Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology- Part- 1

Module-28

By
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Hello and welcome to this manufacturing process technology part 1 module 28.

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We were talking about thermal resistance.

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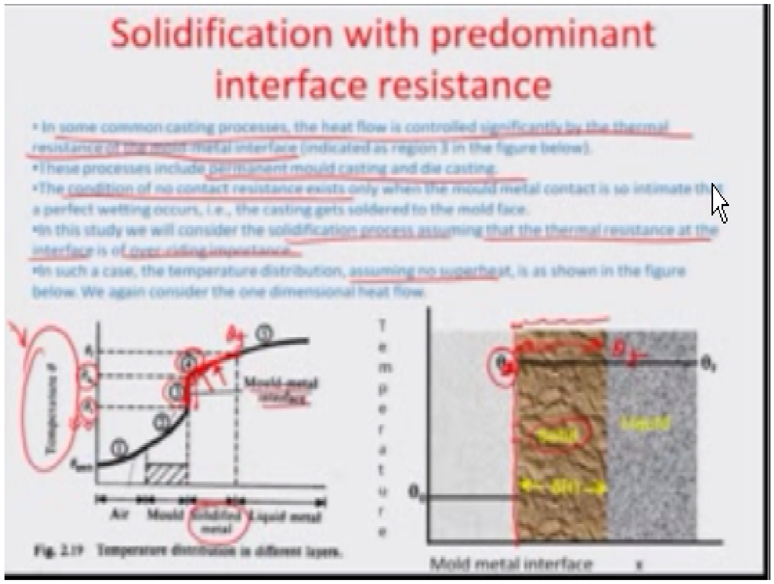

In case the metal boundary with the mold is a non-contact boundary or it has some kind of a semi form boundary so in some common casting processes the heat flow is controlled significantly by the thermal resistance of the mold metal interface so as I told you that temperature is basically the voltage equivalent and the thermal resistance would be the reason because of which the heat flow would actually happen.

So in this particular case as indicated in region 3 this is the mold metal interface okay and in normally permanent mold casting and die casting you know there is a control so there is there seldom that there is a condition of no contact resistance which would exist okay the reason being that the metal is you know it really depends on how the metal is blending itself on the boundary to the mold wall if.

The perfect wedding conditions are there and the metal is supposed to perfectly wet the mold wall then there is no formulation of any contact resistance between the heat transfer process that happens between the solidified front of the metal and the mold wall but if supposing the perfect wedding conditions are not there which is normally the case in you know in real situations that the metal may not be perfectly wetting the surface whether it is a die cast with whether it is like an aluminum mold you know metal mold or it is a sand mold there is always going to be a wet ability issues of that particular surface.

It is really a function of the surface energy of the liquid metal which comes across the surface as well as the surface itself and so the there may be a film which is formulated and you know that's why there is a change in the temperature you can see from θ_S to θS_1 because of the formulation of this field okay so this temperature change is purely because of a very thin film which is formulated between let us say the solid here okay and the you know sand here so there is some kind of a thin film here because of wettability okay or improper wet ability of the metal and this is mostly an air film okay.

So in this study we will consider the solidification process assuming the thermal resistance of the interface and will give some overriding importance to this resistance in comparison to the earlier assumption that the point 2 is same as point 4 okay. so there is always this particular resistance because of which there is temperature drop so in such a case the temperature distribution assuming no superheat is kind of shown here okay we again consider one-dimensional heat flow problem and try to solve this.

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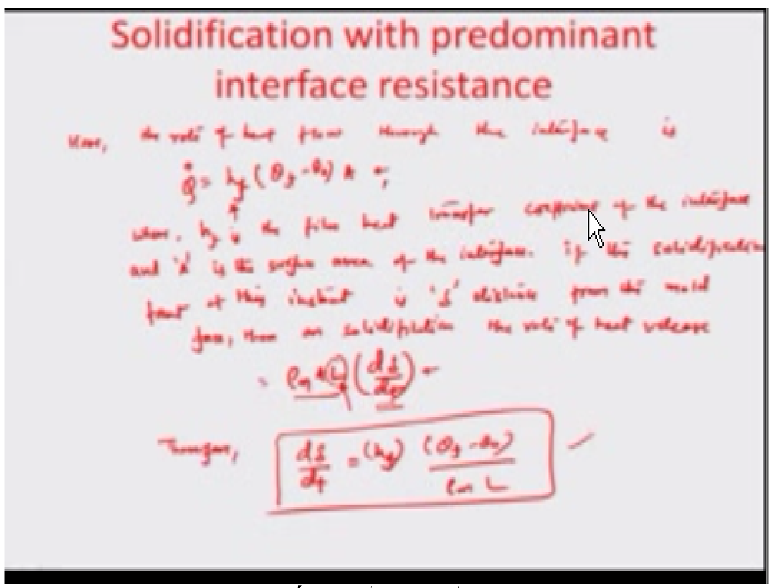

$$\dot{Q} = h_f\left(\theta_f - \theta_0\right) A$$

$$Rate\ of\ heat\ released = \rho_m A L \frac{d\delta}{dt}$$

$$\frac{d\delta}{dt} = \frac{h_f\left(\theta_f - \theta_0\right)}{\rho_m L}$$

$$\delta\left(t\right) = \frac{h_f\left(\theta_f - \theta_0\right)}{\rho_m L} t$$

$$t_s = \frac{\rho_m L}{h_f\left(\theta_f - \theta_0\right)} \frac{V}{A}$$

So our case here is that here the rate of heat flow through the interface is given as Q dot equals h_f .now this is the heat transfer coefficient for the thin film which is formulated here times of θf $-\theta_0$ times A i.e. $\dot{Q}=h_f(\theta_f-\theta_0)$. let us just write this down. h_f is the film heat transfer coefficient of the interface and A is the surface area of the interface okay so if the solidification front at this instant is delta distance from the mold phase then on solidification the rate of heat release can be assumed to be ρ_m AL dδ / dt.

$$\dot{Q}=h_f(\theta_f-\theta_0)A$$
$$Rate\,of\,heat\,released=\rho_m AL\frac{d\delta}{dt}$$

So we can think of it that there is no difference between the pouring and the freezing temperature and that the latent heat normally is that because of the only the conversion the state conversion so obviously the rate at which the solidification front is proceeding at time instants T is this dδ by dt. so the total amount of volume which solve if I is a as function of time is a dδ / dt and this volume multiplied by the density is basically giving the rate of mass solid mass formation.

So $\rho_m AL\frac{d\delta}{dt}$ is basically the rate of mass formation and per unit mass there is L kilo Joules or joules of heat energy which is generated as a heat of solidification okay. so therefore if I just equate the total amount of energy that is released from the solidifying mass and the energy that is absorbed or conducted through the heat the thin film which is formulated between the solidified mass in the mould.

Then we have the equation dδ / dt equals the film heat transfer coefficient $\frac{d\delta}{dt}=\frac{h_f(\theta_f-\theta_0)}{\rho_m L}$

okay. So this is how you will define the rate of movement of the solidification front so I can actually try to find out the δ as a function of time.

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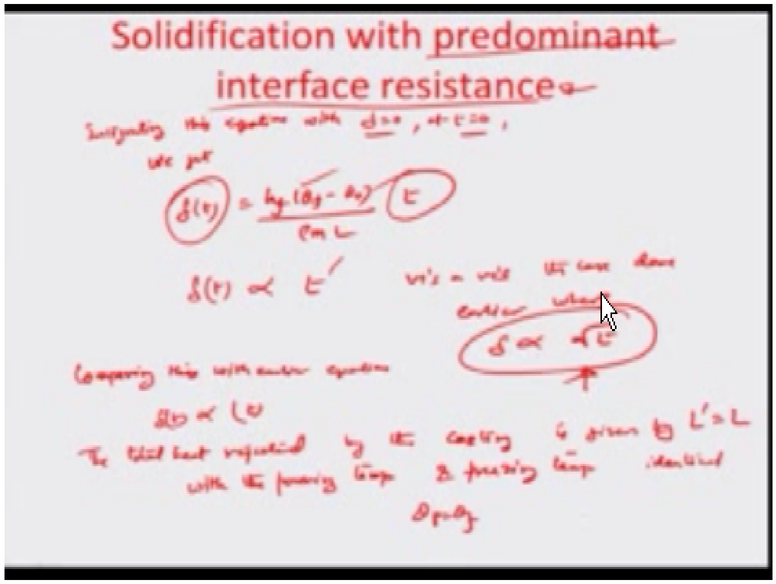

So integrating this equation with let us say δ=0 at time t=0 there was no solidification front produced at the initial time incidence of time when the pouring was happening so we get

$\delta(t) = \frac{h_f(\theta_f - \theta_0)}{\rho_m L} t$. so if I compare this equation with the earlier example we see that the depth of solidification increases linearly here with respect to the time earlier it was proportional to square root of the time.

$$t_s = \frac{\rho_m L}{h_f(\theta_f - \theta_0)} \frac{V}{A}$$

So the difference here is that the δ(t) is proportional to t vis-à-vis the case done earlier where δ was proportional to √t okay so this was the case when we assumed just complete heat transfer across the mold without any predominant interfacial resistance but here at the moment we have introduced the concept of a thin film because of wet ability issues between the metal and the mold you see that the time behavior at which this δ front is moving also changes.

So comparing this let us just write this down comparing this with earlier equation the $\delta(t)$ here is proportional to T okay. the total heat rejected by the casting is given by L dash equals L with the pouring temperature and freezing temperature identical that is $\theta_P = \theta_F$.

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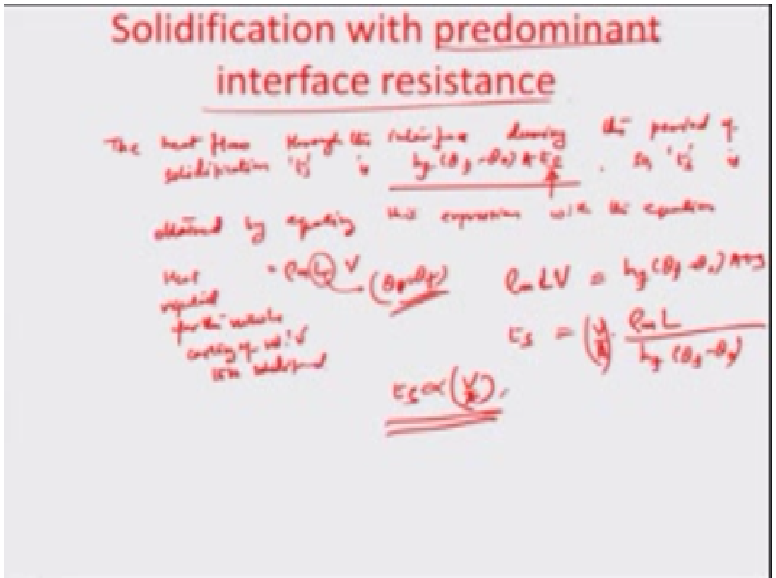

the heat flow through the interface during the period of solidification t_s is h_f * (θF-θ_0) * t_s .just replacing the value to the solidification time so t_s is obtained by equating the expression earlier.

So this expression with the with the equation ρm LV which is the total amount of heat rejected for the whole casting of volume V to be solidified okay so therefore we just equate this ρm LV with respect to h_f * (θF-θ_0) * At_s and so the t_s here comes out to be equal to ρm L. Also we just assumed the pouring and freezing temperatures to be same here please understand otherwise this would be L'. I said as well as had been illustrated earlier in our earlier lectures.

So this becomes equal to ρm times of L divided by h_f * (θF-θ_0) times of volume by area okay so in this case the volume by area is really proportional to the time t_s so this is a completely different case all together because in the earlier case it was $(V/A)^2$ that was getting proportional to the t_s so we will have to really consider the various aspects and you will see that the heat transfer or that solidification time depends quite a bit on this different aspects related to whether the film can be formulated at the surface wetting the whole surface so on so forth.

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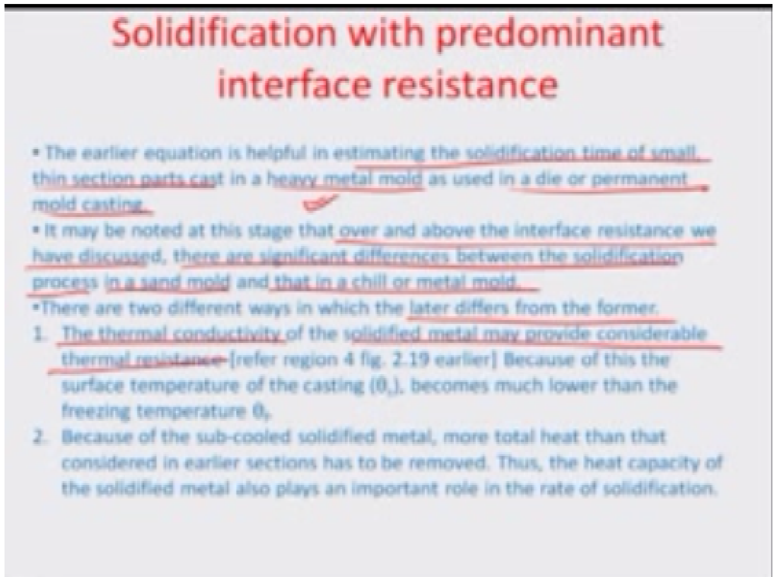

So the earlier equation is helpful in estimating the solidification time of small thin section podcasts in heavy metal mold as is used in die or permanent mold casting cases. there is obviously a contact angle difference between the way that wetting would happen at the surface of these heavy metal molds with respect to the liquid metal so it may be noted at this stage that over and above the interfacial resistance we have discussed.

There are significant differences between solidification process in a sand mold and that in a chill or a metal mold and there are two different ways in which the later differs from the former the thermal conductivity of the solid defied metal may provide considerable thermal resistance let us refer to this region of the curve that we had earlier done here region 4 okay. so this is corresponding to the thermal conductivity based you know of the solidified metal itself.

This is the solidified metal part so there would be a obviously a drop in temperature from the inner boundary to the outer boundary okay because of the resistance of the solidified part of the metal. so because of this the surface temperature of the casting θ_S which is somewhere here okay which is facing the mold becomes much lower in comparison to the freezing temperature. so therefore there is a solid boundary which has been formulated and a film.

So the temperature here may be θ freezing okay because there is a solid liquid interface but here it may be something like θ_S which means that this is after the thermal resistance of the solid metal as well as the air film okay so the temperature is lower in comparison to the θ_F so because of the sub-cooled solidified metal more heat than that considered in earlier section has to be removed as the heat capacity of the solid fired metal also plays an important role in the rate of the solidification process okay.

So that is how the thermal properties of the solicitation metal is important sometimes an estimation of the mold okay so in the interest of time we will now close this module but then in the next model you will be able to formulate you know solidification with constant casting surface temperature there is something that we would like to see including all these different resistances that we have just talked about so that can be it can be more towards the realistic estimation of the solidification time so with this I would like to close this particular module thank you so much.

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