Principles of Casting Technology
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Lecture - 31
Melting and casting of cast metals
Cast iron

Welcome to the lecture on Melting and Casting of Cast Metals. In this lecture we will have the introduction about iron casting and will typically discuss about the cast iron. So, we will discuss about different variety of cast iron, we will discuss about the metallurgical aspects of solidification in case of cast iron and other issues.

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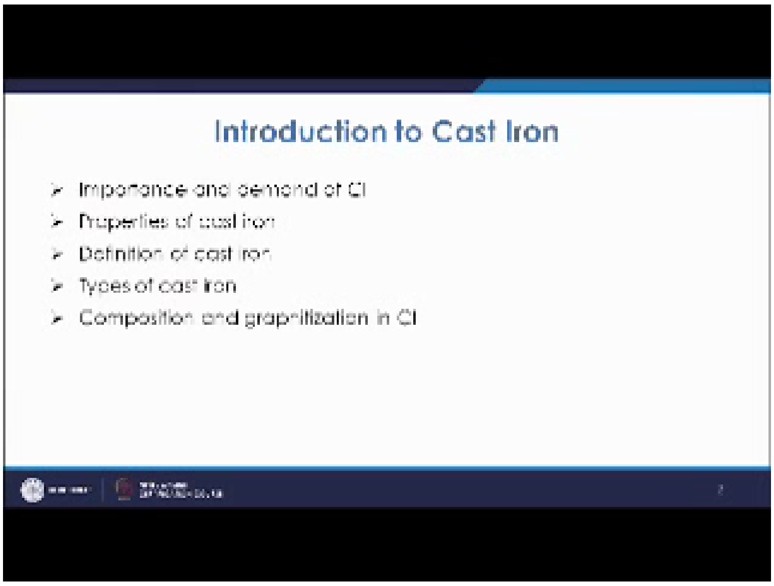

So cast iron, what is the importance and why it is in demand. So, cast iron is basically in terms of foundry casting the amount of cast iron components or the weight of cast iron components which we produced is basically two times then all the other casting. So, this way we can understand the importance of iron castings or cast iron castings.

So, normally when we talk about iron castings we refer to the cast iron, because this cast iron has been used for many hundreds and thousands of years and it has been in importance because of many of the advantages properties, the properties which as edge over other kind of materials like it has a very good cast ability, it has good combinations of machine ability, strength, hardness, kerosene, resistance all that. So, because of these properties and because of the ease with which it can be cast this material is basically giving so much of importance; and most of the components if you talk about the iron carbon system and if you talk about the alloy of iron carbon base then because of certain advantages is associated like in terms of casting you always preferred to have the use of cast iron.

So, what is cast iron basically? Cast iron is the alloy of iron and carbon where carbon percent is more than 2 percent. And apart from carbon you have other alloying elements like silicon, manganese, and small amount of sulfur and phosphorous. So that is cast iron.

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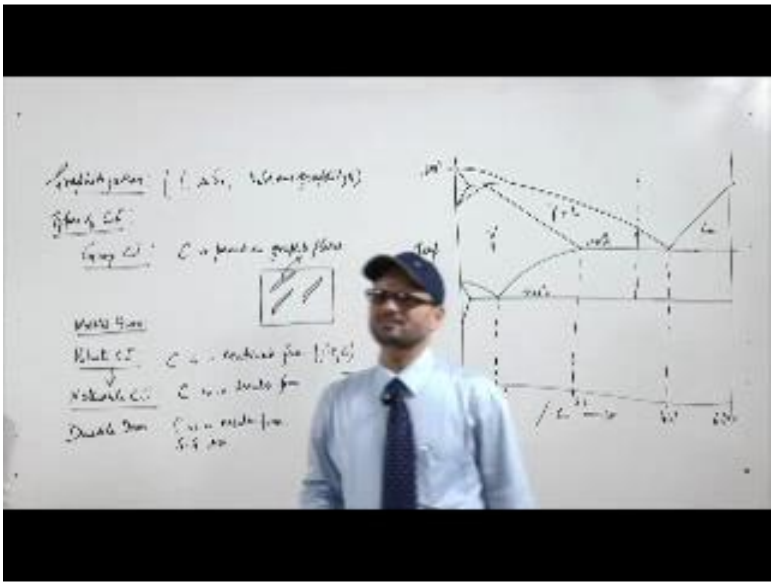

Now, if we try to see what is that difference in case of cast iron and steel? So, when we talk about the steel, if we see the iron carbon diagram at this point it goes like this and here. So, this way it goes and this is a normal iron carbon diagram you have equilibrium as well as meta stable equilibrium diagram. So, in this axis you have percentage carbon and this is the axis of temperature.

So, what we see is this is close to 1535 or 1539 degrees C and then this is 723 degrees centigrade line, this is 1135 degree centigrade line. So what we see is that as the carbon percentage is increased the pure carbon with the pure iron; so this is 100 percent irons and in this direction you have the percentage of carbon increasing. What we see is, when the there is pure iron it melts at about 1539 degree centigrade, but as the carbon percentage is increasing this goes, this liquidus line basically decreases. And this point is known as eutectic point, and here the carbon percentage is 4.3 percent, and this is 2 percent, and this is the eutectoid point, this is 0.8 percent.

Now, what we see is the pure iron which melds at about a 1539 degree centigrade. Once we alloy it with carbon then this melting point at this point again it is at a single point, so it is like a melting or solidification of metals or pure metals, so this is known a eutectic point. So, this is getting finished, this is the solidification is here at this point temperature of 1135 degree centigrade or 37 centigrade. So, the castability basically is improved in the sense of the temperature; your temperature requirement for melting is less. So, even cupola that is why is enough to produce the grey cast iron or cast iron varieties of materials.

However, if you talk about the steel; steel is normally the iron carbon alloy is some alloying elements, but then it is before these 2 percent or 1.5 percent. And if you take this range this is quite high the temperature. So in that case you require a furnace where you have to produce or where you have to melt the material and furnace should be able to generate high temperature. So, in that the furnace requirement has to be different, the lining requirement has to be different.

Apart from that what happens in the case of this cast iron, apart from iron and carbon one of the cheap alloying element which place and important role is the silicon. So, what happens? The silicon is a graphitizer. Basically, the carbon which is there in the steel up to this point this carbon is normally present as in the form of combined form or with iron as Fe3C. So, because this 6.67 percent is the Fe3C this is inter metallic compound cementite.

Now what happens in the case of cast iron, the composition as well as the cooling is adjusted in such a manner that when it cools this excess of carbon is basically changed to graphite. So, that is free carbon. So, in that case this carbon is not in the form of Fe3C. Now it depends upon the cooling rate and composition, the carbon made transform to the combined state that is Fe3C form or carbon may go as the graphite. Now, this process is known as graphitization. So, graphitization means the carbon which is there in excess that basically has to change to the graphite form.

Now let us see what happens if suppose you have this point which is coming, your melting at this point now at this point when you come when you go come at this point; at this point when temperature has become less then this is a liquidus line. So, once you come below this liquidus line then you have liquid plus austenite. So what happens, this is your austenite, this is austenite plus liquid. So, this is your cementite and then this is your basically eutectic line, so that is ledeburite. Now what happens, once you have come to a temperature below this you have at this point austenite plus liquid. So, you have solid crystals of austenite coming out and this austenite has a composition corresponding to this point. So, as the temperature will come down this austenite will basically be losing the carbon, so at this point certainly this is the two percent, so up to this point when it comes the austenite has maximum of two percent of carbon.

Now after this, so once it comes just below this line the freezing is completely complete and at this point you have austenite of maximum this has composition of 2 percent. But once it comes down again the carbon solubility in austenite decreases as per this line. So, once it comes to this line and touches this line, at this line when it comes the austenite which was there it will be losing the carbon and maximum it can have 0.8 percent of carbon, so it will be somewhere close to 0.6 to 0.8 percent of carbon it can maximum dissolve. So, all the carbon which is their extra all these carbons will be disposed off, it will be left by this austenite. Now this carbon once it goes it may appear either as combined for or as graphite form.

Now, the chief role of this alloying element silicon is that silicon is a graphitizor. So, what happens because of the presence of silicon and also because of the low cooling rate this carbon is basically present as the graphite. So, graphite is soft and that is why in the cast iron as you cast in normal circumstances if you have enough of silicon and cooling rate is moderate you get the carbon in graphite form. So, that is how this; and once it further comes down then depending upon the graphitization extend this once we you know that once we come after this line you have this composition this is your eutectoid, so you have these per lighting structure, you have ferrite plus pearlite. So, the mat matrix may be ferrite or pearlite or combined of ferrite and pearlite.

Now again what type of matrix you will get that depends upon the extent of graphitization. So, that graphitization is maximum then you are likely to get the ferritic type of matrix, because most of the carbon which is released this carbon is present in the form of graphite because of the graphitization process. And because of the presence of alloying elements like silicon, so in that case when the graphitization is maximum or it is high rate of graphitization is better in that case you get a ferritic matrix. And if that graphitization is not so high then or that may be because of not adequate amount of silicon present or may be because of slightly larger cooling rate, in that case what happens that you may get a pearlitic type of matrix. So, basically the silicon is working as a principle alloying element which controls the macro structure of these cast iron components.

So what we see, we can look at this figure which tells that; now there are varieties of cast iron as I told. And the as we see in the case of steels the percentage here is silicon percentage is maximum 2, but in the cast iron it goes up to 3 or 4 even. And what we see is when the silicon percentage is more we see that this is grey cast iron. So, grey cast iron once we look at these more there will be more graphitization and carbon will be separated as graphite structure so that is why you get grey iron. Whereas, when the silicon is less you get the white cast iron.

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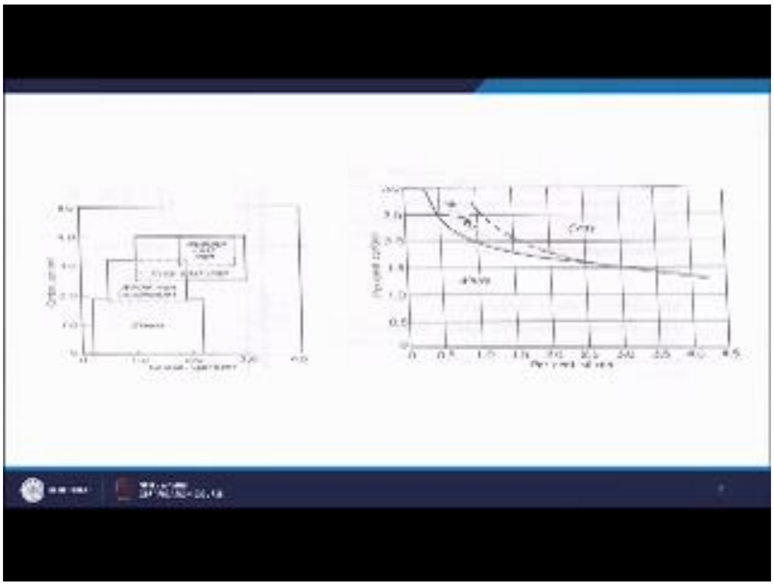

The carbon percentage is more than 2, up to carbon 2 percent you have the variety of steels. However, if the carbon percentage will be more than 2 and silicon percentage is also less in that case what we see is you have at the variety of cast iron that is known as white iron. And white iron basically depending upon the heat treatment given to it is converting to malleable iron that we will discuss later.

What we see is, when the cast iron has larger percentage of carbon as well as silicon in that case more graphitization takes place and because of that this grey cast iron is formed where the this cast iron is basically defined in because the facture surface appears grey. So, in that case this grey cast iron has a fractured grey surface and it has a flaky type of graphite. Then this nodular caster and again it has a larger percentage of carbon as well as silicon. So, here also the carbon has to be there, but in the nodular iron basically the requirement that is should have very less amount of sulfur because sulfur interferes in modularizing process.

This diagram further tells that how you get the different varieties of cast iron. What we see is when the silicon is higher and carbon is higher you get the grey iron. And when you have these smaller quantities you get the white iron and in between you get the molten iron. And if the cooling rate is maintained as low value in that case this curve will shift towards left. So, if the cooling rate is lower than even at the smaller values of silicon and even carbon you may get the grey iron structure. And if the cooling rate is fast then this curve will moved towards right. Means, for the same composition you are likely to get even the grey iron structure or white iron structure depending upon the cooling rate. The cooling rate is less it is likely that you will get grey iron structure or if not then you may get the wide iron structure; if there is that composition for a particular composition.

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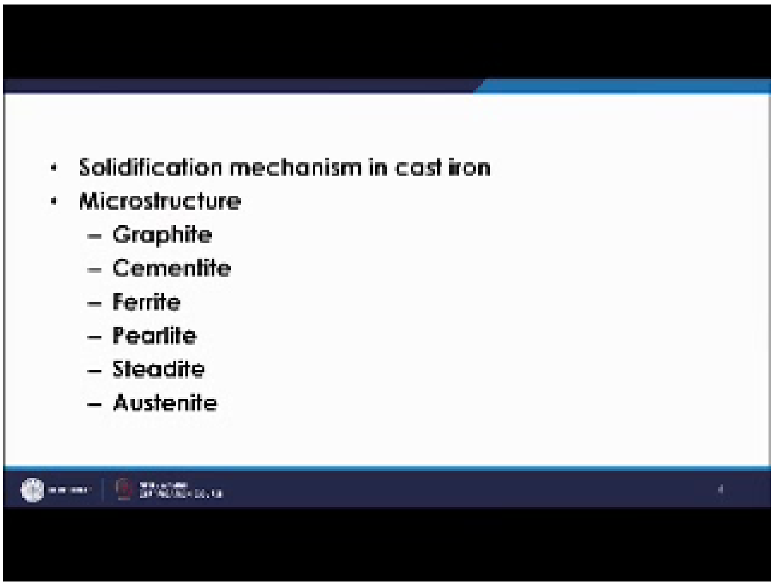

Now, what we see is you have to understand the mechanism of solidification that we have anyway discussed; that how this solidification is taking place when we go below these temperature, how this excess of the carbon will be coming out of this solidification, and then this austenite will also lose the carbon, and then finally as it loses depending upon the conditions, depending upon the cooling conditions and also the presence of alloying element this carbon will either be in the form of graphite or in the form of Fe3C. So, this way at the room temperature you may have different matrix; maybe pearlitic or fereritic. And you may have the carbon in different forms.

So, what we see is we have to discuss about the types of cast iron. So, what we see is in the types of cast iron first variety is grey cast iron. So, grey cast iron is defined as that variety of cast iron where the carbon is present in the form of graphite flicks. The fracture surface appears grey that is why it is known as grey cast iron. Now in the grey cast iron what we have seen is that the value of carbon as well as silicon has to be on the higher side and also cooling rate has to be moderate.

So, in that case the grey cast iron is formed and in the grey cast iron basically your flicks are like this, so these are the flicks. So, these are the graphite flicks which have the pointed ends and this is basically giving the material some in figure properties when they are subjected to tension. But this grey cast iron has other very good properties, so we like good machine ability, good damping capacity so that is why grey cast iron is very much favored for such typical applications like machine beds and many components are made by grey cast iron.

Next variety is white cast iron. In the white cast iron the carbon is combined formed that is Fe3C. Now, when this white cast iron is formed? The white cast iron is formed when the amount of carbon and silicon both are less on the lesser side. Basically carbon as well as silicon both is graphitizers, so carbon and silicon both is graphitizer. So, in this case when the carbon and silicon both are on the higher side then when the carbon separates out, since it has a graphitizing tendency then your carbon is going in as the graphite flicks, but in this case when the carbon is less and silicon is also less and if the cooling rate is little fast in that case this carbon is in the form of Fe3C. So, that is in the form of carbide and that is why this is known as white cast iron and the name white appears because the fracture surface appears white. So, it has very high harness, ductility is less and it is not at all mostly it is not use for any engineering purposes except that where very high comprehensive strength is desired like for rollers in steel plants.

So, what happens there is a variety of cast iron that is malleable cast iron. So, this is basically you are getting from white cast iron. So, from white cast iron since it is of no use we do the heat treatment in that, we basically we are heating that and holding this white cast iron at a temperature of I mean more then the transformation temperature and that temperature we are holding for a very large time. So, in that case what happens due to holding for a large amount of time this combined basically decomposes and this is decomposes to iron plus carbon. So, this carbon is released as free carbon or temper carbon, so in that carbon is in temper form. So, temper or free form this carbon is so small nodules in that case you have to smaller nodule type of structures of free carbon is present and that basically it gives a large amount of ductility and malleability to the component. So, this malleable cast iron although this heat treatment cycle is quite large, but this material is used for many automobile components where you need the malleability of the property or ductility.

The next variety is ductile iron. So, ductile iron is that variety of the cast iron where carbon is in nodular form. So, what happens ductile iron, now in this case you get these small nodules or small free carbon small sizes of nodules, but in the as cast form we can get the nodules of the graphite by doing the treatment of this cast iron. So, for the same composition of cast iron towards the higher side of carbon and silicon, if we treat the melt with magnesium or cerium or atrium; then what happens? You get a cast iron which has larger shape of nodules.

So, this graphite nodules because of this presence of this graphite nodules it is known as nodular iron or even it is also known as SG iron; Spheroidal Graphite iron. So, it has a very good, I mean combination of properties because of this nodular shapes of graphite the adverse effect which we get in the grey cast iron because of the pointed ends that is gone and so its property is quite better. So, we can get it by the magnesium treatment there are many ways of doing the treatment of this magnesium in the case of this nodule ductile iron and we get a good properties of ductile iron.

So, then there are other varieties also like mottled iron. So, what happens that for a particular composition and depending upon the prevailing cooling condition what happens some part appear as white and some part as grey cast iron; in that case they are known as mottled iron, so as we have seen. So, that you have different sections some part as white and some part as grey, so that is known as mottled iron. We have also chilled cast iron. So, because of the chilling effect some part is white cast iron and some part is grey cast iron where the chilling is not there. So, you have this way, but mainly you have these four varieties of cast iron.

Now, macro structures, if we talk about the macro structure in case of cast iron you have mainly the macro structure consisting of few phases and these phases are outlined there. So, what we see is the phases are like graphite. So, carbon is in the form of graphite, carbon may also appear as cementite. So, basically what we see is when carbon is informed of graphite it induces the ductility or malleability to that variety of cast iron, whereas if they are carbon in the form of cementite in that case it induces the hardness or brittleness to that particular variety of cast iron.

Ferrite is the phase as we have understood so far that depending upon the extent of graphitization you may have a ferritic matrix or you may have a pearlitic matrix and or else you may have the combination of these two. Steadite is a phase which is nothing but it is a eutectic of iron and phosphorus. So, somewhere close to thousand degrees or so, so it has a very lower melting point eutectic is formed. So, some of this is used and beneficial and it imparts better fluidity to this cast iron. So, that is why for when we are going to have the cast iron component being cast in shallow sections or thin sections in that case hum some amount of phosphorus which is present, because of this eutectic formation low melting point eutectic formation that may help us to give us large amount of fluidity.

Austenite as we know, austenite is otherwise not a stable phase at room temperature, but then if we add nickel as the chief alloying element to a larger extent then nickel being the austenite stabilizer you also get the austenitic phase in that cast iron. So, depending upon the conditions you may have the formation of these different phases, you may have different kinds of matrixes, and you may get different varieties of cast iron; they are that is grey metal, white malleable, or ductile iron.

So, in the coming lectures we will discuss about the practices of melting for these different varieties of cast iron and what are their characteristics, what are their uses, how to see. So, there is one more terminology like carbon equivalent; so these all these things we can discuss in our coming lectures.

Thank you.