Principles of Casting Technology

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Lecture - 34
Melting and Casting of Cast Metals
Production of Steel Casting

Welcome to the lecture on Melting and Casting of Cast Metals. So, today we will discuss about the production of steel castings. So, we have discussed about the production of castings of the cast iron family, now among the ferrous component is steel is very much used for many applications because of many of its advantages. So, what are the common practices while making the steel, what are the properties of steel? So, these things we will discuss in this lecture.

Now, as we know that the steel is basically the alloy of iron and carbon and we certainly add a number of alloying elements. So, when we classify steel initially it is if we have only carbon and very small amount of other alloying elements, then we categorize them as carbon steels. So, in the carbon steel you have plain carbon steel. So, you have low carbon steel, you have medium carbon steel and you have high carbon steel. So, that is based on the percentage of carbon in that. So, if it is less than 0.2 percent it is low carbon steel, if it is 0.2 to 0.5 it is medium carbon steel and if it is more than 0.5 then it is known as high carbon steel; then we also are adding the alloying elements and based on the content of the alloying elements, they are further categorized as either low alloying elements or low alloy steels or the high alloy steels.

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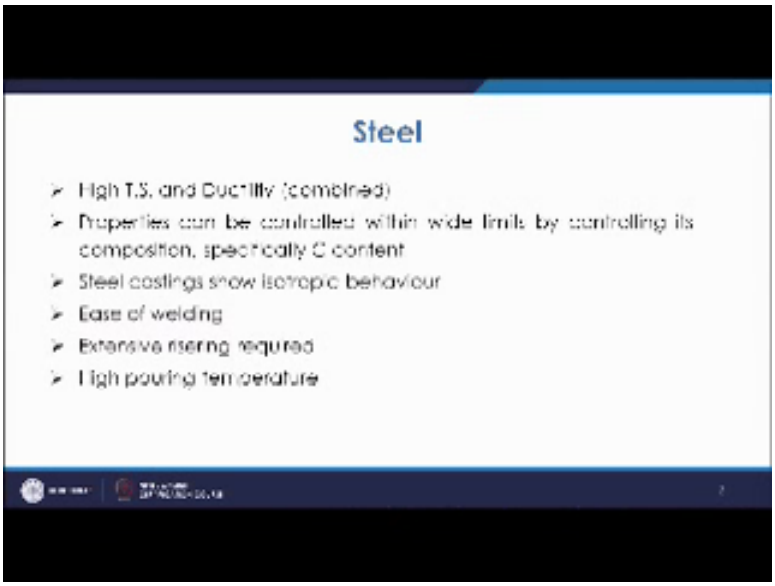

So, that again basis is on the basis of alloying elements if it is not more 8 percent it is the low alloy steels otherwise it is high alloy steels. So, again in high alloy steels you have variety of steels. So, what happens that as we have seen that in the case of cast iron, we have seen that the melting temperature is around 1140 that is for your tactic, but then it may go to the other side at little bit higher on the hyper or hypo site, but the cast iron has certainly some limitations as for as the properties of tensile strength is concerned or may be other properties like toughness then ductile to brittle transition temperatures, corrosion resistance there are other properties which you require on the higher side and at that time steel comes into picture which gives you range of properties and because of that it is basically very important material which is used in our daily uses.

So, the properties can be controlled within wide limits by controlling its composition. So, composition specially the carbon content when we talk about the carbon steels and then even if you go to alloy steels there also we have to see that what is the carbon content based on that and depending upon the alloying element, you can control a lot of properties you can impart lot of properties in the case of these steels. It is also seen that it shows isotropic behavior I mean certainly the casting so isotropic behavior, but in that it is even better in showing that behavior even if it is formed then also it shows. So, it is showing to a larger extend isotropic behavior; there is ease of welding in the case of steel, that also makes it a suitable material for the engineering applications because you have to make or fabricate lot of structures where the welding is required.

Now, the problem with steel the challenge with steel is the extensive risering required because as we know the when we look at the iron carbon phase diagram in that, as the carbon content is increasing, in that case the range of solidification is increasing. So, once the range of solidification is increasing there will be difficulties during solidification in case of shrinkage and for that the extensive risering is required so that there is no solidification shrinkage taking place while solidification.

Another point which is to be considered in case of steel is as we know that you have to go for a temperature which is higher than the iron casting. So, you have to go more than 1600 degree centigrade, so for that you need the furnaces which can give you the metal at that temperature and certainly at that temperature there are lots of challenges, challenges may be related to the refractory life, related to the gases pick up, related to its handling.

So, there lot of issues when we deal the metal at higher temperature. So, these are the issues which are required to be addressed, which are required to be taken into account when we go for steel casting; however, keeping in mind a lot of advantages in terms of properties of steel, I mean this is the material which is basically one of the most important material being used in our even daily practice, we use utensils, we use lot of other components of steels it has become a part and parcel of our life and we should know that how to take care of the production of this steel.

Now, when we talk about the molding process, it is same as other ferrous materials; however, you will have to take care of certain issues.

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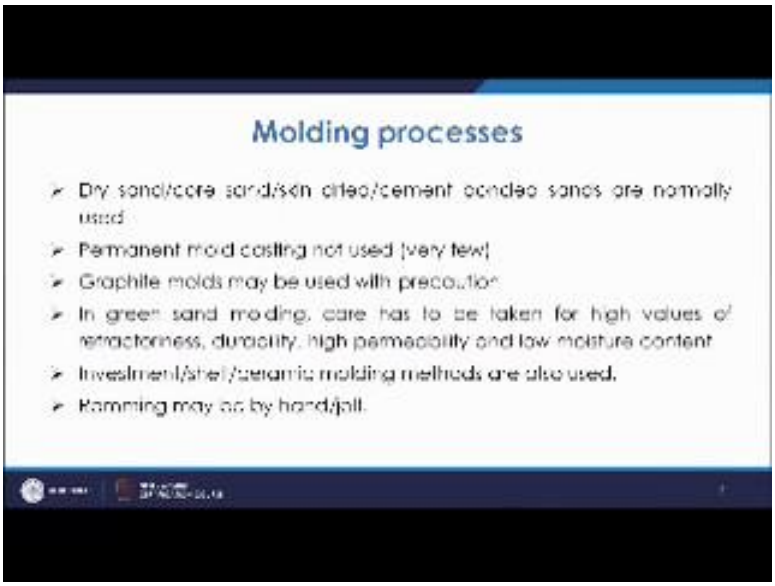

So, one is that you can use the dry sand, core sand, skin dried or cement bounded sands, these are normally used. So, you also use these chromites sands. So, then zircon sands these are also used for steel molding. Permanent mould casting is normally not used as we know that permanent mould castings are normally for the metals which have the lower melting points. So, normally we do not go for permanent mould casting, because you need the mould of a material which is of higher melting temperature than this, so normally that becomes a challenge, we normally do not prefer except very few and we may have the plaster type of casting or small die product using die casting can be made. We also use the graphite molds with the precaution that it has tendency to pick carbon and carbon is more than certain percentage not a desirable element. So, graphite mold are also used with proper care, with the care to see that there may be the pickup of carbon. So, on that account you have the option to use the graphite molds with care.

In green sand molding care has to be taken for high values of refractoriness. So, when we go for green sand molding, first of all you have to see that your material has a very high refractoriness because you are dealing with the melting and pouring at very high temperature, once it goes into the cavity it is in contact with the inner surface of the mold and this sand is basically against that very high temperature where it is likely to fuse. So, you must have the sand which must have a very high refractoriness values. So, for that you use high purity silica sands or any sand which has the purity that is to be used and of appropriate size and shape also which should give you the proper refractoriness.

Durability means as we know that since the molten metal is in contact with the sand, so that fuses and it basically loses its property in the long run. So, you have to see that how much portion of the sand next to the mold wall from the inside is has lost its quality. So, then others bulk of sand if it is not lost its property, you must try the means to further use them. So, this way you can increase the durability of the sand.

High permeability; you will have to use high permeability because in the green sand molding practice you will have moisture and then since you basically pouring at a very high temperature, there is solubility of gases also, more at high temperature and also the moisture even at high temperature will form the gases so that needs to escape. So, for that the permeability of the mold must be adequate enough otherwise if the permeability is not more the gases will not get the chance to escape out and that may lead to gaseous defects; low moisture content is same thing you must have low moisture content, otherwise again this moisture that will form this hydrogen gas and it again there will be problem of getting it skipping out and if that is not the skipped out then that may lead to that defects.

It has also been reported that you can use the investment molds, cell molds, ceramic molds for preparation of castings, ramming can be done by hand ramming or jolt ramming practices are used depending upon the size and degree of automation in the foundry shops. Now about the cores as we know that cores are required to have the hollow projections in the casting. So, the cores are basically subjected to the metal from the all the sides and they are subjected to severe thermal conditions. So, they even require to have higher permeability because the they have to evolve or they have to escape the gases which are basically formed at high temperature and that is why even hollow cores are also practiced more likely they are used for such castings because then it can very effectively allow the gases to escape through it.

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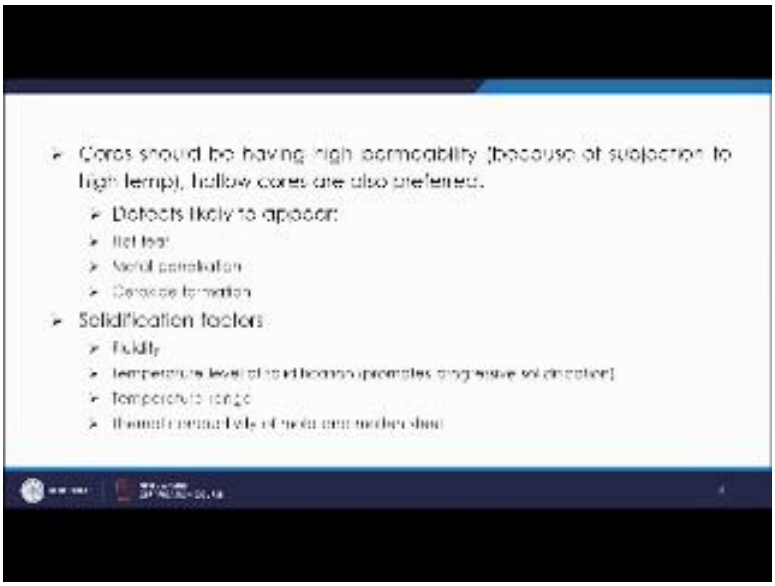

The defects which are likely to appear which are to be considered for such steel castings one is hot tear, as we know that since the freezing range is high, so what happens the towards the end you know when the solid parts, once we go to through the liquidus solidus range, so liquid plus solid range. So, slowly as a temperature falls the liquid portion will be going on decreasing and solid portion will go on increasing. So, what happens towards the solidus line, you will have a stage where more of solid portion will be there and a small of the liquid portions will be there and also because of the expansion related issues, the core are there and the mold is there and because of the geometrical features also because of expansion related issues there may be some tearing and at that temperature the metal is weak. So, in that case there may be tearing experienced by the metal and there may be a cracks form that is known as hot tear and because of the large freezing range of such materials, this probability of having this hot tear is high in the case of steel castings. So, you will have to be careful about how to minimize this hot tear.

Metal penetration; metal penetration as we know it is basically because of the cores grains which are there to prepare the mold. So, metal penetration also depends upon the temperature of the melt, depends upon the pressure of the melt. So, what happens if it has a mold pressure on the melt, then the surface of the casting will have uneven finish. So, because of the pressure they will go in between the sand grains, if the sand grains are

basically cores. So, you will have to use proper mold wash or mold proper type of sand grains of basically proper shape and size so that the metal penetration can be avoided.

Shape and size formation it is basically formation of on the top surface you have glassy like appearance because of the reaction products, so that also is because of the high temperature, that also is one of the reasons that is to be taken care of by taking the suitable molding material. Then discussing about the solidification factors, as we know that when we are going to decrease the temperature, we are pouring the liquid metal into the mold then there are many factors which are important and the factors which are important are like fluidity. So, fluidity basically will be depending upon the temperature as we have studied, that fluidity is a function of temperature, the temperature is have fluidity will be higher and higher value of fluidity is desired.

So, many of the elements control the fluidity like chromium will be detrimental in providing you the fluidity, then silicon is an important element which is basically instrumental in giving you the fluidity. So, this way you can see that you have to choose proper quantity of alloying elements so that fluidity is proper temperature level of solidification, as you know that when the temperature is higher and the heat has to pass from the mold and I mean from mold and it has to go into the atmosphere. So, from the interior of the casting towards the mold surface and then from the mold surface towards the atmosphere, basically being the temperature higher in the interior part a progressive type of solidification is promoted. So, that is the advantage that this progressive solidification mechanism is automatically set.

Temperature range; as we know that in the case of steels being an alloy you have a freezing range and freezing range is not good from the solidification point of view and that is basically we cannot avoid also but certainly the degree of progressive solidification is somewhat hampered as far as the temperature range is concerned. So, temperature range if it is less, you may get the higher degree of solidification, progressive solidification and accordingly. So then thermal conductivity of mold as well as of molten steel, they also somewhere control this degree of progressive solidifications because the thermal conductivity of mold, if you talk about the sand as the molding material it is normally less. So, certainly there is a thermal gradient setup from the interior of the casting towards the mold. So, this basically sets the degree of progressive solidification.

Now, coming to the steel melting; as we have studied you have the number of melting units, in that you have open hearth acidic or basic, then electric arc acidic or basic, convert a process acidic or basic electric induction and then vacuum melting.

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Now acidic or basic; we have discussed about all these melting processes where we use the electric arc in the case of electric arc furnaces you have the use of induction effect for electric induction furnace, then use of vacuum for vacuum melting and these open hearth also we have discussed. So, what is this acid or base it will be depending upon? So that will be controlled by the type of lining which we use on the refractory. So, that will be again controlled by the types of slags which are produced during melting, so that if there is acidic slag you will go for acidic type of furnace, if you are producing the basic slags you are going for basic type of lining. So, in that case acidic means the refractory will be silica based and in this case you will have magnetite base, so that is basic type of furnaces.

Now, what happens this vacuum melting, if this basically is nothing, but this is done to remove the gases; so it is done in the vacuum. So, you have basically from the furnace to you pour to ladle and once you pour from the intermediate ladle to the final pouring point, in that case one of the vessel is maintained under vacuum. So, when you pour all the gases are basically taken away, so this way your melt becomes free of gases and then after keeping it or sometime you can use it for pouring. So, that is you done in the case of

and vacuum melting means sometimes you do the melting in that vacuum atmosphere. So, you see that there is vacuum maintained so that there is no atmospheric or any gaseous contamination. So, this way you ensure that there is no you know contamination by these gaseous products.

Then you do also lot of treatments because in the steel you need the refining, there is large amount of possibility that there will be formation of oxidize products and that will basically spoil its quality. So, you have these are the treatment practices you do the oxygen injection basically that is done, oxygen lancing is done, de oxidation is done to remove the oxygen and keep the oxygen in control and then heat treatment we know, heat treatment is done to induce the specific properties in the material and that properties may be regarding the hardening, tempering, normalizing, annealing. So, all these treatments are given.

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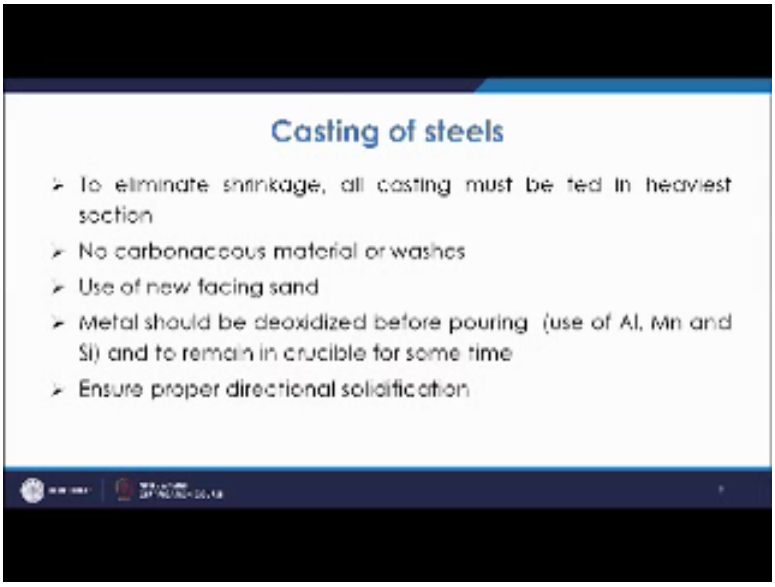

Now, for the casting of steels there are certain practices which are to be followed. Now these practices are like this that, to eliminate shrinkage, all casting must be fed in heaviest section. So, as we know we have studied the risering principle and we know that the better way the proper way is to feed to the heaviest section and then it will move towards the narrow sections because if we try to feed from the narrow section it may so happen that the narrow section in between the pouring is done it may solidify, so that will hamper further filling of the mold. So, to avoid any hot spot formation or any

shrinkage, you have to see that the casting should be fed in the heaviest section first and from there it should go into the narrow cavities then we have also to be careful that because it is more likely its more prone to pick the carbon and that is deleterious in many cases.

So, the carbonaceous materials or the washes which have the carbonaceous compounds, they have used should be judiciously done so that there is no carbon pick up. Use of new phasing sand as we have seen that you have to use it, so that the fusion of the sand on the surface of the casting is avoided; metal has to be deoxidized before pouring. So, there are many methods of deoxidizing, and you have deoxidizers available those materials which are affinity towards the oxygen, they will react with the oxygen and make the slag that slag can be trapped further. So, these are the deoxidizations which are normally used aluminum, manganese and silicon. So, these are the normally used deoxidizers with which we treat the molten metal and then use it for pouring. Now, there is another practice that you leave it in the crucible for some time, the crucible is made of graphite and also it has silicon. So, the silicon which is there in the crucible it will react with this and then it will act as deoxidizers.

Now you have also to be careful about the ensurence of the directional solidification that is very important if you want a sound product. So, we have to see that there is proper use of chills, proper shape, size and placement of risers so that the diaxinol solidification is achieved. So, wherever you have thick sections you may go for use of chills and then you will have to take care of the feeding distances depending upon the type of channels you are feeding, so that proper directional solidification is achieved.

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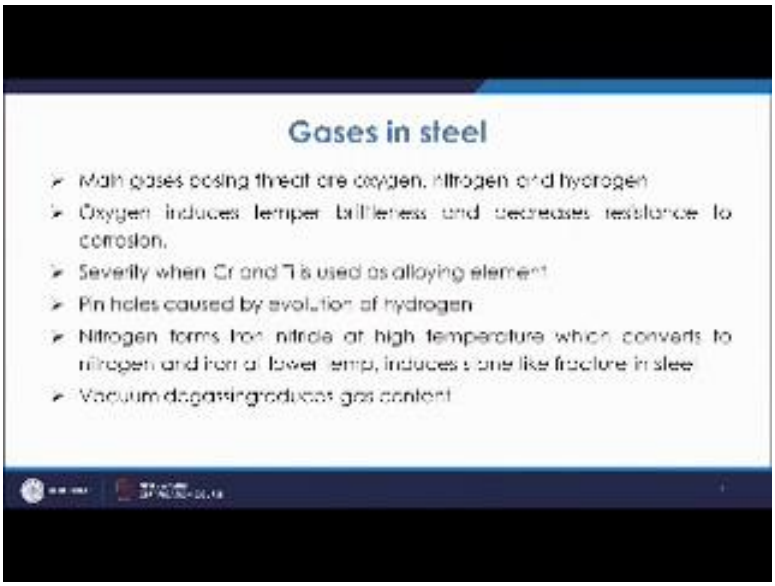

Gases in the steel; as we have understood that gases in a steel pose a lot of problem, they for the oxidized products they are detrimental. So, most of I mean mainly the gases which are posing the threat they are oxygen nitrogen and hydrogen. So, oxygen basically induces the temper brittleness and decreases resistance to corrosion. So, basically that oxygen we have to remove and that is why we have understood that we use the deoxidizers to remove them. It is becomes more severe when we use the chromium and titanium as alloying element because they readily get oxidized.

So, chromium forms the chromium oxide and then it alters the property. So, for such materials which are readily oxidizable these problem of oxidation or oxidize products is be even more severe. In case of hydrogen you are likely to have the pin holes. So, this pin holes means the gases in the later stages of freezing, they try to go out and they leave a very small pin hole type of surface appearance. So, this is because of the presence of hydrogen, most of these problems arise because the solubility of all these gases are very at high at higher temperature and their solubility decreases as the temperature comes down during the solidification. So, these gases are not able to come out if the permeability is not properly maintained or if they are trapped in. So, that is why you must do proper means, you must adopt proper means to take this gases getting spilled off.

Nitrogen forms the Fe2N or Fe4N at a nitride at higher temperature and when the temperature comes down basically this again breaks and forms the gas, nitrogen and then iron will be separated. So, that basically induces a stone like fracture in the steel. So, that is a challenge and this is not desirable. So, this way nitrogen is also harmful. So, we do the vacuum degassing techniques and they are in fact, as we had discussed that you while moving from one ladle to other that in that case the final ladle is normally under vacuum, so when we pour all the gases are basically sucked off, then we must know that there are different verities of steel which are normally used and we already discussed that depending upon the kind of alloying elements or percentage of carbon, you have carbon steels.

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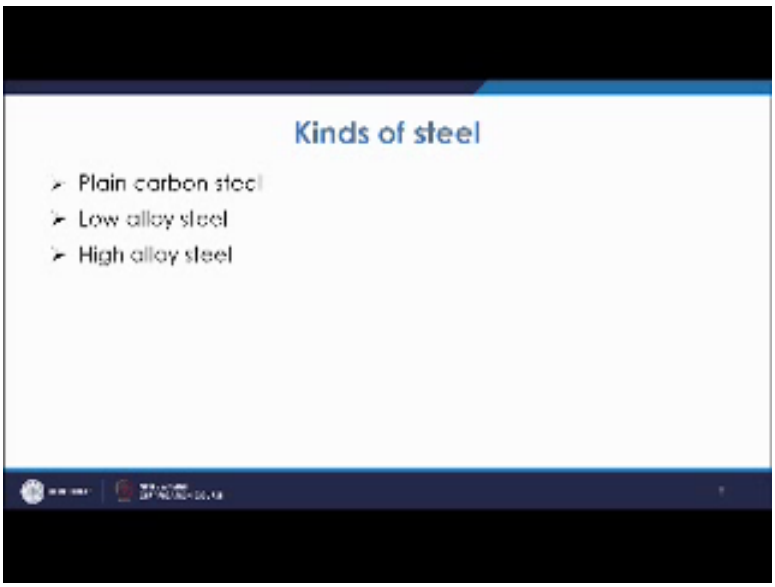

So, it is plain carbon steels where the alloying element is very small and then low alloy steels and high alloy steels which have the alloying content material content may be less than 8, then it is low alloy steels, high alloy steels you have more than 8, then in that case you have variety of steels like you may have the stainless steels.

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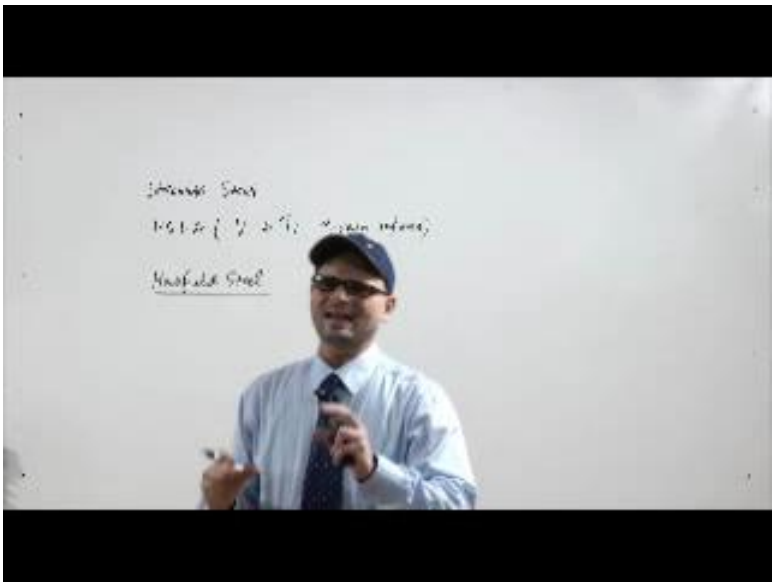

So, that is basically chromium and nickel is the principle alloying element because it forms a layer of chromium oxide that is a stainless, that is why stainless steels you may have the varieties like HSLA high strength low alloy steels which is coming under the category of low alloy steel, where you have use of vanadium or titanium as grain refiners. So, they basically develop a very fine matrix, very fine size because of these vanadium and titanium which are acting as the grain refiners.

In the case of high alloy steels, you have other steels like you have austenitic manganese steel that is Hadfield steel; so, that is austenitic manganese steel you have manganese to a higher level and that gives a large amount of wear resistance. So, basically depending upon the type of alloying elements, you will have the specific properties to different kinds of steels and the process of producing may vary slightly because the treatment may vary, the refinement may vary. So, this way you may study more and more about the different varieties of steel and get used to know about them their uses and their melting processes.

Thank you.