Theory of Production Processes
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Lecture – 13
Introduction to riser design

Welcome to the lecture on Riser Design. So, in this lecture we will have the introduction to riser design. So, first of all we should understand why a riser is required in case of casting. So, the function of riser is to feed the metal to casting as it solidifies. So, as we know that the solidification normally has 3 stages, we had discussed earlier that when solidification occurs in the case of pure metals you will have these 3 stages of solidification.

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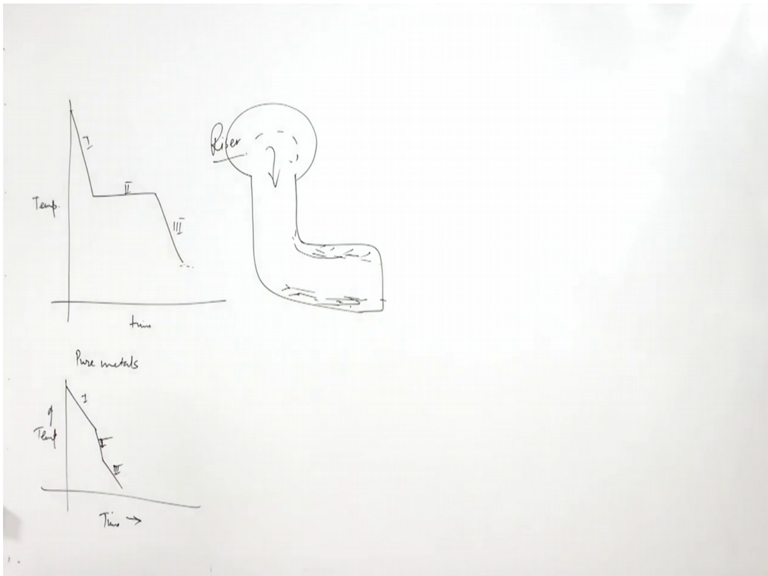

So, in case of pure metals; so this is time, this is temperature. So, as the time progresses you will have temperature decreasing and at this during this stage that temperature remains constant and after that you will have the again decrease in the temperature. So, these are the 3 stages what has been referred here you have 3 stages of contraction now this is of superheat temperature or pouring temperature this is a solidification temperature and then this is the room temperature suppose this is coming to the room temperature.

Now, in that case you will have the contraction in these 3 stages this is the first stage, this is the second stage and this is the third stage. So, this is a pure metals if you take a alloys it will be like this. So, in case of alloys you will have the curve like this. So, the temperature even decreases in this life during this second stage also.

Now, during these two stages, in this stage the metal is completely liquid whereas, during this stage the there is a messy state, the liquid is slowly converting to solid. So, as the time progresses at this point they were 100 percent liquid, but at this point it has become 100 percent solid and during this regime you will have the liquid as well as solid regions. So, that is zone known as messy zone. We will have liquid as well as solid.

Now, when the liquid is converting to solid and since there is a density change normally in most of the cases when there will be transformation from liquid to solid state that this density will increase. So, if the density will increase the volume has to decrease because the mass is same. So, because of the increase of density going to the formation of solid phase there will be contraction or volumetric shrinkage and this shrinkage occurs in these two cases where you have the liquid available and you can compensate this shrinkage by supplying the liquid. So, there must be something a reservoir this should be able to supply this extra liquid metal if you have available.

So, what we do is normally in case of casting we have a separate head. So, that is why riser is also known as a head. So, if you have a head of liquid metal available and whenever there is shrinkage. So, since there will be contraction of the liquid metal as its converts to solid. So, it will require some extra metal and that extra metal comes from this riser.

So, if you have any casting. So, in that case you may have the head here. So, if there is solidification going on here this is going like this and, in this place here the immediate reason we will try to have. So, here they would like to have the liquid and this liquid metal which will be taking from the nearby places and ultimately this riser it will be supplying the liquid metal. So, this is a function of the riser that it basically converts, it basically supplies the liquid metal in the case of solidification or liquid shrinkage. So, that is what the function of riser is to feed the metal to casting as it solidifies. Now, if you look at the different materials different metals as we see you have some contraction on freezing percentage is given.

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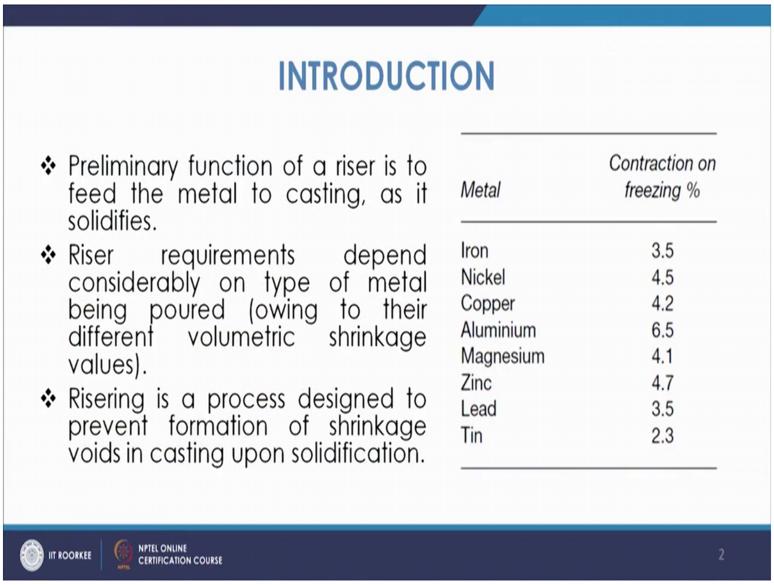

So, based on that you can calculate if you know the volume then this is a volumetric shrinkage. So, you can have the calculation of how much should be the material extra which is required to be fed so that there is no shrinkage. So, that was extra metal has to be supplied now that extra metal has to be supplied by this particular reservoir this is a riser. So, it is not that only suppose you have 3.5 percent of iron is there in the case of iron and if you are you know if suppose you have the volume of 100 centimeter cube. So, in that case 3.5 centimeter cube of metal is required.

Now, this volume only 3.5 centimeter cube will not work because this riser is also like a casting. So, the riser will also solidified. So, this riser in between the casting is getting solidified the riser is also getting solidified. So, the riser volume has to be more than that 3.5 now how much more it has to be. So, that will depend. So, for that do you have different formulations how this it is going to solidify with the mechanism of solidification because being the riser its core portion will have the hottest metal because from the side it will as also start solidifying we will discuss how it solidifies. So, it is to be calculated that what should be the total volume of this riser for that there are different rules and because it also follows the same solidification principle. So, that is why now the riser requirements will depend considerably on the type of metal being poured because it has different materials have the different volume metrics in shrinkages shrinkage values.

So, if the volumetric shrinkage for any material is more the requirement of metal for accounting of the shrinkage that will be more. So, that is how this will vary. So, risering requirement will be different. A risering is a process designed to prevent formation of shrinkage voids in casting upon solidification that is what the purpose of riser is because if there is no riser, if you have cast in any cavity if there is any mold cavity, if you have put the liquid metal all together and if it is closed completely in that case the solidification will start from the sides from all the sides this solidification will start.

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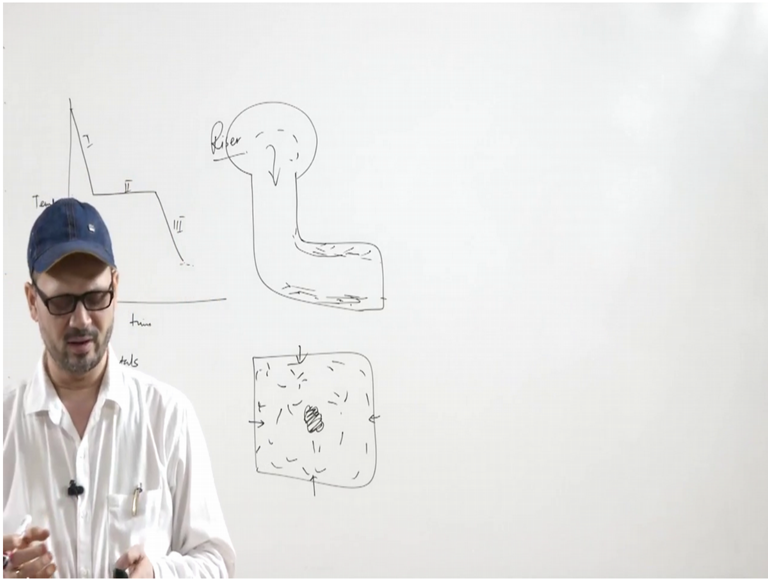

And then ultimately in the end this portion will solidify and then you will have these shrinkages you will have the chances of shrinkage during this portion which is the last one to solidify. So, riser takes care of that reason where there is likely to have shrinkage or because it will supply the liquid metal for seeing that there is no shrinkage.

Now, let us see the example this example shows that you because as I told that that the solidification process in two way in a casting one is the directional solidification, another is the progressive solidification.

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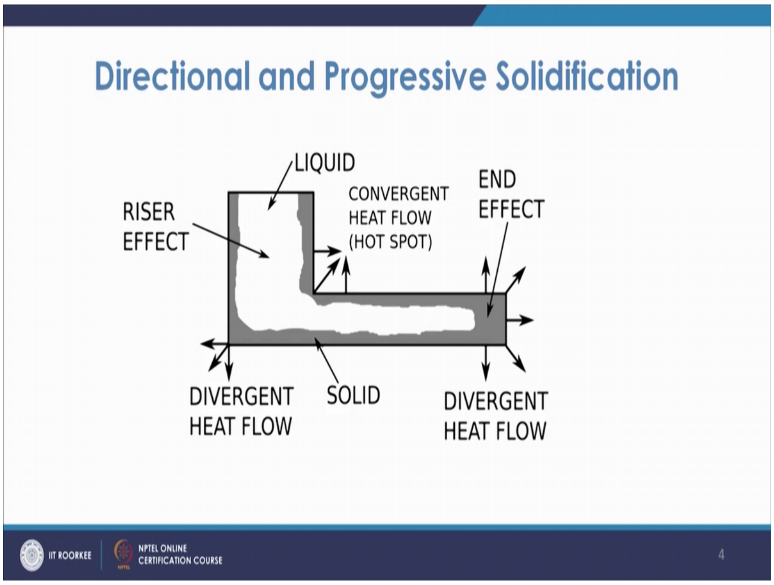

Now, if you see this geometry this figure what you see is when you are casting the liquid metal into the cavity then what you see is the immediately the solidification front will start moving inward. So, from this side it will moved in this direction from this side it will move in this direction from this side it will move in this direction this way and this way or so.

Now, what happens that. So, the movement of this solidified cell from outer ward to inward that is the mechanism of solidification known as progressive solidification. So, the progressive solidification is product of freezing mechanism because the freezing occurs in that fashion. We have seen that during the freezing when it occurs it occurs by the mechanism of nucleation and growth. Nucleation occurs at those places where you have maximum under cooling experienced and when we are basically pouring the liquid metal in that case when it touches these walls on these walls you have the maximum under cooling experienced.

So, you will have nucleus is started and then slowly there will be growth. So, that is why and then it will move inward because there will be divergent heat flow. So, heat flow is going on from this are here from that side in this side direction this direction of this direction. So, since the heat transfer takes place. So, growth is going in the opposite direction. So, there will be growth of grains from the different places.

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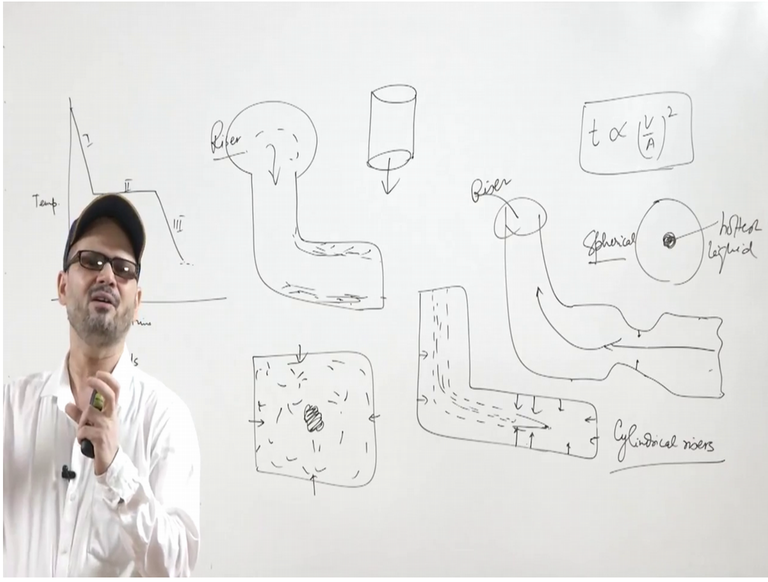

So, you will have, from here you will have growth of grains you will have growth of grains like that that is what it is shown that.

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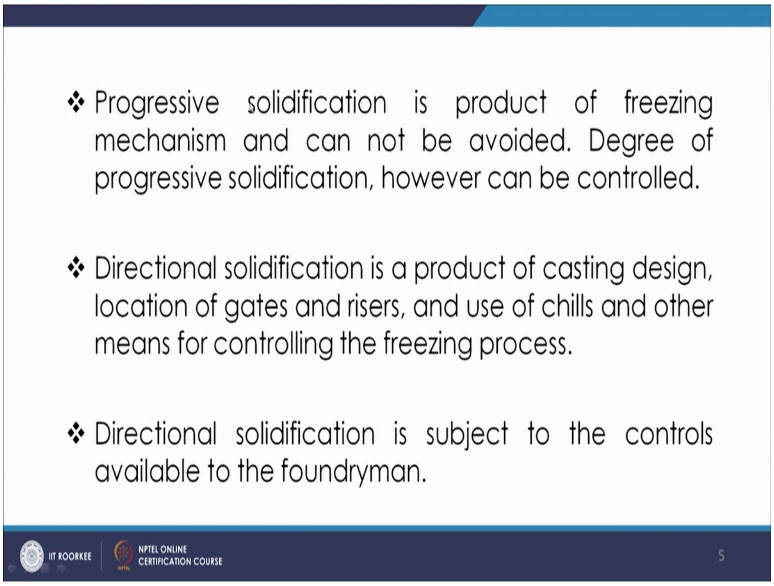

Now, in the case of the progressive solidification as it is written that is the product of freezing mechanism and it cannot be controlled avoided. Although you can control its degree it has to start, if it is touching the walls of the surface where the under cooling is more the temperature differential is there wherever the temperature will be less from there the nucleation will start if that favoring condition is achieved. Like the temperature is going below the equilibrium temperature. And then it will start moving inward and movement of the front from outward to inward this mechanism is known as progressive solidification.

Another solidification is the directional solidification and as you see that this has to move and then what you see is that this zone is the liquid. Suppose this zone having the lower cross section it will try to freeze in lesser time. So, this zone will start freezing. Now, what happens with time slowly this comes like this zone comes like this. So, because of this end effect here in this zone when you have the end effect here you see that the solidified zone is more, now this will start moving in this direction slowly this zone will come here then slowly it will further come in this position. So, this will start moving in this direction and ultimately the last portion to solidify will be in this places because this is the chunky portion. So, here they will come and slowly it will try to solidify.

Now, the thing is that solidification moves has to move from that position which is completely remote and this channel looks to be active this is the zone where the liquid metal is coming up. So, here there you may have a placement of riser. So, since it is in contact with this liquid hot pool this is at higher temperature. So, this portion it will solidify first which is away from the riser and for solidification will proceed towards the riser.

So, since it has a direction in the direction towards the riser the riser pull, the region which is close to the riser will be the last one to solidify. So, that is why this is a type of directional solidification. Now, this directional solidification is basically is the product of custom design location of gates and risers use of seals and other means for controlling the freezing process.

Now, this direction directional solidification it is subject to the control available to the foundry man. So, he has the capacity to control this external solidification. Now, the thing is that in this case the liquid metal will move from this side if we place a chill here then this is going to solidify fast. Now, what we see for the optimum solidification and for avoiding any kind of solidification defect we would see that this portion should solidified, solidify first and then it should move in this direction.

Now, suppose in the in between you have a thinner section then in that case you can have one way that you can decrease the heat transfer rate from that place. So, you can even have the insulator at that place, you can control so that slowly the directional solidification we achieved and then by the time the remaining portion is solidified this portion does not get solidified, suppose this portion becomes very thick. So, suppose sometimes the region comes like this.

So, suppose you have to see that this add show if there is a directional solidification you have to ensure that this portion does not get solidified early. So, in that case you may have to apply some padding, some insulators, insulator padding so that it does not get solidified until this portion gets solidified. If this portion gets solidified before this in that case this portion will be away from the active feed channel and there will be chances of having shrinkage. So, that is why you can have some mechanism by which because there are only progressive mechanic progressive solidification it will start solidifying from here and it will start solidifying from here that you cannot avoid. But then you can control the rational solidification you can have the padding here you can control you can use, such that this portion does not solidify. So, you can use the padding. So, that it that proof that big extent of this progressive solidification is minimum and then once this solidifies after that this solidifies and then solidification proceeds in the direction of this riser.

So, if that goes in that case you are less likely to get any kind of defect. So, that is why the combination of these two which they must have there must be proper control of this progressive and directional solidification so that you have the casting free from any shrinkage defect or so. So what we see is that the treats of this progressive and directional solidification.

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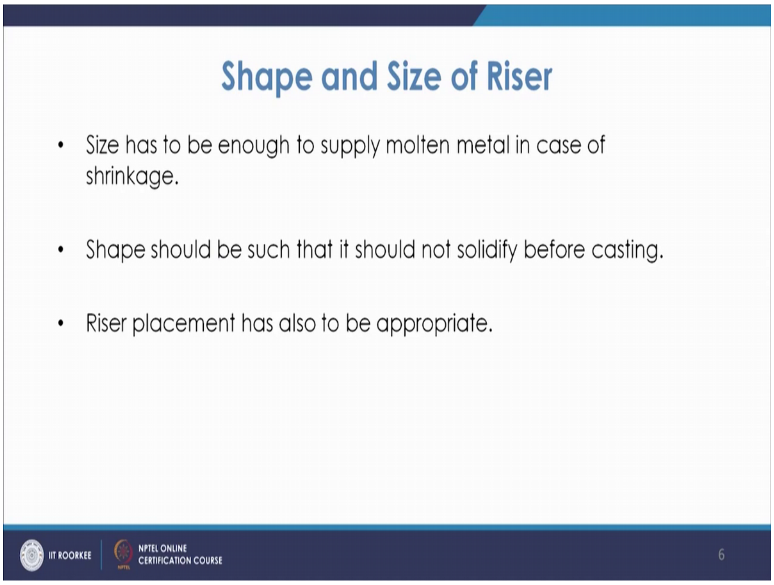

Now, shape and size of the riser when we select any riser. As we have discussed that the requirement is that the riser has to solidify later than the casting, it should not solidify prior to the casting because when the casting is solidifying and if the riser solidifies prior to the casting that there is no point in getting any liquid metal available from the riser. So, for the riser a shape should be such now the thing is that we have discussed about the swaddle of formula where the formula is that these proportional to V by A square. So, this is the Chvorinov's of formula which tells that t will be proportional to V by A square.

Now, the thing is that if there is a riser and there is a casting for them the solidification time will be proportional to. So, for casting it will be volume casting by area casting square and then for riser volume riser by area risers its square. So, that t is proportional to that. So, ultimately you will have t as a function of V by A. So, it will have some dependence on V by A once V by A is a small, V by A square will be more.

So, once anyway V by is a parameter which talks about the freezing time which is something can be correlated with the freezing time. Now, freezing time for a riser has to be more than for a casting means you have to have a shape for which V by A would be higher, if a shape is such whose V by A is highest means what if the volume is constant then that set which has the minimum area that shape basically will be ideal for a riser because for that you will have the maximum time of solidification.

So, for that if you compare the different type of geometries their spherical shape is considered to be the ideal one. For a spherical shape the V by A is basically the maximum or for a constant volume the area is minimum for a spherical shape. So, that is why a spherical shape is considered to be the most ideal for the riser shape; however, when we talk about the spherical shape. If you have a spherical shape now the hottest liquid will be here this will be the hottest liquid and practically you cannot feed the liquid metal from this central portion. So, you need another kind of shape the next best shape will be the cylindrical risers. So, normally for practical purposes you go for cylindrical risers. So, you have some shapes like a spherical cylindrical and cube and you can find the this parameter V by A and you will see that you will have most prefer as a spherical than cylindrical risers now cylindrical riser may have you have we know some ratio of h to d you may have s by d as 1 or 2 or 1 by 2.

So, for that, cylindrical risers are basically preferred for these as a rise, as the ideal shape of the riser and this part will be basically open to those these this is casting. So, from here you can have the supply of liquid metal to the casting.

In many cases you will have cylindrical riser with hemispherical top. So, that is also seen especially in the case of blind risers which is when the riser is not to open we have an open riser or blind riser. So, in that case you will have the hemispherical top because once you have the hemispherical top and then the liquid metal available from this place then there that basically increases this V by A. So, that is how it is going to have more solidification time and riser will have the hotter liquid for more amount of time. So, that is why the shape is important. Now, the size of the riser what should be the size of the riser. So, once we come to the shape then now let us see it should be. A size of the riser size of the riser should be such that it has sufficient amount of liquid metal available for feeding the casting.

So, one very normal formula is that once you know the volumetric shrinkage of the liquid metal then you can find that what should be the size what is that amount of material required. So, there can be some very rude rule that if the shrinkage is suppose 3 percent, suppose you have the casting volume is 100 centimeter cube and if the volumetric shrinkage is 3 percent means the shrinkage amount will be 3 centimeter cube and on a root basis you can say that you can have the riser volume of 3 times this shrinkage amount.

So, you can have a riser of 9 centimeter cube. So, you can have a cylindrical riser whose volume should be 9 centimeter cube. So, this is this has been found in some cases that it may be appropriate, but many a times it does not work. So, basically there are different formulas for calculating this volume of the material required for this riser and we will study the different techniques by which we find the amount of volume or the volume of metal required for the size of the riser.

Next is the placement of riser, so where the riser should be placed. Now, riser placement has to be in such a way that it is connected to the portion which has to solidify towards the end there is no point in placing the riser. Now, if you look at certain channel there is no end if you have the channels which are which have some lower cross sectional area at some points and at some point it has a larger cross sectional area. So, right you have to see that what is the how the progressive solidification has to be move forward, how the directional solidification has to be achieved and you have to identify a place which is more chunky because that portion will be the one which is going to solidify in the end. If you are placing the riser at a place which is having lower cross section in that case there is not going to be much benefit because the portion which is having lower cross section or which is have which has a thin section thickness is less those proportions are anyway going to solidify quickly because of the progressives solidification mechanism.

So, rather placement has to be seen in most of the cases in many times when you have used the top riser you are placing many a times through the riser itself the pouring starts. So, you will have the pouring through the riser and many times you get the side riser. So, that is basically the placement of the riser whether you where you place it either at the top you are placing you may place it also on the sideways. So, that is known as side riser. So, you have either top riser or you have the side riser. So, as we see you have different types of riser.

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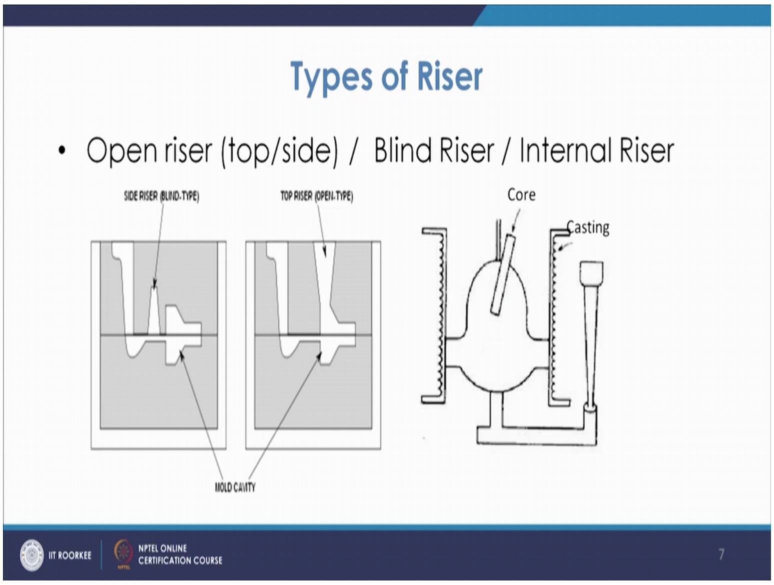

You have open riser that is top or side, so this riser which is open to atmosphere that is known as open riser. Now this riser it may be the open at the or at the open to the atmosphere and also it is working as because as a part of you can say as the example of top gating, so it has come it is coming from the top. So, that is why it is known as top riser. And if it is coming from the side and going at the parting gate type of cases that way it is known as side risers. So, you can see those situations here by looking at these figures you have the mold cavity shown here and this is an example of top riser which is open type.

And then here it is an example of side riser. So, it is from the side it is the liquid metal it can deliver from here and go into the cavity and you can see that this riser is not open this is basically not open to atmosphere. So, that is why it is known as blind risers. So, in the case of blind risers normally you need some mechanism by which you can ensure that it will supply the liquid metal because what will happen when it will supply the liquid metal it needs in the case of these top risers basically the since it is open to atmosphere the gravity force works. So, when the liquid metal is pulled and there is suction created at the bottom that is another extra force created from the top atmosphere. So, that basically facilitates in pressing the liquid metal through the riser go into the portion where the metal is sought.

But in the case of blind risers you need the mechanism by which you can see that the liquid metal should be supplied. So, for that normally a core is inserted which is open to atmosphere and that is known as normally William Core. So, this core basically helps in having that atmospheric pressure working on them so that its effectiveness is more in supplying the liquid metal to the places.

So, as we discussed that the riser shape, shape of surface area of the casting relative to its volume is important in determining the rate of heat transfer because surface area if it will be more you will the heat transfer from the surface will be more effective and if the volume the volume term talks about the heat content of the liquid metal.

So, the volume is more V by S A is more means it will take more time to solidify and if S A by V is more it means it will take less time to solidify. So, basically this you will have to have a shape for which the V by S A volume by surface area has to be more in that case it will be ideal because if in that case this riser will solidify later than the casting. So, that is what can be derived from this Chvorinov's rule and a minimum riser size which is obtained for a particular volume is calculated to be for a sphere then it is followed by the cylindrical size. Then you will cylindrical shape and then you have the cubical shape or so, so that that way you can have the preference of the shape of the riser.

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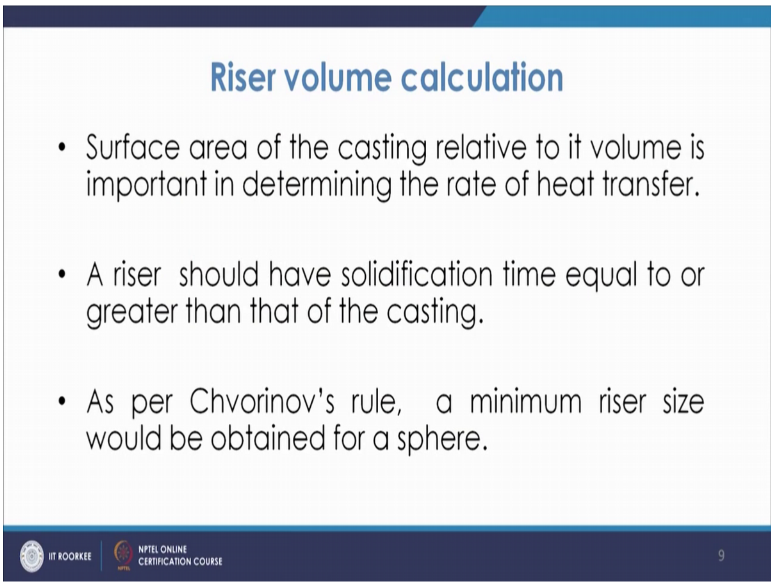

As discussed we have the riser volume calculation, rather volume calculation in that you may we may have that empirical formulas, you may think of having certain times basically the contraction which is experienced or you have the different formulas are there which we will discuss maybe in the next class. Where basically become depending upon the cooling characteristics or the freezing characteristics there are certain curves or there are certain rules by which empirically or by experimentally it has been seen that I mean there is a graph which is available and which tells that if you the casting is of that particular shape or size. So, you can have the riser of this much volume.

So, once you know the riser volume from certain graph now this graph has been proposed by many researchers there are methods like Caine's method, Caine's was researcher cane and, he has given one formula for that. Further there has been naval research laboratory another method is there safe factor method is there. So, you have different methods, by different methods you can find. So, if they have all given a graph so that graph tells that for getting a sound casting what should be the minimum volume of the riser depending upon the characteristics of the casting.

So, depending upon the shape of the casting or size of the casting, you can have the different volume of riser, riser volume requirement and based on that once you have and the shape fixed like you have you are taking the cylindrical shape then you can fix the dimension of the riser. So, that way these riser volumes are calculated.

Thank you very much.