Fundamentals of Manufacturing Processes
Dr. D. K. Dwivedi
Department of Mechanical & Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture - 10
Casting: Introduction and suitability

Hello, I welcome you all in this presentation; this presentation is related with the subject fundamentals of the manufacturing processes and today I will be starting the new topic that is the casting. So, in this presentation, first of all I will talk about what the casting process is, what for it is used, what are the material properties that matters for successful casting as well as what are the important steps of the casting process.

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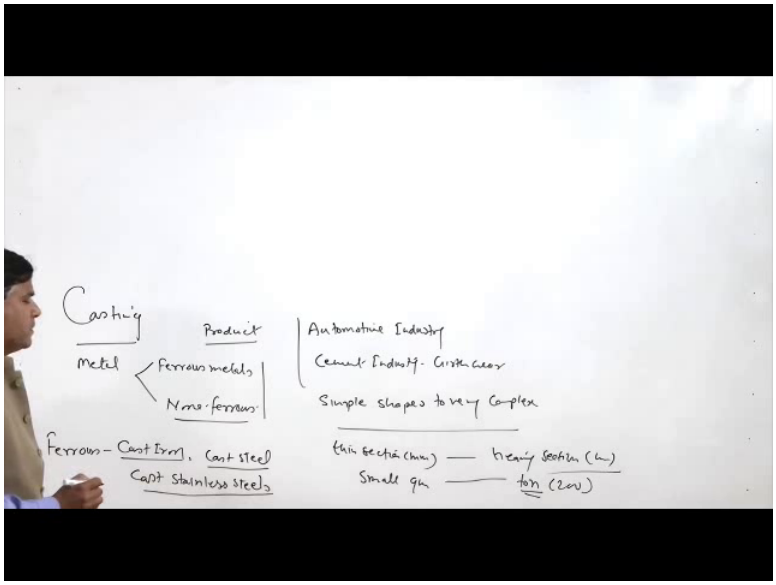

So, as I have said the topic is casting. So, the casting is used for making various products for a wide range of the applications like in automotive industry in form of like piston, connecting rod, engine block etcetera; and like in the cement industry, for making girth gear. So, these components may be from very simple shapes to very complex shapes. So, the process is very much capable to make very simple to the complex shapes of very thin sections in mm to very heavy sections like having the section in even meters for small size castings of you grams to number of the tons like maximum to 200 tons castings also have been made and these castings are these castings. Normally, use the metals of the

two categories we can put them two categories one is like ferrous metals and nonferrous metals.

Since, the ferrous metals are of the higher melting temperature as compared to nonferrous metals, so it is somewhat easier to cast a nonferrous metals, but there are certain ferrous metals also which are extensively used as a casting metals. So, among the ferrous metals we have the cast irons. This is named so because it is very easy to cast, it completely it is easier to melt and then because of the good fluidity, it can take the complex shapes also easily. So, the cast ability of the cast iron is good that is why it is called so. Then it is also used for making products of the cast steel and cast stainless steels are also used stainless a steels. Like cast steel is martensitic cast stainless steel is used for making the turbine hydro turbine blades where good hardness is required for arrozen and cavitation resistance. A cast irons are extensively used because they are cheaper as well as they are very easy to cast so most of the like means full the components products used by the municipality is like manhole or the benches etcetera machine beds are made of the cast iron.

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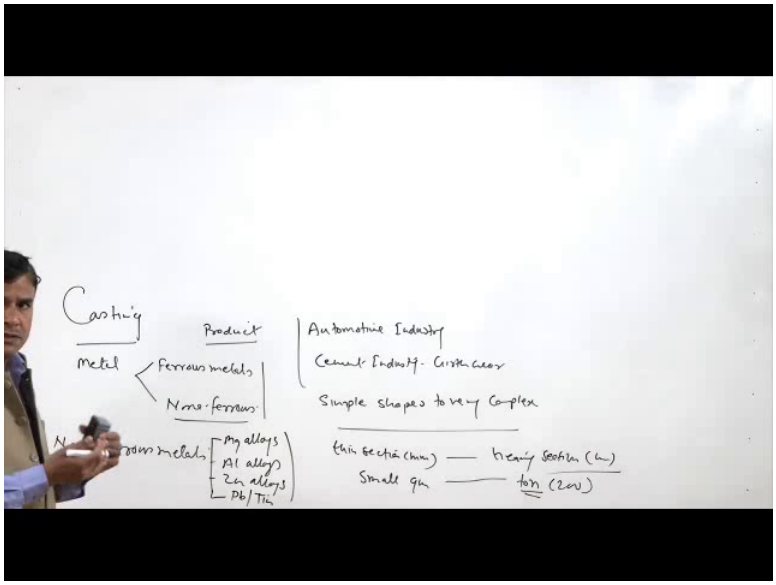

Among the non-ferrous metals, what we have like a non-ferrous metals we have various categories like magnesium alloys, aluminum alloys, zinc alloys and also led and tin are also used as common non-ferrous metals because of a low melting point temperature of these metals these are easy to melt. So, they can be given shape through the casting

route. So, these are the capabilities like they can handle very small size to the large size castings from very simple shape to the very complex shape. And this is the fastest route for getting primary shape of the product which is desired. We need to just melt the metal and put into the mould of the desired shape, so that after the solidification we can get the product.

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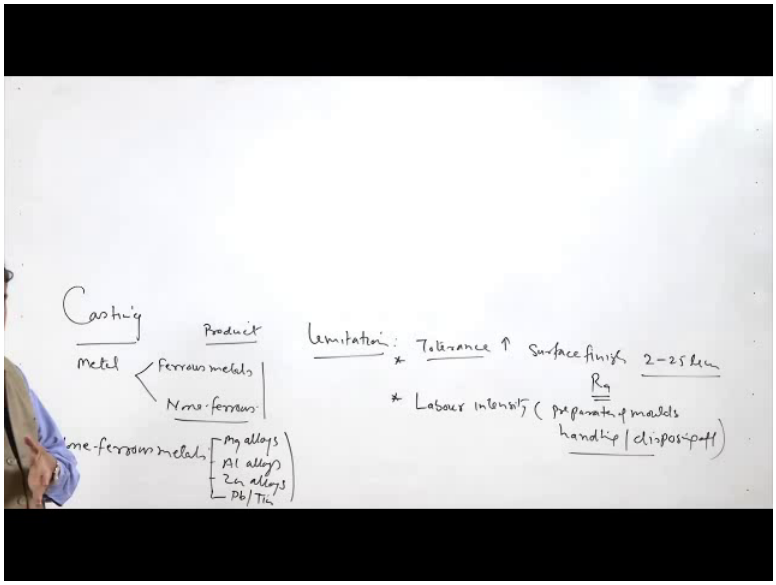

But it suffers with certain limitations also. And these imitations primarily include like the tolerance which is achieved in the cast products is high, it is not very close. So, the dimensional variability is more and the surface finish which is achieved through the casting route is also not very good; most of the time it needs the machining. So, may be very good surface finish of the order of the 2 micrometer and like poor surface finish in sand mould cast components as high as 25-micrometer is the roughness parameter. So, this is a one aspect that the quality in terms of the dimensional control and the surface finish is somewhat poor.

And then second aspect is that the process is very labor intensive labor intensive. So, lot of men power is needed for especially for preparation of moulds, handling and disposing of the used products as well as the raw material or the waste material which is produced as a result of this for handling of the molten metal, handling of the raw material to be melted in putting into them furnace. And then molten metal is to be handled and brought

to the mould; and then it is poured into the mould and after the solidification the component is take an out of the mould. So, all these things required lot of men power.

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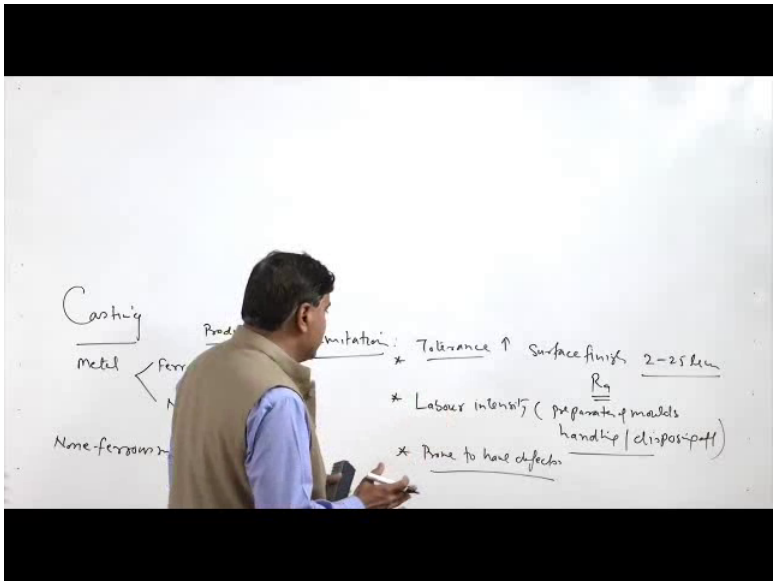

The labor intensive and how are the efforts are being made in order to reduce the extent of labor which is being used currently using the mechanization of the different steps of the casting process, so that the human component as well as the manual intervention related to the casting process can be reduced. Another is since the process involves the melting of the molten metal at high temperature at become sensitive for a reactions interactions with the gases and impurities followed by the solidification in which liquid to the solid state transmission takes place. So, depending upon the cooling conditions the system becomes very prone for castings are prone to have defects if the things are not controlled properly in terms of the design, mould or gating in the riser design. So, the prone to have the defects in the castings. So, these are the limitations related with the casting process as a whole.

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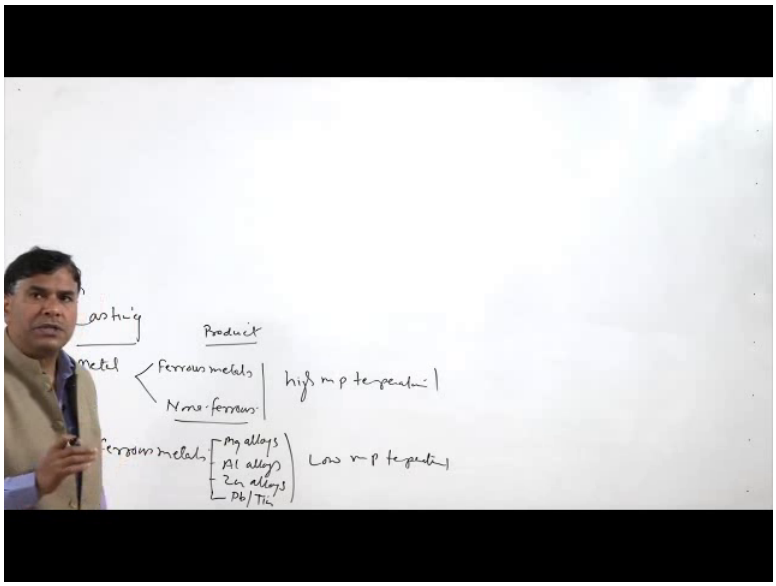

We know that these are metal systems of the two broad categories ferrous metals having the higher melting point temperature as compared to the non-ferrous metals having say low melting point temperature. So, basically melting point temperature determines the ease of the melting and which intern will be effecting the kind of the heating system or the furnace to be used to have the molten metal for the casting purpose. But this is one of the points related with the metals to be processed through the casting route. So, we need to considered in totality what are the factors that metal actually in casting or what are the properties of the metals which are important for the casting.

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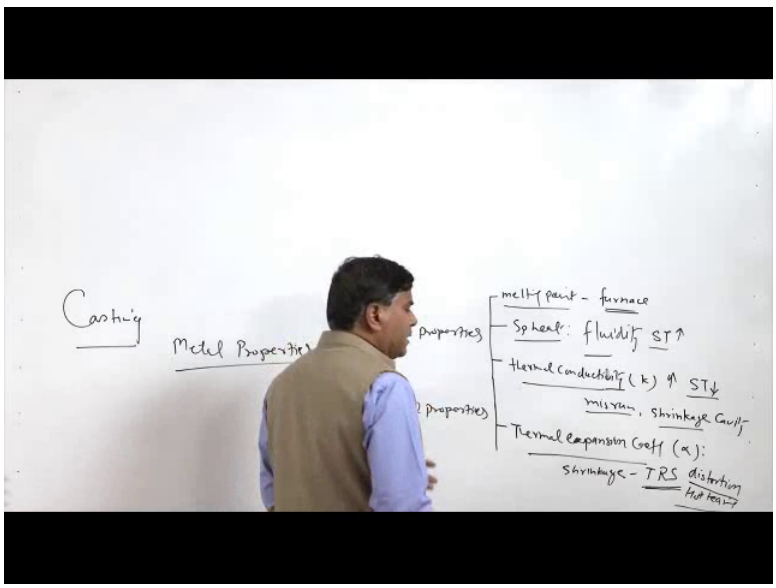

So, metal we will try to look into metal properties which metals for the casting include like metal properties, there are two categories related other metal properties which are important, and these are the physical properties and chemical properties. So, if we try to see what are the physical properties that are important. So, the first is the melting point of the metal. And melting point of the metal must be considered for determining the kind of the furnace or the melting facility is to be used. So, selection of the furnace or melting facility is to be used is determined by the melting point of the metal to be processed.

For sample, resistance heating furnaces can be used for melting the low melting point metals like the magnesium, zinc and aluminum, but like arc furnaces are needed on the other hand for melting the high temperature metals like a steels and the cast irons, although cast irons being of the low melting point like say 1050 to 1150 degree centigrade. So, this is the kind of temperature which can be achieved using the coal fired furnaces also.

Then after of the melting point, we have a specific heat, it is this specific heat related with the metal determines the amount of heated can carry in the molten state. So, that heat must be dissipated to complete the solidification. So, if the molten metal if the specific heat related with the metal is high, then it will require to reject lot of heat to complete the solidification process means solidification time for the high specific heat metals under a given conditions will be more. Which means it will take long time before the solidification, which in turn improves basically the fluidity because the solidification time becomes high with increase in the fluidity. So, basically the specific heat is the another property that the determines the solidification time and which in turn affects the fluidity of the metal means extent of to which it can flow before commencement of the solidification.

Then we have thermal conductivity. Thermal conductivity of the metal is important because it determines the rate at which heat will be transferred from the metal to the mould. So, high thermal conductivity metals will be cooling will be transferring the heat faster as compared to the low thermal conductivity metals. So, this case when thermal conductivity is high then solidification time will be low. And if the solidification time is a limited, then of course it will increase the productivity by reducing the casting cycle time, but on the other hand, it will increase the tendency for the defects like misrun means in complete filling of the mould cavity or it may lead to the shrinkage cavities.

Because the solidification will be completing much earlier, so shrinkage cavity or shrinkage porosity related problems are encountered, if the solidification time is limited.

Then thermal expansion coefficient, thermal expansion coefficient - alpha is important with regard to the two aspect that is the expansion and contraction, which will be occurring due to the heating and cooling. Expansion and contraction, expansion will be occurring in course of the heating and contraction during the cooling. So, especially in case of casting contraction is more important because it determines number of aspects. Like the shrinkage in the two stages which will be occurring or contraction which will be occurring in two stages, one like liquid to the solid transformation due to in course of the solidification. So, it effects basically the riser design. What volume of the molten metal is needed to counter the shrinkage related with the liquid to solid-state transformation that will be affecting this design of riser or that will affect the molten metal, which should be there the riser, so that it can compensate the shrinkage taking place due to the liquid to the solid state transformation.

And another shrinkage which is important is the shrinking occurring after the solidification from the high temperature just after the solidification to the room temperature. So, this kind of shrinkage which is occurring in the solid state after the completion of the solidification cooling down from the solidification temperature to the room temperature lot of shrinkage takes place and that leads to the reduction in dimensions of the casting. And therefore, it affects the design of the pattern or the dimensions of the pattern which is used for making the mould. So, a thermal expansion basically effects the shrinkage aspect which in turn effects the pattern design as well as the riser design.

Other aspects related with the shrinkage also includes the development of tensile residual stresses. Tensile residual stresses due to the shrinkage especially in the cases where core say does not collapse in the core which has been placed inside the mould for making the internal cavity if this core does not collapse then it leads to the tensile residual stresses. Or if the design of the casting is such that it resists the shrinkage which is taking place then also tensile residual stresses will be taking place. And if these develop the magnitude of the tensile residual stresses is too high, then it can lead to the two aspects; one is distortion in the casting inform of the rapping or it can also lead to the hot tearing.

So, high tensile residual stresses will lead to the cracking inform of the hot tearing or the distortion.

So, it is important to look into thermal expansion coefficient related with the metal being processed, so that the design of the pattern design of the riser and design of the casting itself can be taken care of or the mould material can be selected suitably. So, that the tensile residual stresses have been developed can be taken care of or the casting of the desired size can be achieved which is free from the defects occurring due to the shrinkage of liquid to the solid state transformation. Another important physical property is the density. Density for a given volume of the molten metal, density determines the weight of the molten metal or weight of the casting. So, this weight of the casting is important in the two ways.

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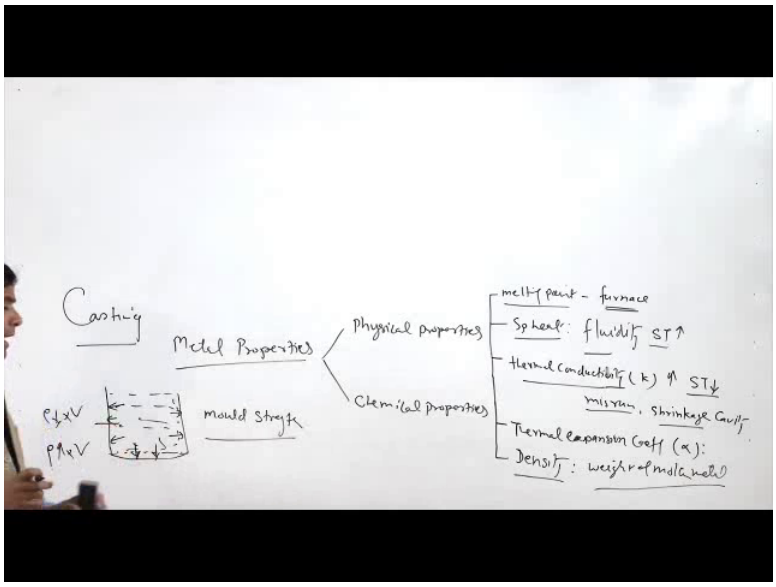

One is that this weight of the molten metal must be supported by the mould. So, if the mould is not able to support this weight then it may sag or it may settle down, so change the shape and size of the casting. So, instead of having the shape before pouring the molten metal it subsequently due to the weight if due to the weight the mould walls are shifted then there will be change in the dimension and the shape of the casting. So, this is one aspect that so the mould strength is influenced by or suitable mould is strength what should be the mould strength that depends upon the density of the material.

Because for a given volume if the density is low then the metallostatic pressure being applied on the walls due to the weight of molten metal that will be limited. And if the density of the metal is high for a given volume then the heavy metal static forces will be acting on to the walls and they will have tendency to shift the position of this walls which in turn will be leading to the change in shape as well as the dimension of the mould. So, the mould is strength what a strength of the mould should be there that is influenced by the density of the metaphoric given volume.

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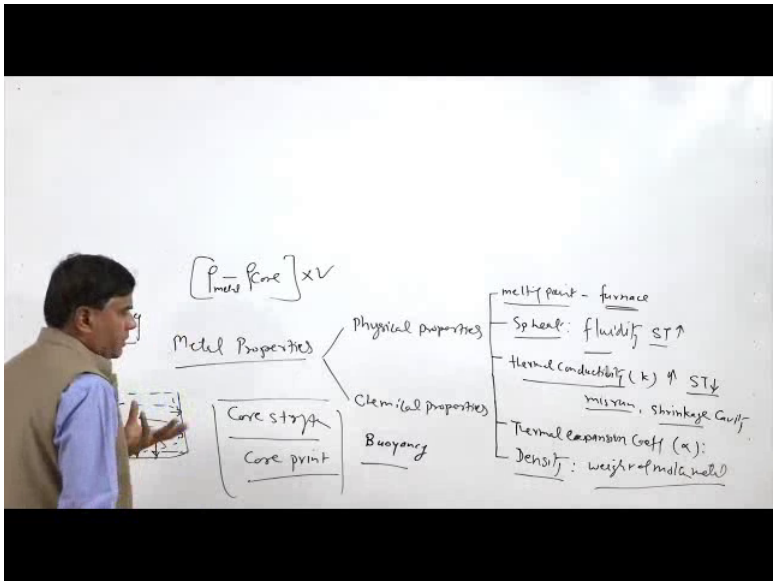

Another important thing is the core strength of the core material as well as the core sheet or the core print, which is need to be there. So, theses two designs are also affected because the entire pressure of the molten metal will be acting on the core as well as the buoyancy force will also be acting on the core. So, buoyancy force is a actually determined by the density of the metal being poured and the density of the core material. So, metal and density of the metal and the density of the core metal.

So, these difference these to multiple by the volume of the core that actually de determines the force which will be acting onto the core. If this force is too high then the core will have tendency to get fractured or collapsed or break, so the core design core strength is influenced by the density of the metal which is being processed. So, considering these points if you see the melting point a specific heat thermal conductivity, thermal expansion coefficient and the density are the important physical properties which

affect the different aspects related with the mould or the melting or casting. So, it is important to consider the physical properties of the metal.

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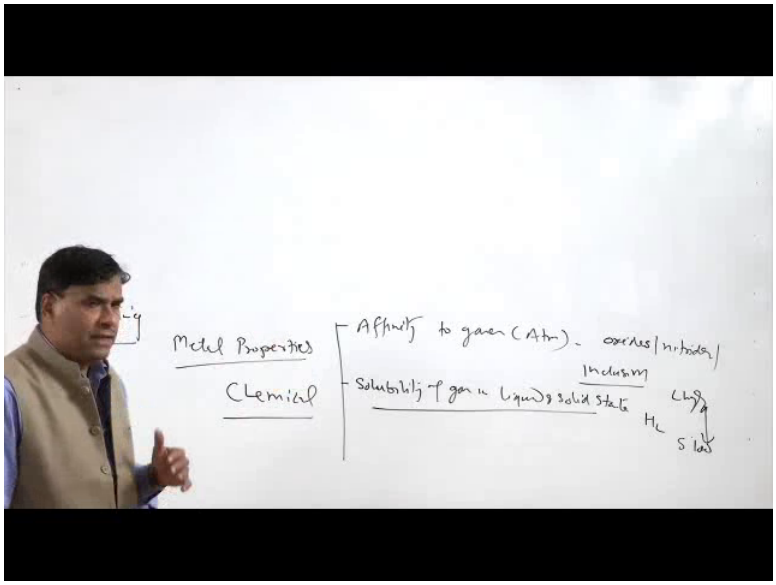

Among the chemical properties which are important for the casting includes a affinity we know that most of the metals become very active at high temperature. So, with the increase in temperature up to the molten state if metal is having high affinity to the gases like atmospheric gases, then they will have tendency either to form like oxides or nitrides etcetera. So, these will be there in that case present as inclusions if not removed or filtered or taken care of properly. So, greater is the affinity, greater will be the tendency for formation of the inclusions.

Another important aspect is the solubility, solubility of the gasses in liquid and solid state, solid state in a given metal. So, the metals for which difference in solid and liquid state solubility to the gases is high means like say if you take any gas hydrogen in the liquid state if solidity is high and in the solid state solubility is very low, if these reference is very large then it leads to the rejection of the gases or rejection of the hydrogen in this case to the atmosphere in course of the solidification.

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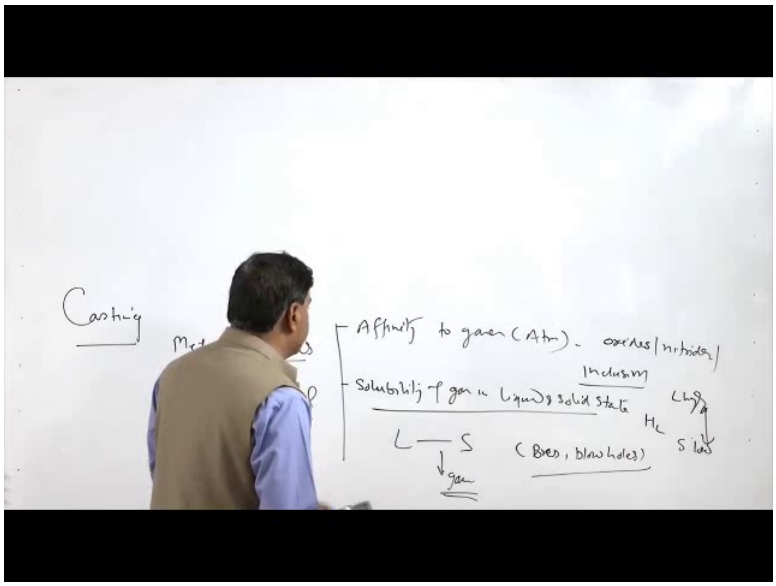

So, we know that you during the solidification liquid to solid state transformation takes place. Since the solubility of the gases in the liquid state is high in course of the solidification these gases will be released. So, the gases must get enough opportunity to escape from the molten metal during the casting and if it does not happen in that case these will be present inform of pours or blow holes. So, these are simply casting defects which must be taken care off. So, basically it is a related with the solubility of the gases in the solid and liquid state. For example, aluminum has lot of difference in the solid and liquid state solubility and that is why it is found very prone to the hydrogen related porosities.

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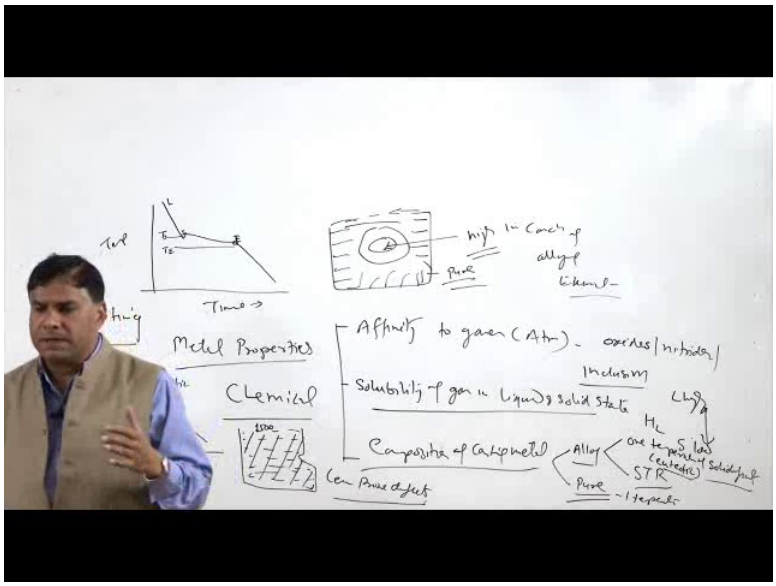

So, another important aspect related with the chemical properties is the composition of the casting metal or metal to be used for the casting purpose. So, there are two things one either it is alloy or it is pure. So, we need to consider both the cases separately. Alloys are also of the two types having solidification temperature range or we can say one temperature of solidification. So, alloys of the two categories, we have a solidification temperature range or the solidification is occurring at one temperature. So, in this case, if we see this the pure metals solidify at one temperature and the alloy of the eutectic composition, eutectic composition also solidify at one temperature. So, both of them fall in same category where there is a drop in the liquid temperature say this is the liquid metal and here the solidification it starts with the nucleation and growth.

So, this is the temperature in which solidification will be progressing and this here, it is starts and it ends and then again cooling is starts. So, this is the kind of the cooling curve which is obtained temperature in y-axis and time in the x-axis. So, this kind of the trend is shown by the either pure metals or eutectic metal systems. On the other hand, there are certain metals with the solidification temperature range means certain alloys with the solidification range, they will be solidifying completely in different way, where initially the solidification there will drop in temperature from the liquid state and then there is arrest in temperature, then temperature will be decrease slowly and here it ends. So, here start of the solidification, here solidification ends, and then again drop in temperature. So, this is the range of the temperature over which solidification will be occurring. So,

here T S and T E we can say temperature start at which the solidification is starts, and T E s the temperature at which solidification ends. And the same way this is the x-axis is time and the y-axis is temperature. So, the temperature remains constant in course of the solidification in case of the pure and the eutectic temperature while the temperature continuously decreases in case of the alloys having a solidification temperature range.

So, what will see the implication of this is what if there is mould of any shape, it is full of the say molten metal. So, since the entire molten metal will be solidifying at one temperature say this is 1500. So, entire mass will be solidifying at one temperature almost simultaneously entire mass will be solidifying. So, this is very good side and this kind of systems are found less prone to the defects. So, pure metals and the eutectics are less sensitive to have the defects as compared to the alloys having a range of the solidification.

Similarly, while in a other case, the things will be solidifying first near the walls and wall of the mould and then it will be progressing towards the center gradually and here at the end we are left with the molten metal to solidify at the center. So, solidification is starts at the wall and then it progresses towards the center or towards the region last true solidify. In this case most of the time, we get the purer system at the walls the region which solidifies first and then region which solidifies at the end in that area, the concentration of the alloying element high in concentration of alloying elements. So, this leads to the lot of segregation when the alloy solidified solidify over a range of temperature, and this kind of segregation leads to the variability in mechanical properties and the tendency for the hot tearing or the hot cracking of the metals.

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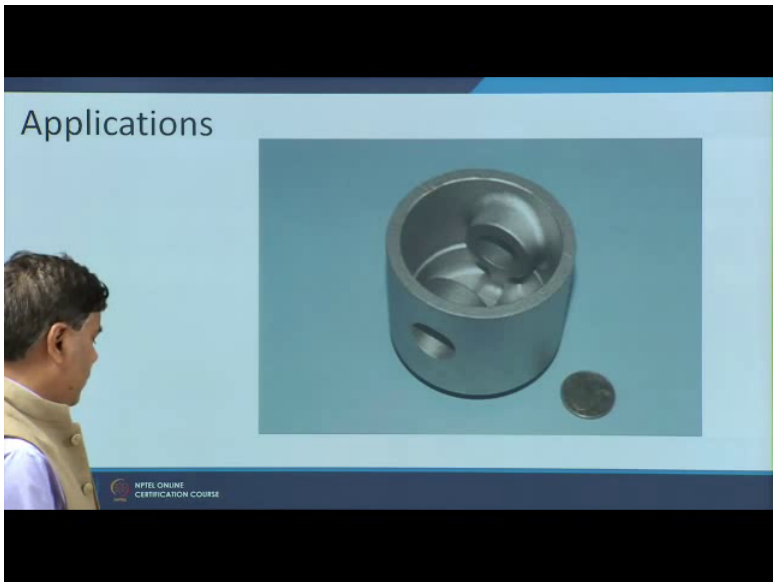

Now, we will quickly go through the typical applications using the photographs relate to the casting like application of the castings simple piston, completely simpler shapes a shape for which casting is used.

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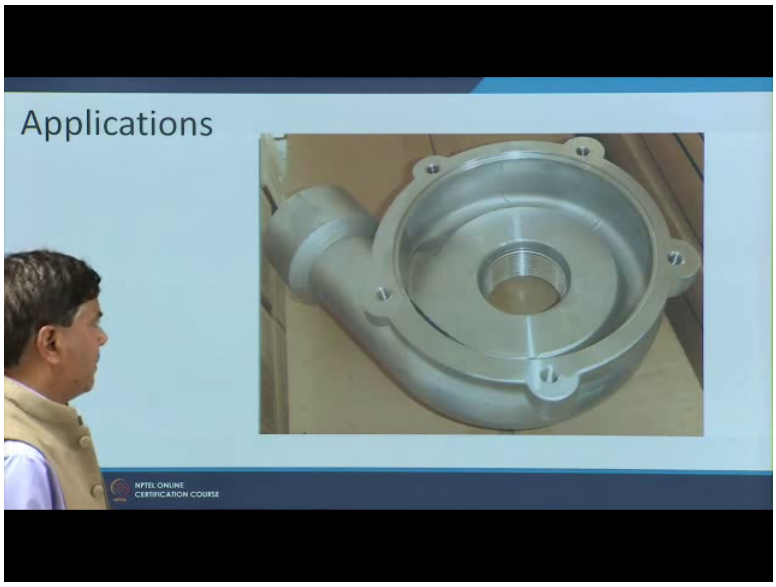

This is of aluminum this is that typical pump casing which can be made this is complex somewhat complex in terms on the geometry.

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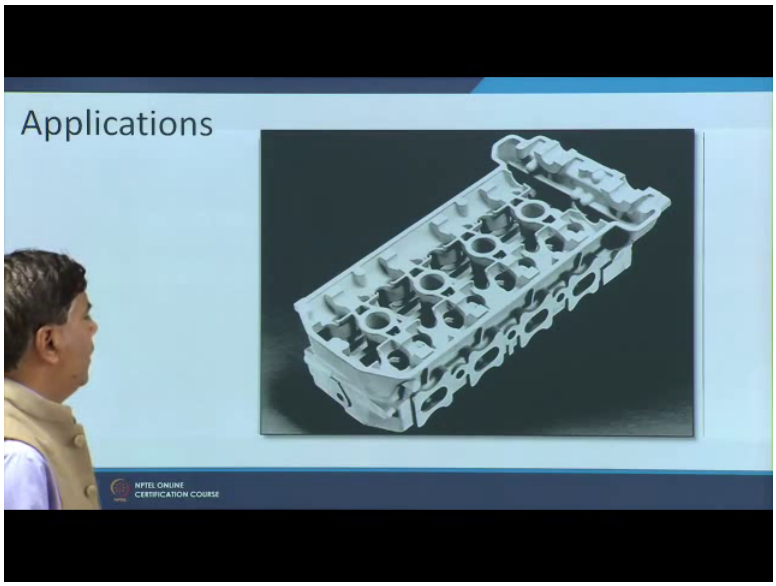

And further complex geometry is of the engine block and such a complex design in geometric components can be produced with the casting in one go

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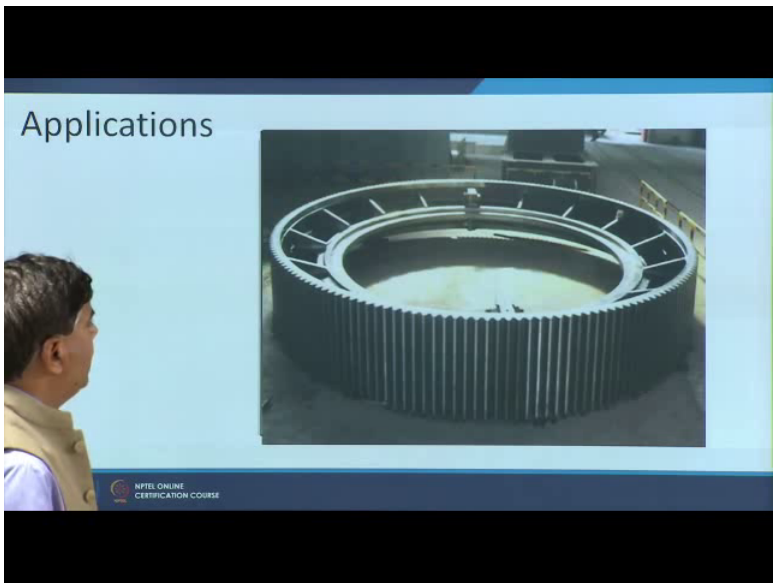

And this is a very large size girth gear which is also made by the casting followed by the machining in order to have the desired geometrical dimensions.

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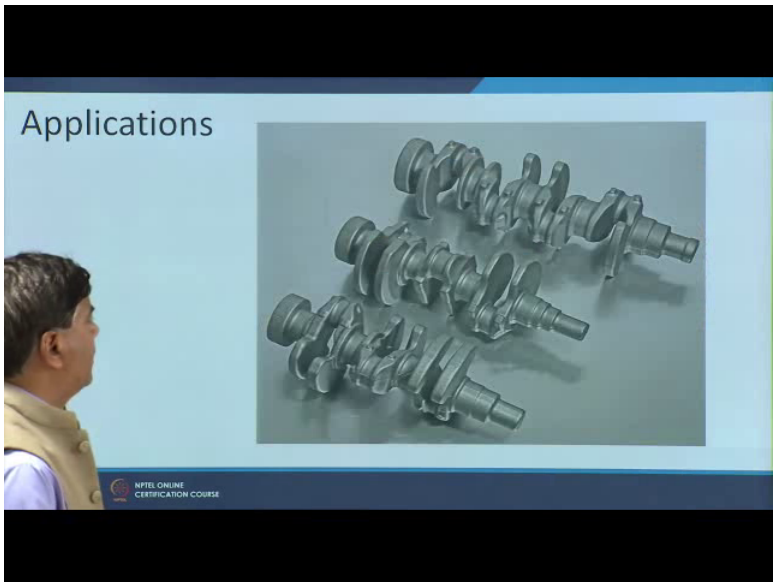

And then further this is the crank shaft which is made through the casting routes and this is subsequently machined and then grinding is carried out in order to have the desired the tolerance as well as the surface finish

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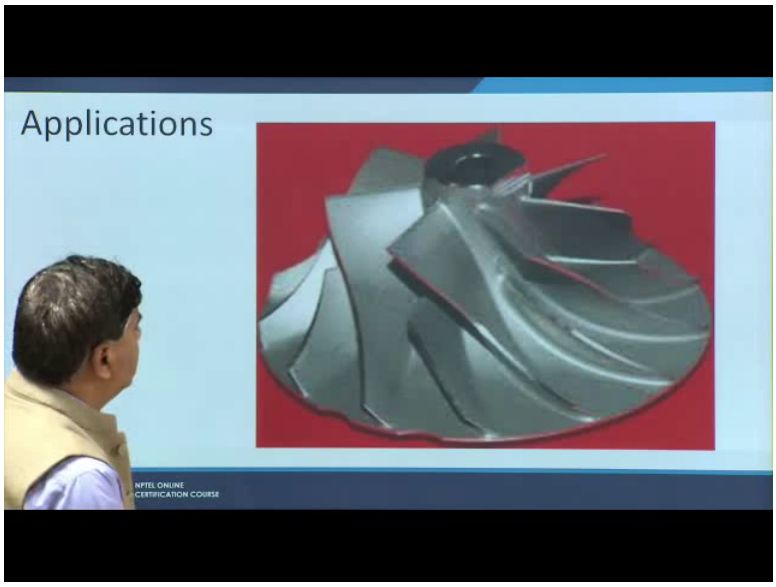

So, the other things like this is also for the complex design of the guide vanes or the blades which can be easily made using the casting process.

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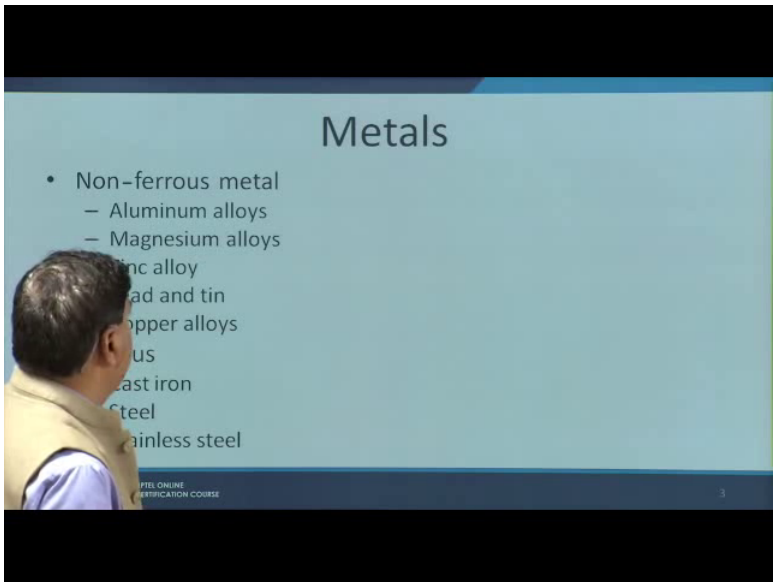

These what I have already talked about the metals. They are two categories non-ferrous metals and the ferrous metals, the aluminum, magnesium, zinc alloy, lead, tin and the copper alloys; in the ferrous category, the cast iron, a steel and the stainless steel.

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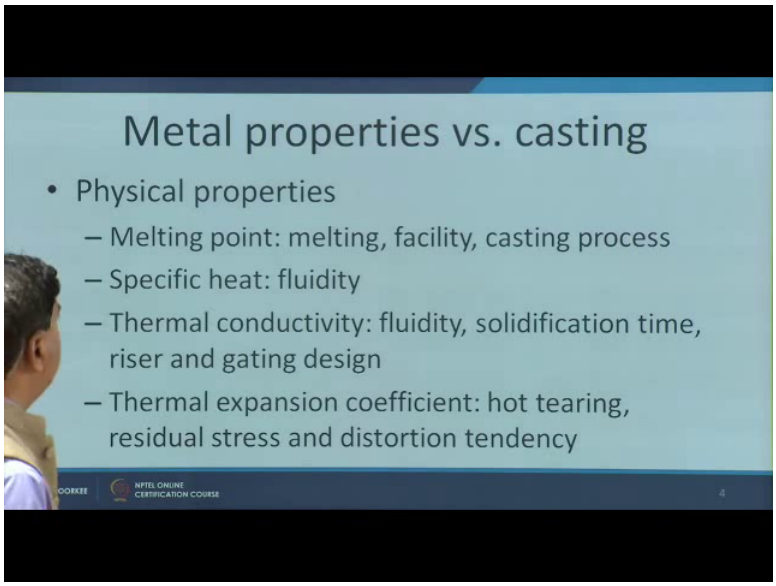

Here we have the metal properties and the casting relationship. Among physical properties it is the melting point which determines the kind of facility to be used and the casting process to be used for the casting purposes like the low melting point metals can be process like for example zinc, lead and tin the hot die casting process can be used.

While for the high temperature metals like aluminum, copper and the cast irons the cold die casting is there used the specific heat effects the fluidity as I have already explained. Thermal conductivity effects the fluidity and the solidification time. It also affects the riser design and gating a risering design. Thermal expansion coefficient effects the development residual stresses which in turned it remains the distortion and the hot tearing tendency. So, this is what I ha have already mentioned here. So, this will also be affecting the kind of pattern design, mould geometry as well as the material to be used to for the pattern making.

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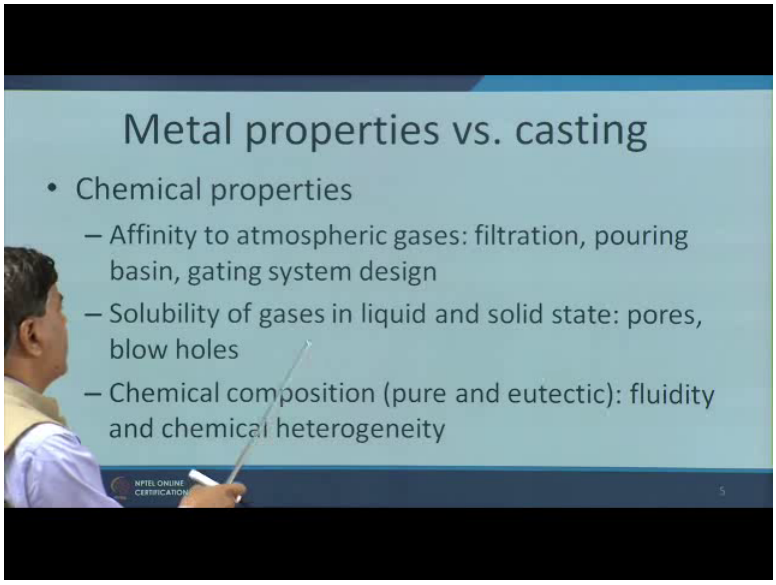

Then the chemical properties in terms of the like affinity to that atmospheric gasses determines the kind of impurities which can be formed in the molten metal. So, more is the impurity formation tendency get (Refer Time: 34:09) with the filtration requirement. It affects the pouring designed, because of the pouring basins is to be design in such your that impurities can be filtered out and it also effects the gating system design.

Then solubility of the gases in the liquid and solid state affects the pores and blow hole tendency formation because of the difference in solid and liquid the state solubility. Then chemical composition affects the fluidity and the chemical heterogeneity pure and eutectic systems solidifying at one temperature for say grater fluidity as compared to the alloys we solidify over a range of temperature. And the pure systems as well as eutectic systems will have better chemical homogeneity as compute the alloys which will be

solidifying over a range of temperature. So, this is what was the brief of the role of the metal properties in the development of the sand casting process.

Here now I will summarize in today's presentation, I have talked about the metal properties which affect the different aspects relate with casting process as well as what are the advantages and limitation as a whole of the casting process and what are the general applications for which casting process is used.

Thank you for your attention.