Principles of Casting Technology

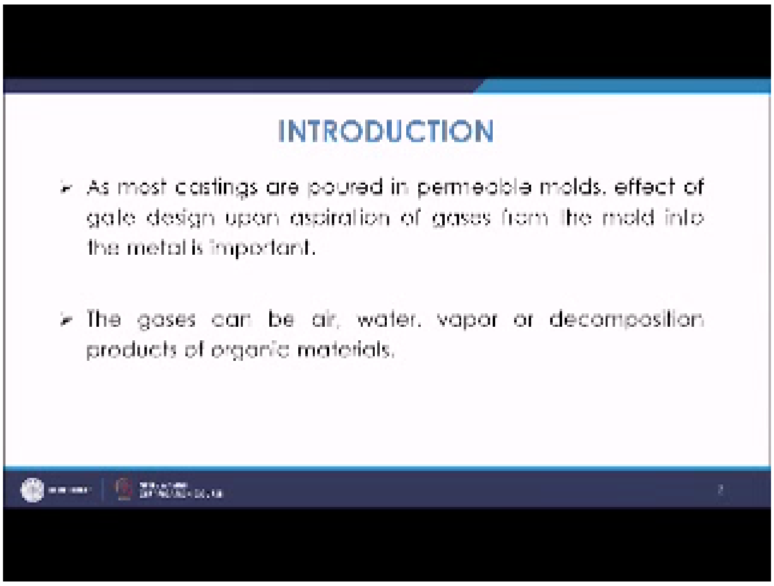
Dr. Pradeep K. Jha
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture - 19
Gating System Design
Aspiration effects in gating system

Welcome to the lecture on Gating System Design, in this lecture we will discuss about aspiration effects in a gating system, what is aspiration basically? Aspiration is nothing but sucking of the air because of a low pressure zone created inside the mold. So, why the low pressure zone is created this zone is created may be because of the prevailing conditions of fluid flow and if you apply the Bernoulli's equation to the different points it may so happen that at some point, there may be a formation of a pressure zone which is below the atmosphere.

So, that is vacuum, and if the mold is permeable which is normally in the case when you are using the sand as the molding material, in that case in that zone if there is formation of pressure below atmosphere then it will try to suck the air from outside or it may take the air either or it may take the gases may be from the mold or those gases which are the product of the combustion or the vaporization, all these things can be sucked into and then that may contaminate the liquid metal.

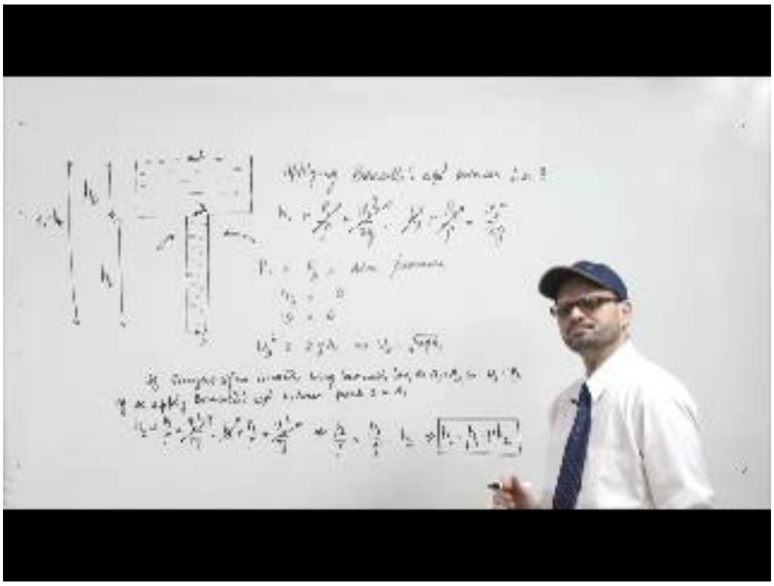
(Refer Slide Time: 01:48)



So, effect of getting design upon aspiration of gases is important because the mold being permeable, there are chances that there may be sucking of air or there may be entry of air or oxidizable product oxidizable material from outside which may come in to the mold and it may induce the harm to the molten metal. The gases can be air, water, vapor or decomposition products of organic materials because of the heat of the molten metal, the carbonaceous materials or certain materials which we are putting in the mold to alter it is properties, to induce certain properties like collapsibility or may be like bold hardness or so, these products they are basically carbonaceous many a times and once they are basically vaporized or they are undergoing combustion then the produced gases.

So, in the mold you have gases and when there will be a zone of low pressure then these gases are likely to come at the points where there is low pressure and at that point if the metal is flowing, these gases may react with the metal forming the impurities or may be in the form of oxides. So, we need to be careful in designing the gating system at those places where there are chances of formation of low pressure zone and there is chance of aspiration of gases. So, we will deal with those cases where there are chances of aspiration.

(Refer Slide Time: 03:43)



Let us see what the aspiration effect in a permeable mold. So, we can see that through a figure and let us see you have a permeable mold and for the time being you take this sprue as the straight one. So, let us see if the sprue is straight what will happen. So, this is the pouring cup and you have the liquid metal flowing through heat, let us see this is point 1, this is point 2 and this is point 3. So, liquid metal once it is here it will try to flow and then they are at the bottom you have this sprue will connected from there it will go into the runner and further into the gates then into the cavity.

So, if assuming that the sprue is straight one, you apply this Bernoulli's theorem between point 1 and 3, applying Bernoulli's equation between point 1 and 3. So, you have this is h 1 plus p 1 by rho, plus v 1 square by 2 g, that will be h 3 plus p 3 by rho plus v 3 square by 2 g. So, what we see is that in this case the p 1 as well as p 3 they can be taken as at atmospheric pressure, because here it is open to the atmosphere here also it is coming. So, all these 2 places you can take this as atmospheric pressure. So, then the h 3 this is the datum line, h 3 can be taken as 0.

So, at this point this is the beings our datum line you have h 3 equal to 0. So, if you take all this points into this equation what we get is, your this and this cancels, this is also canceling and you have v 3 square and the v 1 is also 0 you also get v 1 as 0 because it is it is top surface the liquid metal is at rest, so v 1 as also to be taken equal to 0. So, this term will also cancel in that case you get v 3 square is 2 g h 1 or you can have v 3 as root 2 g h 1. So, this is the height of this point.

Now, let us say if you are having a straight sprue, in that case if straight sprue is used what we see is you have v 2 here and v 3 here, in that case as per the law of continuity, the velocity at this point and this point should be equal. So, using continuity law as a 2 is a 3, so we will have v 2 equal to v 3. Now if we apply the Bernoulli's equation between point 2 and 3. So, if we apply Bernoulli's equation between point 2 and 3 in that case again h 2 plus p 2 by rho applies v 2 square by 2 g it will be equal to h 3 plus p 3 by rho plus v 3 square by 2 g.

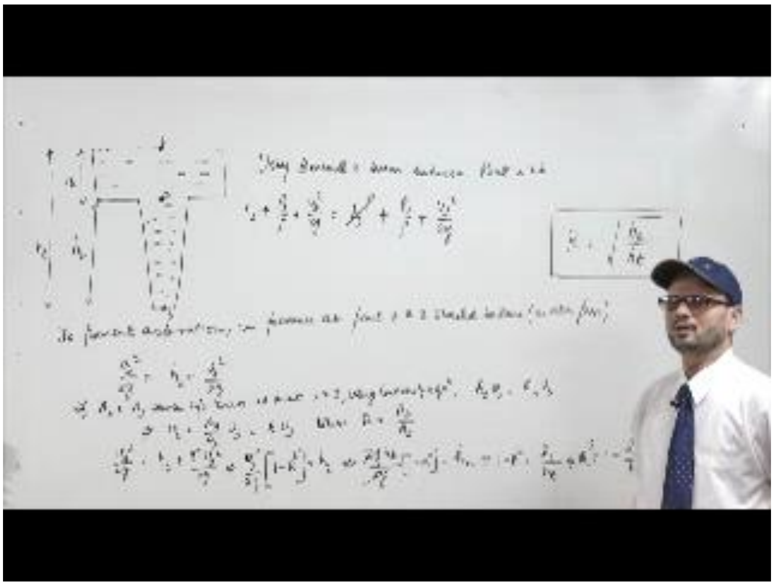
Now, let us see in this case you have v 2 as v 3. So, being v 2 by v 3, these 2 terms will cancel as 3 is any way equal to 0, so, as 3 is 0. Now what you get? So, from this equation you get p 2 by rho will be p 3 by rho minus h 2, this implies that p 2 will be equal to v 3 minus rho h 2; what we see here that p 3 is the atmospheric pressure. So, p 2 will be equal to atmospheric pressure minus rho times h 2. So, you have certain height h 2, this is your h 2. This whole is h 1; this h 1 is nothing but total height, so h 1 we take as h t.

So, that is total height and this portion is taken as height of the cup, in normal convention we take height as h c.

What we see is the pressure at this point 2 just as we as the fluid moves from this position downwards, the pressure at this point if it is maintained at atmospheric pressure in that case pressure in this zone will try to be lesser than the atmospheric pressure. So, that pressure is nothing, but a vacuum pressure, and if the vacuum pressure is created at this point in that case there will be chances of the sucking of air from the size from the mold.

So, this basically leads to a condition of aspiration in the mold. So, this is known as aspiration and this is created because of the generation of low pressure zone in a permeable mold; now next we will discuss how to prevent this aspiration.

(Refer Slide Time: 11:30)



So, what we see is earlier we had this straight sprue, now we will try to have a tapered sprue and we will see how the aspiration can be prevented with the use of tapered sprue. So, in this case you have this point 1 2 and 3, you have liquid metal filled in this case, you have height this height of the cup, so hc and this is the total height that is ht and this is the height of the sprue that is h 2.

So, this being the point 1, this is the point 2 and this is the point 3. How to prevent the aspiration? If you use the Bernoulli's theorem between 2 and 3 using Bernoulli's theorem between point 2 and 3, again what we see is h 2 plus p 2 upon rho, plus v 2 r square upon 2 g will be equal to h 3 that is 0, plus p 3 upon rho that is the pressure term plus v 3 square upon 2 g. So, what we see is in this case to prevent the aspiration the condition is that, how can we prevent the aspiration? The aspiration can be prevented if we maintain the same pressure at this point as well as at this point. So, for preventing the aspiration the condition is that, the pressure at this 2 point should be same and since at this point the pressure is the atmospheric pressure. So, at point 2 also you must have a condition of the atmospheric pressure.

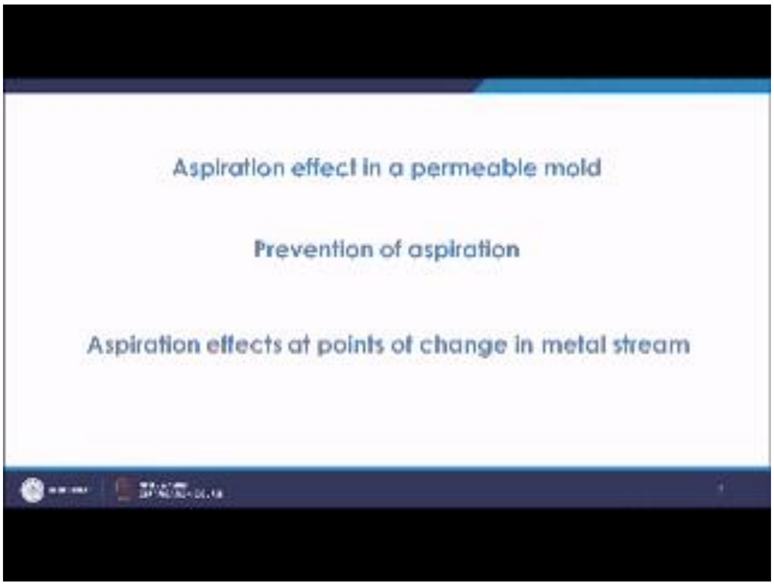
So, to prevent aspiration the pressure at point 2 and 3 should be same that is as atmospheric pressure, in this case you have pressure is same. So, what you get is v 3 squares upon 2 g will be h 2 plus v 2 squares upon 2 g. So, this is the conditions because these 2 terms are canceling because they are equal to each other. So, you have v 3 squares upon 2 g equal to as 2 plus v 2 squares upon 2 g; now the area of cross section at this point is a 2 and area of cross section of the point 3 is a 3. So, if a 2 and a 3 are the cross sectional areas at points 2 and 3, what you get using the continuity equation you must have the condition a 2 v 2 should be equal to a 3 v 3. So, you should have a 2 v 2 should be equal to a 3 v 3.

So, this condition must be satisfied at this point at this as well as at this. So, what we get is from here you will have a 3 as the smaller area. So, v 2 will be a 3 upon a 2 into v 3 and this a 3 upon a 2 this is taken as a factor that is ratio of this area upon of this upon this that is taken as r v 3. So, v 2 can be taken as r v 3 where r is nothing, but the ratio of this area at the bottom most point to this point. So, r is a 3 upon a 2. Now if you are putting this value into the equation what we get. So, we get v 3 squares upon 2 g, we get v 3 squares upon 2 g equal to h 2 plus v 2 square by 2 g and v 2 is r v 3. So, it will be r square, v 3 squares upon 2 g.

Now, this will be nothing, but you will have v 3 square upon 2 g into 1 minus r square will be equal to h 2; now from here now v 3 square will be nothing, but it is 2 g into ht. So, it will be 2 g h t upon 2 g into 1 minus r square will be equal to h 2. So, 2 g and 2 g will cancel. So, 1 minus r square will be h 2 upon h t or r square will be equal to 1 minus h 2 upon ht that is h t minus h 2 bound h t and h t minus h 2 is nothing but h c that is height of the cup. So, it is h c by h t. So, what we see is to prevent the aspiration and to have the condition that you have the same pressure at this and this point, this ratio of the area of cross section at point 3 and point 2 it should be equal to, that is and it is squared term should be equal to h c upon h t.

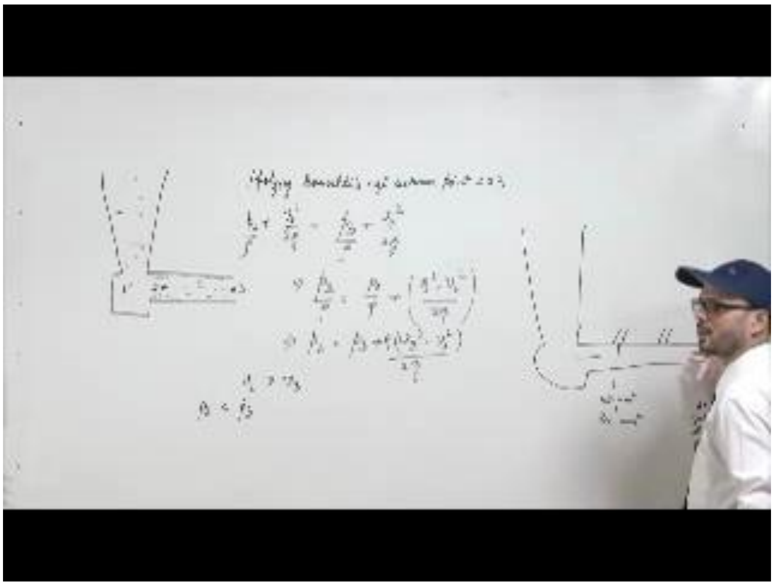
So, the condition for prevention of aspiration is the same that is r equal to under root hc upon ht. So, this is the condition to prevent the aspiration in that permeable mold and this must be satisfied to prevent the aspiration of air from these points.

(Refer Slide Time: 19:51)



Now, we will discuss about the aspiration effects at points of change in the metal stream. So, many a times what happens that at the sharp corners or when the metal is passing through an (Refer Time: 20:01) face then the stream lines of the fluid changes especially in the cases of sharp corners, the metal when comes and goes to the another direction in that perpendicular direction of the stream in which it was flowing earlier then it tries to have a bend shape, because of that a condition is generated and at that point there is possibility of formation of low pressure and how can that be prevented or how it is that case being generated in which there is formation of low pressure zone which may induce the aspiration effect that we must see.

(Refer Slide Time: 20:45)



So, if we see a case, now if you look at in this case, where the liquid metal is flowing from the top and it is coming now what will happen; due to the effect of the momentum when the liquid metal is coming from this place. So, then in that case what happens it basically flows like this it comes like this, it goes like this. Now at this point this is the point which is known as the point of vena contract, here because of this sharp corner this fluid flow lines they are coming at this point. So, if we take this point as 1, this point as 2 and in the stream direction you have at the point here 3.

Now let us see if you apply the Bernoulli's equation between point 2 and 3 applying Bernoulli's equation between point 2 and 3. So, what we see is you have the head that is the potential head is same; the term of potential head can be neglected. So, you have p 2 plus v 2 square by 2 g will be p 3 plus v 3 square by 2 g, the p 2 by rho plus and this side p 3 by rho.

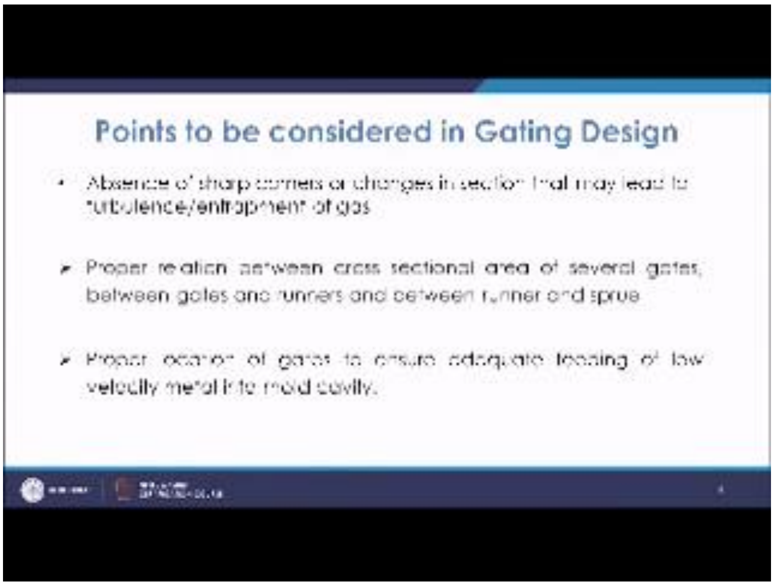
So, now what is there this p 3 is the atmospheric pressure and you have v 2 and you have v 3. So, what happens due to this equation, you get p 2 by rho will be equal to p 3 by rho plus v 3 square minus v 2 square upon 2 g or if you multiply with rho on both the sides. So, p 2 will be p 3 plus v 3 squares minus v 2 squares into rho upon 2 g.

Now, let us see what kind of situation it brings into. So, at this point pressure will be p 3 plus rho into v 3 square minus v 2 square, now this point as the metal stream is flowing this line the area at this point will be a smaller and using the law of continuity, the area being smaller the velocity at this point v 2 will be larger. So, v 2 will be larger than v 3 because of the law of the continuity and because the metal flow stream flow like this, you have the velocity higher at this point as compare to this. So, what will happen this term will be a negative value and that is why if p 3 is the atmospheric pressure? So it will be p 2 will be less than p 3.

In that case what we see is at this point the pressure generated is smaller than the atmospheric pressure and if at this point the pressure is smaller than the atmospheric pressure so you will have chances of aspiration of air from these points if the mold is permeable. So, the remedy is that what we do in the normal practice that, we basically avoid these hard corners and here we basically streamline the flow we are streamlining the flow in this region so that there is no separation of the liquid metal from the surface and we are a streamlining it and you streamline, so that there is no formation a zone which is having lower pressure than the atmosphere and we can avoid the formation of a low pressure zone and the aspiration of air.

Next there are certain points which are required to be considered while going for the gating design.

(Refer Slide Time: 26:06)



So, first thing which we have discussed now is that absence of sharp corners or changes in section that may lead to turbulence or entrapment of gas. So, as we have seen that if you have the sharp corners, you may have a case under which there may be entrapment of gases or air and that may lead to the quality I mean poor quality of the molten method; proper relation between cross sectional area of several gates between gates and runners and between runner and sprue. So, we have seen that you need to have a proper ratio between the sprue area between the total runner area and between the total gate area to maintain a condition in which the molten method either runs full or it is running in such a manner there is that there is quite flow of the molten metal in that gating system; proper location of gates to ensure adequate feeding of low velocity metal into the cavity, so you also need to locate the gates to ensure that properly you have velocity of the metal into mold cavity.

One thing which is required to be understood is that normally what happens when you have the molten metal going into the runner in that case, as you move towards the runner and towards the furthest gate; towards the furthest gate basically what happens the velocity is so if you go from here, now once you go in this direction as you go to the furthest gate, so there will be a gates all along here.

Now, what happens to the furthest gate? At this furthest gate the velocity is minimum and the pressure is maximum. So, at furthest gate velocity is minimum and pressure is maximum, where as at the gate which is closest to this place in the runner here you have velocity maximum and pressure minimum. So, what happens? Bulk of the fluid under the pressure flows comes here and then it is starts to fill from this cavity.

So, basically to maintain the uniformity of flow of liquid from all these gates, normally what we do is we basically make this cross section tapered. So, instead of having the proper cross section same cross section all along, what we do is we go on tapering. So, what we see is in these cases you are making this sprue, this runner cross section going towards decreasing as we move from the near runner to the furthest runner. So, that there is equal distribution of molten metal from all the streams. Apart from that you will have also to ensure that you have the proper placing of the runner well, you have the proper use of all these devices which can scheme out the impurities all these things are important while designing the gates.

Thank you.