Manufacturing Processes – Casting and Joining
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Lecture – 04

Hello and welcome back to the course on Manufacturing Processes - Casting and Joining. Let me remind you that in our last discussion session we started discussing moulds and I showed you one typical sand mould where we have the two parts of the flask.

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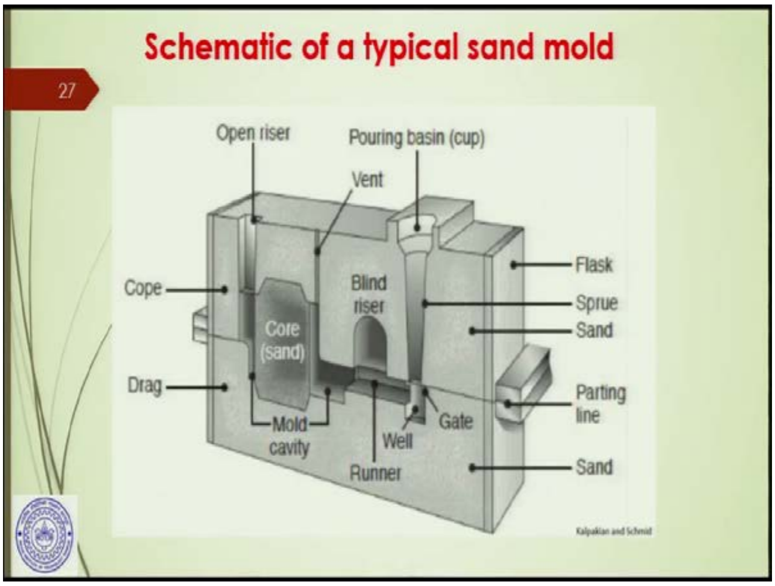

If you lo at this diagram - this is the cross section of the typical sand mold we have the cope which is the upper part and the drag which is the lower part as I said. here if you see the molten metal is poured in the pouring basin which is also called the pouring cup and it flows through the sprue and the gate to the pouring well. From here the molten metal runs through the runner and it fills up the blind riser, which is a cavity, as well as the mold cavity which is also a space for the casting.

Here we have the open riser and . there is a core. This core is used for making the internal cavity or internal shape or the internal silhouette of the casting. this is the entire design of the typical sand mold. This portion is filled up with the sand as you have seen in the video yesterday or in our previous class.

And another thing that it has is a vent. This vent is specially made so that the gases inside, after the molten metal is poured, can escape. This is called the sprue and in our previous class I also told you that in sprue design or in the gating system design, this design is little critical. We will discuss it in details at a later stage. Here as for example, here what you can see is it is a taper shapesprue.

There are different kind of shapes that can be found out from the design and those shapes are particularly made to avoid the aspiration of the air, so that the air does not enter into the molten metal. We will discuss at a later stage why aspiration happens.

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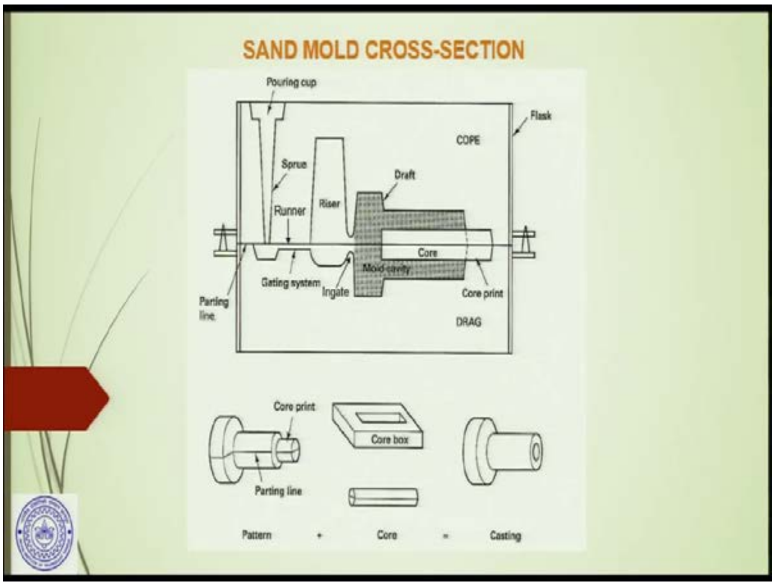

This is the schematic of the sand mould. Here is the pouring cup. Molten metal flows through the sprue to the well. The sprue is of a taper shape. Through the runner the molten metal enters into the cavity. There is a core here that is used to make the internal hole in this case. This is the core print and this is the mould cavity.

Here we have a riser which is a closed riser and the molten metal will run through the runner to fill up this space and through the ingate it flows into the mould cavity to fill it up and to get the casting finally. When the entire cavity is filled up including the riser, we will understand from the level of the molten metal in the pouring cup that you have seen in the video in our previous classes.

Then the pouring stops and it is kept for the solidification. After the solidification the mould is bren. This is the cope, one half of the flask, and the another half or the lower part is the drag. Both of them will be bren and the sand mould is destroyed to take out the casting. Now, if you see here, with the casting you will also have the riser and the entire gating system up to this.

This will also be solidified and it will be attached to the casting. So, in this place where it is attached to the casting, it has to be sheared off , then you will have the actual casting, then of course, the core has to be removed. And then what you will have is a casting with actually an internal hole. This is the final shape of the casting that you can see. This is the core box where the core can be made and in the core box special sand is used with molasses .

A big age of molasses, so that it can bind. Molasses acts as a binder and a special sand is used for the core. Then the core is baked to get the sufficient strength and that core is placed inside the cavity so that around the core when the metal material molten material is filled up, the core can be taken out after the solidification and the casting can be made with an internal hole.

That is the basic purpose of the core that I already told you in my previous classes that for any kind of internal shape we have to use the core in the sand mould casting .

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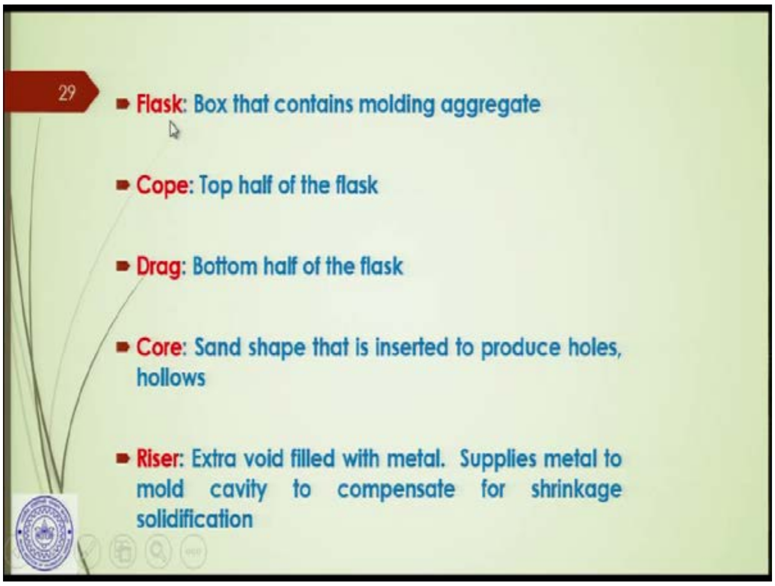

The flask is the box that contains the molding aggregate, the entire thing is the flask this is the box, in this box we have placed the sand, pattern, riser and so on that you have seen in the video clip. Cope is the top half of the flask. This is the cope and the lower half or the bottom half of the flask is called the drag.

The core is inserted to produce the holes, that means the hollow parts here to get this hole we have to get the core inserted in the mould cavity.

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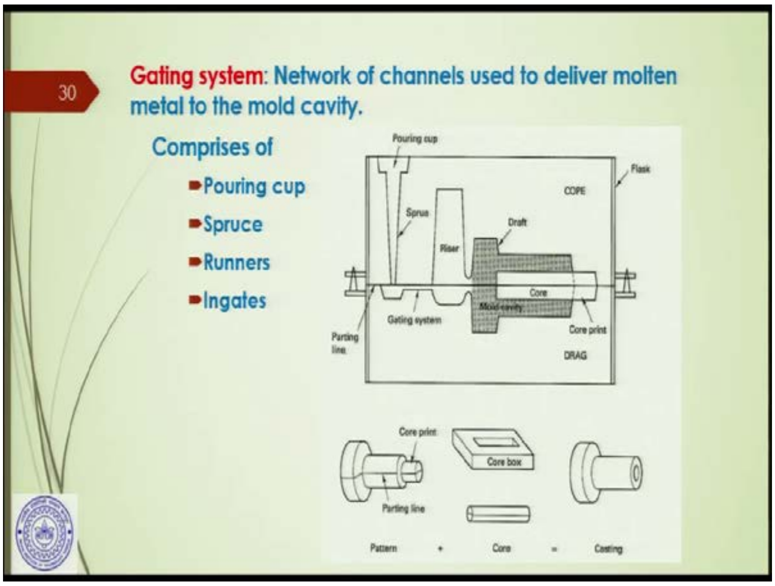

Riser is the extra void filled with metal. It supplies metal to mould cavity to compensate for the shrinkage solidification. I discussed it earlier that riser is actually a reservoir of molten metal. The molten metal will flow in and in the riser design we should make sure that the molten metal inside the riser should solidify after the solidification of the molten metal inside the mould cavity.

When the metal is solidified inside the mould cavity, there will be shrinkage, various kind of shrinkages I already told you, and to compensate for those shrinkages we have to supply molten metal and that molten metal should come from the riser. Therefore, riser is actually the reservoir for the molten metal for compensating the shrinkage cavities and the other cavities in the solidified casting. That is the basic purpose .

Now, the gating system is the network, the entire network, as I told you, is called the gating system. This is the network of channels used to deliver the molten metal to the mould cavity.

Molten metal will enter to the mould cavity from here through this well, runner , and the gate here . All these elements will be included in the gating system, which are pouring cup, spruces, runners, ingates. Ingates are here.

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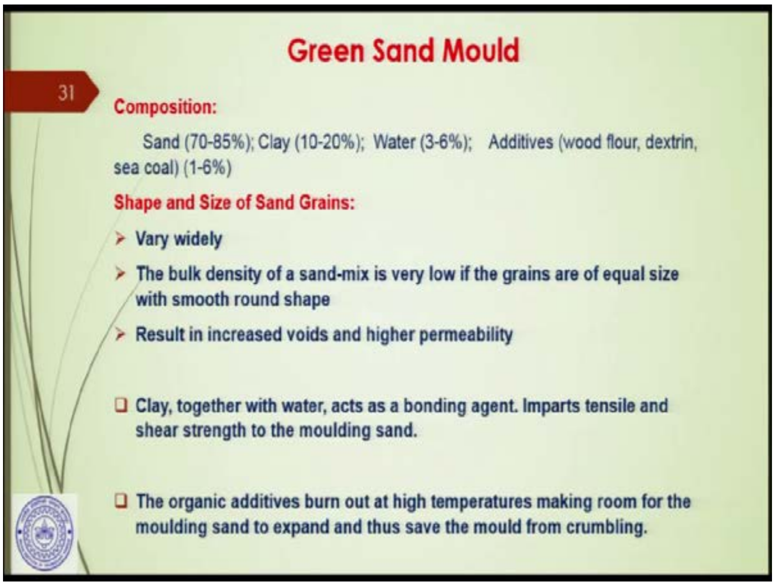

Now all those things have to be sheared off from the final casting, so that the casting could be used. The green sand mold composition is the following: it has about 70% to 85% of sand.

Now, how the sand is selected is a different issue. The quality of the casting will depend greatly on the type of the sand that you are using. Whether it is a coarse or it is a fine grain? How much clay is there? How much water is there? All those things have to be very judiciously considered and those things also we will discuss at a later stage.

Now, along with the 70% to 85% of sand, there is about 10 to 20% of clay ; then 3 to 6% of water. There are additives like wood flour, dextrin, sea coal is about 1 to 6%.

Now, the clay is for binding as you understand and along with the water. Water cannot be less than 3% , otherwise it will not bind, but it cannot be more than 6% ; because otherwise the voids will be filled up by the water ; void is the space between the grains .

Shape and size of sand grains vary very widely. The bulk density of a sand mix is very low, if the grains are of equal size with smooth and the round shape. Because you understand that, if it is of a round shape, then when they are ideally in touch with each other, the distance from the center of one grain to another grain is actually the diameter of the grain .

So, overall we say that, bulk density of a sand mix is very low if the grains are of equal size with smooth and the round shape. Inequal grain size will result in increased voids and the higher permeability.

Increased voids mean, spaces will be more between the grains. And once the spaces will be more between the grains, the permeability will be more; permeability is the possibility or capability of the sand mould to allow the gases to escape, to come out.

Clay together with water acts as a bonding agent, imparting tensile and the shear strength to the moulding sand. Without the clay and water together, we will not get the sufficient tensile and the shear strength of the moulding sand or the overall mould . The organic additives burn out at high temperatures making room for the moulding sand to expand and thus save the mould from crumbling.

Now, I said in my one of my earlier lectures that, we have to be very careful about the material of the flask. Because after the molten metal is poured, the mould will expand and the flask has to give way, flask has to allow this expansion of the mould.

This is helped by these organic additives; they burn out at high temperature of the molten metal as the molten metal goes in, that makes the room for the moulding sand to expand and thus save the mould from crumbling. That is why those organic additives like wood flour, dextrin, sea coal are used to get the flexibility of the sand mould.

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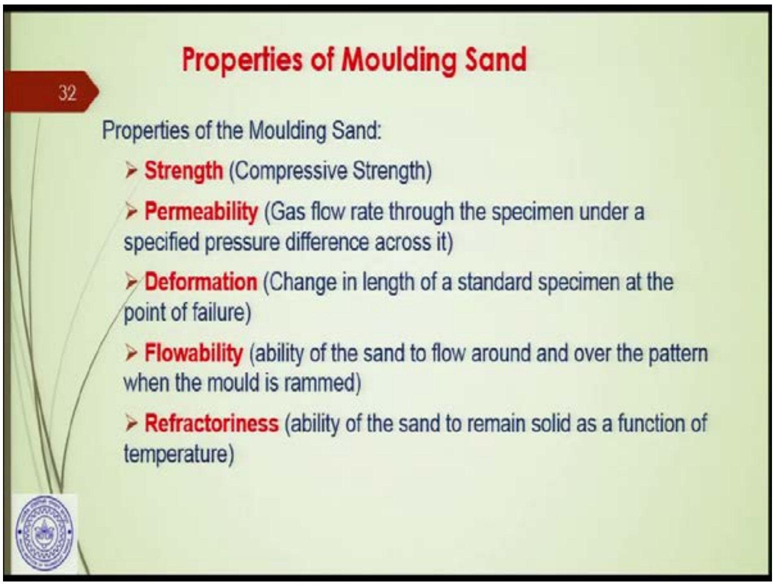

Properties of moulding sand: these are the five basic properties, which the ideal moulding sand should have. First, it has to be strong, that is, the compressive strength should be higher.

Permeability is the gas flow rate through the specimen under a specified pressure difference across it. When the pressure difference is there, the gas will be evolved. And when the gas will come out, it has to be allowed to escape by the moulding sand. If the permeability is less in case when the voids are small or the voids are occupied by the higher percentage of water for example,

in that case, the gas will not be able to come out and it will actually create the porosity; it will create the defects inside the casting. Third property is the deformation that is the change in length of a standard specimen at the point of failure. Next is the flowability; that is the ability of the sand to flow around and over the pattern when the mould is rammed. This is very important that sand has to fill up the entire mould cavity wherever it is required.

That is why it is actually rammed. It is important for the moulding sand to have the ability to flow or the flowability, so that it can fill up, flow around and over the pattern, so that it can wrap the pattern around. And the fifth property of the moulding sand is the refractoriness; that is the ability of the sand to remain solid as a function of temperature.

At a higher temperature, temperature is very high because of the molten metal as you understand, the sand should not lose its strength, or any other property and it should remain solid. That is the refractoriness. So, there is a resistance to heat, so that it can actually withstand that much temperature.

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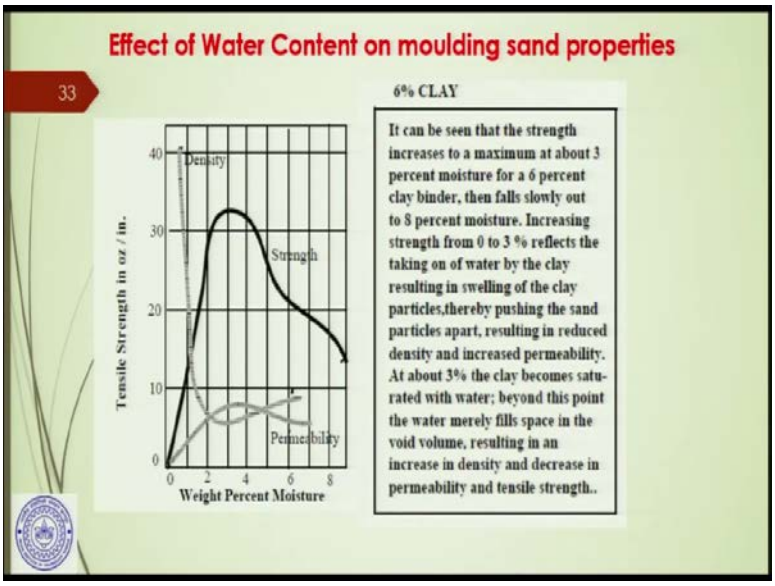

Let us see the curve of the tensile strength and the water percentage, that is the moisture. If you remember I was just telling you that, the water percentage cannot be more than 6%; we said that water percentage is from 3 to 6%. It cannot be less than 3%, so that it can bind properly.

Why not more than 6%? Here is the reason. Let us say this is the curve of the tensile strength and this is the weight percentage of the moisture or the water content. As the water content is increasing; let us say weight percentage is given in 2, 4, 6 up to 8 along the X-axis.

Initially when the water is added to the clay, the clay particles will actually expand. And they will push the sand particles apart from each other, making the voids more and the permeability will be more. Because as I said just now that, as the dimension or the size of the void increases, then the permeability increases; that means the ability of the mould material to pass air, pass the gas will be more.

So, the permeability actually increases and then it goes up to a certain point; let us say it is at 3% here and this experiment has been made with the 6% of clay let us say. So, it goes up to 3 weight percent of the moisture; after that if we keep on adding water, in that case actually the strength goes down.

And strength goes down because of the fact that, the increased voids are filled up by the water. In that case, those voids will not be effective for allowing the gas through them and the strength decreases. If you see here, initially when the water is mixed with the clay, the strength and permeability increase.

Permeability increases because the grains or the particles of the clay are expanding and they are pushing the clay, pushing the sand particles apart from each other. So, the density decreases, permeability increases up to 3% let us say in this case. After that, the permeability starts decreasing along with the strength because the voids are filled up with the wate. And as you can see here the density increases, because the voids are filled up with the water.

So, if you read it here you can understand, this is for your note; it can be seen that the strength increases to a maximum at about 3% of moisture, let us say here this is the 3% . With the further increase in the percentage of water slowly out to 8 percent of moisture, the strength decreases.

Increasing the strength from 0 to 3% reflects the taking on of water by the clay resulting in the swelling of the clay particles, thereby pushing the sand particles apart. This I already explained to you, why this density decreases and why the strength increases and the permeability increases; because the sand particles are pushed by the expansion of the clay particles,

thereby pushing the sand particles apart, resulting in reduced density and increased permeability. At about 3%, the clay becomes saturated with water. And beyond this point, the water merely fills space in the void volume, resulting in an increase in density; density is increased after that and both the permeability and the tensile strength are decreased.

So, this is the curve as shown in the figure. This is what happens with the strength, density and the permeability as the water is being added to the clay in the mould material. When the moulding sand is made, the mould is made, in that case first the clay powder is added and then to that the water is added and this is what happens up to 3 weight percent of moisture.

After that of course, it is detrimental; it does not make any sense in adding more water, because it actually reduces the properties of the sand mould.

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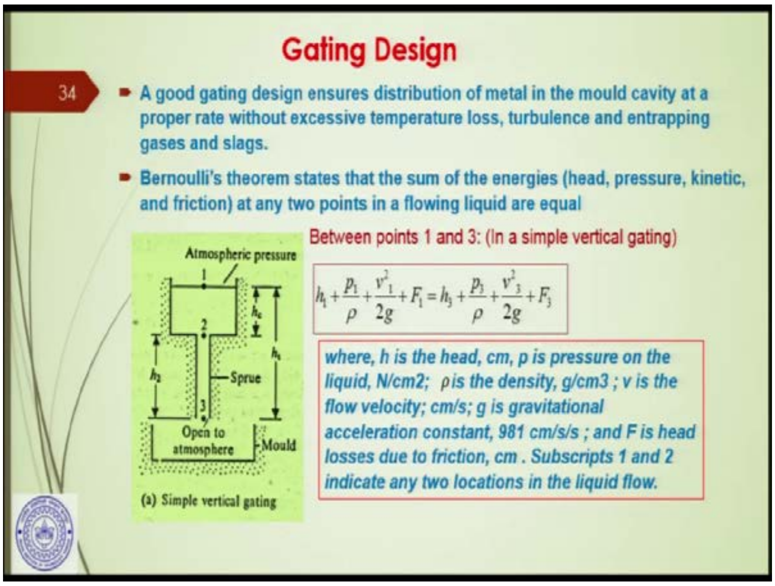

Let us discuss the gating design and this is one of the most important aspects of the casting; because based on this, we can actually make lot of conclusions. Let us see how the gating design is made.

A good gating design ensures the distribution of metal in the mould cavity at a proper rate, without excessive temperature loss, turbulence and the entrapping gases and slags. So, these are the points because of which we have to have an appropriate gating system and that can be ensured by having a proper gating design.

Once again, ensure the distribution of molten metal in the mould cavity at a proper rate. Why it is important? Because as I said in our earlier discussions that, if it is slower, then the molten metal would not be able to reach all of the inner parts of the cavity; before it reaches the extreme corners of the inner cavity, it will get solidified.

Therefore, the casting will have lot of defects in that case. If the gating design is appropriate, then this thing may not happen. I said about the sprue that it has to be tapered. Once again, this is to avoid the aspiration of the gas. There should be a well, because otherwise there will be splashing.

So, these are the points which we will ensure by the proper gating design Second point is that the Bernoulli’s theorem states that, the sum of the energies at the head, pressure, kinetic and the friction energyat two points in a flowing liquid are equal.

Consider this diagram. This is a simple vertical gating system and here we have the cup, then through the sprue, the molten metal goes in to the mould. Here if you take three points - this is the point at the level of the molten metal, up to this level, let us say, molten metal has been poured. This is another point inside the molten metal, inside the sprue.

And here is another point 3. Let us say this distance is h_t, this distance is h_c and this distance is h_2 . Once again, the Bernoulli's theorem says that, the sum of energy heads, that is the head energy, pressure energy, kinetic energy and the frictional energy at two points, any two points within a flowing liquid are equal. Let us consider points 1 and 3.

Here at point 1, the sum of energies will be head energy will be h_1 let us say that is the distance, height plus $\frac{p_1}{\rho}$; let us say p_1 is the pressure here and in this case since it is open to the atmosphere, so it will be atmospheric pressure, . Plus $\frac{v_1^2}{2g}$; so v_1 is the velocity at this point , plus the friction energy f_1 that is the friction energy at this point, this will be equal to the sum of energies at point number 3 which is h_3, which is the distance , that is the head, that is the height .

Plus $\frac{p_3}{\rho}$, p_3 is the pressure at this point divided by the density, $\frac{v_3^2}{2g}$; v_3 is that flow velocity at this point , plus f_3 is the friction here. Here you can see, h is the head; head means that height is the distance, these distances are the called as the head.

This is in centimeter, p is the pressure, p_1 and p_3 pressure respectively at points 1 and 3. This is on the liquid and given by the unit $\frac{N}{cm^2}$; ρ is the density of the pouring material or the molten material .

This is given by the unit $\frac{g}{cm^3}$; small v is the flow velocity in $\frac{cm}{s}$ and g is the gravitational acceleration constant, which is 981 $\frac{cm}{s^2}$, .

Now, f is the head losses due to friction and this is in *cm*. Subscripts 1 and 2 or 1 and 3 here indicate any two locations in the liquid. In this case, what we are considering is the location

and in the beginning, where the molten metal goes in and at this point where it enters the mould
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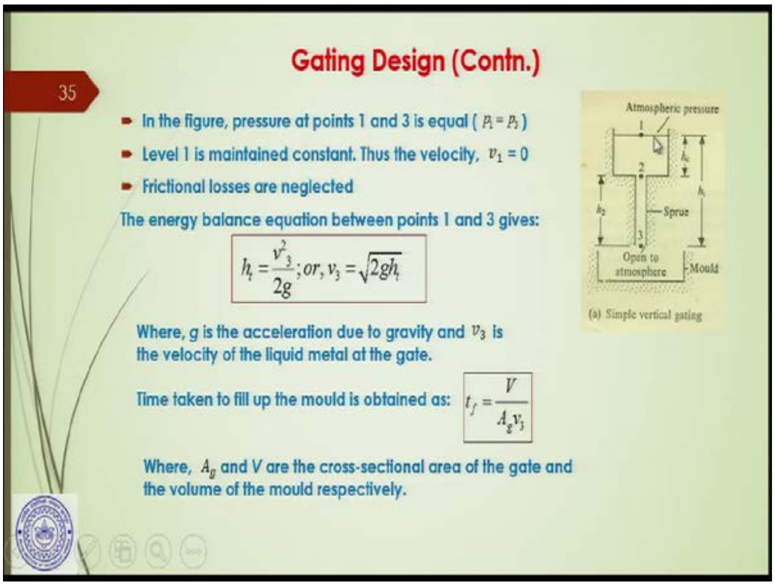

In the figure the pressure at 1 and 3, p_1 is equal to p_3. According to Bernoulli's theorem, the sum of energies at any two points in a flowing liquid is the same. Level 1 is maintained constant, here it is the pouring level. Thus, the velocity here is 0; because it is constant level. Frictional losses let us neglect for the time being, that is, there is no friction loss neither here nor at this point.

The energy balance equation therefore, this equation, if we consider these points that p_1 is equal to p_3, v_1 is equal to 0, frictional losses are neglected, then the energy balance equation between 1 and 3 if we solve that, it will be $h_t = \frac{v_3^2}{2g}$. If you see, h_t is the distance from 1 to 3; let us say with respect to the entrance of the mould , then the h_3 will be 0.

From here we can find out the value of the v_3, the flow velocity at the point 3, at the level 3 . This is coming out to be $v_3 = \sqrt{2gh_t}$.

Now, here of course, once again the g is the acceleration due to gravity, v_3 is the flow velocity of the molten metal at the gate. Therefore, the time taken to fill up the mould can be obtained by dividing this cross-sectional area A_g and the V which is the volume of the mould. If we divide the volume of the mould by the cross-sectional area and the flow velocity which we have determined, from here we can find out the value of the t_f time. The rest of the material we will discuss in our next discussion session.

Thank you for your attention.