Principles of Casting Technology
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Lecture - 35
Melting and Casting of Cast Metals
Production of Nonferrous Metals and Alloys

Welcome to the lecture on Melting and Casting of Cast Metals. So, in this lecture we will discuss about the production of nonferrous metals and alloys. So far we have discussed about the production of the ferrous materials mainly that of cast iron and its varieties and also that of steel. Now nonferrous materials are also used in many situations because of its own advantages. So, what are the practices of melting and pouring and production of these nonferrous materials and its alloys; that we will discuss. Some of the advantages of the nonferrous materials are that they are light in weight, normally they have good specific strength, they have many other qualities like good electrical conductivity may be good resistance to corrosion and there are many other properties which are having better than compare to the ferrous materials.

But then we will also have to understand that what are the factors which are to be considered, while making these nonferrous materials?

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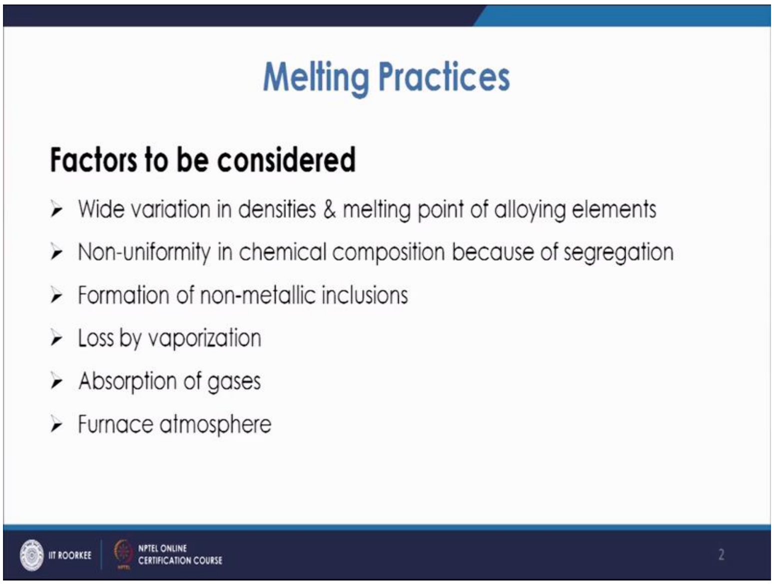

So, while making these nonferrous materials or while making the casting of these nonferrous materials, you have to see that there is wide variation in densities and melting point of alloying elements, if you look at the nonferrous materials like copper or aluminum, that they are mostly used as nonferrous materials which are used for engineering applications. So, in the case of copper and aluminum, if you take the pure of iron I mean copper or aluminum they are not very much used for engineering applications because they are strength is quite low and may be copper is used when you need to have a good electrical conductivity or even aluminum for that case, but then when it is alloyed with different elements then its strength increases lot of properties of these alloys do better. So, mostly these nonferrous materials are in the form of its alloys also they are cast as pure.

So, when we talk about the alloying elements which are used with these nonferrous materials, in that case there is wide variation in densities and melting point of alloying elements and that is a challenge when you cast this nonferrous materials. So, if the density is vary a lot in that case because of that they may go at the top or they may settle at the bottom and in that case the mixing will not be proper, they go at the top there is chances of the oxidation at the top and if they are settled at the bottom then they do not contribute in completely mixed inside basically the apparent metal; then the melting points, so melting points also vary and if the melting points vary there may be associated problems there may be problems related to melting. So, it may be such many times that one melts and at that time the other is already in the volatile state. So, that may be the case. So, these are the challenges in case of these nonferrous materials and there are remedies for that that we will discuss may be you can use the master alloys in such cases.

Non uniformity in chemical composition, that basically leads to segregation. So, if the uniformity is not there in the matrix in the whole domain then there may be segregation at different points and because of that the properties may vary, that may basically degrade the quality of cast product. So, that is also a challenge that you have to be able to uniformly having the distribution of the alloying elements inside the whole matrix. Formation of non metallic inclusions these are basically formed during the melting and because of reaction products you may have the non metallic inclusions. So, they are basically a defect and if they are there in the melt they are retained in the melt they are basically a source of defect they are basically a defect particle and that basically regards the mechanical properties of the material.

Loss by vaporization lot of the elements, so elements when we allow add as alloying elements, they basically vaporize during the melting and that is a loss. So, you will have to do something, so that you balance it. So, during the melting this is very natural and may be that you have to adopt certain means to minimize this loss by vaporization; there is also absorption of gases because most of the gases they are solubility increases as the temperature increases. So, during the melting at higher temperatures, many gases like hydrogen oxygen or nitrogen, they are basically dissolved and they go inside the melt and may do the damage. So, this solubility basically decreases as the temperature comes down during the solidification and if this gases are not able to come out they may give you the gas pockets. So, that may lead to the gaseous kind of defects.

Then furnace atmosphere, what kind of atmosphere in the furnace this is important; you may have the deducing atmosphere, oxidizing atmosphere or you may imply vacuum. So, depending upon the situations you will have to apply the suitable kind of atmosphere inside the furnace. So, that the lining does not give adverse effect on the quality of the material. So, let us discuss about the problems due to variation in properties. So, we had discussed that because of the variation in the properties of the elements, there are a number of problems which is faced; that is difficulty in distribution of alloying elements in the melt.

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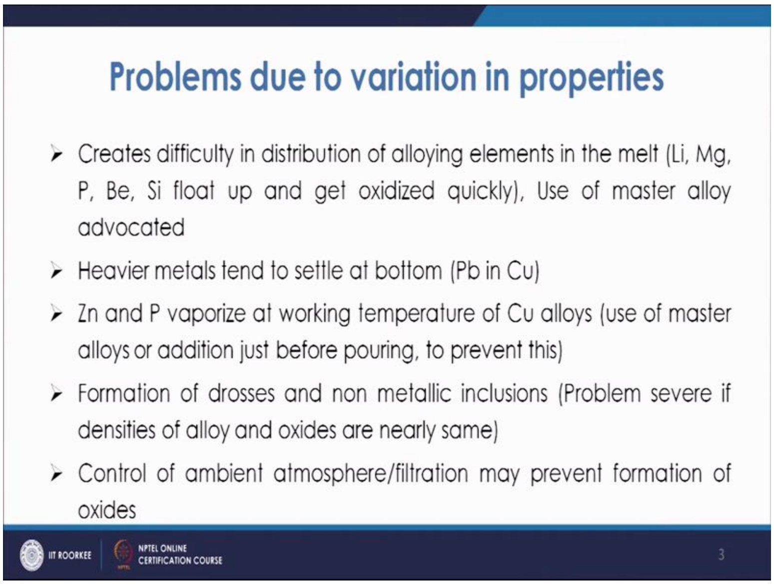

Now, let us see for example, lithium magnesium phosphorus beryllium silicon, now they normally float up and go there and they can get oxidized quickly. So in that case use of master alloys advocated so that they do not go they react and the product does not go at the top surface where it has the chance of getting oxidized. Similarly if the metal is heavier, it may settle at the bottom like led in the copper melt. So, if it is led may go its being heavier, it will go and settle at the bottom, so that is another challenge.

As we have discussed another is vaporization that is zinc and phosphorus normally they vaporize at working temperature of copper alloys, so that is lost. So, basically to minim or to prevent that normally master alloy used this is the first way; second way it may be added also just before pouring so that this loss by vaporization is minimized.

Then formation of drosses and non metallic inclusions; so what happens in many cases there are reactions inside the melt going on, reaction with the elements, reaction with the oxygen may be then we can get the oxides. So, what happens if they are lighter they can go at the top, but if they are heavier they will settle at the bottom and the problems is even more severe when they are densities are equivalent.

So, if the densities are equivalent in that case the separation of this oxides from the melt is even difficult because they will be somewhere inside the melt. So, its removal becomes very very difficult. So, basically for that you have to control the ambient atmosphere inside the furnace, so that you can minimize the formation of these oxides, also or non metallic inclusions, and also it can and if you have want to prevent completely the formation of oxides or you want to take this formation out I mean formation of oxides out, oxides not to go inside the mold, in that case you may have to go for filtration, so that is basically for complete removal.

Now, during the pouring and further solidification process, there are chances of having a lot of defects, so that is needed to be understood and know. So, the defect may be because of aspiration effect, so aspiration effect as we know this is the effect which is basically because of the improper design of the sprue. So, if we have the improper design of the sprue that may lead to aspiration effect and the air or gases may go and that may react with that may come in contact with the liquid metal and it may form undesirable compounds.

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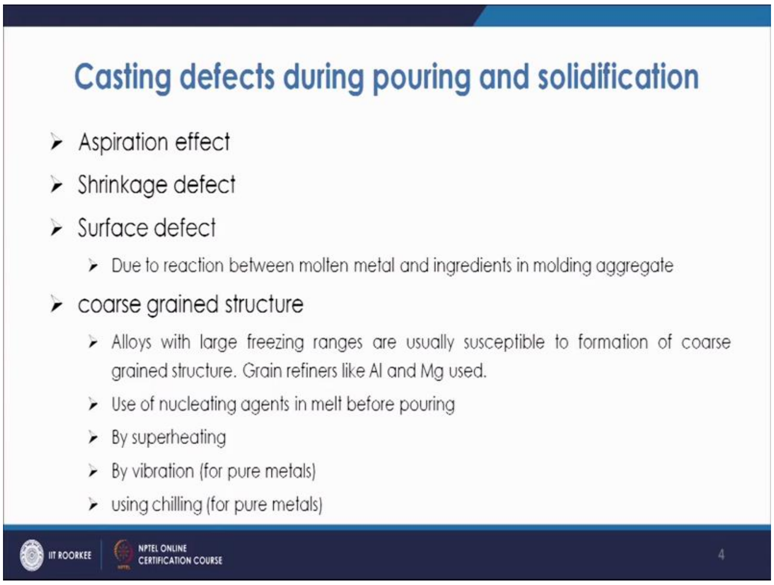

So, for that you have basically to have the proper design of the sprue system so that there is no aspiration. There is a chance of shrinkage defect because during the solidification process there will be shrinkage is going on. So, the shrinkage defect is also likely to occur and as we know that is to be compensated by placing the riser and there are many methods for calculating that. Surface defect become because of the reaction between molten metal and ingredients in molding aggregate.

So, as you have the molding material that is sand if we are using as the molding material and the molten metal inside if they are basically meeting at that surface, in that case they are may be reaction at that particular surface and they are may be the surface defect or reaction product that is formed. Coarse grained structure, so normally it is seen that you get the coarse grained structure and coarse grained structure is not a desirable thing from the mechanical properties point of view. So you like always to have a fine grained structure, because fine grained structure gives you good properties in many ways.

Now, it has been observed that many factors are their which are responsible for the coarse grained structure and the alloys with large freezing ranges normally; they are susceptible to formation of these coarse grained structures. So, as we know the coarse grained structures are because of the growth of the grain which is nucleated. So, when the degree of nucleation is less than the chances of the growth of the grains are mold, it means there is improper nucleation inside the melt. So, to avoid the formation of this coarse grained structures, it is essential that they are should be nucleation at more number of points or they are must be grained refiners at in the melt.

So, normally these aluminum and magnesium are used has the grain refiners, in case of aluminum melt it is titanium boron or other materials are used so you have other materials for all the different materials you have different type of grain refiners which are used. You also used the nucleating agents, nucleating agents do the same thing they go inside the melt before pouring you put it, so that these nucleating agents they are working has the nuclei. So, basically that is a case of heterogeneous nucleation, so they are the preferred sides for the nucleation to occur. So, in this case you get the fine grained structure and get rid of the coarse grained structure. By super heating in few case it has been seen in case of magnesium it is seen if you super heating the material and then further cool fast then it is seen that you get the fine grained structure; for pure metals this two methods are also very much used the used of vibration as well as use of chilling, which is giving you the fine grained structure, so for pure metals these two methods are very much used.

Now let us discuss about few of the alloys like copper; so copper we use we know that copper as very high conductivity, and when you try to cast pure copper then there are certain issues or copper or its alloys even, then we know that when we want to cast pure copper then copper as very high conductivity, but it is seen that if it is added with alloying elements and if it is done impure with small amount of alloying elements, the conductivity is decreased.

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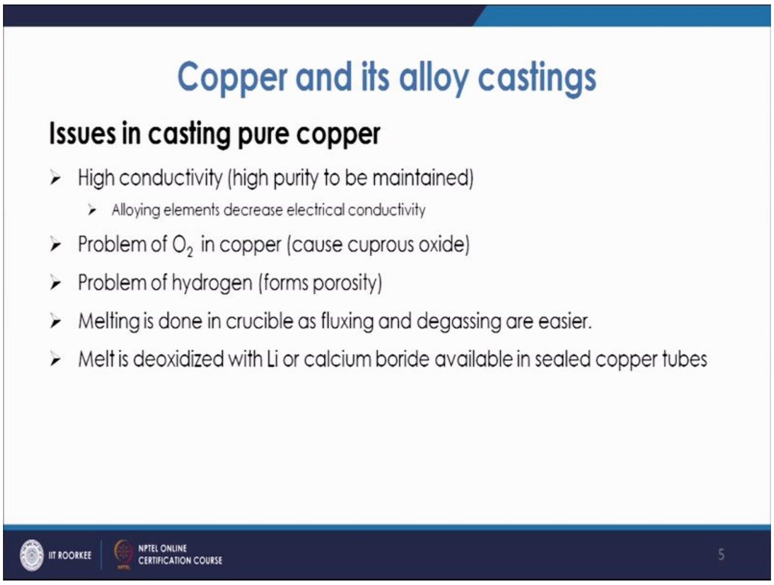

Like if you use the phosphorus even 0.1 percent of phosphorus or will decrease the electrical conductivity to a large extent, there are many elements which are basically decreasing the conductivity of these copper. So, even 0.1 percent or 0.1 of certain element or even 0.1 percent of few other elements, they are reported to cause of lot of change in the electrical conductivity and among them this phosphorus although it is a deoxidized, but it is decreasing the conductivity a lot.

So, that is a challenge while casting or producing the pure copper material because if there is impurity even at slight amount, then it will decrease its properties then the dissolution of the gases like oxygen and hydrogen. So, oxygen what happens they are basically they cause so they form the cuprous oxide.

Similarly, the hydrogen this hydrogen we basically giving you the porosity, as we know this hydrogen solubility these gases solubility, they are higher at low the higher temperatures and they decrease, so they form the porosities. Now normally this melting is done in crucible as fluxing and degassing is easier. So, in this cases when we make the copper casting, we do crucible because here the fluxing and degassing is somewhat easier, deoxidized with lithium and calcium boride available in sealed copper tubes. So, this is the point which is to be understood that you either deoxidized with lithium or calcium boride, which is basically sealed in copper tubes.

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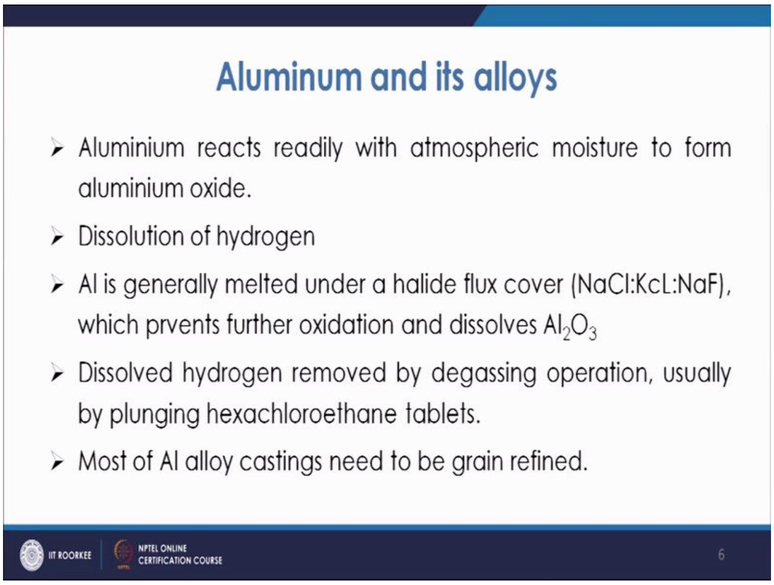

Then if you come to the aluminum and its alloys, so aluminum basically reacts very readily with atmospheric moisture to form aluminum oxide.

So, as we know that aluminum oxide and aluminum both have very equivalent densities, it is very difficult to even separate them out and they very readily form these oxides. So, then dissolution of hydrogen, hydrogen also is basically dissolved at a very high rid in the aluminum, so that is basically challenged. Hydrogen basically is harmful for most of the nonferrous materials. So, hydrogen normally is not used as deoxidizing agents normally hydrogen or carbon monoxide these two are the elements which are used, but then hydrogen mostly is solubility is higher and because of that basically it is not good for the metal, so normally hydrogen is not preferable as the deoxidizer.

So, aluminum is normally melted under a halide flux cover. So, this is a flux and under that cover you do the melting and this flux is either NaCl and KcL combination or NaCl KcL and NaF combination. So, that is there may be NaCl KcL or 50-50 or 50-45 in that ratio you use these halide fluxes. So, that prevents further oxidation and dissolves this Al 2 O 3. So, that basically is the remedy for removing this Al 2 O 3 which is formed as the reaction product between aluminum and the oxygen and also it dissolves. So, this way you can get rid of this material.

Dissolved hydrogen is removed by degassing operation, usually by plunging hexachloroethane tablets. So, what we do is we normally plung these tablets, so that they can be removed these hydrogen gas can be removed; most of the aluminum alloy castings need to be grain refined. So, basically you use the grain refiners normally titanium, barium, which is working has the grain refiner in case of aluminum alloy castings. Now in case of aluminum as we see the aluminum is a preferred material, because it is having low density the specific gravity is quite less as compared to the ferrous materials, its melting temperature is quite low, it is as low as close to 660 or 670 degree centigrade. So, normally because of poor tensile strength, we prefer many kind of alloying elements with aluminum, and it is alloyed with materials like magnesium, copper, zinc. So, there are many elements with which it is basically alloyed and then they are used for different applications.

Coming to magnesium, magnesium is another important material which is very much in demand in the aerospace industries because of low density, high specific strength, good castability, machinability and weldability. So, this material is very much used in the aerospace applications.

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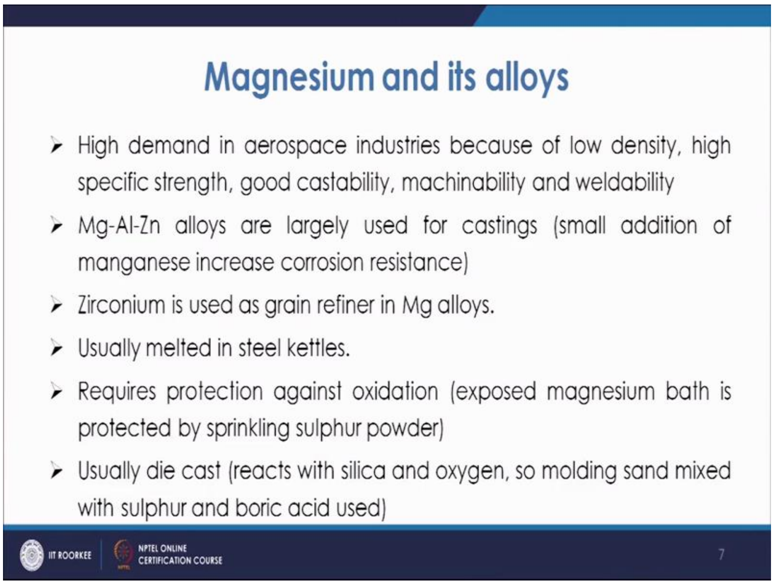

Now, this material normally is used as alloy that is Mg-Al-Zn, it is now largely used for castings. So, what happens? Small amount of manganese this material otherwise as very small corrosion resistance. So, if you add some amount of manganese it increases its corrosion resistance. So, this is further used for many applications.

As far as grain refining is concerned zirconium is normally used as grain refiner in magnesium alloys, usually it is melted in steel kettles, so there it is melted; requires protection against oxidation. So, magnesium basically it is very much prone to oxidation magnesium pouring as to be done in a very controlled atmosphere because is very very volatile; it basically catches fire very easily. So, it is required that a proper atmosphere be there so that the protection against oxidation is there and for that one is that you apply proper atmosphere by using proper gases or we also expose this magnesium bath and protect it by sprinkling sulphur powder. So, this way this magnesium bath is protected against oxidation.

Now, these materials are normally die cast. So, a casting is done using the permanent mold casting, but because the reason for this is that, it normally reacts with silica as well as oxygen. So, as we know with silica as well as oxygen it is highly reactive it into reacts. So, another practice which is common is that the molding sand is mixed with sulphur and boric acid. So, if you use the sulphur and boric acid in this molding sand, in that case there is high probability that there will be no reaction of this silica and oxygen and you can use the molding sand, sand molding process for casting of this magnesium.

So, what is in a nut cell we have other kind of materials nonferrous materials like you have zinc which have quite low melting point. If you talk about the copper, copper is alloyed with lot of alloying elements like aluminum like zinc; with zinc you get the brass. So, which is basically if you look at the phase diagrams, we can come to know that with copper involved with zinc where we up to about 55 57 percent you have the cubic absolute structure. So, it is alloyed to a larger percentage with zinc, which has a very good property that is very much used.

Similarly, in the aluminum, if you look at aluminum is alloyed with magnesium or copper. So, if you look at the aluminum and copper, the copper is normally if you look at copper are normally 4.5 or 5 percent used up to that. So, you have mostly use of aluminum copper alloys in many applications. So, then further use of super alloys are there, then you have titanium melting titanium is a very reactive material. So, titanium melting you will have again a control atmosphere to melt the titanium. So, you can see that most of these nonferrous materials, now they are preferred in many sense because of its low melting points, but they have to be melted under a controlled atmosphere normally; so that there is a minimum chance of the formation of the drosses or non metallic inclusions and then you can get a suitable cast quality.

Thank you.