Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology – Part – 1

Module – 31

by
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Hello and welcome to manufacturing process technology part 1, module 31. In the last module we had obtained some numerical forms for two different cases of casting one with the thick mould another with the thin mould with cooling and we had found out what are the various times of solidification which would result from such an architect on of the mould.

Today we are just going to talk about a little different, slightly different aspect of casting which is also the riser placement and design. So riser as you know is a, it is on the basically one end of the casting connecting the casting which is supposed to fill with liquid metal during the process of pouring. And the idea is that in case the metal shrinks or there is some kind of the ovens becomes of that obviously the pattern also takes care of that.

But still in the process dynamically if you have to do a reverse feed the riser should be able to do that flow in of the material, so that it can fill the mould cavity. So the important question here is that the mould should be able to have a time of solidification which is actually lower than the time of solidification of the lower than the, I am sorry lower than the time of solidification of the riser.

So the riser should be able to be in liquid form to feed to the mould and it is own time of solidification through geometry can be designed in a manner, so that it has a slow cooling or it has a higher time of solidification then the basic mould.

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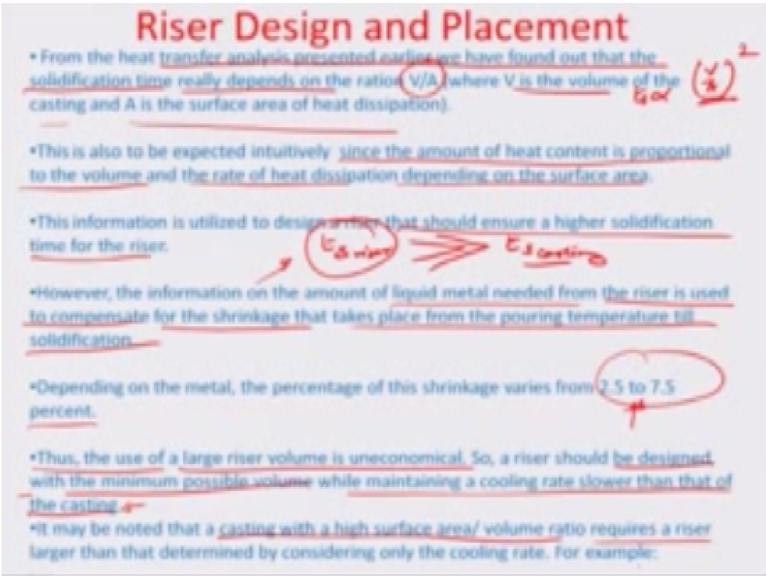

$$t_{sriser} \gg t_{scasting}$$

$$t_s \propto \left(\frac{V}{A}\right)^2$$

So having this premise into picture let us actually see how we do the designs from the heat transfer analysis present earlier, we have found without that the solidification time really depends on the ratio V/A. In fact in some cases what we saw is the ts proportional to $\left(\frac{V}{A}\right)^2$ where V is the volume of the costing and A is the surface area of the heat dissipation. So this also expected intuitively since the amount of heat content is proportional to the volume and the rate of heat dissipation typically would depend on the surface area of the particular cast.

So this information is utilized to design riser that should ensure a higher solidification time. So the basic thumb rule here is that the t_S riser should be higher in comparison to the t_S of the casting. So this would have a higher solidification time meaning thereby that the volume by area raise of the riser should be defined in a manner. So there automatically this becomes higher than that of the casting.

So however the information on the amount of liquid metal needed from the riser is used to compensate for the shrinkage that takes place from the pouring temperature till solidification temperature depending on the metal, the percentage of this shrinkage vary between typically 2.5 to 7.5 %. I think this we had discussed towards the beginning of the casting that from various metals what would be the kind of shrinkage allowance that would be needed for doing the mould designing, etc.

So the use of larger riser volume is uneconomical, because riser is really a part that you need shed off from the basic casting. It is not contributing, it is not adding any value except the fact that it just as reverse flow, so that you can do the filling of the particular cavity. In case there are shrinkage of the metal which takes place in the mould. So riser should be designed in a manner. So that it is most economical meaning there by least volume.

And the volume by area issue of the riser which can easily be manage by changing the geometry should be such that the solidification time of the riser is higher in comparison to that of the casting, so that is the basic premise. So it should be designed with minimum possible volume while maintaining a cooling rates slower than that of the casting through geometry.

So it may be noted that a casting with a high surface area to volume ratio requires a riser larger than that determined by considering only the cooling rate. For example, let us look at this following case here.

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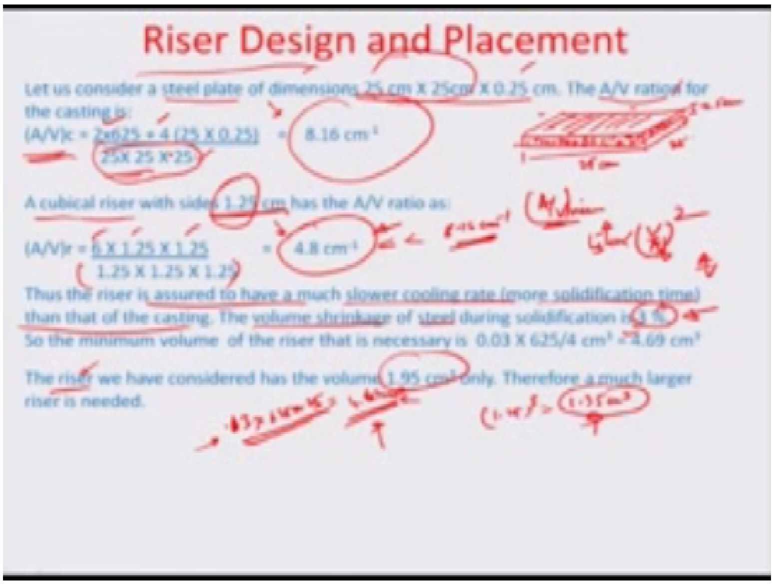

We consider a steel plate of dimension 25 x 25 x0.25 cm. So it is a really 10 steels plate. A steel plate square steel plate the thickness about 0.25 cm and for calculate what is area by velocity of area by volume ratio for the casting can be obtained as. There are two surfaces that this 10 plate would have. So this is the casting that we are looking at and this right here is 0.25 cm this as well as this are 25 cm each.

So we should have a area of the face here and then other area downwards, so the total are that is again 2 x 25 x 25 that is 1250 + these 4 smaller area that the sides let me just for this little more appropriately. So this smaller area as would typically include this four faces on the side and similarly one face here and one face here, so that can be estimated as four times of 25 x 0.25 where are the volume of the whole metal plate should be hold 25 x 25 x 0.25.

$$\left(\frac{A}{V}\right)_c = \frac{2*625+4(25*0.25)}{25*25*0.25} = 8.16\,cm^{-1}$$

So that becomes equal to 8.16 cm inverse. So that is the area by volume ratio of the casting and let us say if we talk about designing riser for this system. Let us say for the first elementary shape that we consider as cubical riser and we have a size of 1.25 cm per side of this cubical riser. So let us calculate what is the area by volume ratio in case of the cubical riser that we are in the questions to you have 6 A^2 as the face area so 6 x 1.25 x 1.25.

$$\left(\frac{A}{V}\right)_r = \frac{6*1.25*1.25}{1.25*1.25*1.25} = 4.8\,cm^{-1}$$

And then the total amount of volume that the riser would have is 1.25^3, so that become equal to 4.8 cm inverse. So therefore, as you know that the time of solidification is proportional to V /A^2in this particular case we talk about A/V, so it is essentially, if the t_S where to be higher, so the A/V should be lower, and this case as you can see that the solidification time of the riser is more, because A/V here is much, much smaller in comparison to 8.16 cm inverse.

So this is just the inverse of V/A, so please be very careful while doing the design questions that may come in the liquid, etc., where you have to understand that A/V is inverse of the solidification time. So therefore, if the riser is slow cooling that typically A/V should be lower of the riser in comparison to that of the cast. Thus the riser is assumed to have a much slower cooling rate and more solidification time than that of the cast. Now let us took at the volume shrinkage that this metal steel would have during solidification typically the experimental observation show about 3% volume shrinkage.

So the total volume that this steel plate would have is close to about may be 155.1 something, so 625 /4 this whole volume. And this much centimetre cube volume when it actually is put in cast 3% of this volume should be the amount of reverse flow needed to by the riser. So 0.03 x 625 x 0.25 is really what we want to find out here as the total requirement. And that requirement is about 4.69 cm^3.

But you see if we talk about the riser volume here the question is within the all this metal can be supplied by the riser. So only 1.95 that is 1.25^3 or this is 1.95 cm^3 only this much volume is supplied and the remaining volume is empty. So the 3% figure is a very, very large number for the cast. So you have to consider a riser which is of a higher volume.
So it is not necessary always that you're A/V ratio is the determinant factor, you also have to consider whether the amount of volume that the riser has of liquid metal would be able to fill up the shrinkage volume of which is formulated because of the heat transfer than the moulding valves. So having said that is how you basically do integrative designing process and then you place the riser in accordance with this process.

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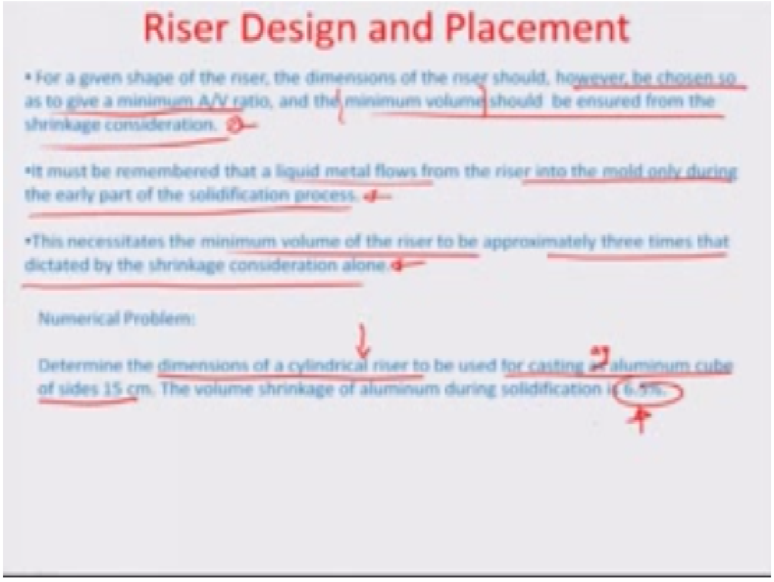

So for a given shape the riser the dimension of the riser should however, be chosen so as to give a minimum A/V ratio and a minimum volume should be ensured from the shrinkage considerations. So this should be the cut off threshold at least this much volume is needed and then you can go on the A/V and try to see what geometry would suffice for the riser to be able to cool the slowest.

So it must also be remembered that a liquid metal flows from the riser into the mould only during the early part of this solidification process. So you should be having the riser placed as near as possible to the mould, so that there is no time delay in the metal running through the channel from the riser back into the casting because of friction and other effects.

I think we have done of lot modelling towards the beginning of the casting lecture where we are talked about how the time of filling is very important for determination whether the metal is able to flow in liquid form that means a time of solidification there is much, much higher in compression to the time of filling.

So the same model needs to be done here on the riser side. So this is necessary is the minimum volume of the riser to be approximately three times dictated by the shrinkage consideration. So if it for a 3% of the volume 625 /4 as you saw earlier which was actually 4.69 cm^3, we should be enabled or the riser should be enabled by designed to have atleast effect A to 3.

$$\frac{0.025 * 625}{4} = 4.69\, cm^3$$

So it should be about may be 15 cm^3 of volume, so that the idea that at least part of that would be able to fill the mould and take care of the shrinkage cavity. So let us say do a numerical problem for considering all these designs consideration are do accounts. So that we can finally emerge with a particular riser shape and size.

So we have to determine the dimensions of the cylindrical riser to be used for casting an aluminum cube and the side of the aluminum cube is about 15 cm, the volume shrinkage of aluminum during solidification has been given to very high 6.5%.

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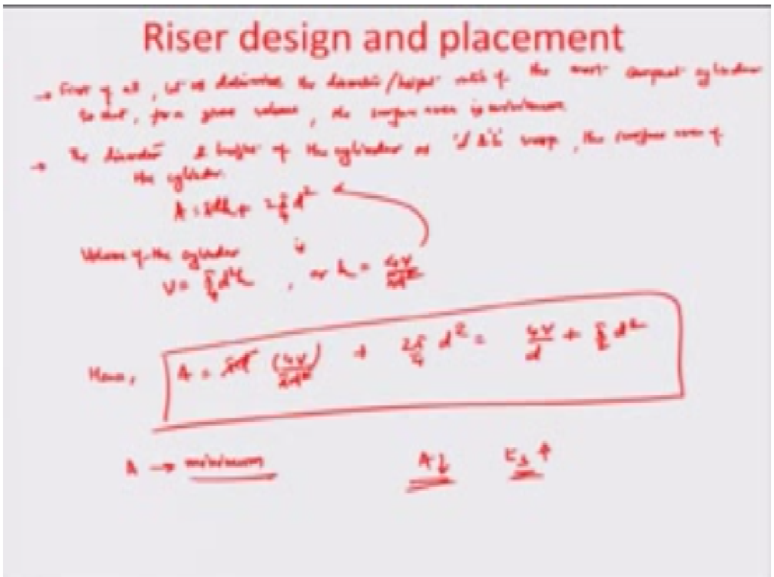

So having said that let us now step by step try to design this particular riser, so first of all let us determine the diameter to height ratio of the most compact cylinder. So that for a given volume, the surface area is minimum with the diameter and height of the cylinder as *d* and *h* respectively. the surface area of the cylinder can be approximately obtained as by π dh +2 π by 4d^2 volume of the cylinder is typically $\pi/4d^2$ h or h = 4V / πd^2.

$$A=\pi dh+2\frac{\pi}{4}d^2$$

$$V=\frac{\pi}{4}d^2h$$

$$h=\frac{4V}{\pi d^2}$$

So we less put the value of h back into this equation to make everything look in terms of D. So that we should be able to now predict A as πd times of 4V / πV^2 + 2 $\pi/4$ D^2 of 4V/D + $\pi/2d^2$. So that is how you can represent the area and we want to go for minimum area, so that the slow cooling happens intuitively also if the area is less the t_S the solidification time increases, because that is very less it transfer possibility just depended on the area directly.

$$A=\pi d\frac{4V}{\pi d^2}+2\frac{\pi}{4}d^2=\frac{4V}{d}+\frac{\pi}{2}d^2$$

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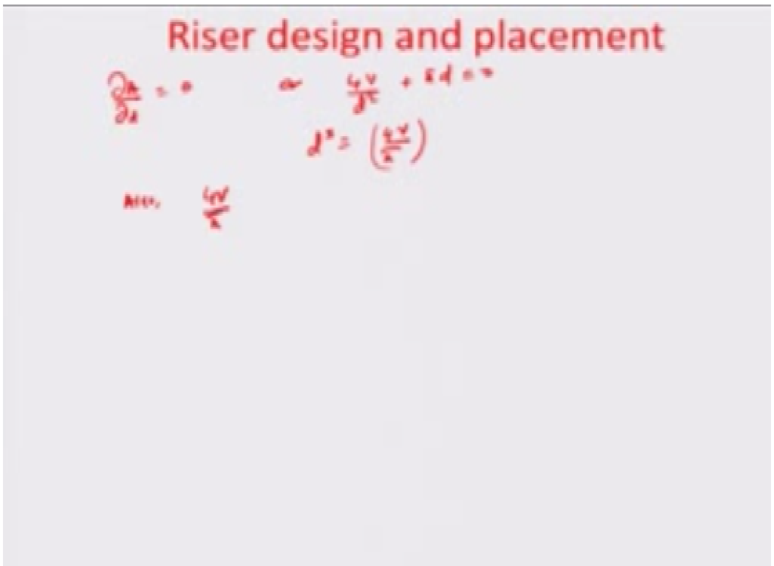

So we have in this particular case dA /dt is zero or $4V/D^2 + \pi D = 0$. In other words you have D^3 is basically $4V/\pi$ and also as you know that 4V x π earlier.

$$\frac{\partial A}{\partial d}=0\,;\vee\,\frac{-4V}{d^2}+\pi d=0$$

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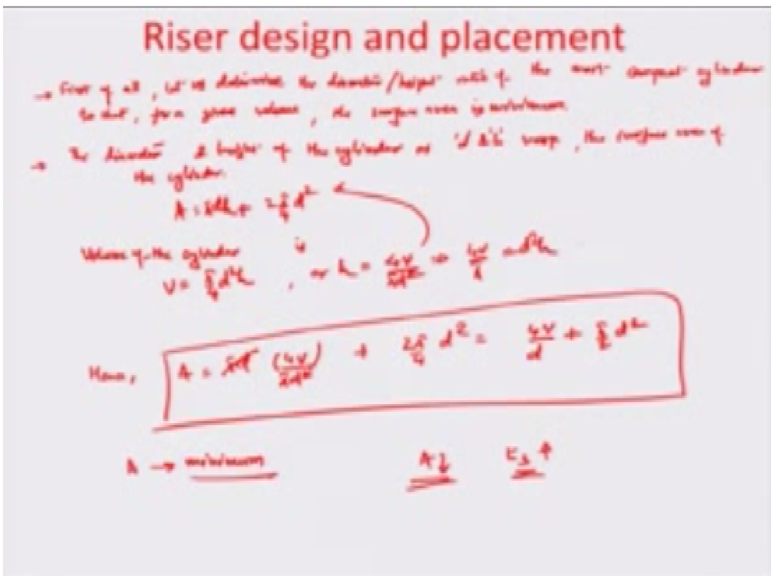

As you have already seen here is equal to D^2 H.

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For A to be minimum,

$$\frac{\partial A}{\partial d}=0\,; \vee\ \frac{-4V}{d^2}+\pi d=0$$

$$d^3=\frac{4V}{\pi}$$

$$\frac{4V}{\pi}=d^2 h=d^3$$

So from earlier presumptions 4V/ π becomes D^2H. therefore D^2H is actually go to D^3 or H =D. So this is the condition corresponding to designing of cylindrical riser where it ensure the total solidification time in this particular case of the cylinder.

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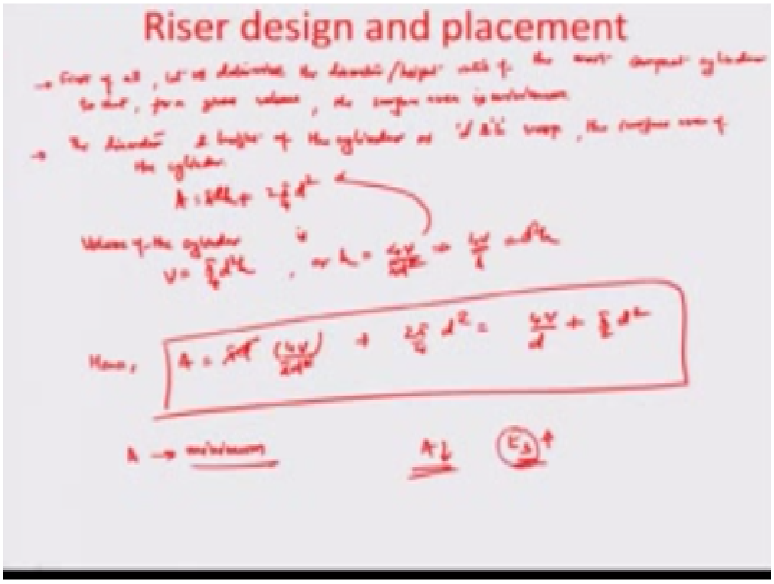

Corresponding to this particular condition is equal to h. So the minimum condition for the ts to be the highest of the sort time of solidification to be highest is equal to h = D.

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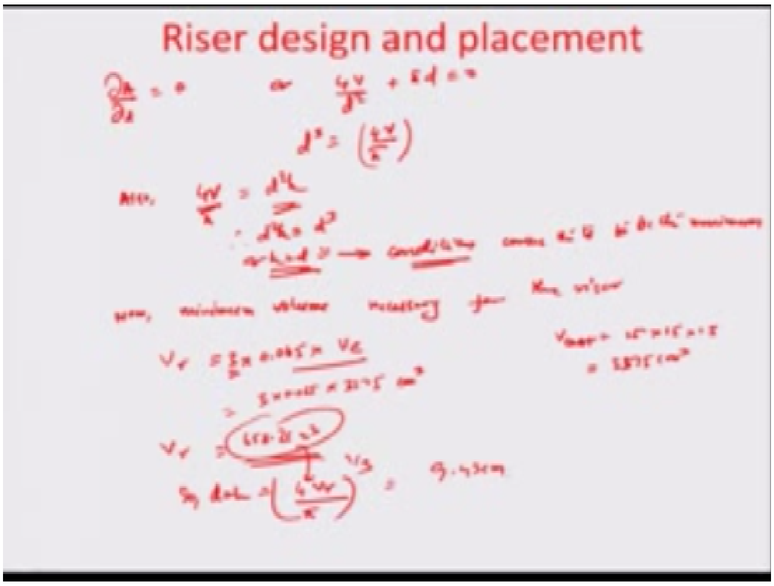

As you can see here, so h = d condition enables the TS to be the maximum. Now let us look at the other aspect that is the minimum volume requirement of the casting, because obviously there is a shrinkage ratio which has been given shrinkage percentage which has been given. So now minimum volume necessary for the riser in this particular cases at least 3 times the shrinkage percentage which is 6.5 %.

And let Vc the volume of the cast that we are considering here which is actually aluminum cube of side 15 cm, so the volume of the cast is basically 15 x 15 x 15 which is around $3375 cm^3$. So therefore, the minimum volume necessary for the riser comes out to be equal to 3 times of 0.065 times of $3375 cm^3$ or that is the V riser and so this for the comes out to be the riser volume V are comes out to be $658.2\ cm^3$.

So from the earlier condition derive for the minimum area d was equal to h for a particular cylindrical riser systems, so this could also represented as 4Vr /V, obviously that is going to be in the minimum riser volume that is needed to feed this particular casting 3 times the total shrinkage volume and that comes out to be now equal to 9.43 cm.

$$h = \left(\frac{4V_r}{\pi}\right)^{1/3} = 9.43\,cm$$

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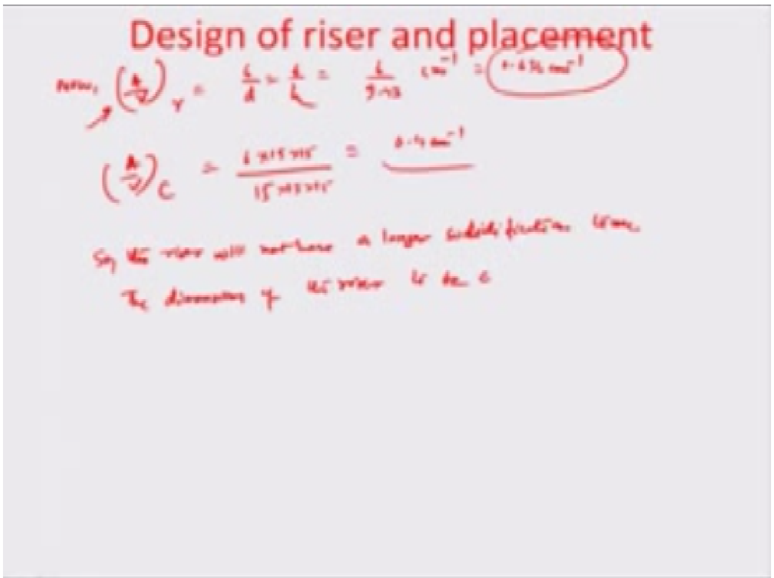

Now let us actually looking to whether really the A/V riser and A/V casting are going to be basically in order, so that the riser solidifies later. So let us now calculate the A/V of the riser which in this particular case A/V of the riser should become equal to 6/d or 6/h both ways and which is 6/9.43 cm inverse 0.363 cm inverse and for the cast A/V for the cast in this particular case would again be 6 times of 15 times of 15 by the volume of the cast 15x 15 x 15 which is actually equal to 0.4 cm inverse.

$$\left(\frac{A}{V}\right)_r = \frac{6}{d} = \frac{6}{h} = \frac{6}{9.43} = 0.636\,cm^{-1}$$

$$\left(\frac{A}{V}\right)_c = \frac{6 * 15 * 15}{15^3} = 0.4\,cm^{-1}$$

So obviously if the A/V of the riser is more in this case and V/A is lesser, so riser should solidify faster. So the riser will not have in longer solidification time which is a problem, because obviously the whole promise for the design was that the A/V of the riser should be lower and comparison to A/V of the casting, so that riser freezes later. So the dimensions of the riser can be recalculated now.

$$\left(\frac{A}{V}\right)_r \ll \left(\frac{A}{V}\right)_c$$

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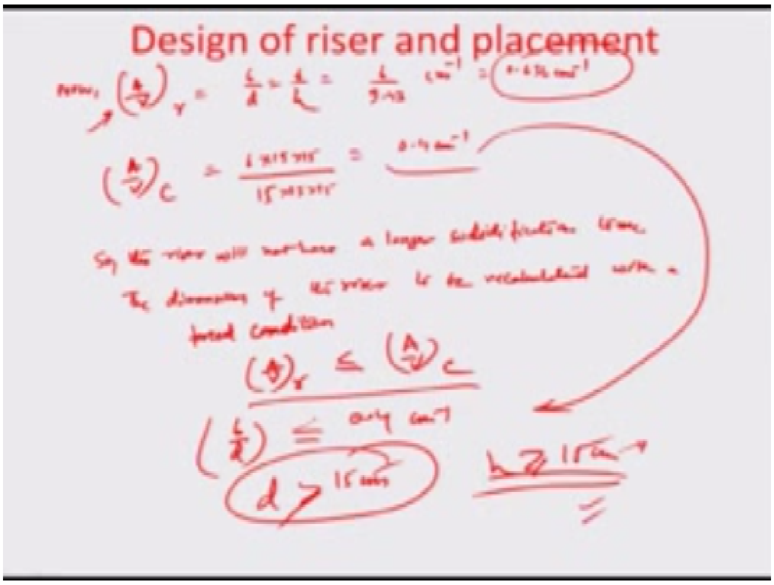

So let us say we just talk about the dimensions of the riser to be recalculated with the forced condition that the A/V for the riser should be lower are equal to A/V of the casting. So let us talk about what would be the minimum and maximum. So you already know that the A/V of the riser is 6/d or 6/h whatever and that should be less than or equal to 0.4 cm inverse i.e. $\frac{6}{d} \ll 0.4\, cm^{-1}$ which are obtained from that of the cast and automatically enables the diameter d in this particular case to be greater than or equal to 15cm and $d \gg 15\, cm$ so is also the height.

So even if it is greater than 15 cm obviously the volume would be much more in the riser, then the 3 times the shrinkage volume limit, but you cannot help about it, you cannot do anything about it, because you have to have the riser time, solidification time to be higher. So in order to enable that to happen you have to go for a higher volume riser than the 3 times requirement and you have wasting metal this way.

But then that is how you do these designs problems about how the riser can be placed had different positions with respect to the casting, so I am going to now take off that problem about what would be the balance metal which has to be enabled in the riser, etc., but in the interest of time I will close this particular module as proportion of it we will carry forward in the next module, thank you so much.

Acknowledgement

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