Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology – Part- 1

Module- 16

by
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Hello and welcome to this manufacturing process technology part 1 module 16 we are going to talk about Furnaces.

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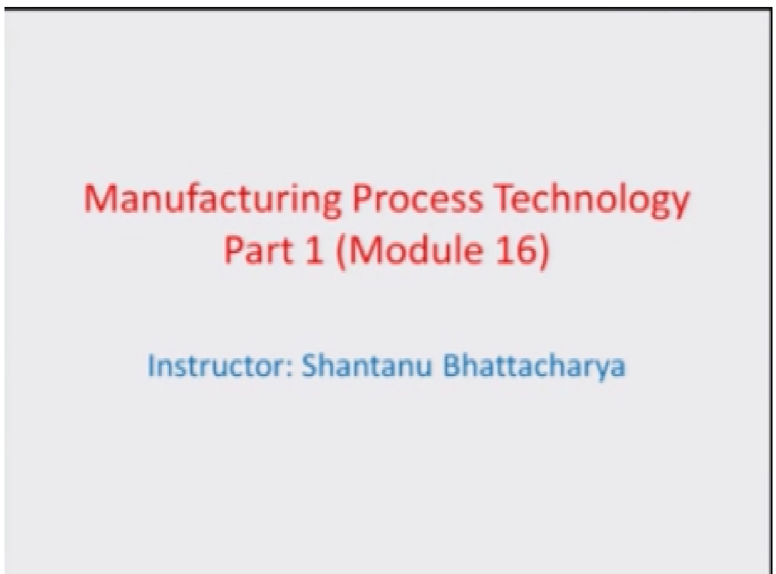

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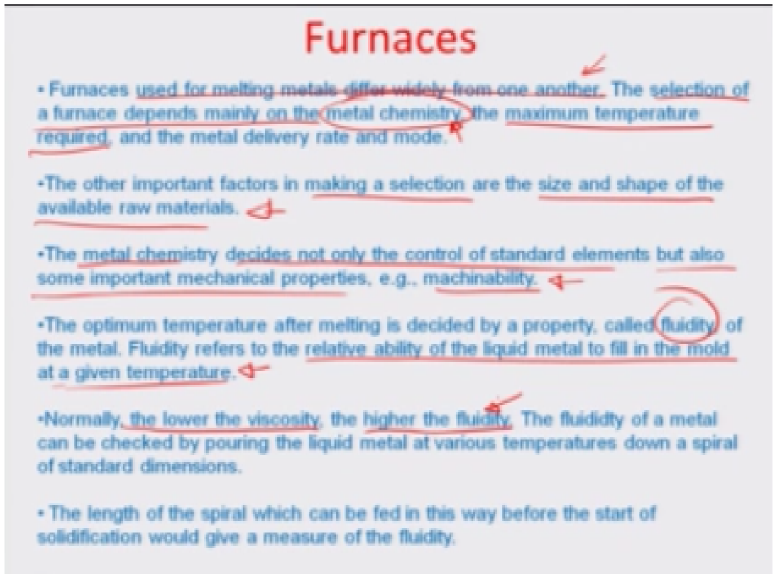

Today and also a little bit of design for the different castings so furnaces use for melting metals the kind of differ widely from one another there may be for example a induction furnaces, there may be cupola furnaces there also may be side blow converter, so depending on the heat transfer modes or depending on how you basically apply energy so that you can melt the material, you can categorize these various different types the selection of a furnace really depends on mainly the metal chemistry which is being used.

And also the maximum temperature that is needed and some cases you need to super heat the material before pouring into the mold so that it can reach longer distances and fill up that serially plays to molds in a gated pattern or something like that so in that event the, the overall temperature has to be much have the freezing temperature of the material and that is called super heat, so not all furnaces can superheat or boil the material of you know because there is some kind of a rate of heating limitation.

And also the maximum temperature limitation of these furnaces. so the other important factor in making a selection are the size and shape of the available raw materials, and the metal chemistry also decided not at all the control of standard elements but also some important mechanical properties like machinability, so therefore some furnaces is more prone to hydrogen attack and nitrogen attack and they may not be selected because the material chemistry there which takes place because of hydrocarbons, oil ,dampness in the furnace gases etc.

May not be amenable to develop good machinability or the material .so there is a very important term called fluidity of the material when we talk about melting the material and the is basically the optimum temperature after melting which decides what is the overall fluidity level and fluidity is a requirement basically, so the fluidity can be referred to as the relative ability of the liquid metal is filled in the mold at the given temperature and normally if the viscosity of the fluid metal is lower than the fluidity is higher you know and vice-versa.

So if it is thick metal slurry which is or thick metal which is moving thick metal liquid or if it is a thinner metal liquid which is viscosity falls down, because the temperature so thinner would move faster obviously. so there are many ways to measure this soluble this fluidity one of the typical raises to use a spiral channel and see at you know gravity feed how much distance of this spiral can be covered by this metal before getting solidified, and that can be good idea of what is the fluidity of the pouring material or pouring metal. so obviously you need a case where you have sufficiently high fluidity so that the overall reach from, the pouring base and to the runner all to the gate of the metal cavity or cavities for example in gated patterns as I showed you before.

That has to be again okay. so the fluidity always checked before you know doing a casting or pouring into a casting, so that you can see whether the input material the output material that you are having out of the furnaces of the correct you know fluidity or correct level of requirements imposed by the molds.

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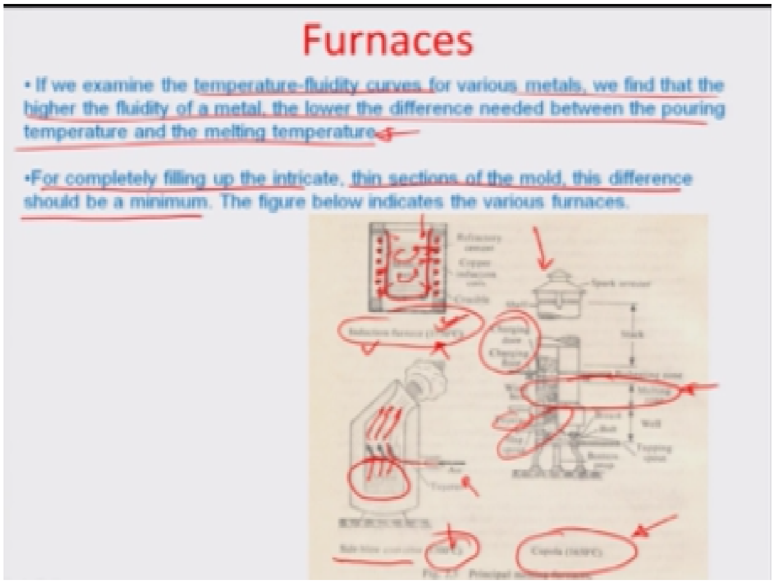

so if we examine the temperature fluidity curves for various metals we find the higher the fluidity of a metal the lower the difference needed between the pouring temperature and the melting temperature okay, so obviously if the viscosity of the metal at liquid state is lower than you will need this difference between pouring and melting temperature to be more or less minimal value, was obviously as soon as it is going to come into the melt it is going to be flowable the viscosity is what I may not add any super heat.

To make it make the viscosity change with temperature for completely filling up the intricate thin sections of the mold this is the difference should be minimum so that you can go everywhere in the mold, and some of the furnaces or shown here which can do this job for example induction furnace can add heat up to a 1750^{0}C and the basic principle here is a induction coil it is copper induction coil where there is a you know magnetic field which is generated because of a flow of current within this coil.

And this magnetic field induces a small local current show within the material here and this currents are also known as eddy currents so this early currents should be able to melt the material completely, by adding I^2R T intense heating and this is by the by a non contact mode, you do not have any problems of temperature gradient from the wall to the center of the furnaces you can see here so you heating through induction, and you are heating the central core of the material until it hits the melting point.

And you can go to a temperature has high as about 1750^0C so typically the metal is kept in the crucible so the crucible sustain the high temperature conditions, where the metal gets into liquid state there is refractory cement which holds this crushable in place so that you know the cement is able to sort of expand and hold the strength at a higher temperature so whatever outflow of heat happens from the mold and metal to the furnace can be sort of protected or one hand and another the strength can be kept intact so that this kept design variance size of shape or does not go down you know, so that is all the induction furnaces obviously there is a side blow converter which can heat up the metal up to 1700^0C, so here the metal is seen the lower pocket of so the metal here is in the lower pocket right about here is you can see and this A theory is basically humping in the hot air, in do the systems so that there is a heat transfer between this blow by and the metal which is there and the gases kind of escape.

From the tope side the furnace so these side blow converters can be heated up to about 1700^0C there are there is a famous cupola furnace which can go up to slightly lower about 1650^0C also a temperature which has a you can see this is the orientation of a cupola furnace, so this right here is the melting zone for example and the you know the again the theories are able to sent hot here throughout this melt where there is slightly into form of air and also which can be loaded and slack can be extracted.

So we were charging door through which the main charge flows into the cupola furnace and there is actually a slaking spout here, which can help you to clean the metal slack, so that is how furnaces is are kind of designed and that is now look at the main important issue of how to design a particular casting okay when we talk about filling times or you know solidification after the full cavity has been filled with metal etc.

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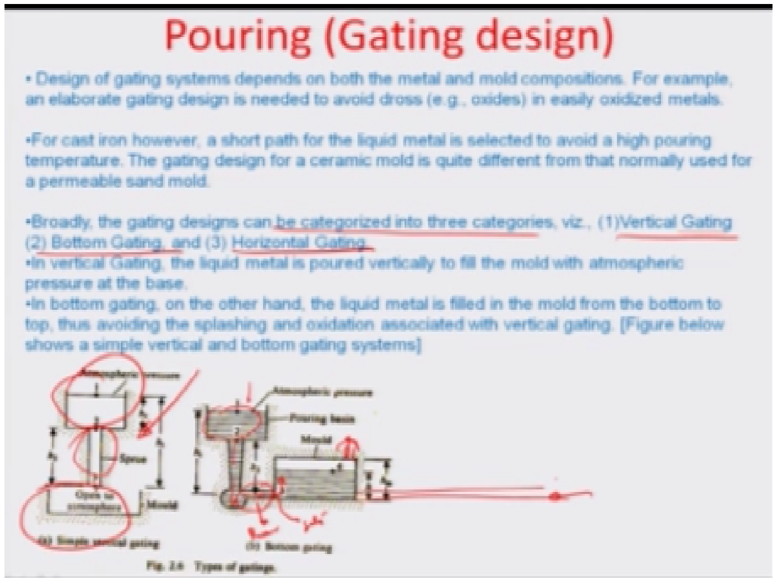

So let us first go discuss the gating design in a pouring process in create details so what is gating, so you know that after the melt is melt and poured and injected into a mold cavity gating design kind of ensures the distribution of the metal in the mold cavity or a proper rate without excessive temperature loss turbulence, and entrapping gases and slacks so obviously one thing that really comes into picture here is that the liquid metal being very heavy and poured very carefully and very slowly because it should not be able to damage by its own weight.

The sand mold which has been made and each otherwise is not a very high strength system okay so it is poured very slowly so as I was just discussing the liquid metal if it is poured very slowly because you know fast metal form read to is damage of the mold, the time overall which the metal mold to take to fill up the mold will be very high and so solidification may start happening even before the liquid metal reaches the mold cavity, so there has to be a proper design and this is actually a pressure driven flow.

Because there is going to be a pouring base at some potential energy and the metal is going to be in liquid state, so it could not comes down like a you know from an over head tank and it fills up the casting space you know the molding or the mold cavity and for filling it up it is through a channel that it fills up so it is a essentially a piping base a network which would allow the liquid metal to go into the mold cavity, so there are many issue here one is obviously the gas solubility because if it is if supposing I heat.

Or superheat the material too much then there may be a problem of gas solubility you know because it may cause a overall faulty metal structures so even that is also not allowed on the other hand if the liquid metal is poured slowly the time taken to fill up the mold can be rather long and solidification may start and you know somehow we have to develop a intermediate solution so that the liquid does not impinge the cast and at the same time, it has enough time for it flow into the material and it does not also damage the material structure as such by having minimum gas solubility.

So for doing that let us investigate what kind of gating designs are normally available. so normally there are three different kind of gating designs one is a vertical gating system as you can see right here, so this is the pouring basin and this part is the we can say it is a sprue or you know it can be some kind of a down draft of the material.

And it directly enters into the mold cavity which is at the bottom here at a different height. so this is a simple vertical gating system similarly you have a bottom gating option where you have you know the mold being filled up side down from the bottom to the top okay so on the other side you can how will you open a riser here to see the materials comes and fills the whole cavity or not, and there is atmospheric pressure on one side which actually gives this metal liquid metal in the pouring rise to flow.

In a down vertically manner and going into this region which is actually known as the runner region okay and this right here is a gate region, so these are the two different kind of gating systems obviously can have horizontally gating as well when you can actually not bother about using gravity, but actually do pressure like casting by introducing metal at a certain pressure liquid metal at a certain pressure, so you can become a high yield process okay so let us now talk about some aspects related to.

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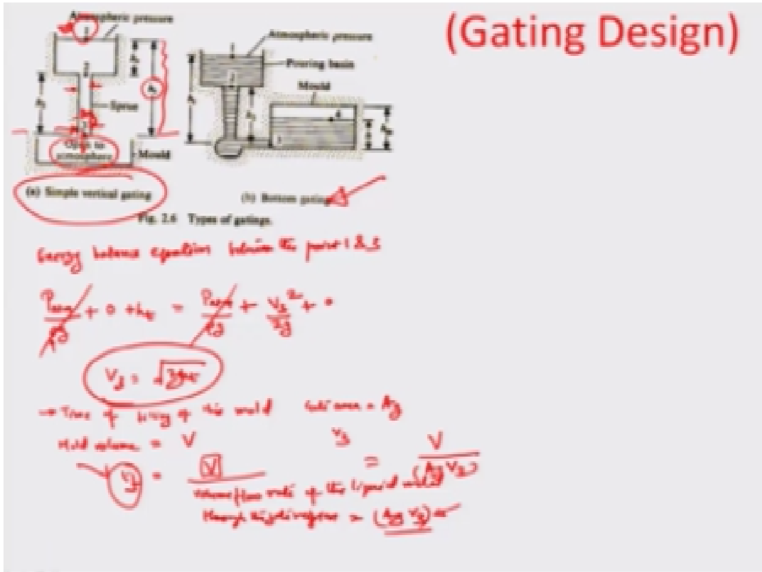

How we can do this gating design so in the simple vertical gating design supposing we are talking about the point 1 and 3, so if I want to use the energy balance equation between the point 1 and 3 in this particular case I can have the point 1 at an atmospheric pressure so let us write P atmosphere here divided by the rho g so that is the pressure had this is the density of the liquid material this is acceleration to gravity plus the velocity had at point 1 which is assume to be 0 because the velocity is assumed.

At the top of this particular horizontal sorry vertical simple vertical gating design to be 0 so the velocity here it is 0 plus the potential head which is actually the height HT over and above the mold surface as you can see right here, this is HT okay and this becomes equal to the you know the pressure which is there at the point 3 of the material okay so basically the mold we are assuming os open to the atmospheric pressure, so obviously the pressure at 3 also at the end of this sprue would also be atmospheric pressure.

So let say P atmosphere here divided by ∂g plus the velocity at point 3 and I assume this velocity to be V3 of the liquid metal, so obviously the velocity has would come out to be $V3^2$ / 2g and then you have the potential head in this particular case, which is actually = 0 because if I assume this to be the datum line so we are add the bottom so we assume this to be 0 here, and so that is how you can actually envision this equation so this gets cancelled of and you are left with V3 = √ 2ghT so that is the velocity at the end of this sprue. $\frac{P_{atm}}{\rho g}+0+h_T=\frac{P_{atm}}{\rho g}+\frac{v_3^2}{2g}+0$.

$v_3 = \sqrt{2 g h_T}$ Write here in the piping design that you are looking at here for doing the simple aiding system. so let us now calculate the time assuming the velocity at 3 is V3. let us calculate time of filing of this mold so obviously if the mod volume that we are considering is V here and Tf is the time of filling so the Tf would become = V divided by the gate area times of the velocity, so if I assume the gate area to be equal to be A_g which is the area write about here let me just rub all this off to tell you about exactly which region is the gate. $t_f = \frac{V}{A_g v_3}$

So this right here is the gate region through which the material is entering into the mold cavity and so area here is Ag cross sectional area is Ag, so supposing there is a diameter of this particular tube, also Ag should be equal to $\pi d^2/4$ okay, so velocity is V3, gate area is obviously Ag, so the amount of time which is needed to fill is the total volume of the mold V divided by the volume flow rate of the liquid molten metal through the gate .so volume flow rate of the liquid metal through the gate region and here the volume flow rate of the liquid metal through the gate region is Ag times of V3 .so the area of cross section times of velocity which is the distance per unit time, so that is an idea of how we calculating the Tf so therefore the total time of filling is the total volume of the mold times of the gate area times of the gate velocity V3 so that is how you can calculate Tf and you have to now try to balance that Tf should be at least equal to time where solidification just is does not happen or does not start to happen.

So it is kind of you know quite simple in way this is simplistic expression although in real sense there will be many more factors like friction and you know velocity of reduction because of friction etc. Particularly in the gated patterns of long kind that for illustrated in the earlier modules so having said that I think we will go to the next design which is actually the bottom gating system and look into how different this gating system is going to be, but in the interest of time I am going to close this module this will analysis will be carried on in the next module thank you.

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