Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology-Part-1

Module -32

by
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Hello and welcome to this manufacturing process technology part 1, module 32.

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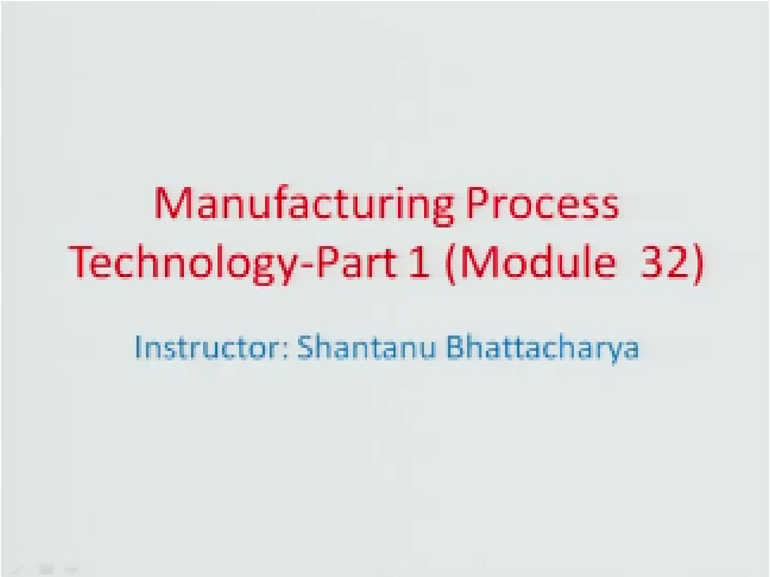

Manufacturing Process Technology-Part 1 (Module 32)

Instructor: Shantanu Bhattacharya

In this last module we were talking about how to design and place a riser, and in context of that we had started doing a numerical problem.

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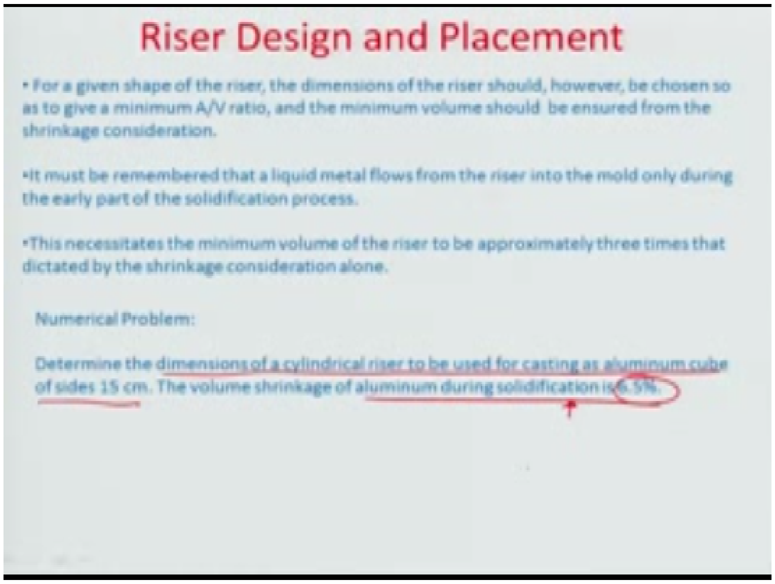

Riser Design and Placement

- For a given shape of the riser, the dimensions of the riser should, however, be chosen so as to give a minimum A/V ratio, and the minimum volume should be ensured from the shrinkage consideration.
- It must be remembered that a liquid metal flows from the riser into the mold only during the early part of the solidification process.
- This necessitates the minimum volume of the riser to be approximately three times that dictated by the shrinkage consideration alone.

Numerical Problem:

Determine the dimensions of a cylindrical riser to be used for casting as aluminum cube of sides 15 cm. The volume shrinkage of aluminum during solidification is 6.5%.

Where we wanted to do the determine the dimensions of the cylindrical riser to be used for casting, as aluminum cube of sides 15cm. The volume shrinkage of aluminum during solidification was assume to be 6.5 %. And then we step by step we tried to figure out how to get the optimum V/A condition, corresponding to the solidification of the riser, time of solidification of the riser beam greater than the time of solidification of the actual melt, which is in the cast itself or the molding cavity itself.

So in that context we did a few things which I would like to just repeat for the sake of recall, before we go ahead into the finalization of the design.

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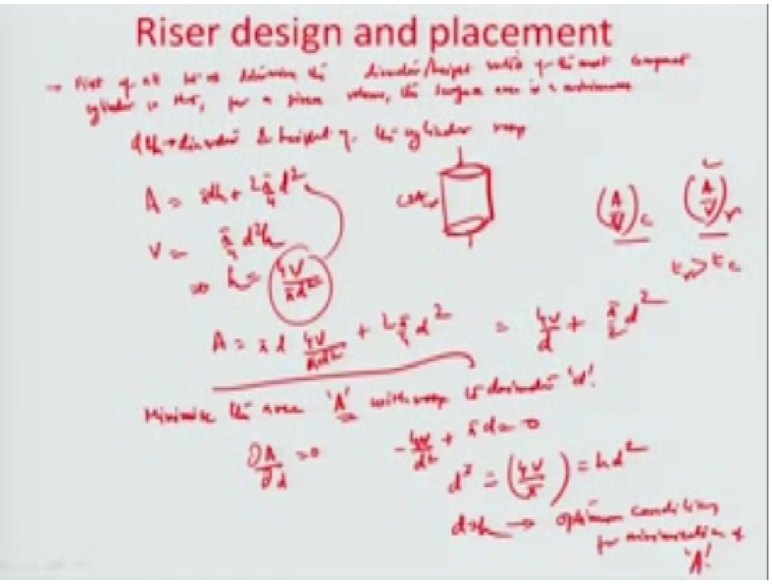

Riser design and placement

So first of all let us determine the diameter to height ratio, and this is what we did last module as well, of the most compact cylinder. So that for a given volume, the surface area is minimum, so if you assume let us say d and h to be the diameter and height of the cylinder respectively. Then we found out that the total area of surface of the cylinder would be equal to $\pi dh + 2\pi/4d^2$ obviously a cylinder has a curved surface as well as two flat surfaces on the top and bottom okay.

So this is the curved surface area; this is top surface area $\frac{\pi}{4d^2}$ and two surfaces together thus the area. Similarly the volume of the cylinder was obtained as π/4 d^2h and we made a formulation from which we found out what is h, in terms of volume so it was $\frac{4V}{\pi d^2}$ and we substitute it that back in to the area equation here, so that we were left with π d times of the value of h which is $\frac{4V}{\pi d^2} + \frac{2\pi}{4d^2}$.

So that is how we obtain the final area, this was $\frac{4V}{d} + \frac{\pi}{2d^2}$, if you further recall we tried to minimize the area with respect to the varying diameter meaning thereby that the whole goal here is that the volume, the A/V ratio for the cast, vis a vis is the A/V ratio for the riser needs to be calculated. So here for the example in this particular case, because of the cylinder riser we are just trying to calibrate what is the A/V ratio for corresponding to the optimum heat transfer condition.

So finally, the time of solidification of the riser should be greater in value than the time of solidification of the cast that was the final condition, that we wanted to sort of you know apply in this particular case. So you minimize the area here and from that we use the derivative of the A with the respect to d and equal to zero, and we obtain a condition, which was $\frac{4V}{d^2}+\pi d=0$ or $d^3=\frac{4V}{\pi}$, so that was what the condition was in this particular case.

We already know $\frac{4V}{\pi}$ was actually equal to hd^2, so therefore d=h was considered to be the optimum condition for minimization of A with respect to the B.

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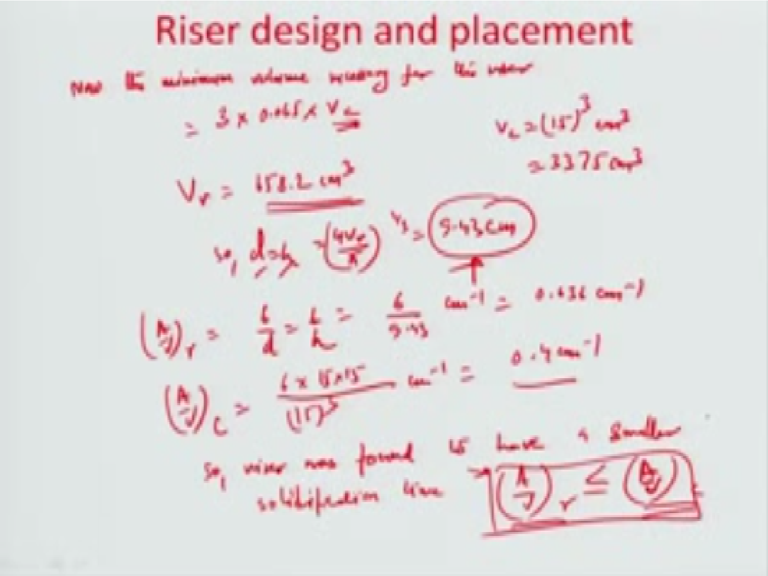

Riser design and placement

Now the minimum volume necessary for the riser

$= 3 \times 0.065 \times V_c$

$V_c = (15)^3 \text{ cm}^3$

$= 3375 \text{ cm}^3$

$V_r = 658.2 \text{ cm}^3$

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

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

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

So, riser was found to have a smaller solidification time

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

So with that we calculated the minimum volume, necessary for the riser, which was actually 6.5 times the volume of the cast, but 3 times of that because the 3 is the factor of safety as I discussed it earlier. So V_c is the cast volume, in this particular case Vc is nothing but 15^{3}cm^3 that is 3375 cm^3, the premise is that you want to cast the aluminum cube of the side 15cm. So with this kind of Vc we could obtain the volume of the riser here, to be equal to 658.2 cm^3.

Further we obtain the d=h as $\left(\frac{4Vr}{\pi}\right)^{1/3}$ and that was corresponding to 9.43 cm, which is equal to diameter of the height of the particular cylinder, riser cylindrical riser and then we calculated, A/V for the riser which is 6/d or 6/h whatever you may call, in this particular cases 6/9.43 cm^{-1} which is 0.633 cm^{-1}. Similarly we calculated that of the cast is A/V cast equal to the 6 S^2 surface area divided by the volume of the particular cube cm^{-1} this came out to be 0.4 cm^{-1}.

So the riser was found to have smaller solidification time, and it would not simply meet the condition that area by volume for the riser, less than or equal to area by the volume for the solidification time okay of the cast. So we have to do a force fit and we tried to that by forcing the volume by area ratio behaved in this relationship, so that the time of solidification of the riser which is actually proportional to the volume by area of the riser.

So in that case the time of solidification should be, the riser should be more than the time of solidification of the casting.

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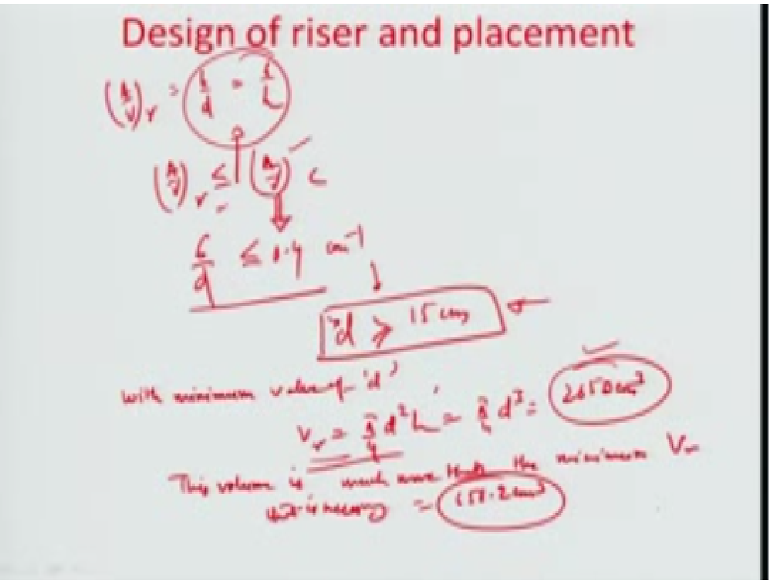

Design of riser and placement

$\left(\frac{A}{V}\right)_r = \boxed{\frac{6}{d} = \frac{6}{L}}$

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

$\frac{6}{d} \le 0.4 \text{ cm}^{-1}$

$\boxed{d \geq 15 \text{ cm}}$

with minimum value of 'd'

$V_r = \frac{\pi}{4} d^2 L = \frac{\pi}{4} d^3 = \boxed{2650 \text{ cm}^3}$

This volume is much more than the minimum V_r that is necessary $= \boxed{157.2 \text{ cm}^3}$

So when we force fit this condition we already have formulated, the area by volume for the riser, as 6/d or 6/h which was actually calculated earlier, but now we are to consider the new dimensions, d and h which would satisfy the condition A/V of the riser, less than or equal to A/V of the casting. So the A/V of the casting as earlier been calculated to 0.4, and so we simply have the force fitted condition as 6/d is greater or less than equal to 0.4 cm^{-1}.

And otherwise d is greater than or equal to 15cm. So this would be value for the d for which corresponding to which the area by volume of the cast would at least be equal to that of the area by volume of the riser. So condition would be obeyed in one sense, currently both of them equal solidification times. And now let us actually see that which this kind of diameter what is going to be the kind of volume that we need or is it going to be again facing to be 6.5% requirement that we have.

So with minimum value of d the volume of the riser simply now become $\pi /4d^2h$ or in this particular case $\pi /4d^3$ which is 2650 cm^3. Now this volume, is much more than the minimum volume of the riser that is necessary. And in that case we already seen that volume is actually equal to 6.5% and 3 times of that is amounting to about 658.2 cm^3. So obviously this value of 2650 cm^3 is much higher, in comparison to the volume that is necessary.

So on one hand with the diameter equivalent to height optimum condition we are getting a riser volume which above the requirement, so which we are wasting metal this way, and that we should not be allowed to do. So we consider to the top riser, and see what happens in that particular case okay.

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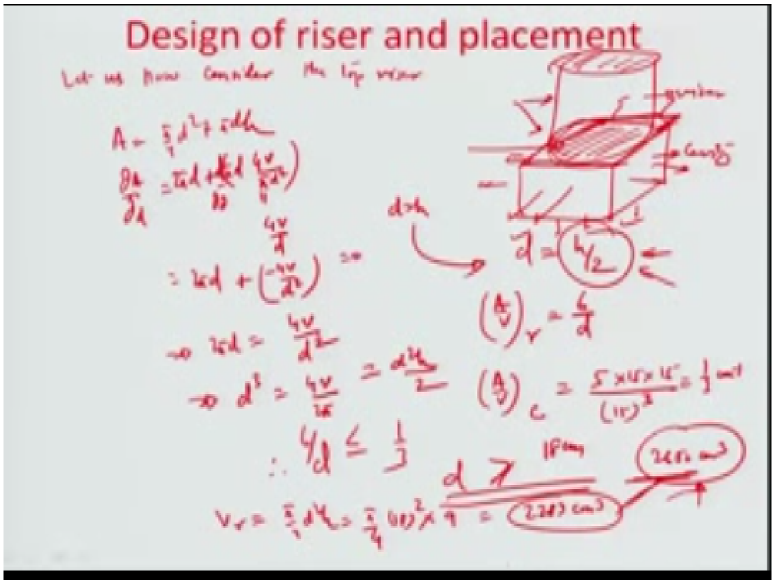

Design of riser and placement

Let us now consider the top riser

So let us now consider the top riser that means you have the cube right about here and on the top of it you have the cylindrical riser sitting of the top of this particular cube, this is the riser, this is the cavity. So now what effectively would happen is that the area of this cylinder or area of the riser become little different, the area now becomes equal to only $\pi\, dh + \frac{\pi}{4d^2}$ okay, that is the curved surface area as well as one of this area and other area being same as the area of the top of the cast.

So it is a common face you can say, so we do not consider that as the area anymore through which heat transfer would take place okay. So in that even now if I do the dA/dd, so we get twice π d plus now we have to substitute for h here, and h was substituted earlier as $4V/\pi d^2$ and effectively this was turned out 4v/d. So in this particular case this comes out to be

$$2\pi d + \left(\frac{-4V}{d^2}\right)$$ okay.

And that is equaled to zero for the optimum condition, so in this particular case the optimum condition becomes equal to twice $2\pi d = \left(\frac{4V}{d^2}\right)$. And the way that we can think of this is that the d^3 becomes equal to $4V/2\pi$, and $4V/\pi$ is already known to be d^2h, so it is $d^2/2$. And therefore, the optimum condition here becomes equal to d=h/2 okay. So just because of this area being removed, because it is no longer a heat transfer phase, the optimum condition changes d=h earlier d=h/2 as in this present case.

So in this particular context if we wanted to sort of calculate again the area/volume of the riser, so the area/volume of the riser still remains same 6/d okay. And the volume, the relationship that we have for the optimum area is d=h/2, so with the large top riser V^3 loses it top surface for purpose of heat dissipation and hence if I now calculate what is the area by the volume of the cast this becomes equal to again instead of the 6 faces that we had earlier.

This phase now no longer is a heat transfer face okay, because there is liquid metal, on the top of it, and so the other phases or all responsible for the all the heat transfer although there is going to be some heat transfer depending on if the temperature of the metal is little different here, but we consider that very negligible, because again the temperature of the metal in the riser as well in the cast before the solidification is happened more or less in the same temperature zone unless heat transfer takes place from the other phases etc, okay.

So her for example, then the area by the volume of the casting would become 1/3 cm^{-1} and we therefore now have the 6/d area by the volume of the riser to be less than or equal to this 1/3 cm^{-1} so diameter greater than or equal to 18 cm. So the riser volume with minimum diameter now is given as $\pi/4d^2h$ in this particular case it would $\pi/4$ times of square of 18, times of h which is 18/2 because of the optimum condition which has been heat upon here.

So that becomes equal to 2289 cm^3 which is very close and reasonable to the value that have been earlier obtained as 2650 cm^3, the minimum riser volume that is necessary. So we have saving lot of metal here, if we do this secondary transient where we assume this top riser with the common phase. And if you slightly change the design of the riser now you can see that just by eliminating one interfacial area from the cast as well as the riser you are left with the situation where with minimum amount of the volume you can just make it to be sufficient to accommodate for the shrinkage volume of the casting and you can also do the risering.

So that is how you have to design the riser geometry as well as the placement of the riser with the respected to the cast surface.

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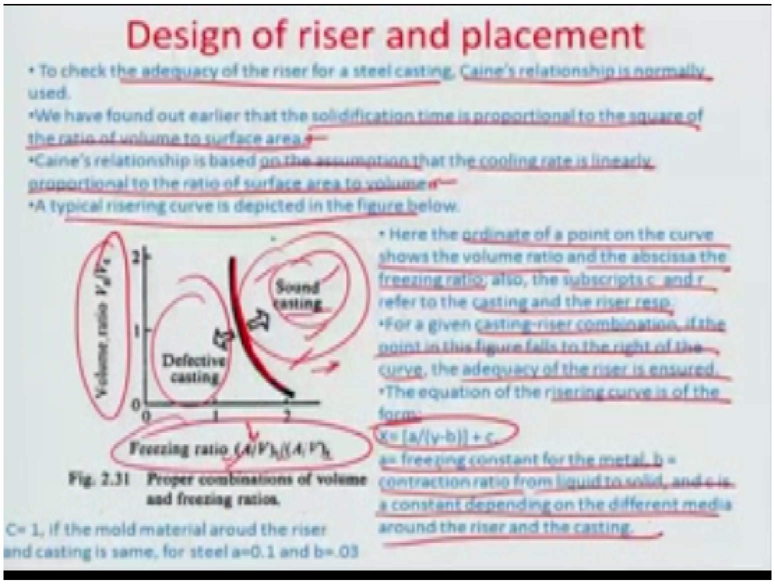

Design of riser and placement

- To check the adequacy of the riser for a steel casting, Caine's relationship is normally used.
- We have found out earlier that the solidification time is proportional to the square of the ratio of volume to surface area.
- Caine's relationship is based on the assumption that the cooling rate is linearly proportional to the ratio of surface area to volume.
- A typical risering curve is depicted in the figure below.

Fig. 2.31 Proper combinations of volume and freezing ratios.

C= 1, if the mold material aroud the riser and casting is same, for steel a=0.1 and b=.03

- Here the ordinate of a point on the curve shows the volume ratio and the abscissa the freezing ratio; also, the subscripts c and r refer to the casting and the riser resp.
- For a given casting-riser combination, if the point in this figure falls to the right of the curve, the adequacy of the riser is ensured.
- The equation of the risering curve is of the form:

x= [a/(y-b)] + c

a= freezing constant for the metal, b = contraction ratio from liquid to solid, and c is a constant depending on the different media around the riser and the casting.

So to check the adequacy of the riser for a steal casting normally people use this Caine's relationship. So we have found out earlier that the solidification time is propositional do the square of the ratio of volume to surface area. So the Caine's relationship is based on the assumption that the cooling rate is linearly propositionally to the ratio of the surface area to volume.

And based on this they draw this typical risering curve which is depicted here, so this is the volume ratio of the riser to the cast, and this is the freezing ratio of the area by volume of the cast with respect by area of the riser and what you can see here is that anything of the right of this particular line drawn you known separating the sound from the defective casting are all sound cast, and to the left whenever the freezing ratio falls down beyond this particular line okay, for a certain volume ratio it becomes a defective casting.

So the ordinate of the point of the curve shows the volume ratio and the abscissa the freezing ratio, also the subscript c and r are referring to casting and riser. So I think you have mostly understood, from all my notation which I done earlier. And for a given casting riser combination if the point on the figure falls to the right of the curve the adequacy of the riser is ensured. So we want to design for all those freezing ratios which are towards the higher side here right about in this particular region okay.

And avoid all the freezing ratios where the casting may be render defective, and equation of the risering curve is of the form x=a/(y-b)+c where A is the freezing constant for the metal, B is equal to the contraction ratio from liquid to solid, and C is the constant depending on the different media around the riser and the casting. So with this I like to end the module and design of the riser and placement.

And this also complete incidentally this section in castings. Next section in the next module that we will take up is the metal to metal conventional machining processes, for now I like to good bye thank you.

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