Theory of Production Processes

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Lecture – 19
Casting design considerations

Welcome to the lecture on casting design considerations. So, in this lecture we will discuss about what should be the considerations related to the casting design, to have the casting free of any defect, and we have economical production of casting. So, what we need to know that successful casting practice; for that you require proper and strong design of casting. If there is no proper and strong design of casting you will get the casting, but not with the optimum properties. So, for that first of all when we start the casting process we start with the selection of you know pattern material, we select the pattern we make the mould for that we make the design, where to have the parting line of the mould where to provide the core, what should be the gating channel design what are the those aspects which are looked to be looked into. So, the one will be before melting and another will be after melting.

So, before melting all these operations are required to be done like the proper selection of moulding materials, proper design of the cavity, proper design of you know the channel or network, and then the you know pouring occurs. So, after pouring now again it depends that how you done the; at what temperature you have done the pouring, and how the solidification will proceed in that particular network which is of certain design.

So, these are basically to be properly seen or addressed for that the designer who is there initially who is making that cavity he has all that in mind, and then the metallurgies foundry man who is practicing, who is looking at the metallurgical aspects also making the all these cavities. So, that basically a foundry man is doing testing all the materials ingredients of the sand, then ensuring that it will lead to proper solidification of the material. So, for that there has to proper understanding and they must know that what are the challenges faced by them on which issues they have to give the proper thought so, that they can complement each other and they can understand the challenges faced by each others.

So, you have the large number of variables which are to be properly controlled for metals or alloys and its characteristics like you have the method of casting; what method of casting you are choosing you are taking the sand casting, you are taking the di casting you are taking the investment casting or so, it depends upon the what kind of metal you are casting, what is the size of the casting. So, based on that you are choosing this method of casting.

You are also choosing the mould or dimaterials. So, that also will be based on what kind of material you are casting. So, if you are casting suppose low metal temperature low temperature materials, and if you have to go for the large production mass production you go for the di casting, then what kind of moulding material you are taking sand what kind of sand you are taking. The different type of sand may be based on the silica sand or zircon sand or chromite sand or so.

So you may have even in the di materials you can go for which kind of di material which type of material cast iron or you may have copper or you may have any aluminium as a di material. So, that also again depends that what kind of material you are casting. Mould or di design this is very important because when you are pouring the liquid metal into it, ultimately you are trying to have a good mechanical property of the cast metal.

Now once the cast metal goes into it, a its property will depend upon how the solidification is taking place, how the other factors like the collapsibility of the mould behaves or core behaves, and how the flow of the liquid metal goes into the cavity. So, if the flow is proper stream and flow is there, then there are less chances of having certain kind of defects and if they are a very abrupt your abrupt sections, if the design is not proper then that is going to create some defect kind of a structures.

So, these different parameters are important when we talk about the casting of product and for that all these aspects they are coming under the casting design. So, casting design is very important for seeing that the productivity of the industries better, the number of rejections are less the property which you like to achieve you really achieve that. So, what are the considerations in casting design?

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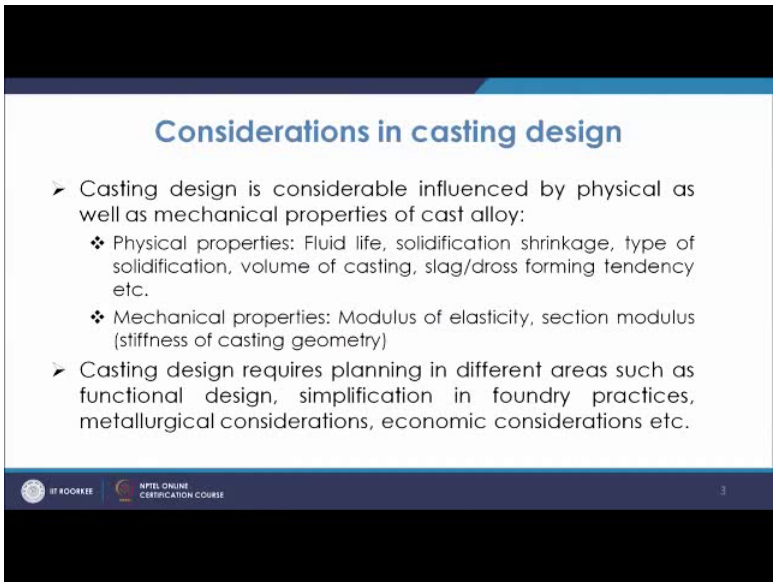

Now, casting design basically will be influenced mainly by the physical and the mechanical properties of the cast alloy. So, like physical properties means you have fluid life. So, that fluid life will be important. So, the how long the fluid goes, how much will be the fluidity so, that that is important. So, if a if the fluidity is not proper in that case there will be defects like misrun or cold shut appearing. So, you will have to have proper alloying elements which increase the fluidity many a times or you will have to have proper temperature, you will have to have proper conditions of this surface like if it is a di casting or if it is a permanent mould casting, there the smoothness is better than the mould casting sand mould casting.

So, in that case the fluidity will be better if the metal is poured at higher temperature. So, that is why if the fluidity is more, you can have the intricate shift casting possible in case of metal moulds or di casting, but then if you use the course grains instead of fine grains in the mould, which is and that too at the surface where the metal is flowing, in that case the fluidity will be less. So, this factors are important to be considered when you go for that. Solidification shrinkage; as we know that the metal solidify when the metal solidify they shrink. Now again this is to be taken care by proper consideration of a riser volume or a riser placement. So, a riser size in one way, and also the placement will be depending upon what will be the dimension of the riser what is the fill in distance for that for a particular riser, what should be optimum position where the riser should be placed.

So, these are basically to be looked into and it is to be seemed that these shrinkages are not appearing, they there is no chance that shrinkage should be you know encountered.

So, that will be the case only if you are not taking care of the proper casting design considerations like you are seeing that any channel, which is the chunky portion or the thick portion and it is aloof. So, during the later stage of solidification, it is aloof from the active feed channel. So, in that case the shrinkages may come. So, you will have to have proper positioning of the risers, and proper you have to see that properly the there the solidification process proceeds like the point in type of solidification. So, what kind of solidification?

So, before that I mean the solidification has to proceed in a proper way, there has to be proper direction of solidification. Then solidification type means you may have eutectic type of solidification, you have the equalise type of solidification so, that also is the factor into it volume of casting. So, you may have casting either of a small size or of a larger sizes. So, in the small size certainly the challenges are less, but if the sizes are larger, you will have to have proper considerations for the position of risers, placement of risers because in that you have thermodynamics more chances of having defects like hot spots or so, so that volume of casting is also important.

Slag or dross forming tendency; so, many a times many of the materials have slag or dross forming tendency. So, they react with the atmospheric gases or air, and even during the during its phases into the runner because of aspiration, of because of the gases present, you it they may found this slag or drosses. So, that also needs to be seen that you have the proper gating network, proper network of the cavity I mean network of the channel which is leading towards cavity so, that you have no slag or dross forming, to the extent that it will hamper the quality of the cast material.

Mechanical properties in that you have the modulus of elasticity that is the intrinsic property of the material, you cannot do much about it, but then the section modulus which is giving the stiffness to the carting geometry, that is based on the casting design. So, what kind of design you are you know following, what kind of mechanism what is you are using the reaps or waves. So, that you have the stiffness to the casting geometry is developed many a times. So, some good practices are preferred, then the conventional once where you simply want to make the geometry in the first way what it looks to be.

But then you can have the re thinking over how to make the geometry little bit different. So, that their stiffness is reduced, you get more stiffer geometries. So, that is also the aspect which is to be looked into.

So, casting design in the nutshell it requires planning in different areas, like you have the functional design where we talk about other things like how to solidify, how to see that the rigidity is there is no hot spot or all that. Simplification in foundry practices that the things are simple, you will have to make the casting in such a way that its simple not very complex. Once you make it more and more complex more interdependences of the processes one after another, in that case there are more chances of mistakes and then defects occurring thereby metallurgical considerations.

So, while during solidification or after solidification what are the considerations, which are to be looked into. So, that the defects are less, and then above all the economic considerations also, because ultimately your aim is to go for the casting which is cheaper so, because it has to compete in the market. So, you must look forward or to produce the casting at the lowest cost possible. So, that is also a step towards the good casting design, because the casting anyway can be with more sophistication with more of the flexibility and other things, in such a manner that you use more of the sophisticated instruments, but then if it is not economic economical in that case its solubility will not be there.

So, that also consideration has to be kept in mind.

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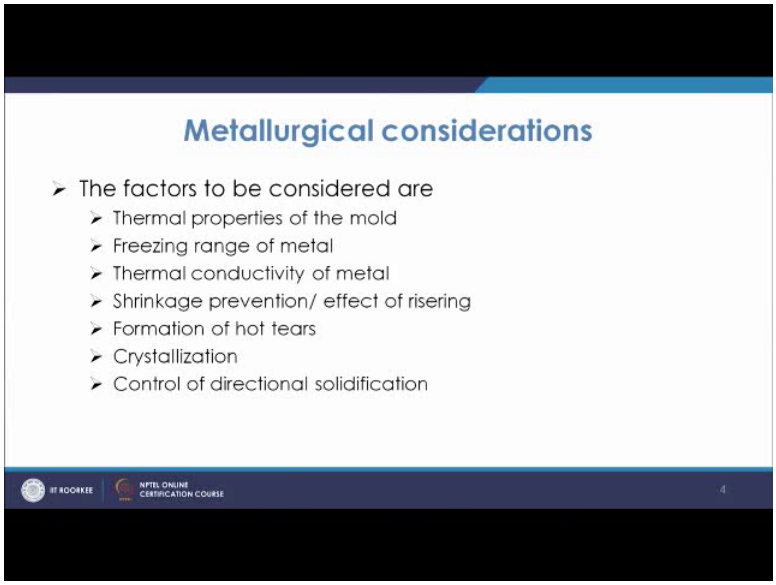

Coming to the metallurgical considerations, what these are the factors which are to be considered. So, just like you have the thermal properties of the mould. So, you can have the mould either in the sand, sand mould or you have the metal mould, in metal mould you have the different kinds of metal then you will have either permanent mould casting under gravity. So, gravity dicasting or you may have pressure dicasting, you may have the mould where sometimes we use also the cooling of the mould in some way like in continuous casting, we use the cooling of the mould copper mould by copper also by water.

So, this thermal properties of mould will be changing the structure of or the properties of the material in the sense that, in that case you have because of the different heat extraction rates the properties of the material or the structure of solidified structure of the material is somewhat changed. So, you get the different properties of the material; freezing range of metal. So, as we know that as the freezing range becomes more the castability is decreasing.

So, as the freezing range becomes more, the requirement for the riser becomes more and more, the chances of having shrinkage becomes larger. So, you will have to have proper practice to see by adequate positioning of risers, adequate size of the risers that the even for the higher range of freezing range of materials, you will have to control these parameters so, that your casting qualities unaffected.

Thermal conductivity of metal is affecting the solidifying pattern, that we have already discussed because that will be I mean guiding the temperature difference or temperature gradient inside the liquid metal pool. So, affects the solidifying structure, then shrinkage prevention or effect of risering. So, that already we discussed that this shrinkage has to be there once you have the formation or transformation from liquid to solid state, but then using the risering, you can decrease the shrinkage chances. So, you have to have proper risering calculations for that.

Formation of hot tears; hot tears are the defects because of the metallurgical regions, and it is basically because of the situation in which the liquid metal now the domain is full of some solid network as well as liquid network. So, in that case the solid which has formed is basically quite weaker, because the temperature is quite high just near the solidus temperature, and in that case any tear or pull because of the geometric you know

configurations or because of the design or because of the improper you know properties of the moulding material or core material specially. Then in that case that leads to tearing and so, at that particular temperature when the strength is low the tearing may lead to this hot tears; you have the crystallization.

So, what kind of solidification mechanism takes places, what is the way solidification is proceeding you have we know that solidification occurs by the nucleus and then further growth. So, depending upon the type of solidification or rate of solidification you have different kind of solidification structure. So, you can have the proper solidification structure to have optimum properties. Control of directions solidification is another point which has to be looked into. So, for that you have the use of cells, you have the proper use of padding and then you have to see that properly you see that no of the none of the channel portion is you know quite distant away from the active feed channel.

So, that way comes you can directly solidification can be controlled and that may lead to the good you know casting, because the placement of riser that will put the pressure and that will lead to the sound castings otherwise you may have the costing which is having the shrinkage.

Next we have to discuss about the design considerations. So, when we are talking about the design considerations, we must design the casting or making the mould in such a manner that these are the points which needs to be kept into mind.

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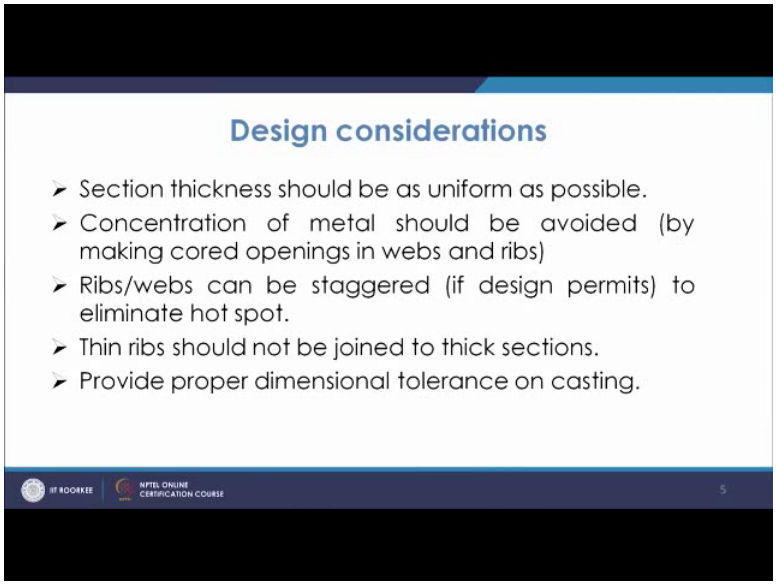

So, that is one is that section thickness should be as uniform as possible. So, many a times what happens that we have the geometry in such a way that, at some lace the section thickness is quite high and at some places it is quite small. Now in that cases what the problem may come is, that the thinner section may solidify early and the thick section in between that will certainly take more time. So, in that case you may have certain results, which are isolated or where there will be change of that that kind of way the solidification will proceed that will change. So, you will this better to have this consideration, that keep the section thickness as uniform as possible. So, that will that is a practice of good casting design.

Concentrated concentration of metal should be avoided by making code openings in webs and ribs. So, many a times we have concentrated metals and they are basically the positions, where there is quite a good chance of having hot spot or shrinkage. So, you should try to have the code opening their use the webs and ribs so that it gives you suffice strength. So, many a times we provide a chunky mass to have that you know that to keep in to bearing in mind that we will it will give us more strength, but then that can be avoided by using the webs and ribs.

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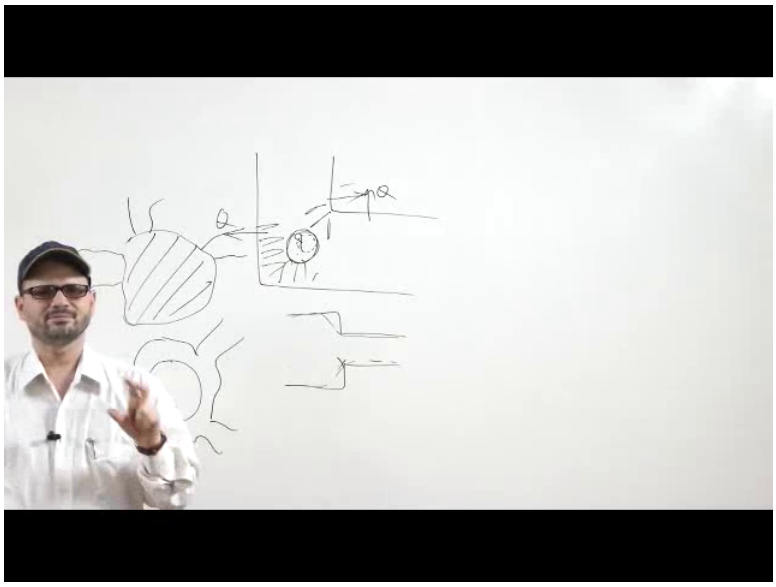

So, many a times you have very chunky parts and then it is combines somewhere it is like this. So, you can. In fact, what you can do is, you can have the code opening n you may have this and then make such kind of structures. So, this is basically preferred then

this because you are giving this mass as the one, which will provide you more strength, but it is better to have these code openings you have code here, and then you have the ribs and with the help of that you give. So, it will give quite a good strength. So, this is one of the good design practice, which should be followed.

Ribs or webs should be staggered to eliminate hot spots. So, that also you have to see that they should be staggered otherwise they may result into hot spot. So, you have to see that as per the design permits, there must be good spacing between then and they should staggered so that the hot spot is eliminated. Thin ribs should not be joined to thick sections. So, that is also one thing because we know that once we have thin and thick section, it has to be seen that the thin has to first of all it will solidify first.

So, depending upon that you will have to see that it should be not joined to the very thick sections; you have to provide proper dimensional tolerance on the casting. So, dimensional tolerance should be there, because you have to go for the you know machining of the material, you will have to take the material out of the you know when we have to draw it, at that time you will have you need the draft allowance you when you make it surface finished, when you need the machining allowance.

So, this proper allowances and tolerances must be properly given tolerance in the sense, that you need to have the plus and minus limits must be there so, that you can have that freedom that you can get that particular value.

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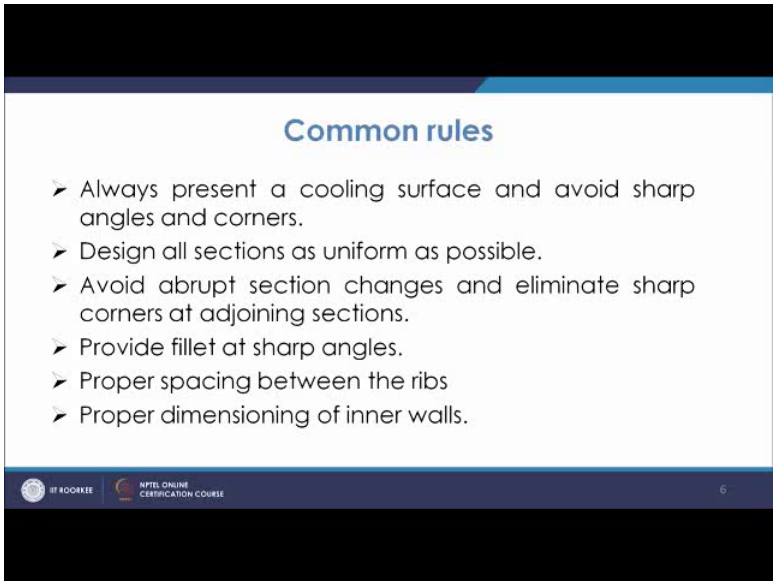

So, the common rules which are there, that always present the cooling surface and avoid sharp angles and corners. So, what it means that, you must have the cooling surface should be there it is not that it is very isolated because it leads to extract the heat, you know you must have; that means, that it should extract otherwise if it is hot for longer time and ultimately all the sides are all solidified, then you will have the chance of having that region isolated, and there will be chances of having the defects in that. So, basically always you have to present a cooling surface. Avoid sharp angles and corners; sharp angles and corners needs to be avoided. So, if you have such kind of designs, see we have sharp and angles and corners you need to avoid it and you make. So, they are basically not preferred.

So, you need to have the stream lining like this. So, you have to have the geometry like this, that we will see by in the figures, later that how can we remove them, provide fillet at sharp. So, if the sharp angle is there then you can provide the fillet at those places where it is having a smooth transition is there. Proper spacing between ribs that is another you know suggestion which must be followed. Proper dimensioning of inner walls should be there so, that you have you know somewhat same kind of spaces they are between the inner walls and the molten metal in between, in some of the structures where the in between walls the liquid metal is flowing.

So, the distance between the walls should be somewhat uniform.

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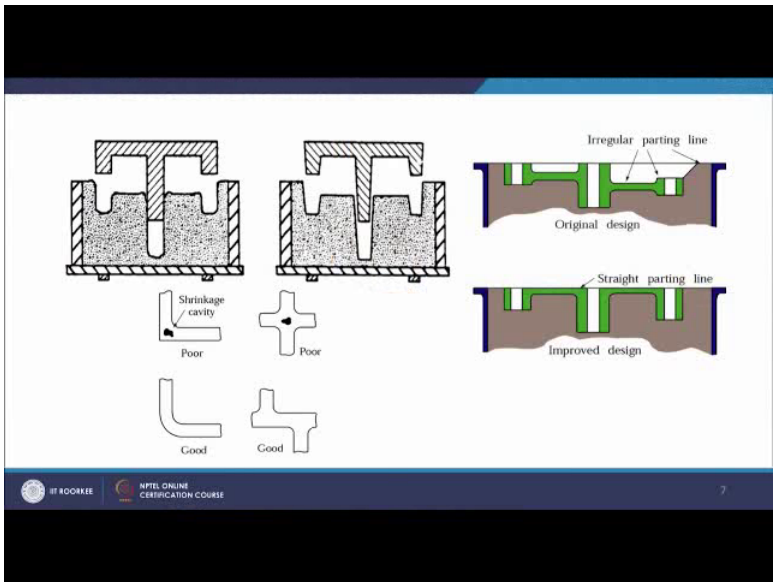

Let us look at some of the figures which is here. So, if we see the, these figures what we see is that you must provide the proper you know draft allowance. So, that there is no in in this case if there is no draft what we see is that it is, touch touching these mould walls and there are chances of erosion this sand when this is taken out. So, once we provide the draft allowance, you see that you have successfully taken it out. Similarly you have this is a poor design because of the sharp corners and because of the improper radii, what you see is that you have the chance of these hot spot; now why it happens because in those cases when you have such cross section.

So, what happens in such cases the solidification starts from here, and the growth takes place. So, solidification will be going on and in that case what happens due to this sharp corners what happens that in these regions there will be chances of hot spot formation because once you have the growth of the grains in this fashion, what happens this is the reason where all the heat which is liberated is released in this domain. So, this domain becomes the zone of high temperatures slowly, as the solidification proceeds solidification will proceed. So, heat will be extracted here this way here in this way. So, it will be heat will be extracted, but then that will also be going in towards this because of the latent heat is released and in that this portion being the chunky ones in the centre it will have the hot spot formation that is what is happening in this case.

So, in this case or in this case what we see is that, in this case here the heat will be releasing like this and this portion will be having high temperature, that similar thing happens here. So, what we do is we normally provide the radius here, and we modify the design in that case what we see that the growth of the economical grains they are not interfering and in those cases what happens the, that may interlock and the growth of these grains may interlock and this region may be isolated towards the end.

So, that is why this region of hot spot is formed or shrinkage is formed. So, we see that this design can be improved by using some changes in the design. So, this is bad this is good. Similarly the parting line will try to have a stiff parting mostly as possible the design permits, because otherwise you will have the problems in the case this is also a good casting design practice, which should be followed in the case of design.

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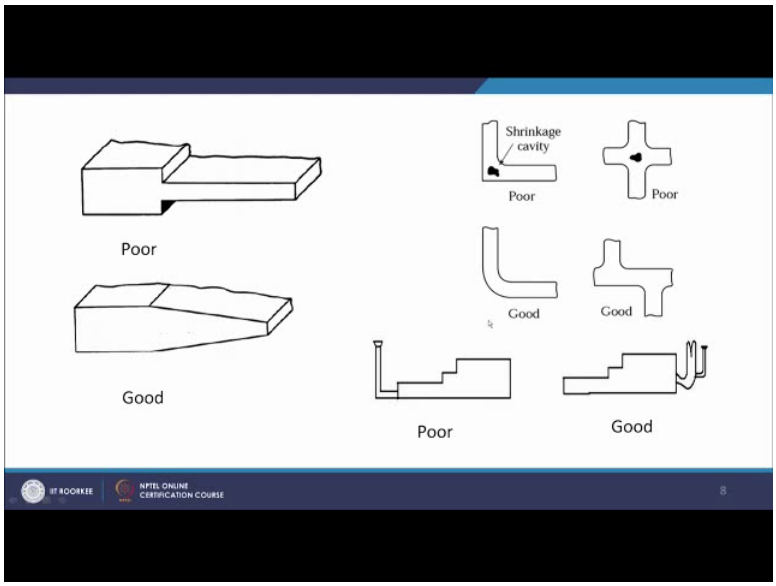

Another example that we discussed is about the stream lining or giving the radius; that you will see here that this is a poor design, and this is a good design that is we will see in that case. Similarly what you see that once you have to provide riser or the runner or you provide the liquid metal through a certain zone, in those cases this is seen that this is good and this is bad why because, this is the chunky portion and this is a thin section portion.

So, once you have done the pouring from this side or the riser is connected to this side, then this portion is likely solid first we solidify it first. And once this portion gets solidified first then you know then there is going to be defect likely in those zone, which is the chunky one whereas, in this case the liquid metal will be flowing from this side. So, this side when the metal comes, it will solidify first and this will be the portion which will solidify at the end. So, that way it is seen that this will proved you the I mean correct design and it will provide you the good sound casting. So, these are the normal methods or normal rules, which should be followed while going for the casting design then coming to the economical considerations.

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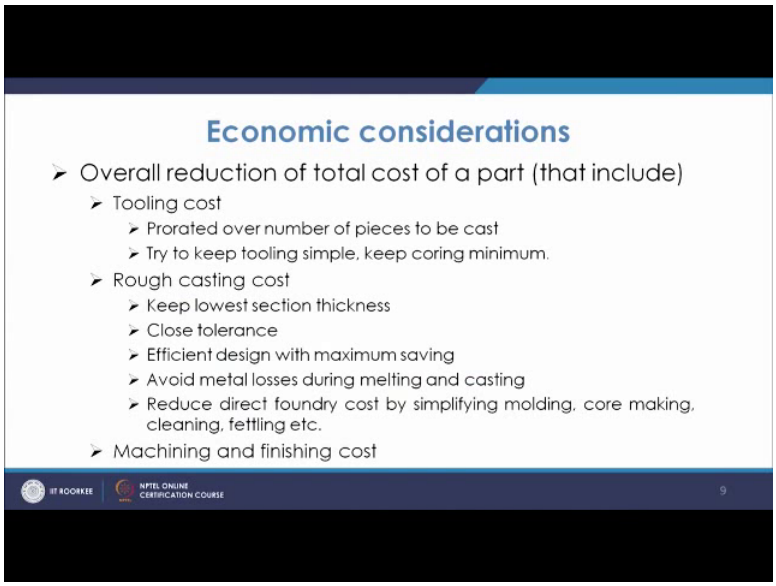

So, this is very important because to sustain in this world competitive world, you will have to work towards improving the economical you know considerations economical aspects every time. Now what is normally the total cost will be normally for you can divide it on one is the tooling cost, another is the rough casting cost and then the last is machining and finishing cost. So, in the tolling cost you are basically you have the tools which are to be used every time. So, they basically the cost on that has to be prorated over the number of pieces to be cast.

So, if you have the order of very large number of pieces to be cast, then you can think of tools which are good one which are very sophisticated one. So, that way you can think of having such kind of materials. Similarly you have to keep the tooling simple. So, and keep the coding minimum. So, so that because if the things can be simplified, if you can get the results in a simple manner, then there is no need to have the you know placement of course, unnecessarily or so. Many a times we have even if the in the interval cavity is smaller in dimension we keep the course not required you I mean unless it has certain thickness we do not need to have course the carting has the thickness if it is very small, it is better to economically machine that small holes. So, you will have to have that in mind then the rough casting cost.

So, that basically has to be kept in mind that you have to have keep lowest section thickness, use the closed tolerance you have efficient design with maximum of saving

avoid metal losses during melting and casting you see that the yield is maximum. So, that you have the metal looses are minimum. So, that you will have more yield, you see that you do not use large number of you know risers which is not required or not very bid runners or so. So that because they ultimately decrease the yield, it reduce the direct foundry cost by simplifying the moulding, core making and cleaning fatling these operations you can simplify and reduce these direct foundry cost.

So, these are basically the expenses, which are related to the rough casting cost; then machining and finishing cost. So, for that you have to see that you are giving proper machining allowances. So, that you have not to remove much of the machining material and that is why you have not to expand much for the machining or the finishing purposes. So, you can have small amount of tolerance, I mean you can have a small amount of these allowances. So, that you have to remove small amount of machining I mean material and you get the desired finish. So, similarly in the earlier we discussed what fatling and cleaning, for that you must see that you have to minimum so that the yield is also improved. So, these are the economical considerations, which needs to be seen. So, that you get the good yield, and the enhancement in the productivity of the casting.

Thank you very much.