Theory of Production Processes
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Lecture – 12
Gating System design: Pouring time calculation

Welcome to the lecture on gating system design. In this lecture, we are going to discuss about the pouring time calculation results. So, as we have discussed that the purpose of gating system is to ensure that the liquid metal once it is poured, it should move in the gating system; and in an optimum manner it should fill the cavity without minimum of turbulence, minimum of time taken also. Because as a time taken will be more, it will try to basically be colder and colder, so there may be defects related to that. And as the molten metal is flowing, so there are certain principles which are applied and these principles are basically related to the fluid flow because it is a fluid which is flowing. So, normal fluid flow principles apply in that.

So, principles of fluid flow for vertical and horizontal passages are used for calculating the pouring time of casting as well as it will give you the advanced warning for any undesirable turbulence and aspiration of mould gases. So, this is what is important to understand in case of gating system that; what are the basic principles. And because when we discuss about the gating system, the challenges which remain are in case of permeable moulds, if you have the permeable mould, and if the channel is not running full, in that case if during the passage somewhere the channel is not running full and if there is a condition generated where the pressure is less than that atmosphere then in that channel the atmospheric gases may enter and that may spoil the quality of cast particularly.

If the customer is prone to getting oxidized or it is a drowsy material, so that is how I mean that can be understood by reviewing the formulations for this fluid flow where you have the basically if you have two basic principle is there. Two important principle are there which are used that is related to fluid flow one is the law of continuity. So, as we know that the law of continuity tells that the mass is conserved.

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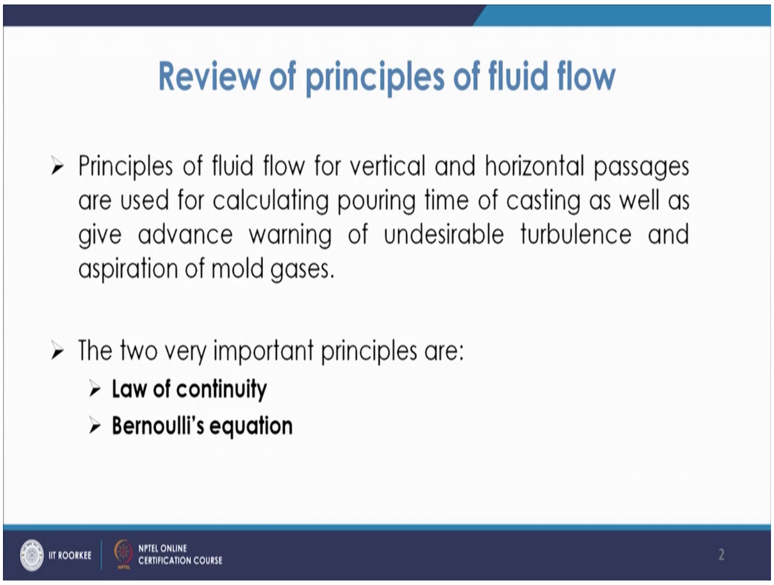

So, when you have any channel, so at two points, the conservation of mass should be a you know applicable. So, conservation of this mass is nothing but rho 1 A 1 V 1 is rho 2 A 2 V 2, so that is how this law of continuity holds good.

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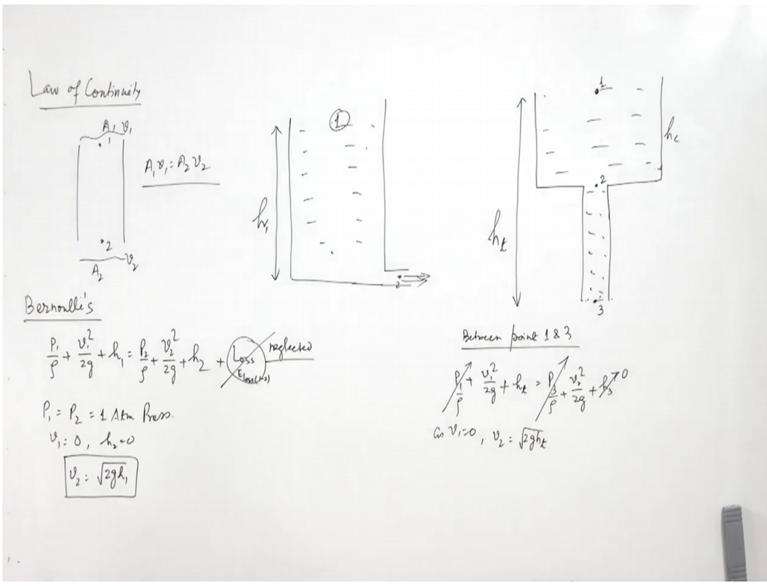

So, in that if the rho is basically rho is the density of fluid, A is the area of cross section of the channel and V 1, V is the velocity. So, if you have two points, so if you have two points then at one and two, so if the area is same if it is area is A 2 and this area is A 1 then A 1 V 1. So, this is V 1 and this is V 2. So, A 1 V 1 will be A 2 V 2. So, this is for incompressible fluid, but the fluid is incompressible fluid, its density is same, in that case this law of continuity is applied so that is one law of continuity.

Now, next is the Bernoulli's equation, which is nothing but the conservation of energy equation. So, Bernoulli's equation is used because in this case the fluid is passing from the pouring basin coming to sprue well then it is moving from there to the runner and then it is going to enter into the cavity through in gates. So, basically there are different heights, the potential head is decreasing. So, in the Bernoulli's equation, what we see that normally energy will be constant, so that is what the sum of the heads of the energies you have three kind of energy which is taken one is potential energy term, then you have the kinetic energy term then you have the pressure term pressure energy term.

So, basically what we see is that at these two places if you try to see the Bernoulli's equation, it tells that this energy will be basically constant. So, what that tells that tells that p 1 by rho plus V 1 square by 2 g plus h 1 it will be p 2 by rho plus V 2 square by 2 g plus h 2. So, that is what normally if you have two points then in that case the energy this term has to be same that is what the Bernoulli's equation tells. Now, in this case basically you may have the loss term, you may have the loss term in between because once it is coming from 1 to 2, there may be losses from 1 to 2.

So, this loss will be energy loss 1 to 2, but then we if we neglect it then in that because this loss will be based on so because it is passing through this path. So, this surface is not smooth, you will have the friction forces acting, you will have viscosity because of that there will be losses. So, this loss comes into picture, but then if we neglect them, in that case if we neglect it you will have this simplified expression that tells that how to find the velocity at different positions.

If suppose you take this position in that case, what we see is that if we look at these two places, if you have a container here, and then if this is full of water and this is 1 and this is 2. So, if from here this is what is flowing out, so in that case and if this height is h, so you can use the Bernoulli's theorem; and in that case this rule will this expression will be valid. Now, in this case this one is also open to atmosphere, and two from here also it is going into atmosphere. So, p 1 and p 2 they are open to atmosphere, so that is basically atmospheric pressure if you assume because if it is open to atmosphere you have one atmospheric pressure.

Now, here the fluid which is there this will be basically 0, so V 1 is 0. Similarly, you have this is as you can see h 1. So, if this is so, s 2 will be 0. So, you will have s 2 as 0, because this is a datum line, so you can take the h as 0. So, you will have s 2 as 0. So, you will have this 0, you will have this 0, this, this and this is cancelled. So, what we see is you say that you say V 2 is root 2 g and then h 1. So, using the Bernoulli's equation, you can see that when a liquid will be falling from a height of h, our height h 1 say or whatever it be, in that case the velocity which is attained when it is coming out of the orifice or nozzle in the case of casting, you will have here the sprue well or the level of the gate from where the metal will enter into the cavity. If it is have having you know potential head, this head is about h 1 or h t total head is as t in that case the velocity which you get it will be under root 2 g into height that is head height. So, this how this is how this Bernoulli's equation is used for finding.

So, this Bernoulli's equation basically this is applied at different places and then you can get certain conditions by which you can come to some cases like when we talk about the casting and in the cavity basically you will have the probability of having certain aspiration. So, we will discuss about the aspiration affect how this aspiration effect comes into picture. Let us say you have pouring basin and this is of height, this is height is at h e and this is height is h t. So, in this what happens in the case of pouring basin, the liquid metal will be here and then from there it will come through this is sprue, this is the vertical sprue and the liquid metal will be coming through this, and it is coming to this lower portion lau. Let us if this is the total height of h t and this is h e. Now, if you have the point as one, this is the point two, and this is point three.

Now, what happens that if you have to apply this Bernoulli's theorem between the points, so suppose you apply this Bernoulli's theorem between point 1 and 3, so between point 1 and 3. Now, if you apply that, so you will have p 1 plus V 1 square by 2 g plus h one. So, h one is nothing but h t and that will be equal to p 3. So, p 3 by p 1 by rho p 3 by rho plus V 2 square by 2 g plus h 3, so that is 0. Now, since this is open to atmosphere and this is also open to atmosphere from where the liquid metal is flowing, so this is also cancelled. Now, you will have V 1 at 0, so as V 1 is 0, because it is at the top surface the velocity is 0, so you will have V 2 as root 2 g ht. This is by is the simple application of this by applying the Bernoulli's theorem in between point 1 and 3.

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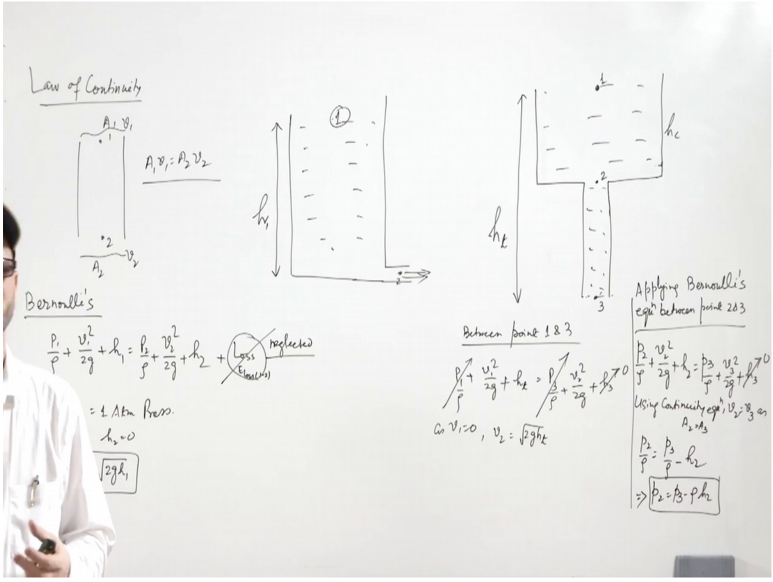

Now, again if you apply the Bernoulli's equation between point 2 and 3, so applying Bernoulli's equation between point 2 and 3, so what we get, we get p 2 by rho plus v 2 square by 2 g plus you will have this height. So, this height will be h 2 suppose then it will be equal to p 3 by rho plus v 3 square by 2 g plus basically you will have the last term is height. So, this height is h 3 that is 0. Now, the thing is that if you apply the continuity equation between these two points, now applying the continuity equation, continuity equation tells that A 1 V 1 will be A 2 V 2.

So, since the cross section area at these two places are same, at point 2 and 3 the cross section area is same. So, using the continuity equation, in that case your area at this place and this place being same, velocity will be same. So, if you applied it, so using continuity equation, v 2 has to be equal to v 3 as you have A 2 as equal to A 3. So, once v 2 becomes v 3 in that case what you see is you will have p 2 by rho, it will be equal to p 3 by rho minus v 2 square so no this minus h 2. So, p 2 will be equal to p 3 minus h 2 rho that is what we get here.

So, this will tell you the result as p 2 equal to p 3 minus rho h 2. Now, what it tells these tells that if you are putting thus this channel straight, in that case at this point p 2 the pressure will be less than p 3 by this quantity. And p 3 is atmospheric pressure, so p 3 being atmospheric pressure at this point the pressure becomes less than atmospheric pressure means you the vacuum is generated. And if the pressure is less here then atmospheric pressure in that case if the mould is permeable then it will try to maintain that must be pressure here, and in that case it will suck the atmospheric air or gases from this side through the permeable mould.

So, this sucking bit of air or gases because of the pressure difference created at this place that is known as aspiration. And this aspiration is not good in the sense that if the material is prone to oxidation, in that case that material get oxidized, it may get impure. So, this aspiration needs to be minimized. So, the aspiration needs to be prevented. Now, how to have prevent this aspiration, this aspiration is prevented by the use of taper and we will see that how this taper has to be done by so that there is no aspiration. So, basically what happens for preventing this aspiration, what we need is this pressure should be equal to this pressure, so that is when the aspiration will not take place. So, that we have to see.

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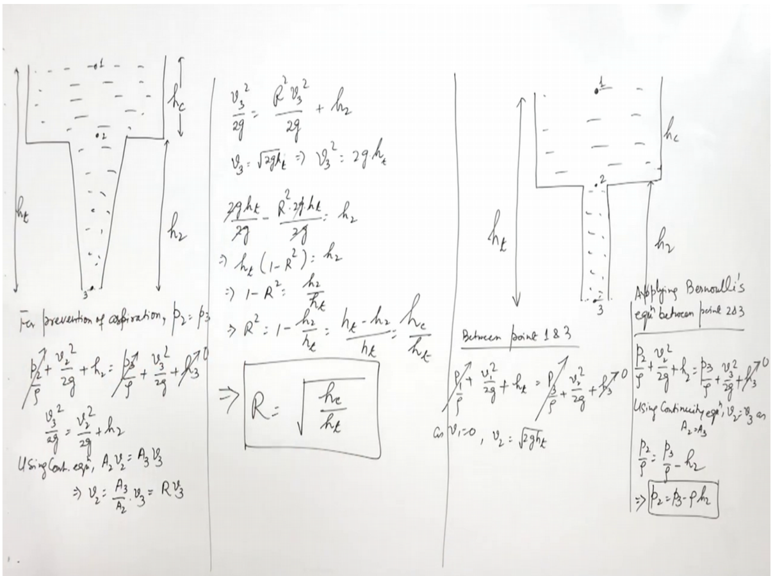

So, we have to see that how this aspiration can be prevented. So, for that again we will see that you have the pouring basin of and h c the height of the cup, h 2 is the height from here to as to sprue height basically. So, here also the this is the height h 2 that we have already taken this height as h 2. Then you have total height h t. Now, in this case if we apply the equation between point 2 and 3, so in that case so what we see that we will assume a case where there is no aspiration. Now, there is no aspiration means what the pressure, so if this is point one if this is point two and if this is point three. So, in the case of no aspiration, so this is for prevention of aspiration. Actually aspiration occurs only because there is less pressure here than atmosphere which is the pressure which is here.

So, for prevention of aspiration, you have to have p 2 as p 3. So, what we see is we have to again take the equation this. Now, in that you get again p 2 plus v 2 square by 2 g p 2 by rho plus v 2 square by 2 g plus h 2 will be p 3 by rho plus v 3 square by 2 g plus h 3. Now, as we discussed that p 2 will be p 3, so this term will vanish because we are thinking of no basically aspiration h 3 will be 0, because it is the datum line. So, h 3 will be 0. Now, v 3, v 3 is nothing but root 2 g h t. So, you will have the v 3 term, v 3 because it is the height of the total height basically. So, as we have understood by using the apply by applying the Bernoulli's theorem, you can have the expression for v 3 square by 2 g this v 3 square by 2 g comes as v 2 square by 2 g plus h 2. This is what we get when we apply this Bernoulli's equation between 2 and 3.

Now, if the area here is A 2 then in that case using continuity equation we get A 2 v 2 as A 3 v 3. So, what we see is we can write v 2 as A 3 by A 2 into v 3. And if this A 3 by A 2 is taking the ratio this ratio is defined as R into v 3. So, this ratio because this is the ratio of the area of cross section at this point and this point. So, if you put this v 2 term into this expression, so I have been substituting this value of v 2 into this equation what we get is v 3 square by 2 g will be v 2 square by 2 g means R into v 3. So, this is R square v 3 square by 2 g and plus h 2. So, now v 3 is 2 g ht. So, we know that v 3 is root 2 g ht this is h subscript t. So, v 3 square will be 2 g h t.

Now, what we see from here that v 3 square is 2 g ht. So, 2 g h t by 2 g minus R square into 2 g h t upon 2 g it will be equal to h 2. So, you will be having these terms cut, h t into 1 minus R square will be h 2. So, 1 minus R square will be h 2 by h t, R square will be 1 minus h 2 by h t that is h t minus h 2 by h t and this is equal to s 2 s t minus s 2 this is s t and this is s 2. So, this is h c, so this h c by h t. So, this R is coming as under root at h c upon h t h subscript c upon h subscript t, this is the condition which should be followed for the prevention of aspiration. So, this is what the condition which must be you know followed, so that there is no aspiration in the gating system.

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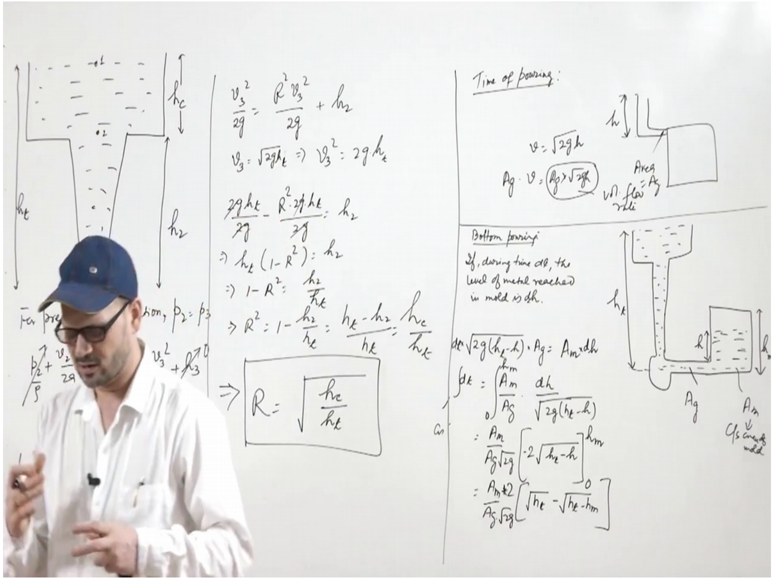

So, we are going to discuss now about the time of pouring. Now, how to find the time of pouring? So, as it is very simple in case of top pouring, because in case of top pouring, what happens that you have the mold cavity and you will have the sprue coming up, and this may go from the side or it may go from the top. So, you know the head. If you know the head this head, if you know this head, now you can find the velocity here. So, in the case of top pouring, simply if you know this total head available, this head does not if it has no change, in that case if you are pouring machine here and pouring machine maintains the fluid level at certain value in that case this head will not change. So, the velocity which will be achieved is under root 2 g h if h is the total head available while it is entering inside the mould.

So, in the case of top getting it is coming from this place or it will be from this place. And once you know this velocity that if you know the A g, A g is the area of cross section of the gate. So, here the area if it is A g in that case A g into v that is A g into root 2 g s, so this will be volumetric flow rate. So, this will be volumetric flow rate. So, in that case the pouring time calculation will be pouring time will be calculated by dividing this volume of the casting divided by this volumetric flow rate. So, this is very simple in the case of you know the top pouring cases.

Now, what happens in the case of bottom pouring? Now, in the bottom pouring cases if you have the situation like this. So, this is supposed here in the bottom caves bottom pouring, suppose this is the total head available as ht and this is the height of the mold h m. This is the mold this cavity, this is the height of the total height that is here you have pouring basin and this is your sprue, and then this is the datum line suppose. Now, in this case, what happens that the head available the head which is available here, this head is basically changing; initially when it starts going inside the cavity at that time you have head available as h t. So, initially the velocity which you get here that will be under root 2 g ht.

However, with time when the height changes, so if suppose it comes to height h at in time dt, if suppose it achieve height h in time dt, now at that particular time the available head is h t minus h. So, velocity will be under root 2 g h t minus h. So, because the this liquid level is decreasing. And at this point, when it is filling at that time effectively the head available is h t minus h m. So, the height I mean the velocity using the Bernoulli's equation can be calculated as under root 2 g h t minus h m.

Now, if suppose here the area is A g, and if area of the mould A m that is cross sectional area of mold. Now, what happens in this case if suppose in the time dt it has come to d h height. So, you assume so now we are going to have the case for bottom pouring. And if during time dt, the level of metal reached in mold is h. Now, this will be basically at that time, the area is A g. And the velocity which is here this velocity will be basically so what we see is the velocity will be root 2 g and h t minus h, so that will be the velocity. And velocity into area - area of the gate this will be the basically volumetric flow rate, this is area of the gate, and this is the volume this is a velocity at which it is flowing through that.

Now, this will be nothing but you will have the volume multiplied, so that will be now it will be equal to v. So, this is the area A m, so that will be A m into the height h actually we will take this height. So, during the time dt this height should be d h. So, this will be d h basically at particular distance the height is h. So, during that time dt, the height achieved is d h at a particular instant this height is h. So, it will be d h and this is achieved in time dt. So, you will multiply this with dt.

Now, this is the equation which you get this equation needs to be integrated. Now, this dt once integrated will give you the total time taken, and this d h will be from 0 to h m. So, you bring so dt integral dt will be A m upon A g into d h upon root 2 g ht minus h this is what you get and once you integrate, so this will be also integrated. Now, this d h will be integrated, so d h will be varying from 0 to h m. So, from here you get A m upon A g and then this root 2 g will come out. And once you integrate, so this will go from 0 to h m. So, that will be 1 by root under root h t minus h. So, it is basically 2 into under root h t minus h. And then it will be again minus because this is minus h. So, once you are integrating, this minus sign will come and you are putting the values from 0 to h m.

So, this is how you are basically finding the value. So, it will come as A m by A g root 2 g. And then first of all you will put h m, so it will be h t minus h m. And since it is minus, so this is 2 is coming here and then. So, first term will be root h t minus under root h m. Now, this is the expression 2 A g upon 2 into this is A m 2 into A m upon A g into under root 2 g and then in bracket under root h t minus under root h t minus h m. So, this is the pouring time calculated for this bottom pouring system.

So, whenever you are given the bottom pouring system, in that case you will have to see now you suppose this mould height is such that it is coming up to this place. So, in that case, this term will vanish. So, this way you can calculate the pouring time. Now, depending upon this height this term will be changing, you have h t as fixed. So, this is how you can calculate the pouring time for basically the bottom pouring cases.

Thank you very much.