Principles of Casting Technology
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Lecture - 33
Melting and Casting of Cast Metals
Foundry Practice for Production of Malleable and Ductile Iron

Welcome to the lecture on Melting and Casting of Cast Metals, now we will discuss about the foundry practice for production of malleable iron and ductile iron. So, we had earlier studied about the varieties of cast iron and as we know that apart from the gray cast iron you have the formation of white cast iron and then since the white cast iron is normally not much of engineering use because of extremely low amount of ductility and extremely high brittleness. So, that is basically transformed to malleable iron and then we also formed the SG iron by another treatment process where that is also known as ductile iron, which is normally replacing normally steel in many applications, so will discuss about the methods of production of these 2 types of irons.

So, first of all we discuss about the ductile iron. So, ductile iron is also known as SG iron that is spheroidal graphite iron. Now in this case the carbon is in the form of spheroids or nodules.

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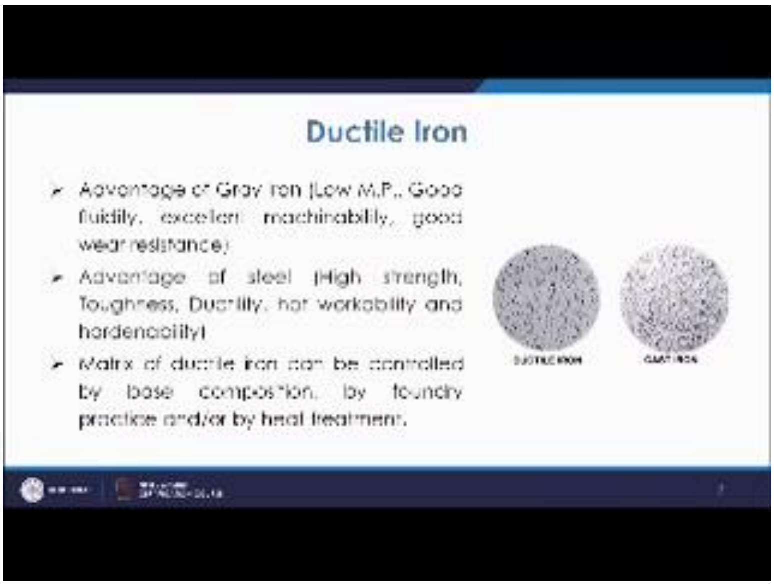

So, these nodules are basically in the varying sizes. So, and this nodules basically give you the benefit which the graphite flex are not able to give you.

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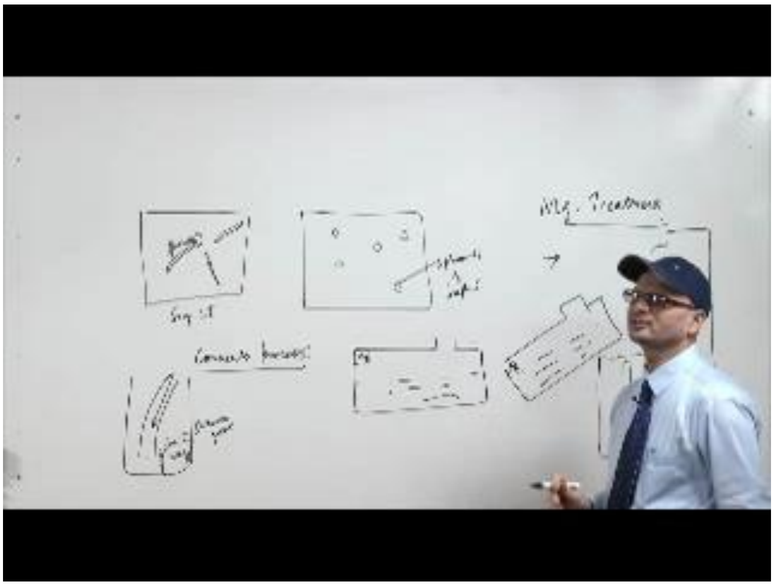

What happens when you have the grey cast iron? You have in the gray cast iron, you have graphitic flex in this shape, so this flex in the case of gray cast iron they are basically giving you the point of large stress concentration and they basically are the places because of which in the (Refer Time: 02:35) takes place easily and the metals so for us little fracture.

So, what we do is we have to get rid of this kind of flakey structure. So, although there has been other methods of changing this flakey graphite structure and one of them is malleable iron which is basically the byproduct of or the product of white cast iron, but without going for the heat treatment process or angling process, which is the very large process in the case of white cast iron transforming to malleable iron. By casting also you get this flakey graphite tilts to another kind of morphology that is ductile iron.

So, what happens in the case of ductile iron? When we treat, so that becomes in the form of spheroids, once you have spheroids, these spheroids are the graphite spheroids. So, disadvantage which are there because of these pointed ends in the flake that is basically gone. Now the casting conditions in terms of temperature or you know eutectic points or so, normally that temperature requirement for pouring little higher in the case of AG iron that will study later, but otherwise the cast ability is similar.

So, you see that as you have the advantage of gray iron in terms of you have the low melting point because the composition is normally the same, the fluidity is quite high better because you have the same level of normally the carbon and silicon somewhat even higher level, then you have good machine ability, good wear resistance, all these properties what cast iron achieves that you get in terms of you know for this ductile iron. So, that advantage you are getting; however, because of this transformation of the flakey graphite to the nodular graphite, you have the advantage of steel coming up so that steel is high strength toughness ductility hot workability and hardenability.

Because you are not having this disadvantage now, so you are getting the property as compared to that of steel. So, steel had this advantage that, you are trying to have a better property like steel; in steel normally the carbon composition is carbon percentage is quite less, so your melting temperature becomes quite high, it will be going close to 1600 degree centigrade, which comes very less in these cases normally close to 14 to 40-50 degree centigrade. So, your castability improves and you have the better properties of both gray iron as well as that of steel.

Now, the matrix of ductile iron can be controlled by base composition, by way foundry practice and or by heat treatment. So what type of matrix you are going to get it can be controlled. Now solidification of ductile iron; so, solidification of the ductile iron is normally at higher temperature as compared to that for the gray iron.

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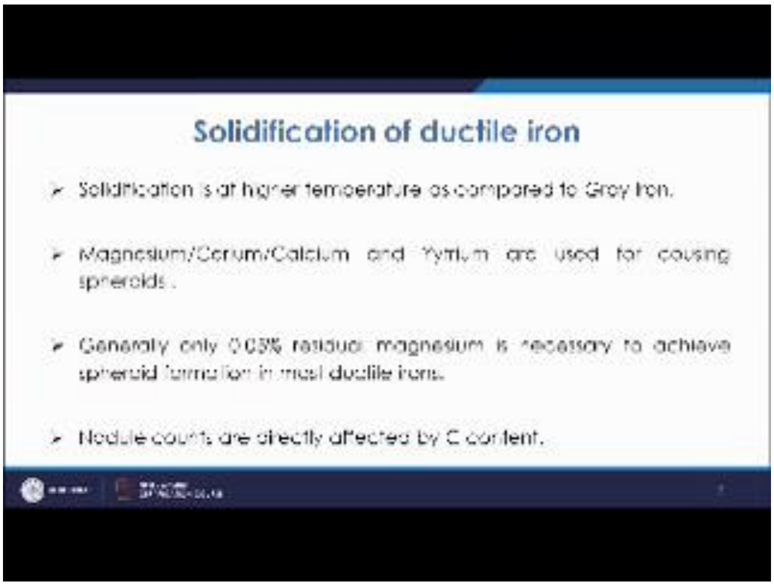

Now, in this case what happens in the cast iron, you have to see that the carbon and silicon composition has to be on the higher side, so you have to have the graphitizes in the melt so same thing applies here; here also you will have to have the graphitize so that carbon is transforming to graphite. Now in normal condition this carbon will transform to graphite in the flake form. However it was seen that in the presence of these elements like magnesium, cerium, calcium and atrium these are the elements, which if they are present inside the melt they are basically causing their spheroids to nucleate. So, that is why the presents of these are known as the elements, causing the graphite spheroids to nucleate.

Now about 0.05 percent of residual magnesium is necessary, now what happens in normal case we normally go for the M g treatment. So, that is why there is a standard term known as magnesium treatment. Now, the role of magnesium is two way; the magnesium basically first of all remove the sulphur, in the production of ductile iron, the element which is very detrimental is the sulphur, is the sulphur is there it will be in emitting the transformation of graphite into spheroids. So, first of all you will have to have the melt composition in such a manner that you have minimum amount of sulphur.

Now, if there is still sulphur into it, there the magnesium if it goes the first stay initially his job is as a deoxidizer first of all. So, and then it is a de sulphurizer. So, magnesium will react with the sulphur and there is certain amount of magnesium required like you will have some percentage of magnesium required there will discuss later for removing certain amount of sulphur. Now once the sulphur content is coming below certain limit then the residual magnesium which is left, the residual magnesium will be doing the job of spherioding the graphite structure.

So, that is why the residual magnesium very small amount of point 0.5 of residual magnesium is only required to cause the spheroid formation of graphite. Also the nodule counts are affected by the presence of carbon content. If the carbon equivalent is more than 4.3, it promotes the development and growth of graphite spheroids. So, as we see your carbon equivalent if it is more than that it will be promoting the formation of graphite and spheroids. Silicon content increases amount of spheroid form doing (Refer Time: 10:03) formation and strengths hence iron by strengthening spheroid. So, as we know silicon is graphitizes. So, silicon will basically take all the, so it will innovate the formation of the carbides and it will that way, it will basically go on having the spheroid formation more and it is also said to strengthen the spheroid. Sulphur content after treatment should be as low as 0.015 percent. So, as we know that the sulphur must be low as possible for the nodulization to take place more effectively.

Phosphorus affects adversely the toughness and ductility. So, a maximum of 0.5 percent is usually specified. As we know that the phosphorus forms eutectic, that is low temperature eutectic steatite is formed. So, normally that affects the toughness and ductility that is why you try to maintain maximum of 0.5 percent of phosphorus.

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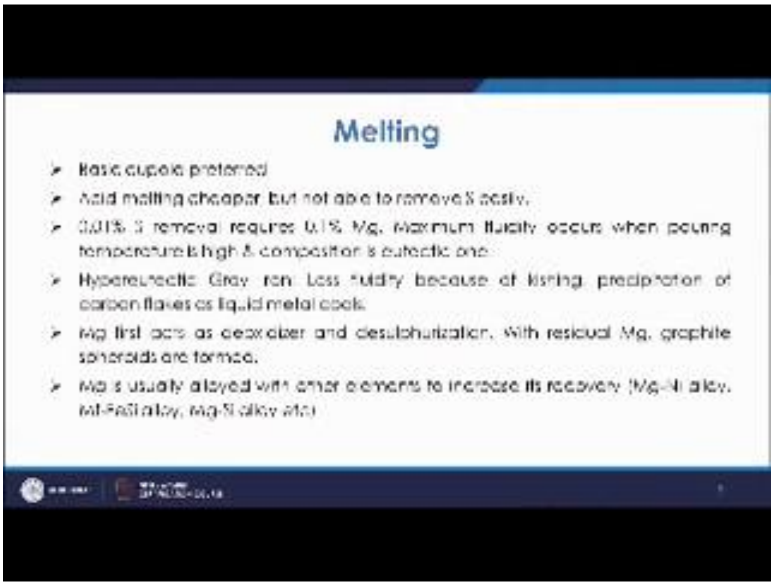

Coming to the melting practice for the s g iron or ductile iron, in this case you prefer the basic cupola melting or basic type of melting because in that case the removal of sulphur is easy, although acid melting is cheaper but in that case the removal of sulphur is somewhat difficult. So, that is why the basic cupola melting is preferred. Now it is seen that about 0.01 percent of sulphur removal you need 0.1 percent of magnesium. So, you see that first of all if the sulphur content in the melt is more, you will have to first of all bring it down to a very small level and accordingly you will have to supply the amount of magnesium. So, magnesium first of all will go and reduce the amount of phosphorus I mean sulphur by reacting with sulphur, forming magnesium sulfide that basically being the slag goes at the top and then once all that sulphur level goes below certain limit, then this magnesium reacts in the metal it causes the graphite to turn into a globular form or a graphical I mean spheroid graphite form.

So, the mechanism is still not clearly known why it happens so? But then it happens that the graphite is basically growth, the growth of graphite takes place equally in all the directions and due to that the fell type of graphite appears; maximum fluidity will be there when pouring temperature is high and composition is eutectic one as we have seen in the case of gray cast iron, it is the same as we have seen in the case of gray cast iron where you have hyper eutectic gray cast iron.

Now, here also you will have fluidity is less because of the kissing. So, your precipitations of carbon flex as liquid metal cools. So, similarly to that here also you have the problem of kissing occurs, as we have understood M g will first act as deoxidizer and desulfurizer, it will remove first the oxygen and sulphur content and then graphite spheroids will be formed; now the treatment of magnesium is normally done through certain alloy and this alloy is normally manganese nickel alloy or manganese ferrosilicon alloy or manganese silicon alloy with varying percentages of manganese nickel in these cases or manganese furrow silicon in these cases.

So, that basically used to treat the molten metal. Methods of magnesium treatment; there are different methods of treatment of magnesium to the melt.

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Now, in that case you have open ladle method. So, in the open ladle method magnesium alloy will be kept at the bottom of treatment ladle and metal is poured over it. Now as we know magnesium burns very quickly, it oxidizes so quickly. So, the reaction is volatile.

So, what happens you have to keep at the bottom and then pour it? So that because otherwise the recovery of magnesium will be quite less that is known as M g recovery.

So, in this open ladle method you put the magnesium in the bottom and then pour the liquid metal at the top of it. So, that it reacts and slowly it induces the spheroid formation. Then there is another method known as converter process. So, in the converter process, what happens? You are a converter and what you do is in the converter in the side you have a pocket, so the converter can be tilted. So, initially in the tilted and horizontal position you. So, if you have the horizontal position. So, you have the horizontal position and you give the magnesium here and then you are basically melted. So, what happens? So, slowly it will slowly come in contact with the liquid metal. So, once you give in the horizontal position, you had the magnesium and then this liquid metal slowly come in contact with this magnesium.

So, this converter which is there on the horizontal first you have. So, this called a converter process and then once you bring in the vertical state that will react with that and then it will make the reaction progress and then graphite spheroids are formed. The process is the sandwich method. So, what happens? Allow alloy is placed into a recession in the refractory bottom of ladle and covered by steel plate, iron chips, ferrosilicon or an inert material. So, what happens when you have direct contact of the molten metal and the magnesium? There is large probability that large amount of magnesium will be basically lost it will vaporize. So, for avoiding that the practice is that once you have the ladle or you have any vessel, in that case, in this portion you give the alloy and this is covered with this plates iron plates then you have all these iron chips and ferrosilicon inert material and then the stream is thrown away.

So, once it comes over these, slowly first of all it will try to dissolve these iron chips which is there over that and then it will come in direct contact with the magnesium alloy. So, the alloy I mean having magnesium, so in that case the magnesium recovery becomes little higher. So, this is known as a sandwich process because you have the alloy and then you have all these materials and then over that there is the liquid metal slowly comes and then it comes slowly in contact with the liquid metal that is sandwich method. This is plunging method in this case the magnesium alloy is placed into a container, positioned within a vented graphite or refractory bell.

So, basically you have a vented graphite or bell is there which is vented and in that you have a plunging rod, it is placed into a container positioned within a vented graphite or refractory bell and then you have the cover and when one liquid metal is poured and this is vented, you have the liquid alloy here and then this treatment takes place because of this plunging rods, so it is known as plunging method. You have mechanical feeder also because it will continuously feed by mechanical means it will try to send the alloying material without magnesium alloy that is ferro manganese or so on magnesium silicon. So, that is basically used and that is given at the predetermined times mechanically, so that the treatment goes on.

So, once the liquid metal is completely free of, you must be ensured that the liquid metal is free of sulphur and then continuously you can gave by mechanical means, by mechanical feeder you can give this M g treatment and then you can cast it. So, these are the methods of making the magnesium. So, making ductile iron using the magnesium treatment; then as we have seen for gray cast iron, here also we go for the inoculation treatment that increases basically the number of his spheroids formed during the solidification.

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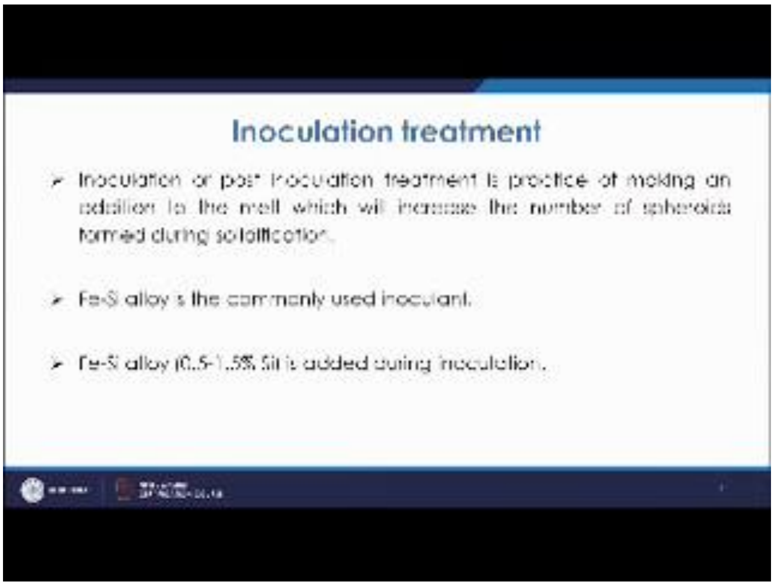

So, in this case the main purpose is to increase the number of spheroids and that is done by the inoculation treatment. So, normally the ferrosilicon alloy is the commonly used inoculants. So, 0.5 to 1.5 percent silicon is there, that is added during the inoculation and that will basically increase the number of spheroids which are there in the magnesium I mean ductile iron. So, this inoculation treatment is important even for the ductile iron production.

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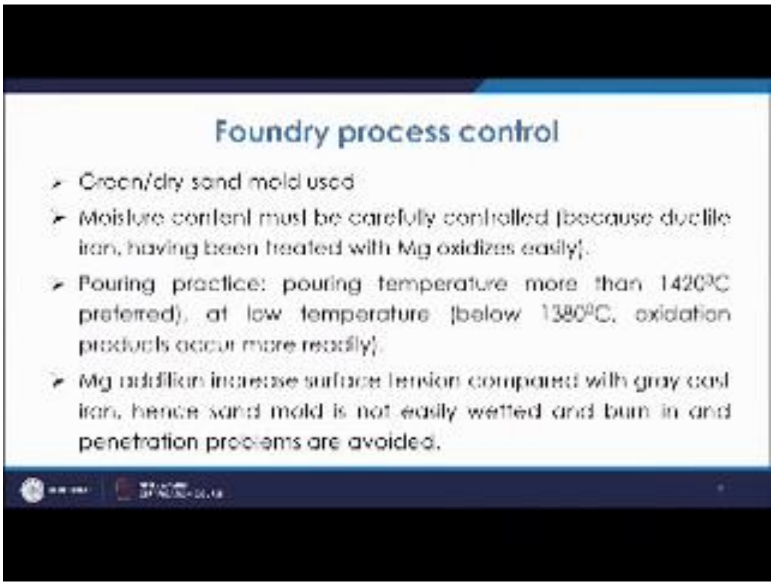

Foundry process control; so, when we go to the foundry shop, there it is seen that you can go for green or dry sand molds, moisture must be controlled because the M g will oxidize easily, so that is why moisture has to be properly controlled because the M g treated ductile iron, that is likely to oxidize very quickly in this case. Pouring practice as we have earlier discussed that in this case the temperature has to be more than 14 under 20 degree C, normally it has to be kept larger than that for gray iron and if it is less than 1380 degree centigrade normally. So the oxidation products are formed very easily. So, in this cases the difference between the gray iron and the ductile iron is that, you need to do the pouring at a higher temperature something temperature larger than 1420 degree centigrade.

Now, what is the advantage of M g edition? As we have understood earlier that in the case of gray iron there is chances of fused product formed on the surface of the casting, now in the case of ductile iron because of the M g edition, this edition basically increases the surface tension. So, because of the increase of the surface tension this sand mold is not easily wetted; once it is not easily wetted then the probability of fusion of the sand or the sand burned that basically decreases and that is why you get a better finish. So, basically that is one of the advantages of producing this ductile iron.

As we have understood in the case of gray iron, there is in advertently the formation of fuse sands on the surface, in this case you do not get because of the. So, increase of the surface tension. Gating design; you have to use green or dry sand mold, you have at a discussed.

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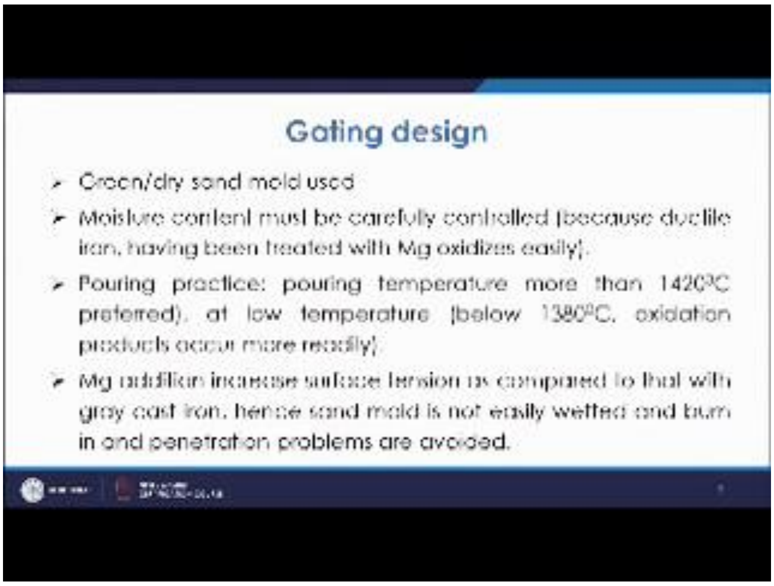

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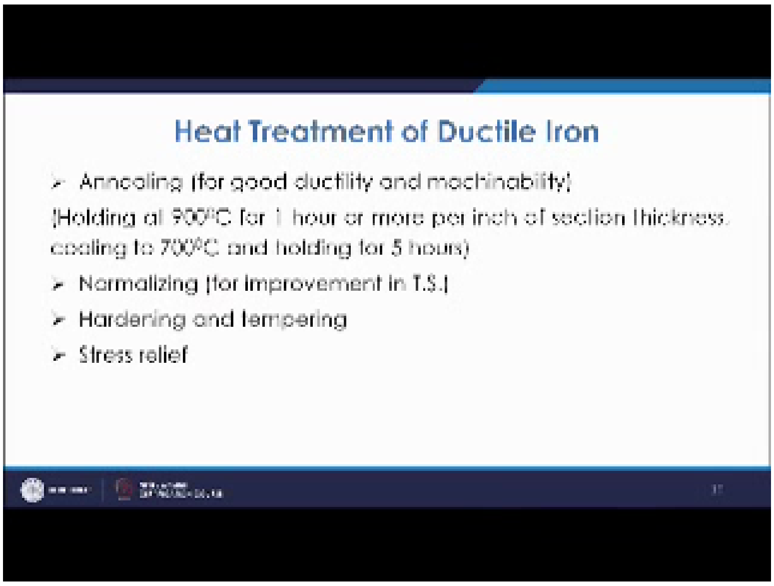

Now heat treatment of ductile iron; you do number of the heat treatment processes and among them are annealing, normalizing, hardening and tempering and also stress relief. So, annealing will be done for getting the good ductility and machinability that is done by heating at 900 degree C up to that holding for one hour and then further even more one hour plus for again one hour per inch of section thickness and then you are cooling to 700 degree C holding for 5 hours then further cooling.

So, in case of slow cooling you get this annealing treatment gives better ductility and machinability, and then if you do go for normalizing cooling the air that is gives you improvement in tensile strength, hardening and tempering will be giving you basically the better hardness better tensile strength so by quenching or by water cooling and then stress relief also done in the range of temperature of 500 to 600 degree centigrade to stress relieve the materials, so these are the normal heat treatment methods for ductile iron.

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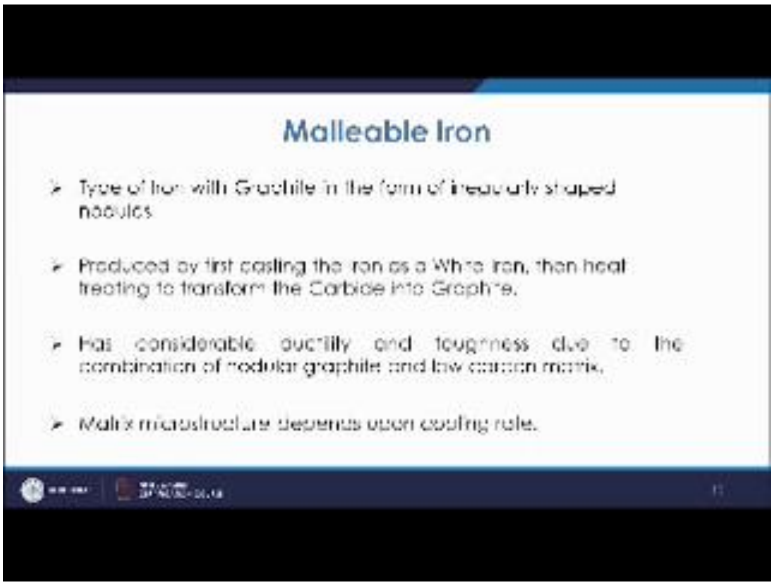

Next variety of the cast iron is the malleable iron, as we know that malleable iron is prepared from white cast iron. So, earlier when you had only the gray cast iron, then gray cast iron has the limitation, it had poor tensile properties because of the presents of graphite flex. So, the white cast iron which is normally of no use because of its high brittleness and very poor ductility. So, then it was seen that if the white cast iron is given some annealing treatment for a prolonged duration at somewhat higher temperature, in that case the carbon which is there in the combined form that basically transforms to the free carbon or temper carbon.

So, that is how and then it was seen that the matrix also could be changed, the matrix become ferritic or even pearlitic you can make it so the ductility was basically induced and that type of material was known as malleable iron, because its malleability was improved. So, earlier for getting the products which require the malleability, you used this heat treatment process to get this malleable iron and you had the formation of small nodules of graphite it was dissociation of these carbides into iron plus carbon at that higher temperature during that prolong heating or annealing process.

So, it is produced from the white cast iron and then treating that further transforming to carbide to graphite, it has considerable ductility and toughness due to combination of nodular graphite and low carbon matrix, because as it is annealed it is seem that the carbides are basically transforming to graphite, the finer temper carbon graphites are basically coming out at that temperature after prolong heating. So, matrix structure will again depend upon the cooling rate. So, as we see in these cases once we go for that treatment of white cast iron for large amount of time, what we see is they are as smaller nodules, so this is how this white cast iron will transform to malleable cast iron and a structure looks like that.

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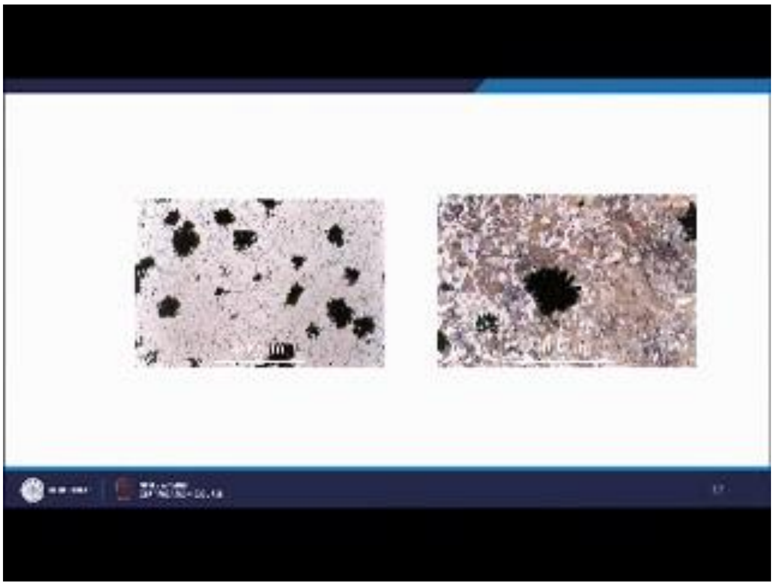

Now for that basically we go for heat treatment process and this heat treatment process is known as the annealing cycle.

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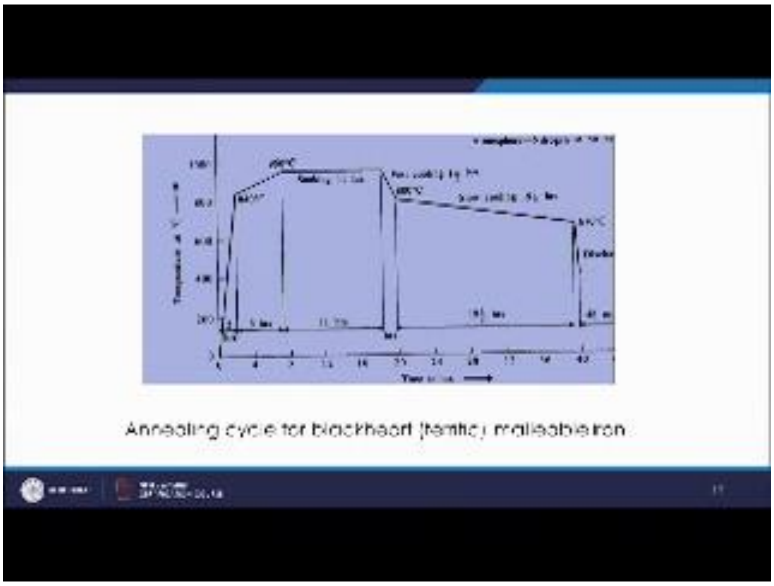

What we see is, because it is done at very high temperature. So, at that temperature reactivity becomes quite high. So, nitrogen atmosphere is maintained and then what you see is you are heating up to 840 degree C at in 2 hours and then further 18 to 950 degree C we are going in the above the lower critical temperature line, then you are soaking there for 11 hours and then after that your fast cooling to 800 degree C, furthers low cooling to 910 and half hours and then from here you are cooling. So, this way what happens you are getting a blackheart ferric type of malleable iron.

Now what happens at this high temperature as you heat? As you go above the Austin rising temperature, then what happens this pearlite will move to the to the austenite reason and then from their once you heat for larger time then in that case the carbide breaks up. So, this carbide Fe3C will break through Fe plus C this known as temper carbon. So, this is known as temper carbon small nodules of carbon it dispersed into the matrix and in that case this structure has got a very good ductility. Now in this case you have the stages of graphitization. So, initially when you heat when it will go into heat it will try to dissolve. So, initially it will go into the austenitic zone, the pearlite will transform to austenite. So, you have two stages of graphitization, first stage and the second stage graphitization; in the second stage the massive carbides are basically broken into the graphite. So, first stage and second stage of graphitization basically leads to the formation of graphitic structure and the graphite which is their earlier in the combined form it comes as the free carbon.

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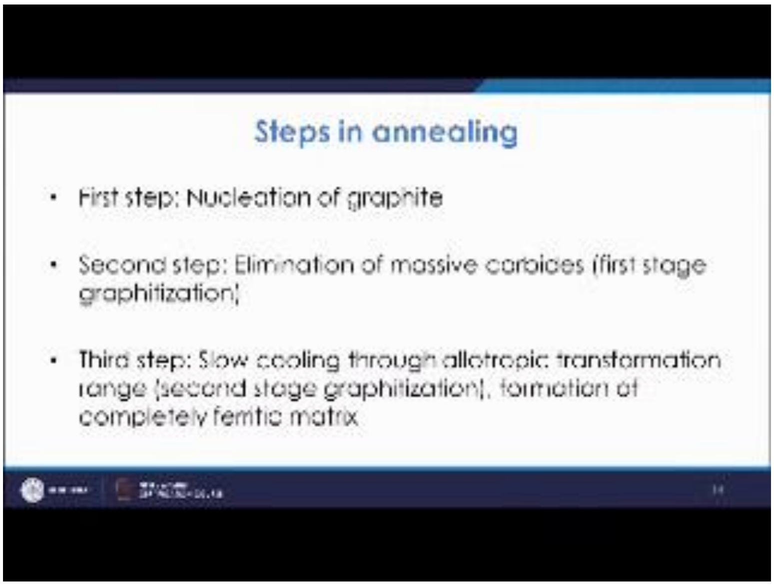

So, first step is the nucleation of graphite and the second step you are elimination of massive carbides that is first stage of graphitization and second stage of graphitization, in that case what happens once you slowly cool through allotropic transformation, in that case you have formation of completely ferritic matrix formed.

So, these are the three steps in which the annealing process is carried out and after these the matrix becomes very very soft and ductile. So, that is how you get the malleability and ductility induced and it is used in most of the automobile components because of the malleability and ductility property. So, nowadays because it involves a very large extensive and for long duration heat treatment process, we normally avoid for such treatment so, we go for a ductile iron castings, but it has its own benefits and its own uses.

Thank you.