Theory of Production Processes

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Lecture - 57
Weldability of steels

Welcome to the lecture on Weldability of steels. So, in this lecture we are going to discuss about the weldability aspects of steel. We have discussed about the weldability aspect of another ferrous based material that is cast iron. So, in the case of cast iron the carbon amount is more, it will be more than 2 percent. So, once we go to that range you have the cast iron and its varieties come.

Then before that in the lower range of carbon and with suitably more alloying elements, you have the variety of material that is steel. So, we will discuss about the weldability aspect of a steel because steels are very much used in most of the engineering applications and we need to know, because there are varieties of steel you have depending upon the content of carbon we categorize steel into low carbon or medium carbon or high carbon steel.

Similarly, depending upon the alloying element content, we also categorized as low alloy steel or high alloy steel and similarly you have the stainless steels also which has the special properties of stainless character. So, in that again depending upon the type of matrix you know type of phase you have so, that is ferritic or martensitic or austenitic type of stainless steel. So, all that different variety of steels are used for different applications and their weldability behaviours also different. So, we are going to discuss about there are different weldability aspects.

Now, coming to the different you know varieties of steels, you if talk about steel we call it either first of all is the carbon steel. So, the carbon steel basically you have it will be differing from the cast iron and they will be having about 0.1 to 1.5 percent of carbon.

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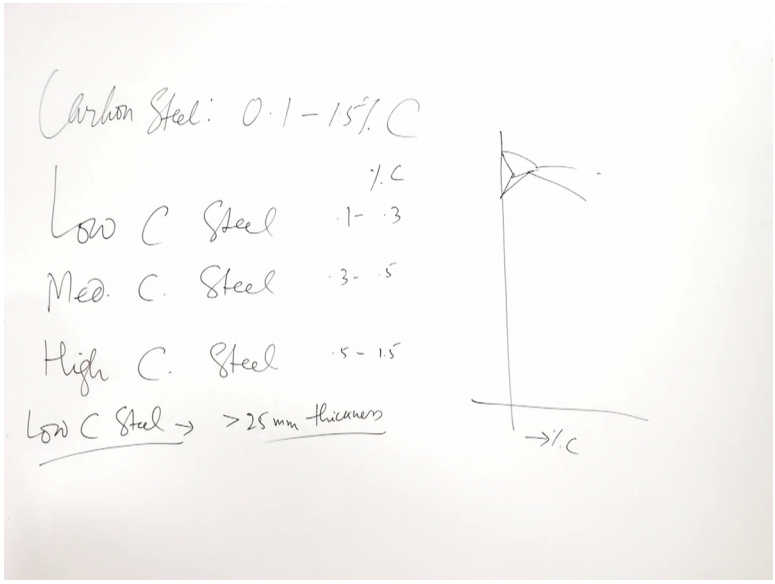

So, you have carbon steel it has 0.1 to 1.5 percent of carbon and more than that once we go I mean more than 2 percent or so. So, 1.5 percent later on that is it does not be is not regarded as steel. So, that is regarded as cast iron. So, in this that can so, you have the range from 0.1 to 1.5. So, when the carbon content is quite a small so, you have the low carbon steel and similarly so, up to 0.5 percent or 0.3 percent; from 0.1 to 0.3 suppose you call it as the low carbon steel. Similarly, when you go from 0.3 to 0.5 percent, we call it as the medium carbon steel and then when we go from 0.5 to 1.5 percent we call it as the high carbon steel.

Now, as the carbon percentage becomes more and more, the ease of welding becomes lesser. So, as the carbon content will be lesser the ease of welding will be more. So, once we are so, we have low carbon steel and we have medium carbon steel and then we have high carbon steel. Now, the thing is that in normal circumstances if you try to because the carbon percentage will be in this case around 0.1 to 0.3; this will be 0.3 to 0.5 and then this will be 0.5 to 1.5 percentage carbon. So, like that.

Now, as the carbon percentage becomes more then the weldability is decreasing because of the obvious reason that if the carbon percentage becomes more the hardenability increases. And then you will have more chances of formation of the martensitic phases in that hazard and then once that phase is undesirable because it has unduly high amount of hardness. So, that way the weldability aspect is changing. And so, when you are in this

range of you know low carbon steel then it can be welded with most of the welding operations and if the thickness is up to certain reasonable value then even the preheating or post heating is not required.

But then if there is a large amount of you know thickness then certainly so, there will be some requirement. But then as the carbon percentage becomes more the difficulty of welding becomes more. So, you need to have the proper you know operating process parameters changed. So, that the welding quality is better. So, that is what we will discuss today.

Now, we know that you have the different applications of these steels in different regions and as far as the low carbon steel is concerned it is very difficult very easy to be welded and to be machined. So, and its melting temperature will certainly be a little bit higher because we can recall that if we have if you see the so, as you know as so, as you go on increasing the carbon percentage; so, the melting temperature goes on decreasing.

So, towards the lower value of the carbon you have larger little bit about 20 to 30 degree centigrade higher melting point. And normally because of the less amount of carbon your welding processes are quite inexpensive. You do not have to bother much about the welding aspects.

Now, in the case of medium carbon steel, its melting temperature will be slightly smaller, even 20 to 30 degrees smaller than the low carbon steels. But then here you need to have you know the provision for preheating or post heating because the presence of carbon makes it difficult to be welded. And once you go to high carbon steel then it becomes very difficult to weld and mostly we are limiting these you know this type of components only for repair purposes; that to under very controlled conditions we try to welded with high carbon you know electrodes or with other parameters being adjusted, so, that we will discuss.

Now, when we talk about the low carbon steel welding; Now, in this case when your thickness will be more than 25 mm, so, for low carbon steel as so, for more than 25 mm thickness you required to have the pre heating conditions. Otherwise you do not require preheat and it is quite easily welded. So, pre heating as well as the post weld heat treatment for stress relief is required in the case of a low carbon steel welds.

Now, most of the processes of welding like you have oxy acetylene welding or you have the shielded metal arc welding or submerged arc welding or gas metal arc welding that is MIG or TIG. All these plasma arc welding or thermit welding, they all are used for the welding of these low carbon steel you know place which are to be welded. When we talk about to the medium carbon steel; now in the case of medium carbon steel because the percentage of carbon is becoming more; So, you will have the increase in harden ability of the you know the joint and you will have more chances of formation of the martensite.

So, as the martensite is a undesirable phase which should be avoided. So, what we do is normally we use the special welding techniques and also we try to have the preheating. Now, in this cases also you have the processes which are used or like you have flux shielded metal arc welding or oxy acetylene welding, then you have resistance welding, thermit welding; these are the processes or submerged arc welding. These are the processes which are used even for the you know medium carbon steel welding components.

Now, in this case we go for the preheat and preheat temperature will be varying from 150 to 200 degree c normally and that induce I mean that tries to eliminate the hard and brittle areas. So, this preheating is a practice. Also your post heat treatment is also carried out. So, normally we post heats the job may be around 600 to 650 degree centigrade or 675 degree centigrade and depending upon that the timing also is there for how long.

So, that normally we follow the principle of about 1 hour for 25 mm of say some thickness. So, that is the holding time and then we are cooling it. So, in this way we are trying to achieve improving the metallurgical structure, we are increasing the ductility of such components because otherwise if your formation of martensite takes place that is going to affect the ductility of the welded component and also it will reduce the residual stresses which develop during the welding.

So, these are the precautions which we take in the case of medium carbon steel and we imply the different type of welding processes as we discussed and when we use the oxy acetylene type of welding, we normally try to see that we give more acetylene you know.

So, you will have a coveraging flame type of welding process because the carbon content should not be becoming less. So, that is how we proceed in the case of the medium carbon steel welding. We also have the problem because of the hard and brittle

constituent during the cooling and that is why we do the this post weld heat treatment of the medium carbon steel welded samples.

Now, coming to the welding of the high carbon steel samples; now in the case of high carbon steel normally we try to confine to for the repair purposes because it is very difficult to be to weld them. And normally when we use the flame welding then we try to use the coveraging flame in that case also because the carbon content should not be less, so because you have the large amount of carbon.

So, we use the you know very carburizing flame type of you know welding process, for welding these high carbon steels. Also we have to have proper care and you have to see that the object should not be overheated and the well should be completed fast and you know it should be heat treated after the welding.

So, these are the precautions which are you know followed while doing the welding of these high carbon steels. And the processes which are used are the oxy acetylene welding, then you have thermit welding, you have flux shielded metal arc welding and the resistance welding. These are the processes which are used in the case of these high carbon steel weldments. So, this is about these.

Now, we will talk about the welding aspect of the low alloy steels of these ferrous materials. So, in the case of steel we also alloy with certain compositions; certain elements to make the properties better and when the alloying addition is done to the smaller side I mean the is the percentage of alloying element is less we call it as the low alloy steels and then we have the alloy steel where the percentage becomes more.

So, in the case of low alloy steels your alloying elements does certain specific you know the contributions and the alloying elements are like molybdenum tungsten and cobalt, boron, copper. These are the you know alloying elements like chromium, nickel.

So, these are the alloying elements and they normally provide better corrosion resistance, they provide better harden ability, then you know grain size control is also imparted by these alloying elements; you have the greater strength impartment is imparted by these alloying elements and the machinabilities improved and also the high or low temperature stability as well as the ductility is also improved. So, these alloying elements are normally added to improve these mentioned properties.

Now, all these type of alloying elements like carbon or this chromium vanadium, nickel, copper; so, all these have this specific type of you know you know contributions and that is not to be studied in this. But we will are going to discuss about the welding properties or weldability of the low alloy steels and among them one of the very important material is the low alloy high strength steels.

So, these low alloy high strength steels are about 10 to 30 percent stronger than the carbon steels and certainly once we add the alloying elements, then they become little bit more expensive as compared to the medium carbon steels but then owing to its better properties we always try to prefer them.

As far as its weldability is concerned it will be depending upon the hardenability characteristics. So, and the hardenability will be again depending upon the composition. So, we have earlier studied that hardenability will be again depending upon the carbon equivalent and carbon equivalent will be depending upon the percentage carbon and the fractional values of the percentage of the alloying element.

So, depending upon that you will have the weldability characteristics being varied. And similar to the medium carbon steel they are also carried out the welding of these lower high strength steels. And the important you know one of the important trait of welding these high strength low alloy steel is that the there is prevention of underbid or cold cracking. So, that is basically less. So, that way we are having that advantage over the other type of medium carbon steels

Now, different type of welding processes are used even for these low alloy high strength steels and they are like you have residual stress welding, you have also you know oxy acetylene welding that is also practiced for such kind of materials, you have a flux shielded metal arc welding and then submerged arc welding, thermit welding are used.

So, in a nutshell it should be you know kept in mind that normally depending upon the hardenability you will have to have the proper welding processes because if the hardenability is more you will have to go. Similar, to the line of carbon steels you will have to go for the preheat and post weld heat treatment and if it is less then you can go accordingly; you can take the suitable welding process.

Then there is another variety of steel that is tool steel. So, you have a lot of varieties of to tool steel and it may be based on tungsten. So, tungsten high speed steel, you have molybdenum based high speed steel high carbon, so high chromium steel air hardening steel. So, there are varieties of tool steels and in the case of tool steel the welding is required because many a times it is very very costly to replace the tools. So, if you have a small type of repair or Thomson welding is required you need to do the welding of even tool steels.

So, in case of tool steels the weldability consideration is also important because you will have the compositional variation of the different tool steels; the composition will vary. In some cases you may have the different composition of vanadium or different composition of chromium or tungsten or so. So, plain carbon tool steels they can be you know welded without much of the difficulty and you do not require the preheat or post heat treatments.

But if you have the high carbon steels or high alloy steels in those cases you will must use the proper preheating and post weld heating treatments for these tool steels also. And the processes which are used for welding the these tool steels are oxy acetylene welding, shielded metal arc welding, then submerged arc welding, atomic hydrogen welding and other welding processes. So, that is how we do the welding of tool steels.

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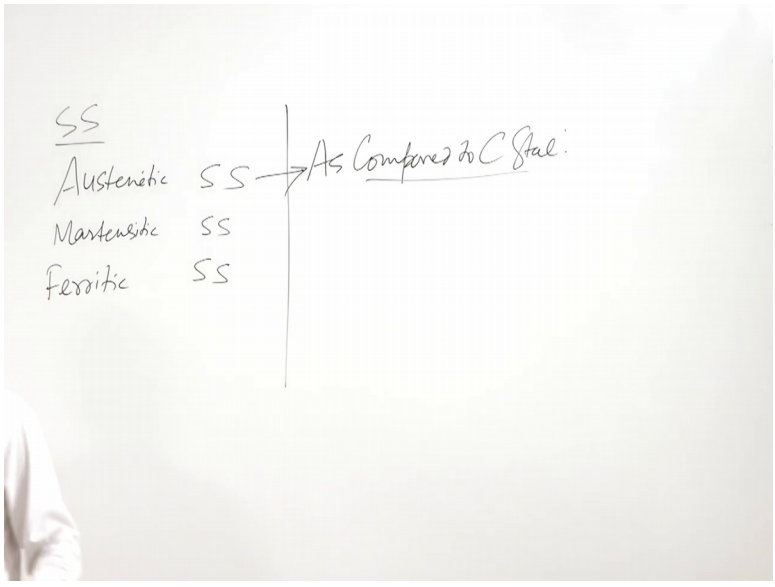

So, then the next variety is the stainless steel; so, which is also known as SS. Now stainless steel has been used very extensively nowadays because of its unique properties that is being stainless. So, this is basically achieved because of the presence of chromium more than certain limit and in that case the chromium will react with oxygen and it will make a layer of chromium oxide. So, this chromium oxide imparts this stainless property and that gives you know quite a corrosive resistant property. So, that is how they say it is very much demanded material.

Now, the stainless steel is normally of three types and it is categorized as austenitic type of stainless steel and then you have martensitic stainless steel and ferritic stainless steel. Now, depending upon the you know type of microstructure which you get if you have austenitic matrix, you have austenitic stainless steel; otherwise if it is ferritic then it is ferritic metal stainless steel and if it is martensitic phase then you have martensitic stainless steel.

Now, the austenitic steel they have some special properties; that they possess the authentic structure at room temperature; that is why they are known as austenitic stainless steel. Then they have the highest corrosion resistance among the three varieties of the stainless steel. Then they possess the greatest strength and scale resistance at even high temperature. So, that is another special quality of this austenitic stainless steel.

They are ductile at temperature even approaching absolute 0. So, that is another special quality of this austenitic steel because at lower temperatures when you go because of the ductility to brittle transition. So, near that absolute 0 every material most of the materials will become behaving in that fashion but this material still behaves in the ductile fashion.

So, that is special quality of that and also they are non-magnetic. So, they can be identified easily when we are trying to see that how to differentiate them and they have special applications in the aircraft industries, you have chemical processing industries, food processing industries or so.

Similarly, you have the ferritic stainless steel. Now, they have the microstructure which is primarily ferritic. So, that is why they are known as ferritic stainless steel. Now, they are basically they have low carbon to chromium ratio. So, you know as compared to this austenitic stainless steel and they are magnetic; they have good ductility and the another

property with ferritic stainless steel is that they do not work harden and to any appreciable degree.

So, you cannot increase the hardness by work hardening to appreciable degree and they are more corrosion resistant than martensitic but less than the austenitic. So, so you will have austenitic first and then marten ferritic and then martensitic. And they have normally manganese of about 1 to 1.5 percent; silicon about 1 percent and chromium is from 11 to 27 percent of the you know chromium is there and they have used in the heating elements for furnaces. Similarly if they have for the lining for the petroleum industries; screws or fittings oil burner parts are made by these ferritic stainless steels.

Then you have martensitic stainless steel; the martensitic stainless steels have the martensitic structure. They have high carbon to chromium ratio. So, and they are magnetic in all the conditions and they have the best thermal conductive among all the varieties of the stainless steel. And their hardness, ductility and ability to hold this hardness or high temperature; the that is giving a proper age; I mean a an advantage all other varieties and they can be cold word without difficulty. So, this way these are the special traits of these martensitic type of stainless steel and they are used for pump and valve parts and turbine buckets and so.

So, these are the you know uses of these three varieties of stainless steel; Now, coming to the weldability issues of austenes austenitic stainless steel. Now, in this case they have if you talk about the properties of austenitic stainless steel, now their electrical resistance is 6 times that of the carbon steel. So, and similarly the melting point is 90 about 90 degree lower or 10 degree lower than the carbon steel. Then thermal conductivity is also 50 percent lower. So, thermal conductivity is about half and but the thermal expansion coefficient that is quite 50 percent higher than the carbon steel.

So, if you take these points like you have you know 6 times so, as compared to carbon steel. So, it has as compared to carbon steel what you see is you have 6 times electrical resistance; you have lower you know 100 degree lower melting temperature and you know 50 percent lower thermal conductivity. So, all these properties they give you the lower welding current requirement. So, that way the the weldability issues are less in that sense, you have better weldability characteristics.

However, they are expansion; thermal expansion is 50 percent higher than the carbon steel. So, that basically is going in the other way because of these expansion properties; improper expansion property, higher expansion coefficient; their chances of distortion in the case of this austenitic stainless steel is higher. So, the chance of distortion becomes more. So, warpage and distortion may take place and there may be high chances of weld cracking if you try to give their will restraint.

So, that is normally the problem with the austenitic stainless steel and particularly you know that is more severe when your alloying additions are more. So, also when you are making the welding of these austenitic stainless steel and when you are heating in the range of about 450 to about 870 degree centigrade and you are slowly cooling through that region, then what happens; that the chromium carbide precipitation takes place.

So, this way there will be depletion of a carbon. So, chromium basically reacts with carbon and makes the chromium carbide precipitation and so, the chromium availability for making that chromium oxide layer which imparts the corrosion resistance property that is also hampered.

So, you will have to see that when you are cooling through that range about 480 to 870 degree centigrade; at that time you will have to see that you are cooling at a fast rate. So, that is the precaution which is taken when you are making the welding of these austenitic type of stainless steel.

So, for that you will have to have the selection of the stainless steel with lower carbon content because lower will be the carbon content then lower will be the chances of formation of chromium carbide and that is how chromium will be available for making the chromium oxide, also the time during which it is cooling. So, that also time has to be shortened. So, that in that process the chromium carbide precipitation which is taking place that is also you know lowered. So, that is another way of controlling that.

Also we can take care of this carbide precipitation prevention by adding certain type of alloying elements like titanium or tantalum or columbium which make which have the more affinity towards carbon and they make carbides. So, you have less availability of carbon for the chromium carbide precipitation.

So, these are certain you know methods or by giving proper heat treatment process also where you are heating to about 100; 1000 or 1200 degree centigrade and holding for certain time and then cooling in a controlled way. So, that also tries to eliminate or dissolve this chromium carbide precipitation. So, these are certain means of coming out of this related effect of chromium carbide precipitation.

Apart from that as we discussed that if you leave that austenitic stainless steel we have ferritic stainless steel and we have the martensitic stainless steel. So, they are normally known as straight chromium stainless steels and here they have in the case of in these cases you must have following few points to be kept in mind that ferritic stainless steels, they are not hardenable to any appreciable extent by the heat treatment and the martensitic steels they are hardenable by austenitizing followed by rapid cooling in the air.

So, when we talk about the weldability issues of these ferritic stainless steels or martensitic stainless steels; then what we see is that normally the grain growth will be taking place. And when the temperature goes above 900 degree centigrade, so you have to see that the temperature does not go more than that. Then you have the expansion coefficient of these steels are similar to that of carbon steel as well as while we discussed expansion coefficient of stainless steel is somewhat higher.

So, in those cases you have the lesser chances of distortion. So, you can use the processes of welding in a more safer way that will give you more desirable results and electrical resistances of these steels are basically higher. So, in that case it was less in the stainless steel and here it is more.

So, because of these what we see is that in these cases you require less heat input you know than for the carbon steel and also preheating and post heating are basically desirable to control the cracking tendencies in these martensitic and ferritic type of stainless steels and distortion problem is not as severe as that of the austenitic stainless steel.

So, this is all about the weldability issues or weldability characteristics of the different varieties of steels. Although there are many more varieties of steel exist and you can refer the welding characteristics or welding processes which are used for the welding of such steels.

Thank you very much.