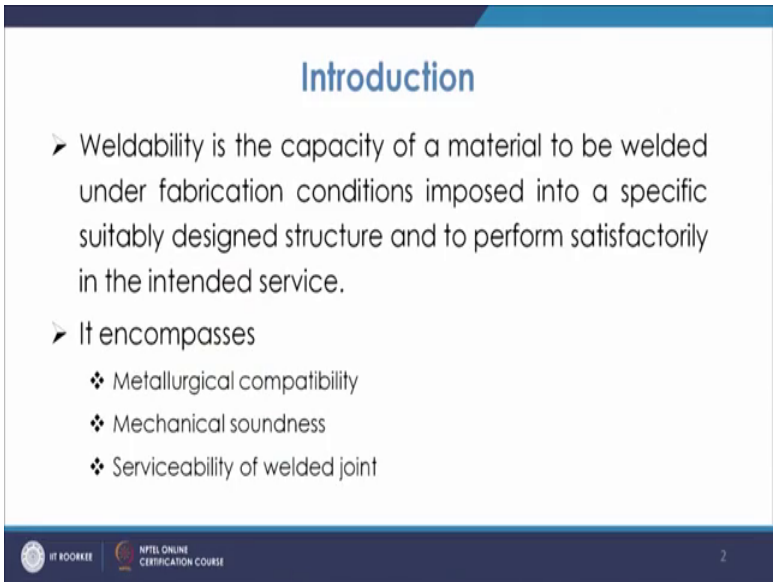

So, when we talk about weldability so, it is the capacity of a material to be welded under fabrication conditions imposed into a specific suitably design structure and to perform satisfactorily in the intended service. The thing is that you are welding the material or joining, sometimes a you have different conditions you may have the joining with one way like you may use the you know flame welding or you may use arc welding or you may use the non-conventional welding processes.

Ah so, you may have you know specific fabrication conditions. Now, and also you have a particular structure which is to be welded. So, when you are doing the welding a you feel that after welding the structure should perform satisfactorily you know for the intended service. So, it means that you know once the welding is proper, the properties will be you know as per desire whatever you expect the material to behave, whatever the way you expect the material to behave it will behave in that fashion. So, that is that is when you can say that the material is proper weldable.

Now, a weldability basically encompasses 3 points. So, first point is the metallurgical compatibility. So, a that is a metallurgical compatibility of metaler alloy with any specific welding process. Now, when we talk about the metallurgical compatibility it means, that the base metal and the weld metal they can be combined with the you know proper degree of dilution. So, within certain degree of dilution they can be combined and that will not adversely affect the property of the welded structure.

So, that is what you know because, what happens that when you talk about the weld metal during the weld metal zone. If you are using the filler metal you shall using is to electrode they do not have basically the same composition as that of parent metal. So, you have some degree of dilution. Now, that dilution which is or you have different alloying elements also we put in into the weld metal zone. So, that basically gives you the dilution.

Now, what degree of dilution upto what degree of dilution can be observed? So, that is known as metallurgical compatibility because, many times if it is not metallurgical compatible it means, it may lead to some different assets of phases which may give you undesirable structures or undesirable properties like, you may have deformation of different type of carbides or you may have undesirable very hard phases so.

So, that will basically be affecting the property of the material or the welded joint. So, that is why we talk about the metallurgical compatibility and this is a very important you know point because, if they are metallurgically compatible if you are taking the the plate material as well as in the material in that weld pool.

So, that way if they are not having good compatibility then, you may have the you know deposition of carbohydrate all are on the grained boundaries that may induce you know the brittle behaviour of the material or you may have different phases, which may be undesirable which may decrease the ductility or ductile between transition temperatures. So, this way if there may be effect on those points.

So, metallurgical compatibility that way very important when we talk about weldability the second point is the mechanical soundness. So, mechanical soundness means the material which you are welding and the in that weld pooled, when you have the solidified weld then it should be mechanically sound because, ultimate in the mechanical properties will depend upon the absence of impurities or absence of the blow wholes or cracks or defects.

So, the, you know a weld must be mechanically sound then only you can say. So, in most of the cases when you which will be mechanically sound then, at least you can ensure that they will not it be pre mature failure of that joint. Because, it is mechanically sound. Otherwise if you have for the formation of wires if your do not control the, you know the porosities in the weld zone, or if you are not able to see that you have different kinds of

well profile or you have cuts or cracks or. So, in that case it will not be a sound weld, and then a it will reflect on the mechanical properties of the welded joint. Third part is the serviceability of the welded joint.

So, you know it will be talking about the different you know service conditions under which the weld metal has to work. When we do the welding because, this failure of the component or breaking of the component may occur at any place. So, when we do the welding we feel that after welding the materials should work satisfactorily, or you they can give you the service satisfactorily under any condition like, it their maybe condition of the impact their maybe condition of low temperature. So, so the material must be performing satisfactorily under the different a conditions of service like, low or high temperature impact loads and also.

So, in a nut cell when we talk about the weldability of a material then, a if the material has adequate weldability we must be in a position to tell with confidence that, the materials strength and toughness should be quite high after welding. So, because what to happens the these are the challenges in welding, when you do the welding and if the heat extension it will be too fast in that case hardness may increase but toughness may go down.

So, what you required? What you aim after welding is that you must have the proper strength and toughness even after the wedding. Similarly, even with the high dilution you are able to give the good quantity quality of weld. So, that is another requirement which you know is there for material to be good weldable then, you have there is no change in the course on resistance of the material after welding.

So, because maybe because of the formation of different phases, and because of the formation of undesirable phases at the gained boundaries also deposition or. So, the course of assistance may come down. So, that properties also interact there is no change in that property. Similarly, when your stress relieving that time also there is no you know there is no brittle type of phases which are forms. So, paraphrases in brittlement should not be there.

So, these are the points which are basically important when we talk about the proper is a weldability of the material. Now, when we talk about the weldability then in the weld

pooled you have different alloying elements, and how these alloying elements are going to affect the weldability of the material.

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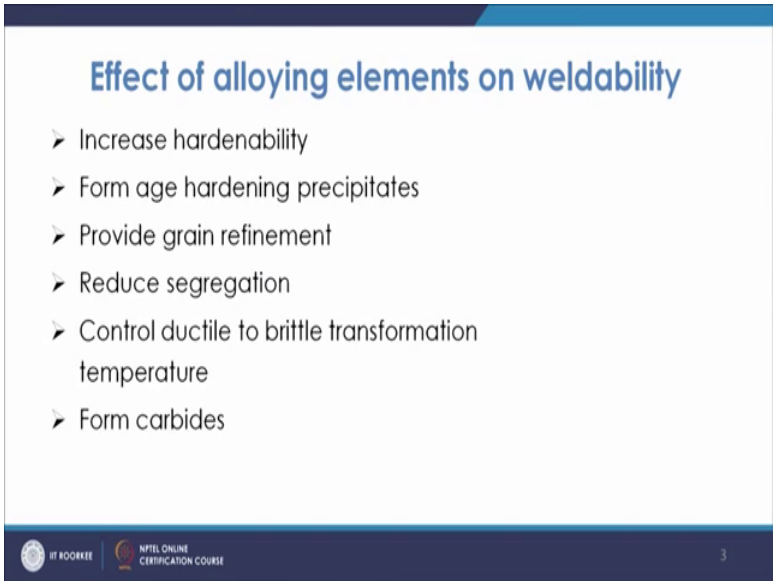

So, for that will discuss so, first is that increase or decrease the hardenability. So, as we know that the alloying elements have a great effect on the hardenability of the material. Now, hardenability is nothing that, but by the use of this materials, when the material is more hardenable it means that, the material will be more hard even under the normal conditions. So, use of suppose paraphrase materials. So, it will try to from the martensite phase even have the normal cooling rate. So, a with certain type of alloying elements they may increase the hardenability.

So, hardenability of the adjacent is very important and some of the alloying elements increase the hardenability, and some of the alloying elements decrease the hardenability. Whereas the hardenability is increase there will be more chances of formation of the very undesirable phases in the adjacent, and in that case there maybe you know improper behaviour or improper properties which will be set up in the material.

So, the elements which are basically said to have a large effect on the hardenability in case of steel they are carbon manganese molybdenum, vanadium, chromium all these a you know nickel or silicon, they have a large amount of effect on the hardenability. And some of them have the positive effects on the hardenability and some of them have the

negative effect on the hardenability. And hardenability is basically can I mean quantized or they it is basically represented in terms of the carbon equivalent volume many times.

And this carbon equivalent volume can be expressed as the percentage of carbon plus certain fractions of this alloying elements percentages like, you may have certain type of expressions like percentages of carbon plus percentage of manganese by 4, or plus percentage of nickel by 20 plus percentage of chromium by 10 or so. So, like that if you have a steel of certain composition which we have these alloying elements then, a these alloying elements like manganese nickel or chromium they have a positive effect on the hardenability, they will in try to increase the hardenability of the material or not hardenability.

Basically, they are a going to increase the carbon equivalent value and then, elements like molybdenum or vanadium they are going to decrease that because, they from the carbides so, they are consuming that carbon.

So, that way they decrease the hardenability and larger will be the value of this carbon equivalent. So, we will find this carbon equivalent values depending upon the carbon percentage and they percentage of the, this alloying elements. And if the carbon equivalent value is larger than the hardenability will be more and more chances of having the formation of martensite in the adjacent.

So, that has to be properly controlled you have to see that what is the you know hardenability, I mean when you have to express that in terms of carbon equivalent and then a properly because then, weldability can be further you know define for certain materials that if it has that was a carbon equivalent, what should be the welding procedure? So, that it will give you the proper you know structure of the welded component. Similarly, you have the alloying elements also take part in the formation of age hardening precipitates.

So, mostly in the case of non-ferrous materials, what happens that if you have alloying elements and as we know that a hardening takes place because once you know do the welding. So, after welding because of cooling rate is quite fast. So, after the welding is done, then the age hardening precipitates may fault. So, the alloying elements will be you know making that is hardening precipitates, then they will be you know giving

accordingly the property there will be modifying the property of that you know area the reason where the precipitates are fault.

So, the, this is another role of the alloying element. Alloying elements also provide the grain refinement many a times the alloying elements are used for the grain refinement, and in that you have normally you know elements like aluminium, maranium, titanium, zirconium and naturism they are acting as the grain refiners. So, what happens that in such cases they will be acting as the hydrogen nuclear agents? And then they will be making the fine grains.

So, they are acting as grain refiners in the low alloy steels. So, these alloying elements will refine the grain and once you have refined the grains. So, that way you can have the elements presence of the alloying elements in the in the zone. And they you can assured to be having a fine grain structure that will provide a better mechanical properties. Then reduce segregation so, the alloying elements also they will try to reduce the segregation at times, they will be controlling the ductile to be till transformation temperature.

So, the, that is another challenge because many a times when you do the welding, than the material which you otherwise could have behaved in a ductile manner. That starts behaving in a brittle manner I mean. So, if there is a temperature which is there. So, above that temperature material has to behave in a ductile manner, and below that material that has to you know behave in a brittle manner. So, that temperature may be you know altered. So, that that also is controlled many a times while using the alloying elements. So, this is very important for those reasons where your working temperature is less.

So, suppose we are working in a very high region, dark region or in the region where the temperature is very, very low in those region this is very important and in those region this is also become in important because, while you do the welding the it becomes very, very fast. The cooling becomes very fast because the externally external ambient temperature is at a very low temperature. So, that makes another challenge.

So, but any way this ductile to little transformation temperature is also effected because of these alloying elements. Then alloying elements have another important you know role that is the formal so, the carbides. So, as we know that many a times the, you have carbide forming elements and they will be forming the carbides and they provide the

hardness. So, that is the example of. So, like you have a vanadium or tungsten or these are the strong carbide forming elements.

So, that will be you know they with a form that and they may affect the a weldability of the material. So, another important role of these alloying element is that basically, they also provide the deoxidation of the metal without loss of we primary alloying elements. So, normally they will have for the strong affinity towards oxygen, and they will react with oxygen. And you know I am the alloying elements loss will be and less which is basically required for the better properties of the material. So, they normally act as a very good oxidizers in a many cases like aluminium, silicon or even zirconium or titanium they also work as the, you know deoxidizers.

So, they do the deoxidation of they remove the oxidation oxygen from the melt. So, that way these alloying elements they are and then, once you have the purposes that by this means we are trying to achieve we are trying to see that the zone, which is where the welding is carried out the weld metal zone or so. That has a minimum of the impurities minimum of you know the, you know phases which are undesirable for the good weldability of the material.

So, that is why these you know alloying elements are is any it is effect on weldability is required to be you know known, that what way there affecting the and hardenability or what way they make the precipitates, or what way they whether they are contributing towards grain refinement. So, or whether they are contributing towards the you know ductile to little transformation temperature or so.

Now, the next thing which is important to be understood in the case of weldability is, that how to test the weldability. So, for testing the weldability the purposes is to gather the information about the behaviour of material during the welding so, that you can establish the correct welding conditions. Now, for when you are doing the welding under with certain conditions like, if you are welding a material at certain temperature condition or with certain typical machine, you may do the welding of the same component using either the frame welding or in the arc welding. In the arc welding also, you can do with (Refer Time: 21:51) electrode you can do with tig or mig or you can go for solid state welding or so.

Now, the thing is that you must know, that in in all the specific conditions what should be you know the other conditions under what condition the then the welding when you do, it will have a satisfactory performance.

So, basically the tests are carried out and these are the weldability tests, and these weldability tests they help you know to know about the behaviour of this material you know. So, that you can establish correct welding conditions for a typical process and that way you know they will provide you the information about what will be the appropriate welding process selection?, what should be the best possible welding process for a particular material like, you are trying to weld a material which has suppose composites now, in in the composite or even the aluminium alloys.

Now, let us say about the aluminium material. Aluminium based composites aluminium alloys let us say first. Now, the basic challenge with aluminium alloys is that aluminium being very, very fast conductive heat. You have to see that you have to have a selection you cannot do with frame welding also because, the heat extraction rate is quite high heat input rate is very slow.

So, rate of heat input is very slow. So, you cannot go with that. So, also it has a input rates into oxidizes. So, this way you have to see that, but it does not mean that it is not weldable. So, you have to have the proper process you will have to experiment different processes, and you have to contract the different challenges which you are facing during that welding process. So, that you ultimately come to a process which gives you the better or an satisfactory you know welding process and gives you a satisfactory joint.

So, as similarly when you are doing the, you know welding of certain composite materials. So, in that case you have different material which is softer, which is lighter and then you have you have the you know met these a reinforcement matrix. Now, they have different properties all together it may be lighter it may be heavier, if is heavier when you are doing the fusion welding they may go and settled down at the bottom. So, we will have segregation of the alloying elements or are the elements.

So, that will basically not the giving you the same property of material as that of different parent material, and then you will say that weldability is poor, but then you will have to design you will have to know that what should be the proper process by which even these materials also can welded. So, may go for some kind of solid state welding,

where you do not give the time even to fuse them you are. You are joining by other solid-state welding processes because of the, you know friction which is generated like friction star welding or so.

So, what we mean to say that in this case we try to have the appropriate you know welding process selection. Similarly, there may be you know information about the preheat many a times. We see that if you do the welding in a normal way it gives undesirable property, it there may be hard phases there may be cracks, but then if you do the preheating you may do that test using different amount of preheat, and then you can see the property of the material.

So, it will talk also talk about the pre heats. Now, if you change the preheat different value of preheat and then, you judge the quality of the you know weld pool the strength of the weld pool, that will help you in assuring that yes, the property will be better at which degree of preheat. It will also help you to decide about the degree of preheat.

Then you have also the information about the energy input what should be the proper energy input, but which will give you the sound weld in those cases then, other you know about the joint design, what should be the proper joint design which will be giving you the weld of good quality. So, all these they are giving you the testing test are carried out to give you the different types of these information's which you which comes out from these test. Now, the weldability test basically when we talk. So, they are classified as either you know theoretical test, simulated test or you can have the actual welding tests.

So, when we talk about the theoretical test what we do there is, that we have a member of knots bend specimen and it will be astonished at certain temperature supposed 1150 degree centigrade, and then we are a cooling at some calculated rates to duplicate this process. So, that you get the expected the hardness of the h a z and then you try to see the to bend the specimen through 10 to 20 degree.

If you are able to bend it you are say telling that it is having good weldability, otherwise you say that yes weldability is becoming poor. So, this is about the theoretical type of test which is carried out in the case of weldability. Similarly, you have a simulated type of test. So, in that simulated test what you do you are going to treat that material.

So, you are giving the heating and cooling to in the metal specimen, or the thermal cycle just as a that is subjected in the case of welding. And then you are basically, so you have a simulated type of behaviour same the way the material subjected to that thermal treatment in the case of welding, that type of treatment you given then you check the properties of the materials that is your simulated test. So, similar to that actual welding condition, and then you have actual welding test basically that test is normally you have 2 types of you know test that is one is you have the fabrication weldability test.

So, in that we do that hot cracking test or cold cracking test or all that is hydrogen induced cracking test or root cracking all that test is carried out. Similarly, so you have other service serviceability welding test. So, that service weldability test includes all that properties like, property having a tensile hardness then impact test, and fatigue corrosion all that type of test can be done and you can talk about the weldability issues.

So, how of once you have done the welding whether how much it has affected the tensile properties or the you know hardness or. In fact, properties or could corrosion or fatigue. So, this way also you can test the weldability if it is not affected means the weldability is better and if it is affected means. So, it has affected the weldability or weldabilities poor in that aspect. So, this way you have different aspects based on which you can even check the weldability of the material.

So, similarly, you have we discussed about like how you can judge about this welding processes selection. So, you can have you know different processes like may be fusion welding or you can go for the solid-state welding. You can go for non-conventional welding and you can dangerous that how sometimes you can see that a material is completely not weldable, because of with certain process. But that is possible to be welded with some other process.

So, these all will talk about the different types of you know processes, which will be suitable for welding certain specimen. So, this is about the weldability of material. That is you know very important for this welding you know students you should know because, weldability itself is a very, very you know vast area. And a weldability issues are there with the typical elements like, weldability issue can be discussed for a typical material like may be for iron-based material or for nonferrous materials for nonferrous of

different materials different categories so, that way may be you know discussed may be in the coming lectures.

Thank you very much.