Principles of Casting Technology

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Lecture - 32
Melting and Casting of Cast Metals
Foundry Practice for Production of Grey Iron

Welcome to the lecture on Melting and Casting of Cast Metals. In this lecture we are going to discuss the Foundry Practices for the Production of Grey Iron. So, in the last lecture we have discussed mainly about the varieties of cast irons, they are measured. Now we will discuss the foundry practices and some of the characteristics of the varieties of cast iron and one of the main varieties the grey iron. So, we will discuss about it.

So, what are the issues which are to be discussed while discussing the foundry practices when we melt and produce the grey iron castings? As we know that grey iron castings are used very extensively because of some of its remarkable qualities like, good cast ability, good machining, abilities, and other things.

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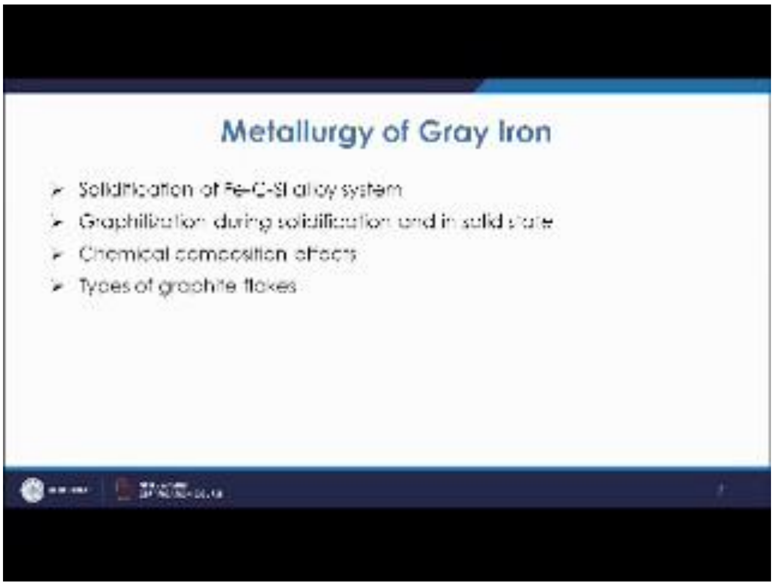

So, we will discuss in brief the solidification of iron, carbon, silicon, alloy system because as we know that although the grey iron or the cast iron is normally of iron and carbon but already we have discussed that silicon is one of the prime alloying element which basically controls the graphitization process. So, we will discuss the iron carbon silicon alloy system, because the presents of silicon basically induce certain changes in the iron carbon equilibrium diagram system.

Then we have the graphitization during solidification is in solid state. Basically what happens, as we have understood that when the carbon percentage is more than 2 percent then in that case the carbon may segregate either as graphite or we know that carbon will either we in the graphite state or in the combine form. So, the graphitization process will be in the different stages; one will be during the solidification state, another will be when it is in solid state. Then also depending upon the alloying element and the cooling rate the graphitization process takes place, and based on that basically the matrices structure is controlled.

So, that also we will discuss. Chemical composition effects means the effect of the alloying elements that we have already discussed what are the effects of different alloying elements like silicon, manganese, chromium or so. Then types of graphite flacks, because once we have we know that in cast iron the graphite is in the form of flacks. So, what are the different types of graphite flacks?

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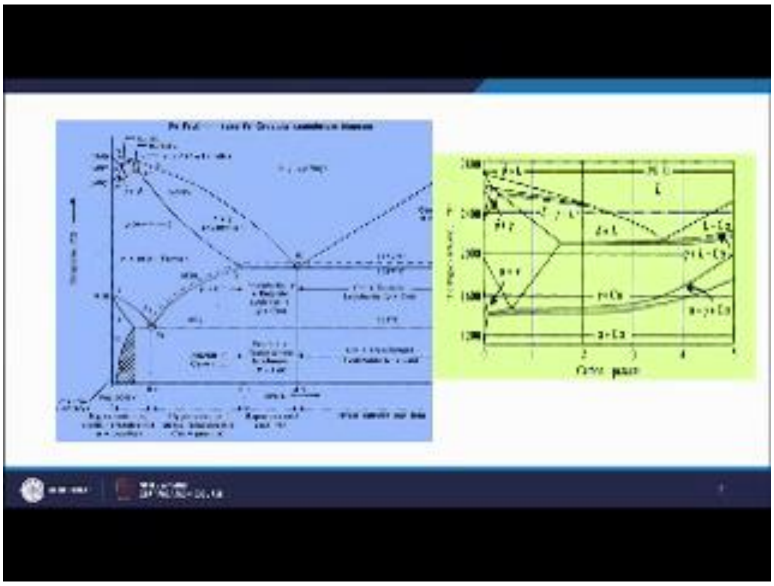

Now, let us see the iron carbon equilibrium diagram. So, this is the typical iron carbon equilibrium diagram which tells that these are the different regions as we know this is the pure iron where the 0 percent carbon and then we move towards the varying percentages of carbon towards this end we will have the 6.67 percent where we have the formation of cementite.

So as we see, when if you take this is the call the eutectic point and this eutectic point is nothing but it has I mean it has the property that solidification is at a constant temperature. So, this is normally in the absence of silicon this carbon percentage for this composition is 4.3 percent. However, with the addition of silicon the percentage of carbon requirement where this eutectic takes place is changes.

Now because of this change there will be depletion of carbon content, because there will be shift at this point and also at this point. So, all these points are shifted towards left. So, first of let us see what happens in normal case if you have a composition of eutectic as we know this is the eutectic ledeburite composition that is known as eutectic ledeburite that is pertain into this 4.3 percent of carbon. If we come to this side if we have the hyper eutectic composition in that case you have the formation of. So, as we move from here to here than once we move. So, we will have cementite plus liquid this zone and then so cementite will try to precipitate. And once you are coming below this temperature then you have for this you have should eutectic will ledeburite plus cementite. So, this portion will be eutectic ledeburite plus cementite. So, cementite will be on this side and the eutectic ledeburite at this composition.

Now, as the temperature further goes down. So, as we know this austenite which is here for this temperature as the temperature goes down we know that solubility of carbon in austenite also decreases. So, that also we will lose the carbon. So, you will have this eutectic ledeburite. And then that further once it comes down it is further transforms, so we have cementite plus once it comes. So, graphitize and takes place in the case of graphitizing elements it will lose the carbon and in the presents of graphitizing element this carbon will transform to graphite or if there is not that particular condition promoting the formation of graphite or graphitizing tendencies is there in that case you will have the formation of carbides.

So, as we move down then so once you come to the temperature below this you can see you have the formation of different phases like this. So, you have cementite plus transformed the ledeburite. So, it is will pearlite plus cementite. This is basically when you do not have this silicon present this is the equilibrium diagram for iron carbon system.

Now what happens in the case of silicon? Now what can happens in the case of silicon this is the typical iron carbon equilibrium diagram when there is 2 percent of silicon. Now what happens? In the case of 2 percent silicon we see that this eutectic point is shifted towards the left. So what happens? In the case of 2 percent silicon this point as well as this point so earlier this was 2 percent now you see it has shifted to this left. Similarly this point also, this was 0.8 percent this, the eutectoid point this eutectoid point also is shifted little bit towards the left.

What does it mean? It means that as the silicon percentage is increased all these points the eutectoid point, the point of maximum solubility for carbon in austenite as well as this eutectoid point all these points shift towards left; means they are depleted in the carbon content. So, if there is no silicon in that case you are having this transformation of pearlite in that case it is happing this austenite is having 0.8 percent of carbon. Whereas, once we have silicon has 2 percent it goes below 0.8 percent. So, that is depleted. So, the carbide composition is depleted, the carbon basically. So, if you see that in that case that is why silicon is known as the graphite promoter. So, once the silicon is there it will promote the formation of graphite. So, silicon if it is 4 percent it will further move towards the left.

So, basically on that there is a term known as carbon equivalent. So, because once you have the presents of silicon in that case the point where this eutectic takes place that change.

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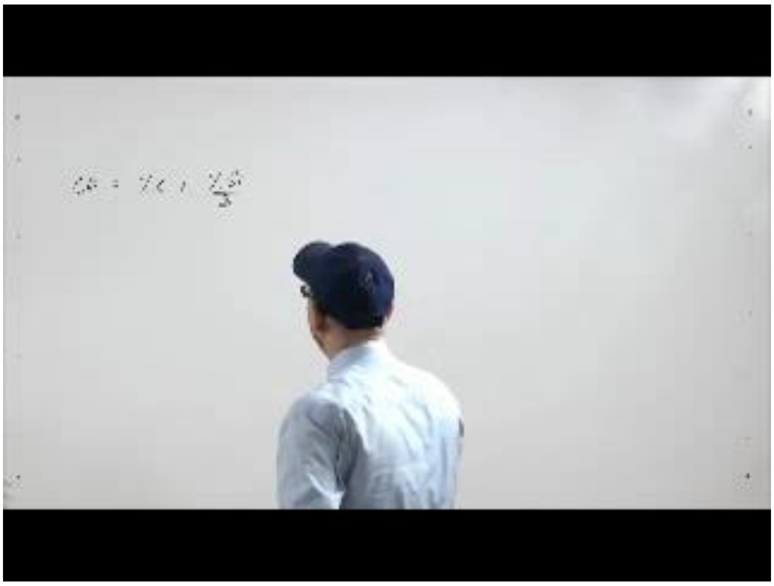

So, in that case the carbon equivalent is basically percentage carbon plus percentage silicon upon 3. So, that is basically the rule which tells that in the presents of silicon this carbon equivalent will be changed. So, as we see if the silicon percentage is 2 percent in that case your 2 percent will be 2 by 3, so 0.67. So, basically smaller amount of carbon only is required to get this eutectic point. So, with the smaller amount of carbon you get the carbon equivalent as 4.3.

So, you need a carbon equivalent of 4.3 and for that in the normal case in the absence of silicon you need 4.3 percent of carbon, whereas in the case of having 2 percent of silicon it will be 4.3 minus 0.67. So, somewhere close to 3.6 percent of only carbon is required to give you that eutectic composition. As is clear from here that you see close to 3.6 values have the formation of this eutectic point.

Similarly, this point also shifts towards left and this austenite is having lesser amount of carbon. So, once it transforms further austenite will transform to pearlite plus; so this is this system (Refer Time: 10:59) pealite, this pearliting transformation will take place. So, in this is basically depleted in carbon. So, basically what happens, the presence of the silicon changes the morphology each of these; I mean changes the composition it promotes the formation of graphite.

Now what happens in normal case when you have a slow cooling rate and we have good amount of carbon as well as silicon both carbon and silicon is graphitizers, so what happens as we have understood as we have already discusses that you have the formation of flakey type of graphite and this is the flakey type of graphite which is obtained in the case of grey iron.

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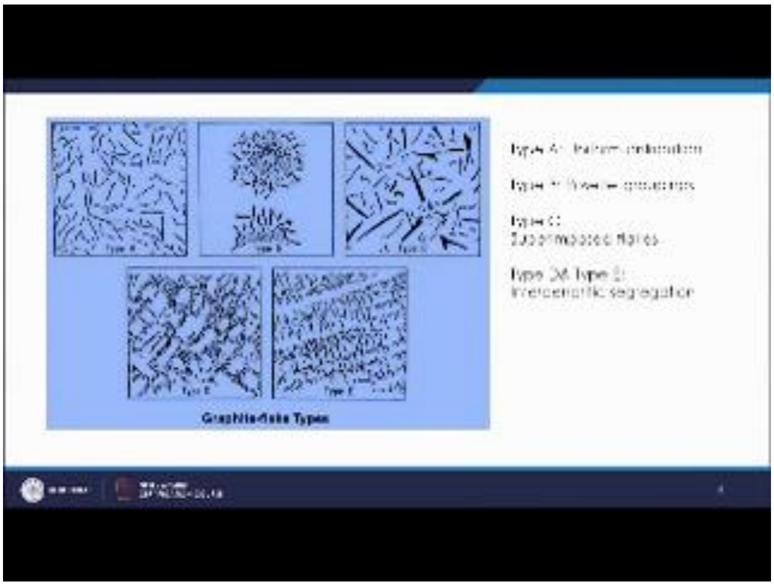

So, that is what grey iron is characterized by the presence of flakey type of graphite’s. And this flakey type of graphite may have the different kinds. So, different types of flacks are their like type A, type B, type C, type D and type E.

So, type A is the most desirable which is uniform distribution and random orientation. So, we normally preferred to have this type A type of graphitive flacks and this is the most desirable for giving you the best mechanical properties. As we know this is the type B which is known as rosette grouping type of graphite structure with random orientation. Similarly this type C is known as the super imposed flacks type of graphite with random orientation. Type D is the interdendritic segregation with random orientation; we see that this is the interdendritic type of segregation. And then you have the random orientation here where are type E it is also having interdendritic segregation type flacks, but it has a preferred orientation. So, normally type D and type E are not the preferred options and the type A is the most preferred options as for as the graphite flacks type of concerned.

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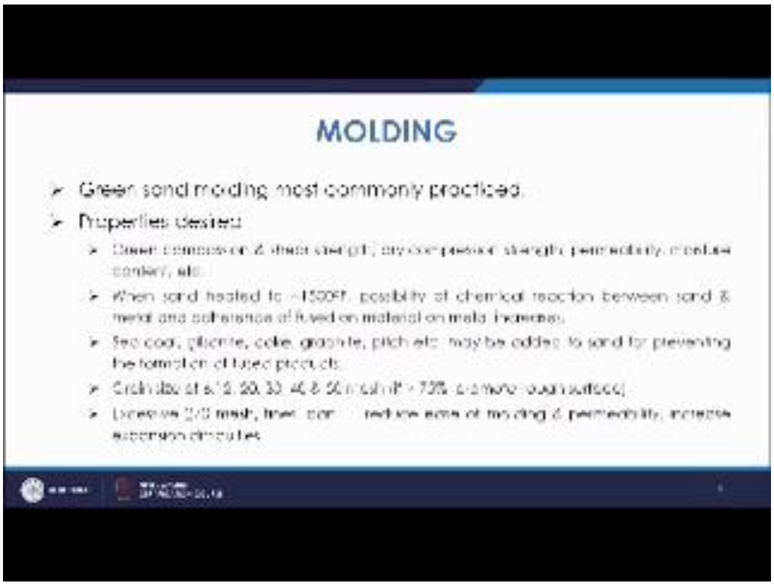

Now once we go to the molding practices for the grey iron, you know grey iron is. Normally done in the green sand molding practice mostly the green sand molding practice is adopted. And as we know once we go for the sand molding you need to have a better property of the sand mold. So, all these properties of sand mold like green compression shear strength, dry compression strength, permeability, moisture content, etc all are to be properly controlled.

Now, what happens when sand is hilted to about 1500 degree Fahrenheit? So, in that case basically there is possibility of the sand metal reaction and that is known as; so because of that there may be fusion of these sand particles on the casting surface so that fusion that basically has to be minimized but it is a process which is their which is in advertantly it has to take place and that he has to be basically that is why it has the surface has to be cleaned.

Now to minimize that, to minimize this binding on you provides certain additives like sea coal, gilsonite, coke, graphite, pitch all these things are added as additives in the sand so that this huge product which is formed on the surface is basically can be avoided. Regarding the green size as we now the grain size will be, and is normally represented by a number that is grain finest number. So, smaller is the grain finest number courser is the second particle. So, you have to have a proper size of the sand grains. So, if the sand grains are two course and they are larger in quantities like 6, 12, 20, 30, 40 or 50 mesh means if they are courser and they are basically making 75 percentage of the molding sand then you can have a course surface finish on the casting as well as the metal make penetrate there.

So, we know that the courser particles are basically desired for giving better or they give provide you better refractoriness, but then they give a poor finish. But, on the other hand if you take these fines or pan or 270 mesh that is on the higher side very fine particles they are basically giving you all though better finish, but then basically that provides a lot of difficulties reduce each of molding and then permeability basically is very much reduced, and then accordingly the related defects like gausses defects or others or the expansion difficulties also may occur because there is no wide space in between them; so that the expansion can take place that can be taken care of. So, these difficulties may arise. So, you have to see that you take the combination of course as well as fine sands.

Foundry properties of grey iron; so, we will discuss about few of the properties of grey iron which has to be discussed while casting the grey iron. One is fluidity characteristics.

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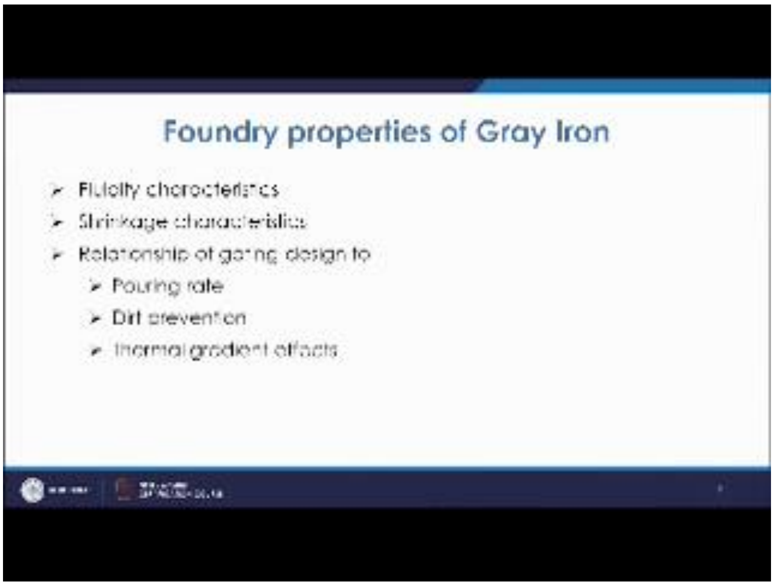

So, as we know this fluidity is defined as the ease with which a metal basically goes into the remotest corner of the cavities so without stopping or without you know pre mature solidification or pre mature its delivery at the corners of the casting. So, let us see fluidity. So, as we know fluidity is measured by a test known as the spiral fluidity test. Now if the fluidity is basically less in that case you will not be able to completely fill the mold cavity. So, fluidity has to be at an optimum level.

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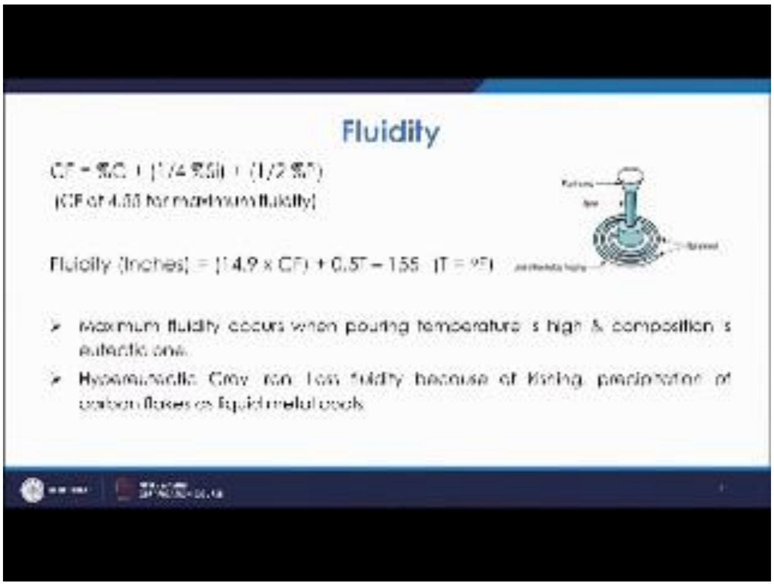

Now, in the case of fluidity as you see this is a spiral fluidity test where you see that this is spiral casting is made you have the sprue runner. And these there are standard dimension of these spirals you have certain cross section and then it has surgery certain gap also in between the spirals. And there is marking at inches of the spirals, and then once the metal is seen that at up to how many inches the metal travels; so if the fluidity is more the metal will travel to larger distances that are known as the spiral fluidity test. So, fluidity has to be good as we know that most of the metals have good fluidity because the solidification is at a constant temperature when there is a temperature range of solidification then it also affects the fluidity. There are many factors which affects the fluidity. And in cast iron if it is of eutectic composition certainly its solidification mechanism is just like that of pure metal. So, for that fluidity is better.

Now for finding the fluidity there are few terms: one is composition factor, and composition factor is basically defined as per percentage of carbon plus 1 by 4 percentage of silicon plus 1 by 2 percentage of phosphorous. So, basically these three are the elements which control the fluidity, and for that first of all this composition factor is found out. So, once you know the percentage carbon, percentage silicon and percentage phosphorous then after finding the composition factor this expression is further used 14.9 times composition factor plus 0.5 times disporting temperature T that is in degree

Fahrenheit and then minus 155. So, this expression is used which gives you fluidity in inches.

So, from this as you see that if the temperature of pouring is higher the fluidity is going to increase. Similarly your composition factor of 4.55 normally is known to have give you the maximum of fluidity. Now what happens that when it goes even more when you go to hipper eutectic type of cast irons as we will see later then because of this kishing process kishing phenomena because there will be formation of the graphite initially. So, this carbon flacks the graphite will initially precipitate out and that basically because being lighter it will float, so that basically known as kishing graphite, it will go on the surface and that basically reduces the fluidity.

So, it is maximum normally in the range of the eutectic composition, so the fluidity is basically dependent upon the temperature. The composition factor the temperature is high then fluidity will be high. The composition eutectic the fluidity will be maximum. So, once it goes above the eutectic point that is hipper eutectic case there also fluidity decreases because of the kishing process, because of the formation of this graphite which is occurring.

So, then you have the shrinkage characteristics. So, as we know there is also shrinkage when there is solidification process. So, when we are converting the stage from liquid to solid then there is shrinkage.

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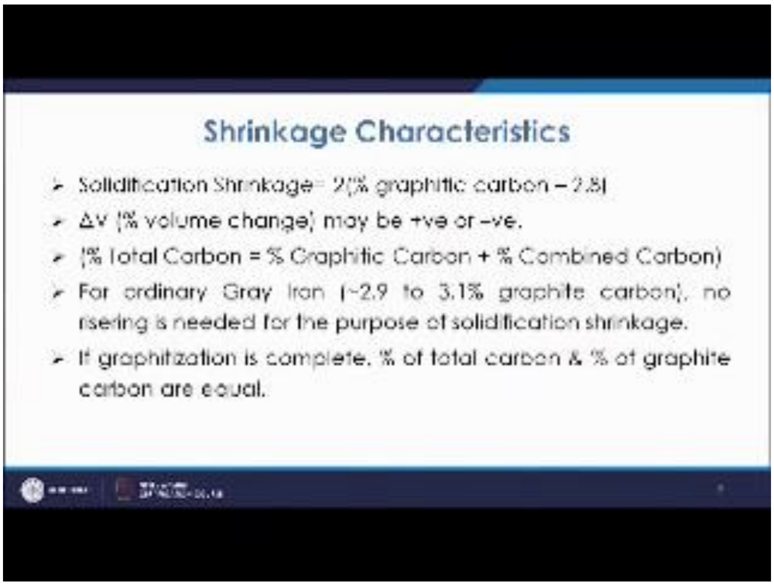

Now, solidification shrinkage is normally defined as two times percentage of graphitic carbon minus 2.8. So, this is the solidification shrinkage and that is delta V; so, this volumetric change.

Now as we see the graphitic carbon is basically controlling the solidification shrinkage in case of grey cats iron. Means, if this amount is 2.8 or more in that case it will be positive and so its value can be positive or it can be negative. So, the percentage total carbon will be defined as percentage of graphitic carbon plus percentage of combined carbon. As we see that you have total carbon in that you will have the graphitic carbon plus you have the combined carbon that carbon which is in the form of cementite. So, for a larger values of this graphitic carbon in that case your volume change it may be positive, because if it is more than 2.8 the volume change will be positive.

So, for ordinary grey iron where you have 2.9 to 3.1 percentage graphitic carbon in that case your risering is not needed for the purpose of solidification shrinkage. Because, in the case of grey iron with larger amount of silicon the graphitic carbon becomes more, because as we know that once you have silicon the combined carbon amount is less because the curve is shifting towards left so in that case that comb point, so combined carbon becomes less in those cases and graphitic carbon becomes more when you have the presence of silicon. And once you have that the volume change is basically positive. And in that case you do not have the riser requirement in case of the grey irons.

So, that is why sometimes it is also known as riser less casting. So, in those cases you do not needs the risers for that process although riser is required. So, that there is pressured applied and to get the sound casting there will be riser, but then you are not very much thinking about the requirement of riser for supplying the extra metal because of these volume requirement.

If graphitization is complete percentage of total carbon and percentage of graphite are certainly equal. Because if the total carbon is changing to graphite it means complete total percentage carbon is nothing but the graphitic carbon. On the other hand if it is not at all any graphitization so percentage of total carbon is the combined carbon. So, no graphitization has occurred it means percentage of graphitic carbon is 0. So, there is total carbon is nothing but the combined carbon.

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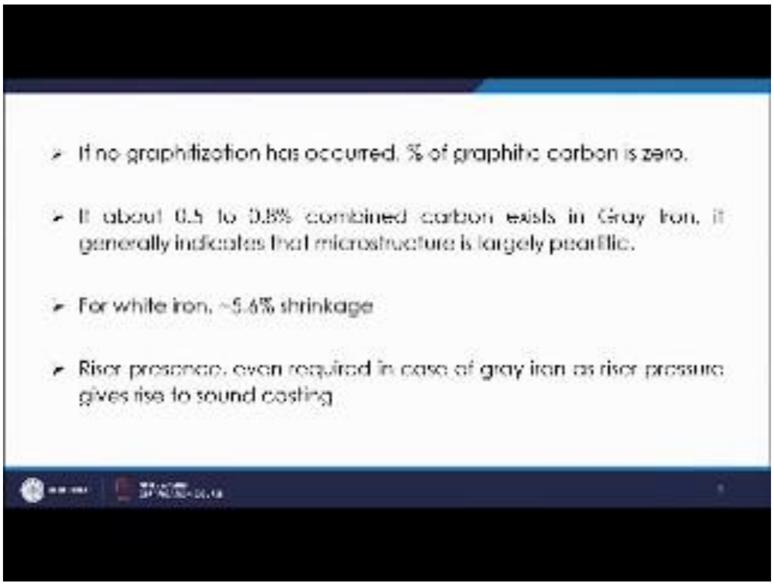

So, about 0.5 to 0.8 percent of combined carbon if it exist in the grey iron it generally indicates that macro structure is largely pearlitic. So, once you have the 0.5 to 0.8 percentage of combined iron as we know that when in the absence of silicon you have 0.8 percent of carbon for the eutectoid composition. And once it cools under normal conditions there will be pearlitic matrix.

For white iron if you see you look at this for white iron you do not have graphite graphitic carbon. So, what you see is you have about 5.6 percent of volumetric shrinkage. So, that is why in the case of white iron you see you have the requirement of risers. Although riser is required as we discussed for the riser pressure which is required to give you a sound casting.

There is an important treatment the treatment is known as in occultation treatment. So, in occultation treatment is nothing, but the treatment to give the better nucleation of graphitic flacks.

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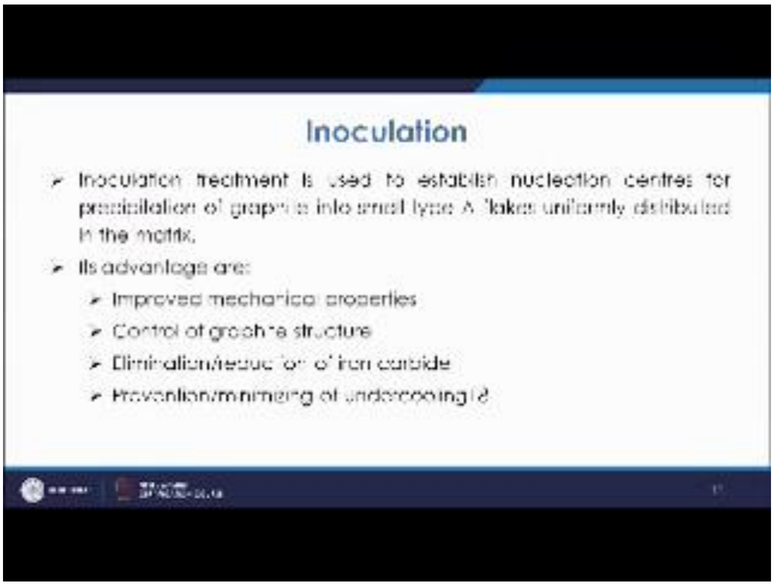

So, it is used to establish nucleation centers for precipitation of graphite into small type A flacks uniformly distributed in the matrix. So, basically you have the nucleation of graphites and for its better flacks and type A flacks this in occultation treatment is done. So, what happens if you have the better in occultation treatment and better nucleation of graphite, better type A flacks are formed in that case you are getting the better mechanical properties.

It also basically minimizes the under cooling. So, the under cooling is basically minimized and because of that you have the graphitization tendency further promote it. If there is more under cooling in that case you may have the chances to as a formation of white carbon. Then you have the reduction of iron carbide and control of graphitic structure.

So what is the practice? The practice is that in occultation may be done in the ladle or in the mold. So, in the ladle you give the inoculants. And then bring it you may have the use of tabulates.

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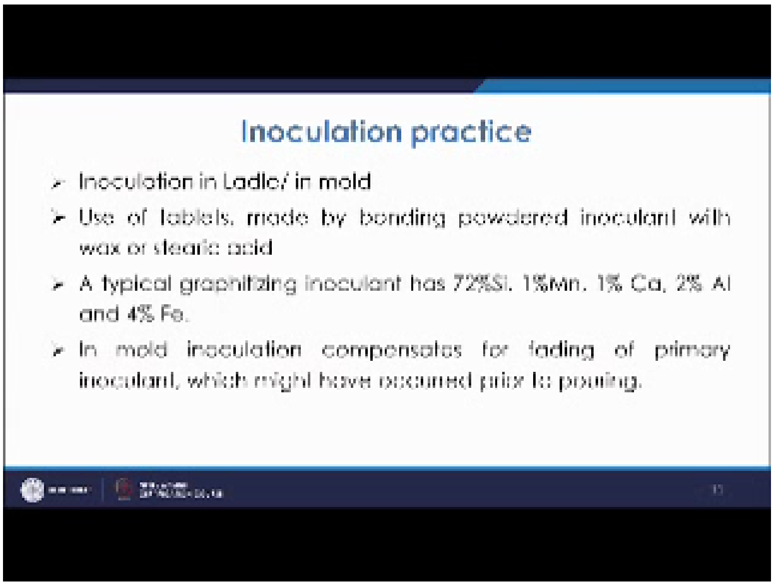

So, basically this inoculants are in the form of tabulates which are normally the ferrosilicon is used as the inoculants and where the silicon is normally 72 percent manganese calcium and aluminum 1 and 2 percent and 4 percent of iron; basically they are bounded with stearic acid. So, then you are making a tabulate of it and then you are putting into it.

And then you also do the in occultation in the mold. So, that if there is any further fading of or any fading of the pre pouring occultation then during that process of going through the going into the mold then in that case it can be compensative. So, for that also we do the mold in occultation. We also do the heat treatment of grey iron to get the improved properties.

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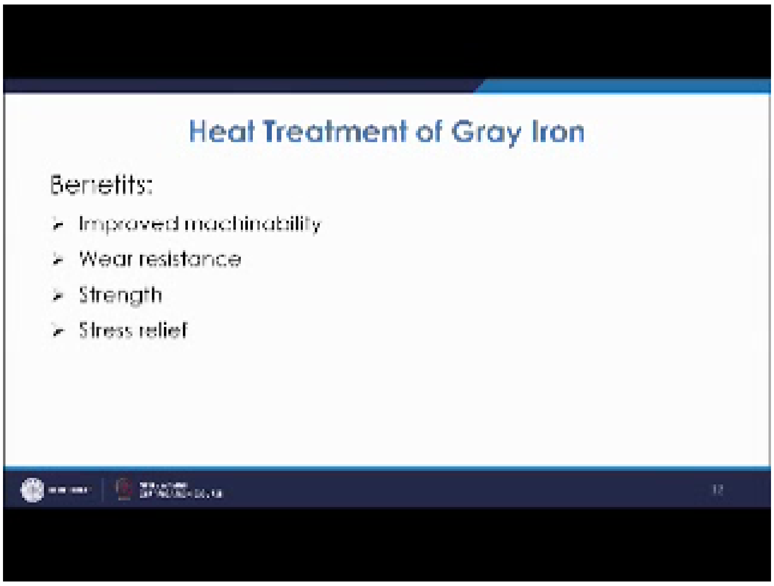

So, the properties which can be improved by the heat treatment process are the improved machinability, wear resistance, strength and stress relief. So, as we know that forgetting the improved machinability you will have to go for (Refer Time: 29:07) treatment where you heat and then you are cooling or you are holding in the furnace and then cooling slowly. So, in that case your machineability is improved it become soft.

For wear resistance if you heat and then do the normalizing treatments, allow the specimens to cool in the air in that case you get the better wear resistance. So, normally for the piston rings you go for such treatment. For getting the strength you go for the quenching treatment, you heat and above the transformation temperature and then cool and then cool in or quench in the water or oil, so you get the better strength. You also do the stress relieving treatment below the lower critical temperature holding it so that the stresses are relieved. So, these are the different kinds of heat treatment processes which basically modify the properties of the grey cast iron.

Thank you.