Theory of Production Processes
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Lecture – 18
Production of steel and non-ferrous castings

Welcome to the lecture on production of steel and non ferrous castings. So, in the last lecture, we discussed about the production of iron castings, what are the steps what are the precautions need to be taken; what are the varieties of iron castings, which are required and which are normally produced in foundries. So, let us have some insight about the production of steel as well as some of the non ferrous castings, which are normally very popular among the foundry industries.

So, as we know that steel has a unique properties it has very high combination of properties and so, it is used in many sectors you have large foundries which make steel, normally because steel components which are of larger size they are made in those larger foundries, you need big space you need larger furnaces, because of high temperature involved in the production of the steel or the melting of the steel. So, coming to some of the properties of steel, steel is normally has very tensile strength and also ductility. So, you have the combination of both tensile strength as well as ductility, and the properties can be controlled within wide limits by controlling its composition specifically the carbon contents.

So, you have varieties of steel, you have the plane carbon steel, you have medium carbon steel, you have high carbon steel you have alloy steel. So, that alloy steel again comes because of the percentage increase in the alloying elements. So, you have low alloy steel then high alloy steel.

So you have varieties of the steel and it has you know specific properties, they are very much useful engineering alloy, which is replacing many of the metals specially whenever you have large corrosion assistance is required, large thermal stabilities required, protection against high temperature is required in all these positions or for the industries you know for construction industries or any industry, steel is replacing many of the metals because of its own advantages unique advantages.

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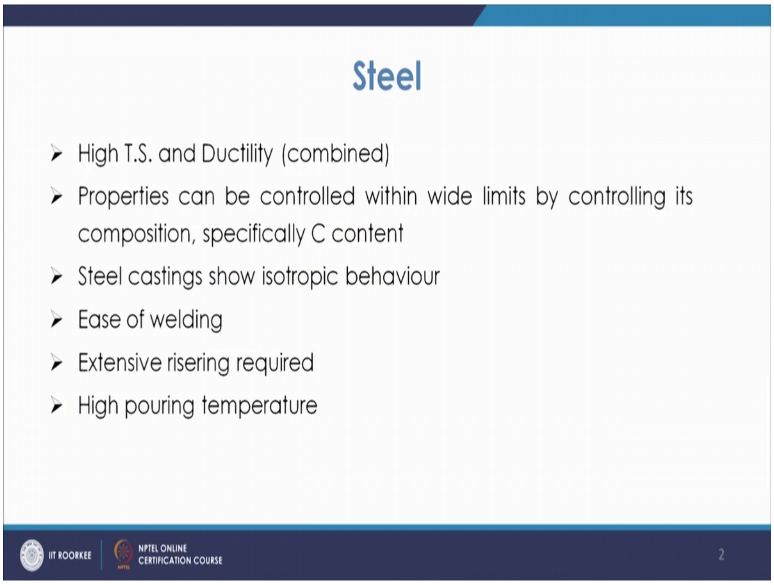

Now, steel castings also show the isotropic behaviour so that is also one of the advantage ease of welding. So, when you weld it is there is ease of welding weld ability is good. So, that is how it is also preferred for fabrication purposes when you have to join the two pieces, then there is because of ease of welding it is preferred over many materials, but there are certainly certain challenges in steel casting. So, one is that extensive risering is required, because once you take steel and if it has first of all we are going to high temperature then also you have the freezing range involved. So, that freezing range necessitates the use of risering to a larger extent.

So, that you have to use the risering also whenever you use the heavy sections, and if you thin sections combined and if you have the large chunky portions. In those cases the risering requirement has to be properly addressed, because otherwise you will have the defects the hot spots or shrinkages or so. So excessive risering is required in case of a steel, you have to have proper understanding and control of these defects like shrinkage defects where risering proper risering will address those issues.

Then certainly we know that we have high pouring temperature in case of steel. So, that is also one of the challenge for that, you need to have proper furnace which can give you the large pouring temperature. And if the pouring temperature is large certainly the defects related to high pouring temperature, needs to be taken care of and you have to properly control that because the defects related to high pouring temperature are like you have the gas absorption at high temperature.

So, as we know that as we increase the temperature, the absorption of gases increase with increase in temperature and then the solubility of these gases as we decrease the temperature and solidify the basically solubility decreases, and they need to be thrown off of the mould and for that you must have a proper mould design a gating design so, that the gases are coming out, they are not producing any kind of gases defects.

So, so these kind of results I mean defects may come, then other you know defects because of this high pouring temperature may be the formation of you know fluid surfaces at the metal and sand interface. If you are using the sand in that case if the there may be fusion at the metal sand interface because of very high pouring temperature. So, you need to see that what kind of you know surface you want to have, and what should be the additives used at the surface or what should be the moulding material composition so that you get a proper surface finish.

So, these are the factors which are basically required to be understood and to be properly you know taken care of when we go for producing steel castings.

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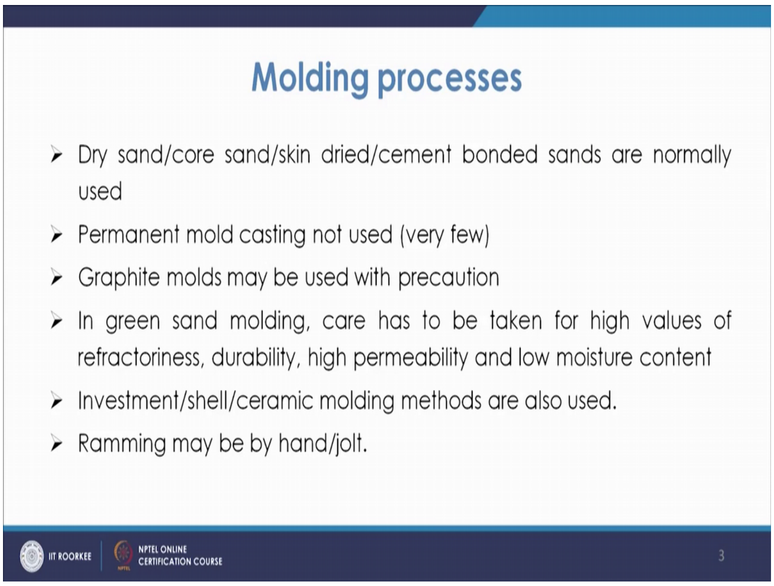

So, normally when we talk about the moulding processes. So, in the case of steel we will use either dry sand moulding process or core sand or skin dried or even cement bonded sands, these are they normally used you know mould because you need to have the strong mould with large strength.

So, for that we use these kind of sand moulding, and then permanent mould casting is not very much used because of very high temperature. So, as we know that the permanent mould casting. So, permanent moulding method, so that is used normally for the materials which have lower melting points. So, normally that is used for nonferrous materials because of very high temperature and then you have the limitation of having certainly the moulding material.

So, except for few casting processes like if you take the example of continuous casting, there we use the permanent mould made up of copper normally for casting the steel. So, there the mould has to be designed properly and then the proper attention is made on the cooling of the mould, because otherwise you cannot get the cast of requisite quality. So, that is copper mould and then it is cooled externally by water. So, that we go for permanent mould casting even used for steel castings. Graphite mould is also used, but with precaution that there should not be carbon pickup.

So, that that is special challenge in case of steel casting because the proper control of carbon is very much important, because if you do not have the adequate or the optimum amount of carbon, carbon may lead to formation of carbides, it may be iron carbide it may be carbide of alloying elements. So, carbon you know percentage is very much an important factor and graphite moulds are used only with precaution that carbon pickups should not be there.

In green sand moulding, the care has to be taken for high value of refractiveness. So, we must take the sand so, that you have quite high refractiveness because of the extremely high temperature of the molten steel. Then its durability because you can use it for longer duration longer time you can re cycle them you can further use them then high permeability is required because at high temperature, you will have the lot of gases formed especially if you have the grain sand mould then because of that high temperature you will have large quantities of gases formed inside even the mould and also you will have the gases inside the metal.

So, all that gases need to be spelled off so, for that the mould has to have extremely high permeability. And also low moisture content because more will be the moisture content more will be the gases formed or vapour formed. So, that needs to be driven off. So, for that you have to take care of these points like high refractiveness durability, high permeability and low moisture content.

Investment casting shell casting or shell moulding then ceramic moulding method they are also used, but their used like investment certainly it will be limited to its size then ceramic moulding also may be used for typical applications then the ramming has to be done either by hand or jolt machines. So, that is normally the practice in case of steel moulding coarse have to be of very high permeability because they are subjected to very high temperature.

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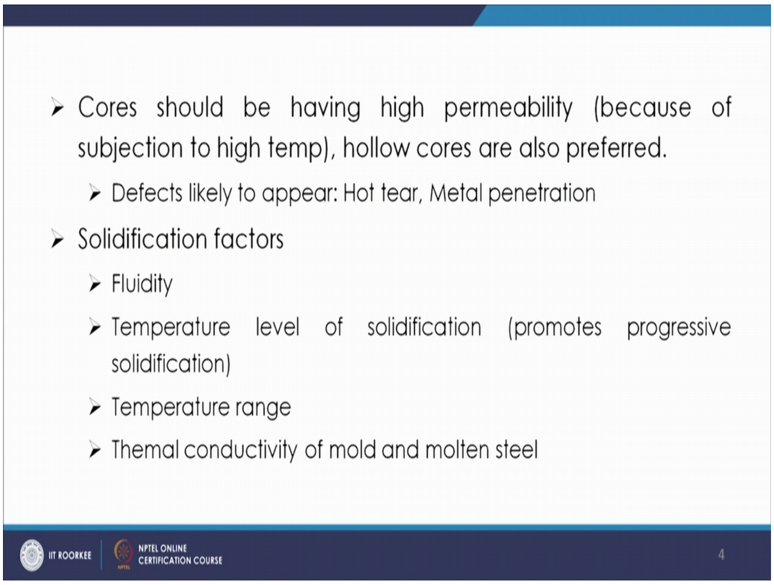

So, we also prefer to have the hollow cores in many cases, and where the defects may come because of the improper quality of or the properties of the cores and the defects which are likely to come are like hot tears. So, suppose there is improper collapsibility of the core, in that case this this type of hot tear defects may come if you know because of the. So, that we know that in hot tear you have because of the pulling you know at that interface and then the lower strength of the steel at that higher temperature.

So, if that time if you have the poor expension property, in that case this hot tear may crop up. Similarly metal penetration may be because of the very core sand of the mould that is core. So, if you rate using very core sand in the core then in that case the metal penetration may also come up. And that apart from that you have other defects like set of side formation is there also in the case of cores. Then you have the factors like solidification factors. So, in the case of solidification factors you have to be careful about certain factors like fluidity.

So, fluidity is as we know that fluidity is very important in case of solidification or in case of basically filling or the mould. So, you will have to have proper fluidity, and fluidity as we have studied it depends upon many factors and the important factors are like the temperature of the material when it is poured, then the basically what is the freezing range. So, that is also one of the important factor in case of fluidity.

So, normally there are certain alloying elements which aid in fluidities. So, that also should be seen that proper fluidity is there, because in case of integrate shape castings fluidity is important and it has to be given proper attention. Temperature level of solidification so, that is also important because you need to have the progressive solidification. So, once we give the temperature at higher temperature and because of the temperature gradient, you know the molten metal touching the wall will start solidifying then it will move towards the inner side. So, that will promote the progressive solidification.

Temperature range as we discussed so, that is also freezing range is there. So, that affects the solidification mechanism thermal conductivity of mould as well as molten steel. So, that also is important factor because we know that this basically tells us that how fast the heat can be extracted or sometimes because of thermal conductivity of metal, whether what will be the temperature gradient inside the basically the casting. So, that affects the so, freezing pattern.

So, this has to be taken care of coming to the steel melting.

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So, for a steel normally we go for open hearth that is acidic or basic melting then we go for electric arc that is acidic or basic melting. So, that we have already seen that either we have the acidic slag or basic slag based on that, we go for that kind of refractory lining and then that kind of that is why it is that kind of melting.

So, further you have the converter process also which is used in case of steel melting, you have induction furnace which is used for you know steel melting; vacuum melting is also important to be addressed because many a times being very much reactive in nature or because of the chances of contamination of liquid metal with the atmospheric oxygen or the gases, its better we go for very important casting units or we want to have very pure casting in those cases the vacuum melting is also preferred.

Then basically the challenge with steel melting is the presence of the gases, and the gases are normally oxygen nitrogen hydrogen or so. So and many a times we also do the oxygen injection also for other stratification purposes, then we go for deoxidation the, we are putting alloying elements which are good de oxidisers which are more affinity with the oxygen. So, they react with oxygen and make the oxides. So, these are the treatments which are practiced for steel melting, and then heat treatment is a practiced normally to achieve the desired properties many a times to relieve the residual stresses, the stresses which are developed during the cooling of the casting. So, these are the treatments which are practiced in case of steel melting.

Next for the casting of steels so, for eliminating the shrinkage, the proper practice is that you are the casting must be fed in the heavier section. So, basically many a times you have the position of riser also. So, that is normally attached that has to be normally attached to the heaviest section. So, that there is no shrinkage because the thinner section will go on solidifying early. So, you need to provide the liquid metal in case of shrinkage at the portions, which are going to solidify towards the end and that is normally for the heavier sections the casting has must be fed in the heaviest direction section from there it should go to the thinner section. So, that the heavier section is connected to the feed channel of active feed channel of the, you know gatings network.

So, that there is less possibility of having shrinkage in those regions. No carbonisation material or losses should be there, because as we know that this is a challenge in the steel casting that there should not be carbon pickup. So, that is why we have to be careful about it. Use of new phasing sand because that will provide the better refractiveness the fusion at the surfaces that tendency will be lesser. So, that should be there, metal must be deoxidised before pouring. So, for that normally we use the deoxidisers and these are the aluminium magnesium and silicon are the deoxidisers which are normally used. So, they once they are going into the melt they if the oxygen is there, normally these oxygen works as a defect because they go and segregate at the grain boundaries making it brittle.

So, normally; so, these oxides, normally this oxygen has to be removed.

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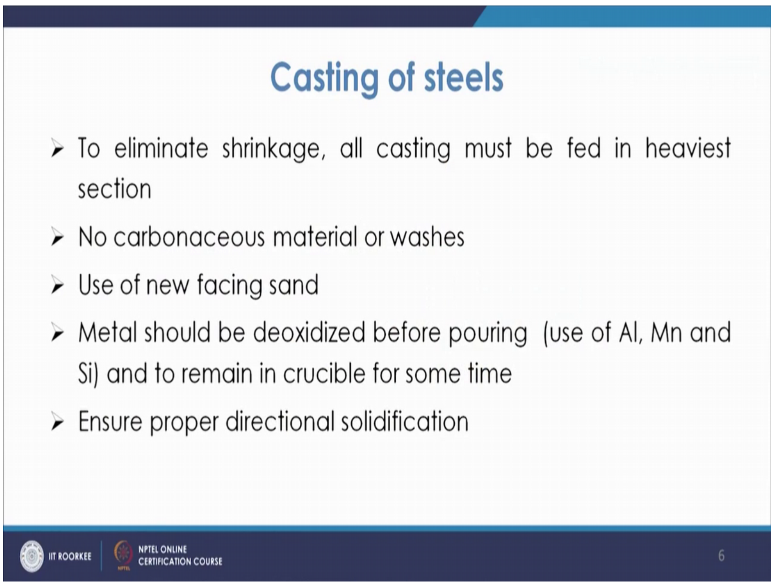

And this oxygen is removed by these deoxidisers, which have a great affinity towards oxygen. So, they make oxide and then take the oxygen out. So, you use the. So, we do the deoxidising practice, and also we should ensure that there is proper direction solidification.

So, that has to be seen by proper gating practice where you have to see that the different sections are proportionately placed and proper placement of riser is there, proper size of riser is there. So, that you have proper directional solidification that is minimum shrink while chances of shrinkage at or minimum chances of having certain region isolated from the active feed channel. So, that also needs to be understood.

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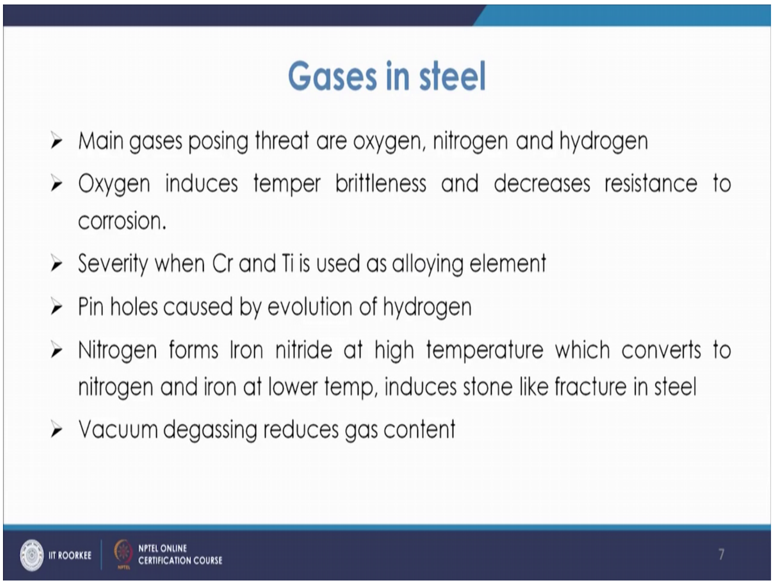

The gases which are normally posing a threat in the steel making are oxygen nitrogen and hydrogen. So, oxygen basically induces the temper brittleness and decreases resistance to corrosion, and it is severe when the chromium and titanium is used as the alloying element.

So, basically that is why we go for the deoxidisation of the melt so, that the oxygen is removed. If the hydrogen is there then as we know because of the presence of hydrogen, you have the chances of pinhole porosities because towards the end when the hydrogen solubility becomes too low, when it tries to come out when it goes in in the form of pinholes. So, this pinhole porosity chances are more if the hydrogen is more. So, that is why you have to see that properly hydrogen is controlled. Similarly nitrogen will form the nitrites. So, that is again that will induce the stone like fracture that will induce the brittleness. So, that is why nitrogen also is undesirable when you need to reduce it. So, vacuum degassing is also one of the way to reduce these gas contents.

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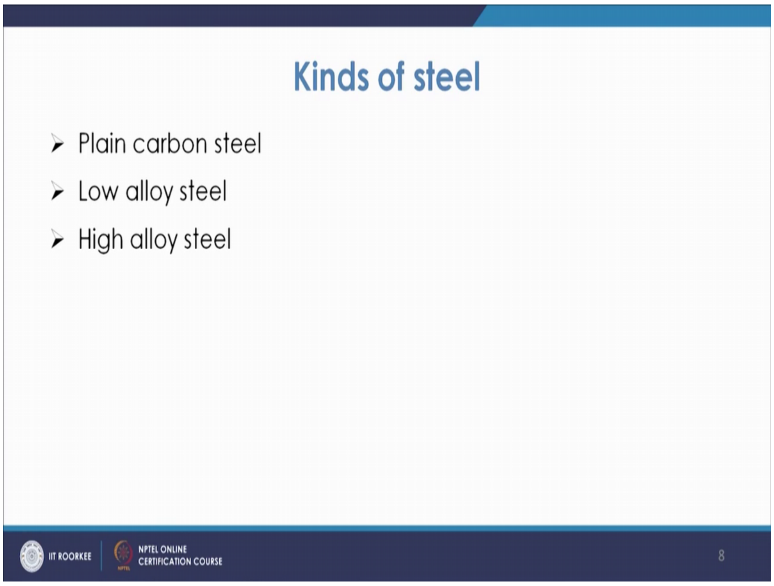

So, as we know we have different kinds of steel plain carbon steel low alloy steel and high alloy steel, which are normally used and you have the different methods suitable methods for the melting of the such steels depending upon its use, you have to see that how you are going to supply the alloying elements that needs to be seen, how there will be minimum of losses and depending upon the kind of steel you are melting, you need to have the different kinds of alloying elements, then you in that also you will have suppose in steel itself you have austenitic steel, you may have ferritic steel, you have martensitic steel, depending upon the different composition of the alloying elements and then they have the typical usage.

So, that needs to be seen that what kind of steel you are going to melt, what kind of steel you are going to prepare and accordingly you can go for proper selection of process parameters. Now, we will discuss about the melting practices for nonferrous metals and alloys.

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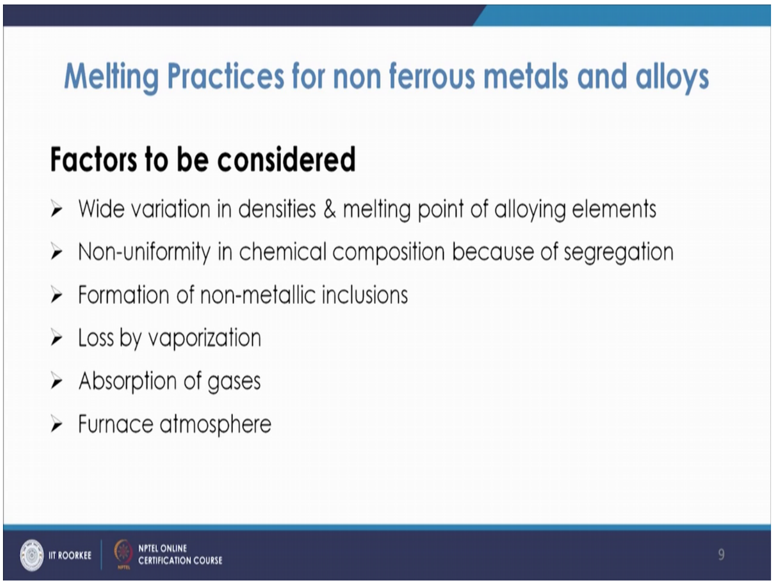

So, nonferrous metals and alloys are very much used for in the foundries, because many of the components are made by nonferrous materials going to its light weight ease in casting and also better machining and many of the nonferrous materials have high strength to weight ratio they are easy in handling.

So, it is not symmetry to discuss about its uses at this stage, but we know that they are they are all around us and these foundries, nonferrous based foundries are very much there which are for the production of the nonferrous components. Now in the nonferrous metal production and alloys normally in nonferrous materials we go for the alloys because the pure material is used only whenever we have only specific properties required like you require very high thermal conductivity, high electrical conductivity or so. So you have for engineering purposes you go for alloys, now there some factors we require to be understood which are important.

So, the factor is first factor is the wide variation in densities and melting point of alloying elements. So, in the case of nonferrous materials where you use the make the alloys, in those cases you have the different elements which have different density and melting point. So, for that you need to have proper melting process, as we know that because of the you know solubility of one material into other, which can be seen by looking at their phase diagram you will have the different temperature ranges for melting.

If you change the composition the melting temperature will change. So, that basically are the important factors which are to be kept in mind. Also many a times you have density variation. So, one of the element is light another is heavy. So, if the element is light it will try to float up, and if the element is heavy it will try to settle down at the bottom. So, that makes the challenge because then that leads into non uniformity in chemical composition, many a times because of segregation one is that you have the settling of the alloying element at the bottom or the top depending upon its density, another is that many a times because of other substances of the related properties or other properties you know they try to segregate. So, you will see that if there is no proper process going on if there is no proper mixing of the homogenisation of the melt, in that case or the proper studying of the melt, in that cases some of the elements try to segregate. So, they will be at one place. So, once they segregate at one place that is not going to give the optimum properties.

So, that is will be creating a kind of defect. So, this is the challenge in case of this melting of nonferrous materials. So, normally whenever we go for these nonferrous materials we will have to see and we are alloying with certain elements to improve its properties we will have to see that if they change in the density and if they change in the chemical composition that way. So, for making them homogenised for making the, uniform you will have to adopt the methods in which you have to see that they do not segregate at the bottom or the top, or they are not segregated at one place. So, if there is they are segregated at one place and they are not uniformly distributed, the kind of property you expect that cannot be achieved.

Similarly, formation of non-metallic inclusions are there. So, that again because of many a times because of the reactions, because of you know their affinity with the gases or because of improper working conditions or the melting conditions, there will be formation of non-metallic inclusions and these inclusions. If they are coming at the top they are easily getting skimmed or taken out that is fine, but if they are entrapped in the casting they are source of defects. So, this is also to be challenged and for that you have to have proper gating practice. So, that you remove these inclusions and proper melting practice. So, that these inclusions are not formed.

Another challenge for these melting practice of nonferrous materials are the loss by vaporisation, because these materials are very costly and if you use improper melting procedure; improper gating procedure for pouring procedure in that case during the melting itself there may be loss of these precise elements by vaporisation. So, because the temperature normally is lower many a times. So, they vaporise. So, there will be loss of the key alloying elements. So, that may lead to improper combination of mechanical properties.

Absorption of gases is another challenge because if they are there are gases there are materials which are very much prone to the absorption of gases they have affinity towards gas pickup at that temperature. So, that also needs to be seen they are you will have to have proper furnace atmosphere many a times, in most of the cases you have to control the furnace atmosphere. So, that there is minimum absorption of gases there is minimum reaction taking place from outside world.

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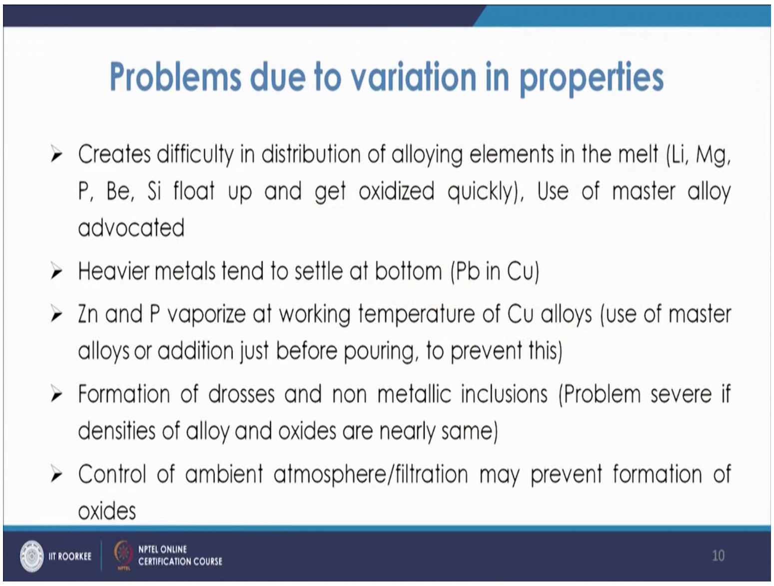

So, problem due to variation in properties like you have you have the difficulty in distribution of alloying elements in the melt. So, if there are many elements like lithium, magnesium, phosphorus, beryllium, silicon which float and get oxidised quickly. So, for them normally we advocate the use of master alloys. So, this is one of the practice which is used heavier metals which are heavy they normally try to settle at the bottom. So, that is another challenge that we have discussed direct like lead, tin, copper, then zinc and phosphorous vaporise at working temperature of copper alloys. So, you will have to have the use of master alloys before pouring. So, that you can or prevent them, then you have formation of drosses and non-metallic inclusions as we discussed because of certain metals which are very much drossy, which make oxides and also control of ambient atmospheric or filtration may be done for preventing the formation of oxides in many cases.

There may be defects because of the pouring and solidification processes like.

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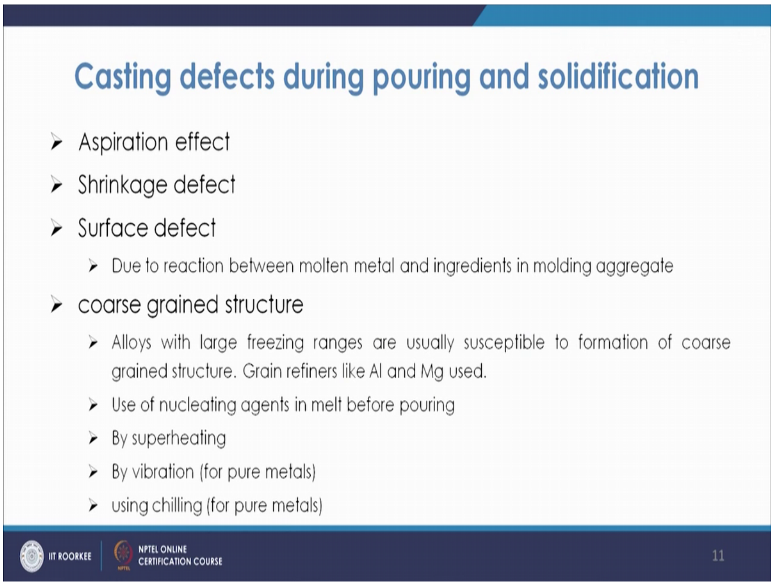

If there is improper gating practice you may have the aspiration effect. So, there will be setting of atmospheric gases from the outside through the sprue or in the runner. So, that may lead to the formation of oxides. So, that may lead to wastage of the material, you may have shrinkage defect because of improper size or position of the risering. You may have surface defect because of the reaction between molten metal and the ingredients of moulding sand. So, that will lead to improper appearance or improper surface, which basically give you glassy surface and then sometimes while machining. If you have oxides entrapped or so, then that leads to the formation of rough surfaces so, that spoils the casting.

Then you have the coarse grained structure also, like if you have the large freezing range of alloys. So, they are usually susceptible to formation of coarse grained structure. So, if you are because of what happens if you have in the larger range. So, in that case during the solidification itself you will have the growth of the grains in such a manner that you have the large grains structures in those cases, and many a times you use the nucleating agents in the melt before pouring.

So, in the case of nonferrous material this is very much practiced that we use the alloying elements, and many a times many of the alloying elements its main purpose is to act as the nucleating agent or they try to basically find make the grains finer. So, that is one thing, because of the super heating also you have the chances of coarse grained structures you have many you know methods like you have the vibrates use of vibration is there using the chilling ,no now these are the methods which is practiced to avoid that.

Now, we coming to particular materials like copper. So, in the copper basically the challenge is about the higher conductivity.

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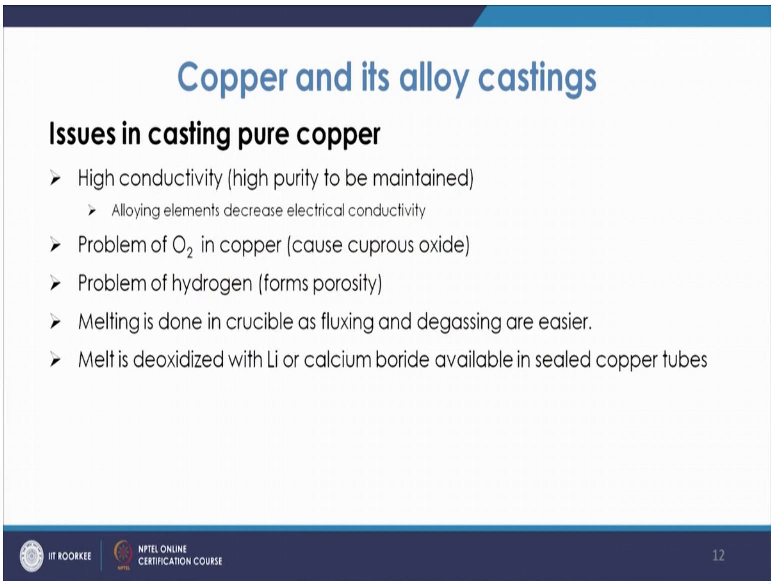

So, this is the challenge which has to be faced, because of the higher conductivity the casting is because the temporary gradient is not maintained that way because conductivity of the metal itself is very very high.

So, the alloying elements decrease the. So, what happens when you make the alloying alloying and you make the alloy of copper with some other material, then the main aim of having high conductivity is sometimes compromised. So, then you have problem of o two also in copper like cuprous oxide you know formation is there, that needs to be minimised because that will alter the property of the alloy, typically for that conductivity and others. Then hydrogen if is there you it will form porosity then in case of copper it is the melting is done in crucible and fluxing and degassing becomes easier in that case of crucible melting. So, we go for crucible, and also it is sometimes deoxidised with lithium or calcium boride so, that you know the proper deoxidisation takes place.

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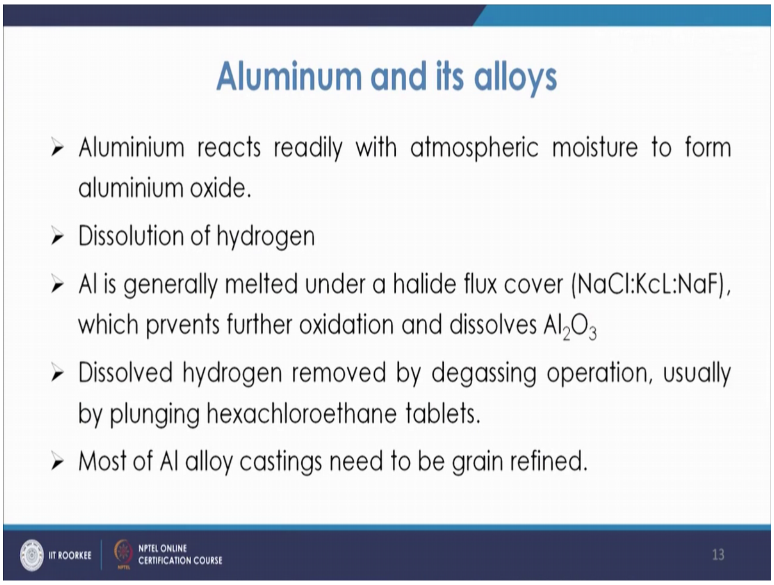

Similarly, aluminium the challenge is that it will react with atmospheric moisture to form aluminium oxide, which is undesirable. So, that needs to be seen that how can we prevent that, the dissolution of hydrogen is another challenge. So, that also needs to be looked into for that normally aluminium is melted under a halide flux cover, which is NaCl is to KcL is to NaF and that will basically prevent further oxidisation and the dissolution of Al2O3. So, that is another thing which is important in the case of aluminium, dissolve hydrogen is also removed by degassing operation.

So, normally we put the tablets of hexachlorophene. So, that basically removes that dissolved hydrogen, and then we also do the grained refinement most of the aluminium alloy castings by using the proper graining refinery we do this for the grain refinements.

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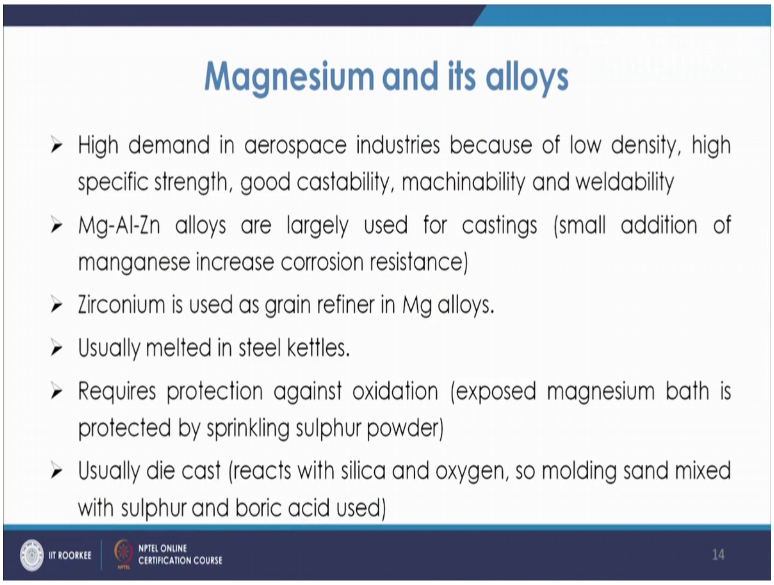

Similarly, for magnesium and alloys, you have magnesium again it is a very reactive material very drossy. So, you will have to have proper melting procedure. So, they are used in many you know areas because of its high castability, machinability, and weldability good specific strength.

So, then zirconium is used as the grained refinery in magnesium alloys, and normally you melt in steel cattles, then requires protection against oxidisation as we discussed earlier, then it will be normally dicast because it will react with silica and oxygen. So, that is why many a times you mix with sulphur and boric acid this moulding sand to prevent that, but normally it is dicast material. So, this magnesium and its alloys. So, this is about the production of nonferrous materials, and alloys there are other nonferrous materials and alloys and melting practices and production also that you can refer and get your knowledge enriched.

Thank you very much.