Metal Casting
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Module - 02
Sand Casting Process
Lecture – 14
Design Of Gating System-I

Good morning friends, in the previous classes we have seen how to design the risering system. Now today, let us see how to design the gating system. So, today our lecture the title of our lecture is design of gating system. First of all, what is meant by gating system?

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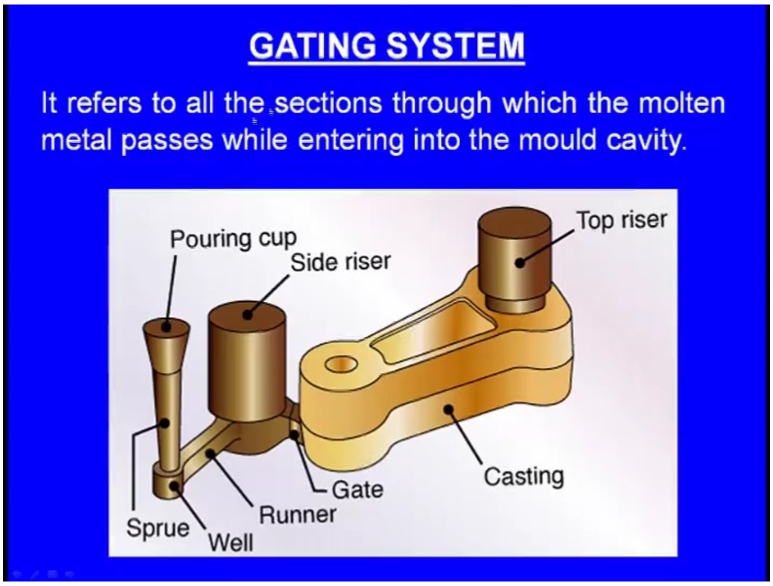

It refers to all the sections through which the molten metal passes while entering into the mould cavity. We this is the gating system, this is the pouring cup. We pour the molten metal through the pouring cup, the molten metal flows into this sprue, the vertical passes. Then, it falls into the sprue well, then it passes through the runner, the horizontal passes, then it passes through the gate. Of course, here there is a side riser, then this is the casting cavity, mould cavity and this is the top riser. Finally, the molten metal passes through the sprue, it passes through the runner, it fills the cavity and it rises through the riser.

All the sections through which the molten metal passes while, entering into the mould cavity is known as the Gating system. Gating system means it is the group of elements through which the molten metal passes while entering into the mould cavity. Gating system includes the pouring cup, it includes the sprue, it includes the sprue well, it includes the runner, it includes the gate and so on.

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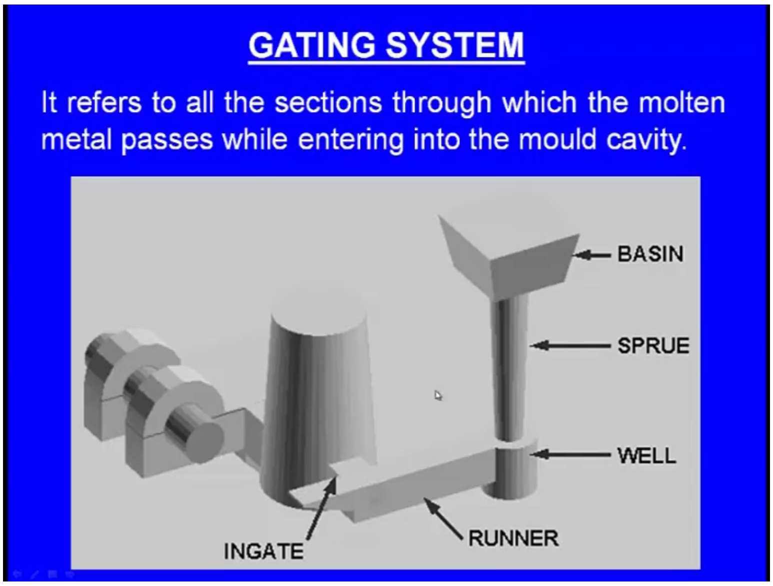

Here, we can see another whatsay casting and with another gating system. So, this is the you can see this is the casting. This is the casting and here we can see a core and this is the side riser and this is the pouring basin and this is the sprue and this is the sprue well and this is the runner.

So, this whole system is the gating system means, all the sections through which the molten metal passes while entering into the mould cavity is the gating system.

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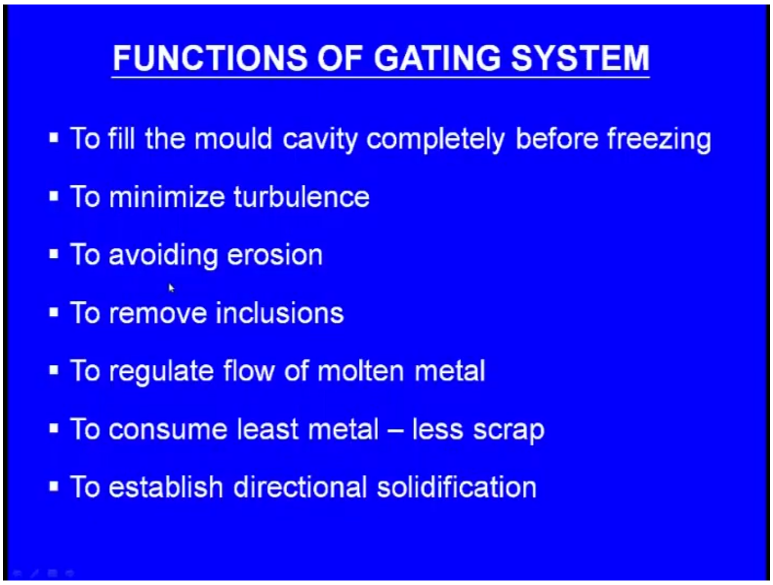

Now, what are the functions of the Gating system? Why gating system? What are the functions of the Gating system? These are the functions of the gating system. To fill the mould cavity completely before freezing. So, that is the first function right, before the solidification commences the molten metal has to fill the cavity perfectly without any gap that is the first function of the gating system.

Next one to minimize the turbulence, it is possible that while the molten metal is entering into the mould cavity, it may cause turbulence because of that it may erode the sand particles and in which case there will be casting defects will be there. So, there should not be any turbulence, while the molten metal is entering into the mould cavity. So, this is the second function, there should not be any turbulence or the turbulence should be minimized that is the function of the gating system.

Next one to avoid the erosion yes while the molten metal is entering into the cavity it should not erode the sand, molding sand. Next one to remove the inclusions, yes there will be some foreign particles will be coming along with the molten metal. The sources may be different. They may be carried through the, what say laddel in the molten metal or they may come in the molding system. But, whatever be the case the inclusion should be eliminated, that is the another function of the gating system.

Next one to regulate the flow of molten metal right, what does it mean? The speed should be optimum. The speed should not be too much; at the same time, the speed should not be too slow. That is the regulating of the flow of the molten metal. Next one to consume least metal so that, there will be less scrap. While designing the gating system, the system should be such that it consumes the least liquid metal, minimum quantity of the liquid metal so that there will be less scrap. One should remember that when we are designing the gating system, the molten metal fills the entire gating system. But what is required for us, only the casting. Afterwards, the metal solidified in the riser will be cut and it will be removed. The metal solidified in the pouring basin, the metal solidified in the sprue the metal solidified in the runner, all this will be the scrap, we will cut and remove.

So, since all these whatsay elements are going to become scrap after solidification; they should consume least molten metal or minimum molten metal. Next one to establish the Directional solidification, Directional solidification means, what does it mean? The point where from the riser should solidified first. Slowly the solidification should propagate towards the riser, this is the directional solidification. So, a good gating system should enable the or should establish the directional solidification.

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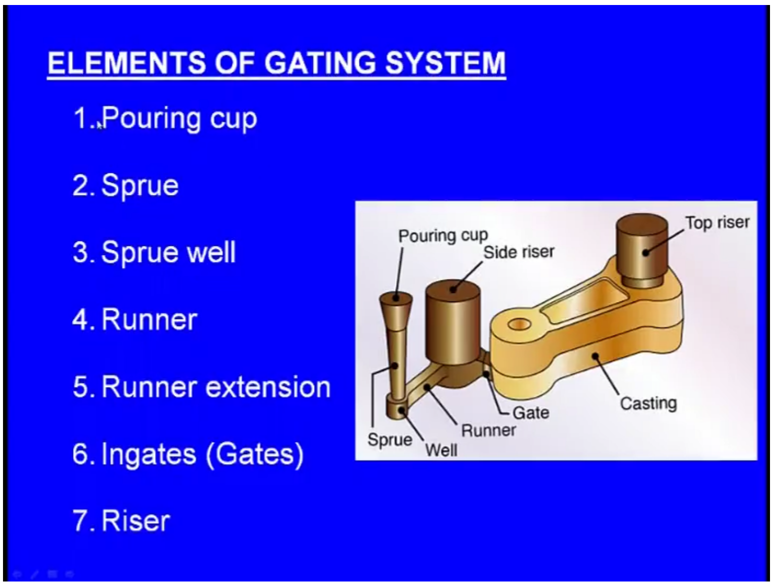

Now, these are the elements of the gating system. First element is the pouring cup, second element sprue, third element sprue well, fourth element runner, fifth element runner extension, sixth element ingates, these are also known as gates and finally, even the riser is also considered as the one of the elements of the gating system. But design of the riser we have already seen in the previous classes. So, in this lecture we are going to concentrate on the pouring cup, sprue, sprue well, runner, runner extension and ingates.

Now, let us see this gating system.

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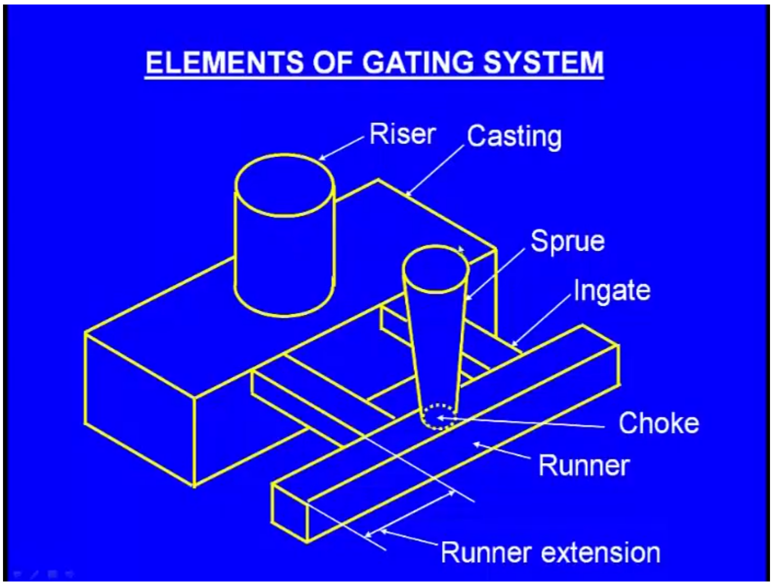

So, this one is the casting. This rectangular one block is the casting and here we can see this is the sprue. The sprue is a whatsay vertical passage. Here we can see the diameter of this sprue at the top is more and the diameter of the sprue at the bottom is less, its a tapered one. Now here the smallest diameter of the sprue at the bottom is known as choke.

Now, this is the runner the horizontal passes is the runner. So, the molten metal is entering like this, then it will be flowing along the runner like this, then after flowing into the runner, this is the ingate, it flows through the ingate. Next one another stream is there, this another stream flows through this ingate. So, these are this is one ingate and this is another ingate and this is the top riser. Now here we come across another element that is the runner extension. Here, we can see the molten metal enters through this sprue and it passes through the choke; then it passes through the runner and it enters into the ingate like this. Then, what is the purpose of this element? runner extension because the first molten metal carries certain slags and impurities.

So, straightaway, they will be flowing into the runner extension. After these runner extensions are filled with the first molten metal which includes the scrap sorry which includes this slag and other impurities, they will be trapped in this runner extension. Next one, the next coming molten metal, flowing through the will be flowing through the ingates. So, that is the purpose of the runner extension. Now, let us see the design of the pouring cup how to design the pouring cup.

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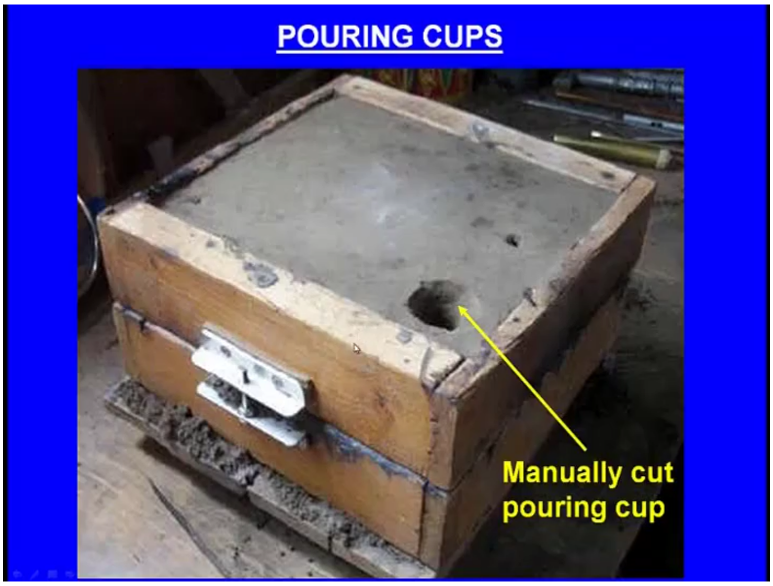

Now, here we can see this is a molding box and this is the coke and this is the drag, this is the whatsay here, we can see a pouring cup is there. This is manually cut pouring cup. In most of the cases, in small scale industries and also in some medium scale industries these pouring cups are cut manually. So, there are no what say hard and fast rules how to cut this pouring cups, but these are cut manually. But what is the limitation, sometimes one may cut too large or sometimes one may cut too small and there are some ceramic pouring cups are also available.

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We can see here in different shapes and in different sizes. We can see, so this is one ceramic cup and this is another ceramic pouring cup and this is another one and this is another one.

So, they are available in different shapes and different cross sections and also in different sizes.

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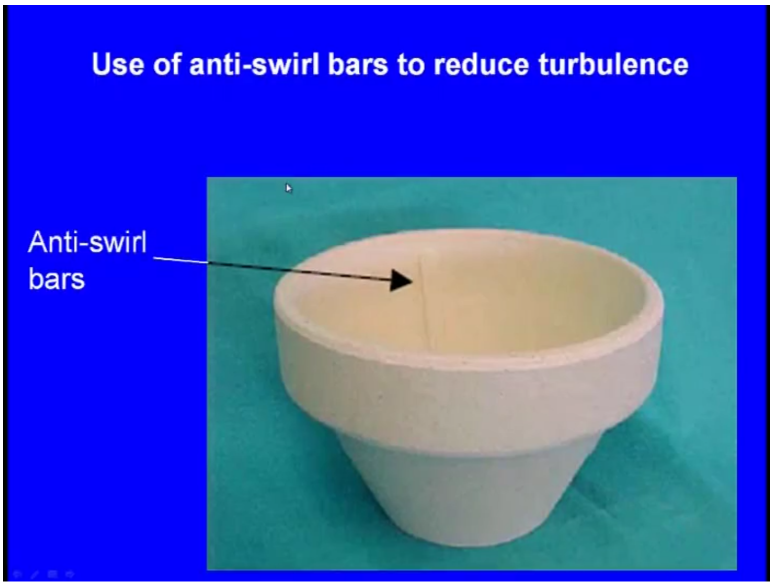

Now, these whatsay a ceramic pouring cups, have got one specific advantages. They have got the anti swirl bars are there inside. Here we can see, there is any anti swirl bar is there a just a thin projection upwards. Now what happens, when we pour the molten metal in this process, it is possible that the molten metal can cause a vertex; it may swirl inside the pouring cup and with swirling is still in progress, it may go inside this sprue and also into the mould cavity. Then what happens, if the molten metal is continuously swirling, it will erode the molding sand.

So, we want to minimize this whatsay erosion and also we want to minimize the swirling of the molten metal. For that purpose, here, there is an anti swirl bar is there. Now because this bar is there, this is a thin projection upwards as the molten metal tries to cause a vertex or as it is about to swirl, this anti swirl bar what say prevents and resist the swirling of the molten metal. Thus, the turbulence is minimize. So, that is the advantage of the these readymade ceramic pouring cups.

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TYPICAL DIMENSIONS OF POURING CUPS

Round inlet and round outlet

Inlet diameter (mm)	Outlet diameter (mm)	Height (mm)
51	25	38
127	64	133
203	76	140
254	102	203

Now, these are the typical dimensions of the pouring cups. Here we can see, round inlet and round outlet is there. Here we can see round inlet and round outlet. Again, they are available in different dimensions right. So, we can see in one case it will be the inlet diameter the inlet diameter will be 51 centimeters, this is the inlet diameter and the outlet diameter the bottom one will be 25 mm. The inlet diameter will be 51 mm, outlet diameter will be 25 mm and the height will be 38 mm and in another case it will be inlet diameter will be 127 mm, outlet diameter will be 64 mm and the height will be 133 mm and in another case the inlet diameter will be 203 mm, outlet diameter will be 76 mm and the height will be 140 mm and in another case the inlet diameter will be 254mm, outlet diameter will be 102 mm and the height will be 203 mm.

So depending upon our requirement, we can choose any of these pouring cups. So this is all about the whatsay round inlet and round round outlet pouring cups. There is another type.

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TYPICAL DIMENSIONS OF POURING CUPS

Square inlet and round outlet

Inlet dimensions (mm)	Outlet diameter (mm)	Height (mm)
78 × 90	33	117
105 × 134	38	127
140 × 159	51	152

Here we can see square inlet and round outlet, square inlet and round outlet and what are the dimensions? The inlet dimensions are 78 into 90 mm, outer diameter will be 33 mm, height will be 117 mm and in another case the inlet dimension will be 105 into 134 mm, outlet diameter will be 38 mm, height will be 127 mm and in another case the inlet dimension will be 140 into 159 mm, outlet diameter will be 51 mm, height will be 152 mm.

So, the we have completed the pouring cup. There is not so much to learn about the pouring cups either one has to go for the manually cut pouring cups or the readymade ceramic pouring cups. Next one let us, learn about the sprue.

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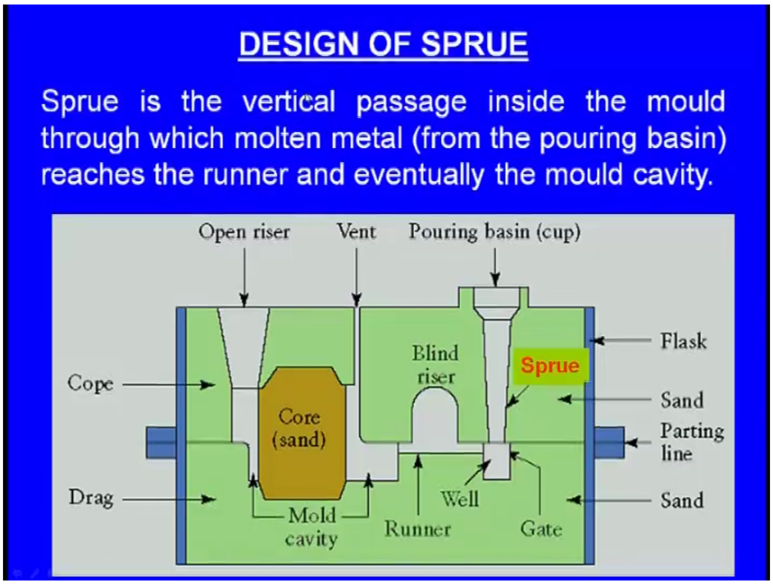

What is sprue? Sprue is the vertical passes inside the mould through which molten metal from the pouring basin reaches the runner and eventually the mould cavity.

So, here we can see this is the pouring basin. Here, we pour the molten metal, then it passes through the sprue and it falls into the sprue well, then it passes through the runner and finally, it fills the cavity. So, sprue is the vertical passes right, inside the mould through which the molten metal from the pouring basin reaches the runner and eventually the cavity. So, this is the sprue. Rules for design of the sprue, How to design this sprue? What are the rules we have to follow, while designing the sprue?

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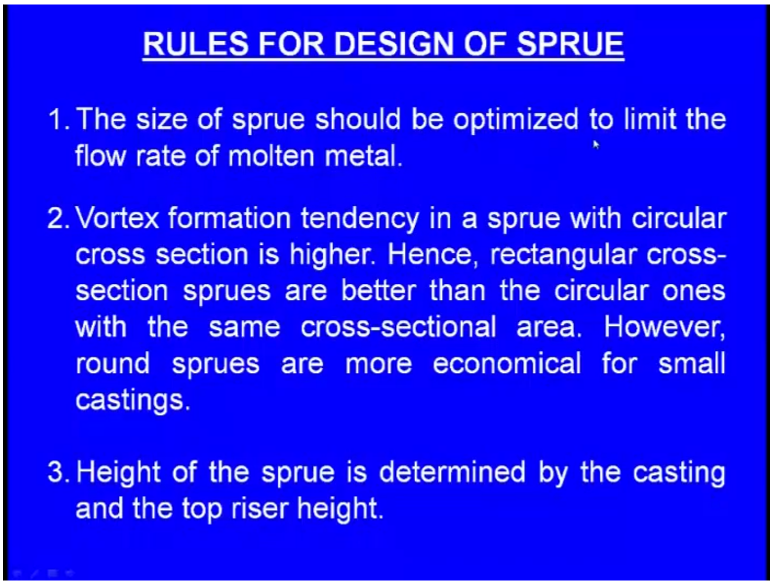

The size of the sprue should be optimized to limit the flow rate of molten metal. So, that is the first rule, the size of the sprue must be optimized. Second rule is vortex formation tendency in a sprue with circular cross section is higher. Just now, I told you the vortex formation means the molten metal used to what say swirl inside the pouring cup and also the sprue. Then, what happens because of that there will be turbulence. So, this is the vortex. So, in a circular cross section sprue it is higher right. Hence, rectangular cross section sprues are better than the circular, what say once with same cross sectional area compared to the circular cross section sprues rectangular cross section sprues are better or the square cross section sprues are better. But, however, round sprues are more economical for small castings, if the casting which we are going to produce is a smaller one, so whether, we use the what say round, what say circular sprue or the rectangular sprue it hardly makes any difference. But when, when we are making a very large casting and the that time if we go for a rectangular sprue, it will it would be beneficial.

Next one height of the sprue is determined by the casting and top riser height. Next one the fourth rule.

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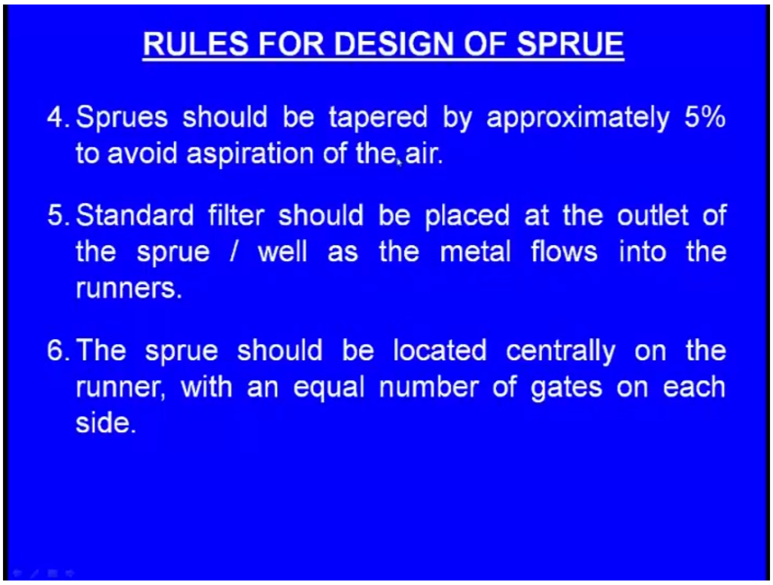

Sprues should be tapered by approximately five percent to avoid aspiration of the air. The sprue is always tapered, it is never a perfect cylindrical what say element. The diameter of the sprue at the top will be more and the diameter of the sprue at the bottom will be less and this taper should be approximately about five percent. Next one standard filter should be placed at the outlet of this sprue or the sprue well as the molten metal flows into the runners.

So standard filters are available to what say, filter the impurities. Now these filters should be what say placed at the outlet of the sprue or the sprue well. Next one the sprue should be located centrally on the runner within equal gates on each side right. So, it should be centrally located on the runner. So that on both sides there will be equal number of gates or the ingates.

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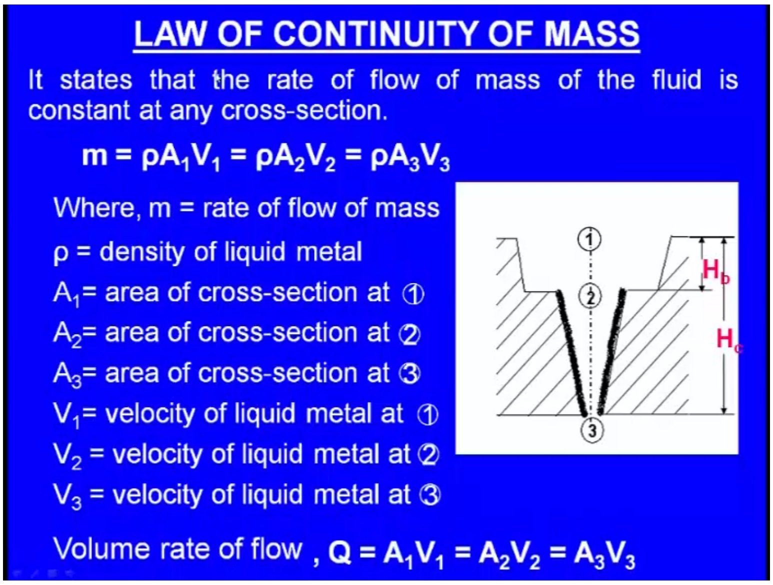

Now we will be learning about one law that is known as the law of Continuity of Mass. What is this law of Continuity of Mass? It states that the rate of flow of mass of the fluid is constant at any cross section.

So, if m is the what say mass of the fluid that is flowing at a at any cross section, then m is equal to rho A 1 V 1 are that is equal to rho A 2 V 2 are that is also equal to rho A 3 V 3. Where, m is the rate of flow of mass and A 1 is the area of cross section at point 1here, that is the area of cross section. A 2 is the area of cross section at point 2 here, this is the area of cross section at point 2. So, this is the A 2.

Next one A 3 is the area of cross section at point 3. So this is point three. So this is the area of cross section at point 3. Next one V 1 is the velocity of liquid at metal of metal at point 1. So here, what is the velocity of the metal? So, this is the V 1 and is this is the point 2 and here what is the velocity of the metal, molten metal. So, that is the V 2. Next one this is the point 3. Now, what is the velocity at this point 3? This is the V 3.

Now, the Law of Continuity of Mass says that m is equal to rho A 1 V 1 that is equal to rho A 2 V 2 that is also equal to rho A 3 V 3. Now if we calculate the volume rate of flow, then, how this expression would become? First of all, what is volume? Mass divided by density. Now this in this same expression, we divide this by density, then what will happen? This rho will be eliminated. Then this expression would become right

Q is equal to A 1 V 1 that is equal to A 2 V 2 that is also equal to A 3 V 3. Where, Q is the volume rate of flow.

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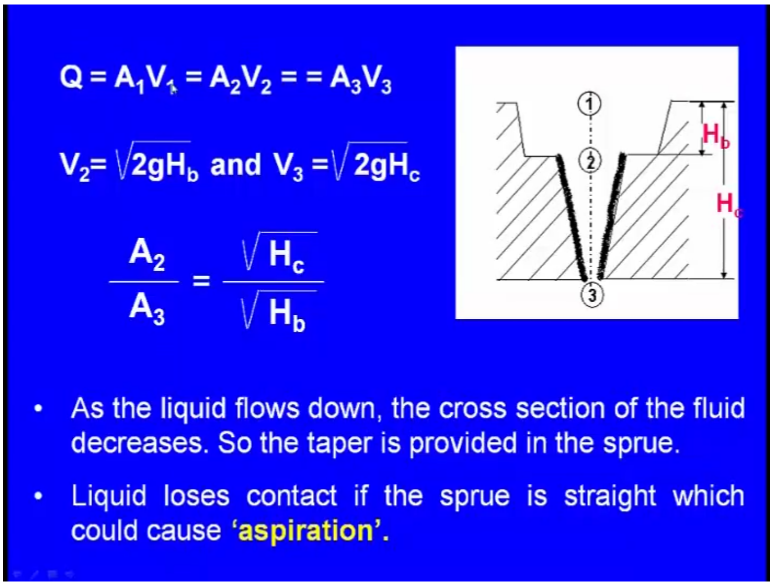

Just now we have seen that Q is equal to A 1 V1 that is equal to A 2 V 2 that is also equal to A 3 V 3. Then, V 2 is equal to root of 2 g H b and V 3 is equal to root of 2 g H c. What is this H b? H b means this height this height, height of point 2.

Similarly, V 3 is equal to root of 2 g H c. What is H c? Height of point three, you see this is point three. So, this is H c, this is H c. So, the molten, this is the pouring cup, this is the pouring cup and this is the sprue and this is the exit of this sprue which is also known as the Choke. Now A 2 by A 3 from these two expressions, we can get A 2 by three A 3 is equal to root of H c divided by root of H b.

Now, from this expression, what we can learn? A 2 by A 3 is equal to root of H c by H b. H c is a larger quantity you see, H c is larger quantity and H b is a smaller quantity. Both are the heights, here we can see. Now what is A 2? A 2 is the area of cross section of the sprue at its entrance. What is A 3? It is a area of cross section of the sprue at its exit. Now A 2 by A 3 is equal to root of H c by H b means, what does it mean? A 2 by A 3 is equal to H c by H b means, this ratio is greater than one because H c is a what say larger quantity and H b is a smaller quantity. What does it mean? A 2 by A 3 is equal to greater than one means, what does it mean? A 2 or the area of the cross section at the sprue should be larger and A 3 that is the area of the cross section at the exit of the sprue must be smaller.

So, that is the interpretation of this expression. So as the liquid flows down, the cross section of the fluid decreases. So, the tapper is provided to the sprue. So that is why, a tapper is always provided to the screw sprue. Next one liquid loses contact if the sprue sprue is straight which could cause aspiration. If that sprue is totally a straight one then, what happens, even if we keep a straight sprue, the liquid will be taking a taper inside.

Now as you go to the bottom of the sprue, there will be a clearance between the flow of the metal and the wall of the mould. So, there is a clearance, there is a gap. So, the air will be entering. This phenomenon is known as the Aspiration.

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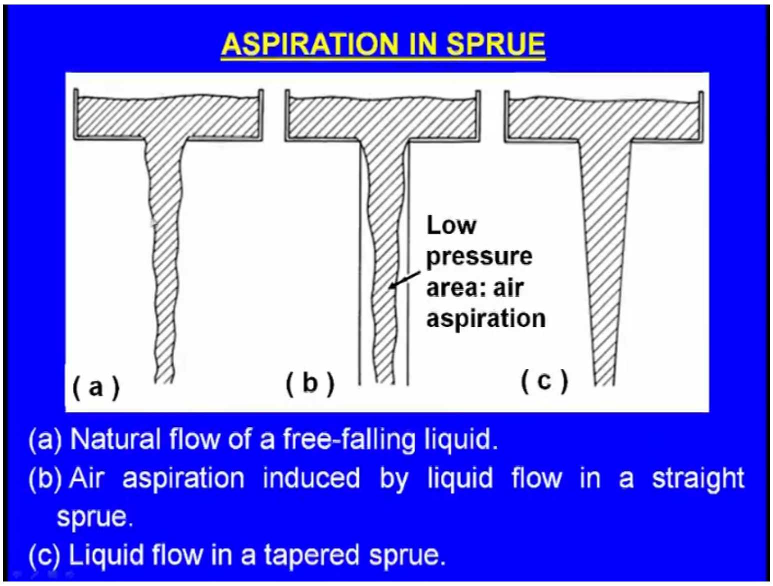

What is here, we can see this is the aspiration in sprue right. Here, we can see three cases. We can see here, the natural flow of a free falling liquid, it will be like this. Here we can see, the area of cross section is more and as we are coming down, the area of cross section is less.

Next one what happened here, we have arranged here sprue; a totally straight sprue is there. Then, what happens? Even if, we arrange a totally straight sprue, cylindrical sprue, what will happen? Still at the bottom, it will be occupying a lesser cross section means here there is a gap and this is the mould wall. This is the mould wall, this the mould wall and here is a gap at the bottom because there is gap at the bottom air enters. So, that is the whatsay Air Aspiration.

Now, what is the remedy for this? The sprue should be tapered, as we see in the third case. Here we can see the sprue is there and it is tapered because it is tapered even the molten metal by default it will be taking lesser cross section at the bottom. So, there is no clearance at the bottom between the mound wall and the flow of the molten metal. Hence, there is no chance for the aspiration.

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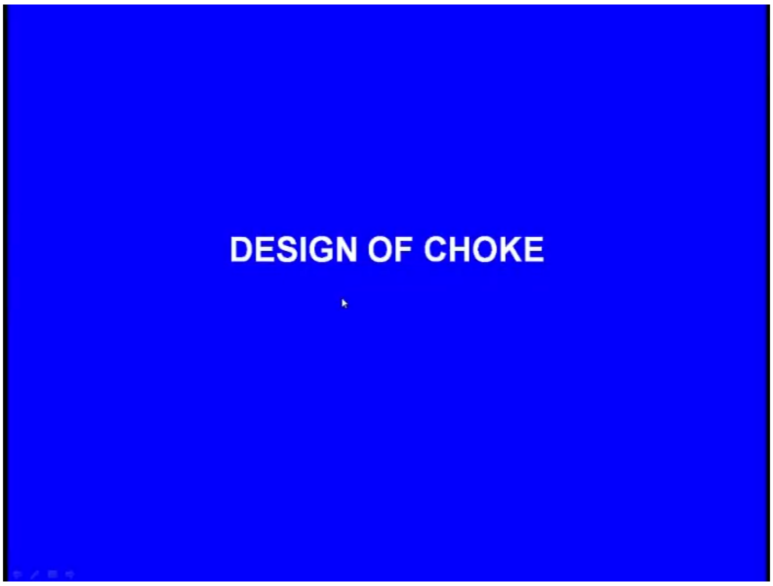

Next one let us see the design of the Choke.

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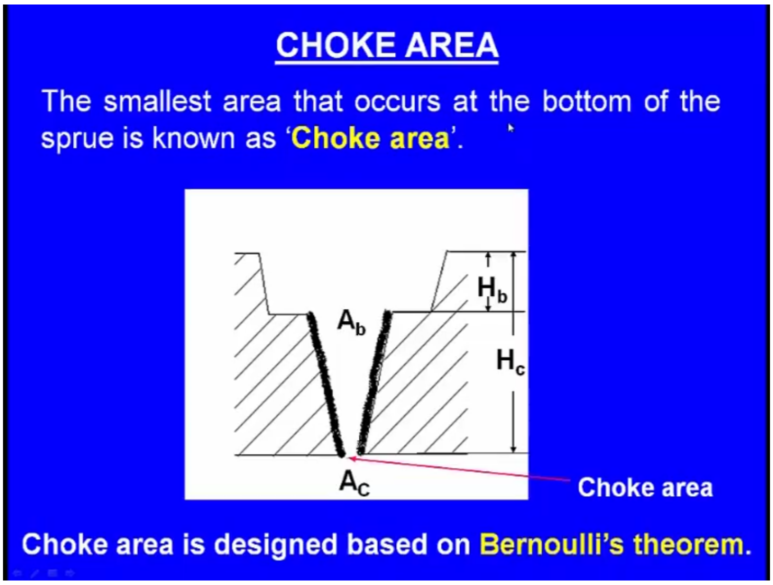

The smallest area that occurs at the bottom of the sprue is known as the Choke area. First of all, what is meant by Choke area? Here we can see, this is the pouring cup and this is the sprue and this is the entrance of the sprue and this is the exit of the sprue, then it enters into the mould cavity.

Now, what is the definition for this Choke area? The smallest area that occurs at the bottom of the sprue is known as Choke. Choke area that occurs at the bottom of the sprue, this is the bottom of the sprue. So, the smallest area, that occurs at the bottom of the sprue so means, this area at the bottom most of the sprue is known as Choke area. Now choke area is designed based on Bernoulli's Theorem.

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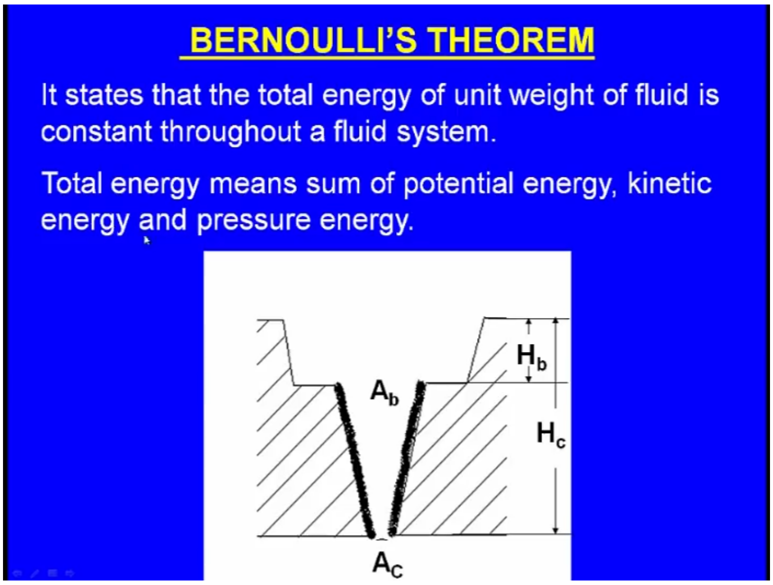

Now, what does this Bernoulli's Theorem state? It is based on the principle of conservation of energy and relates pressure velocity and elevation and here, you can see the same case, this is the pouring cup and this is the sprue and this is the choke. The height of the entrance of the whatsay sprue is the H b and the height of the exit of the sprue that is the choke is H c. We can see height of choke and this is the height of the entrance, height of the entrance. It states that the total energy of unit weight of fluid is constant throughout a fluid system. Total energy means sum of potential energy, kinetic energy and pressure energy and here we can see the same thing.

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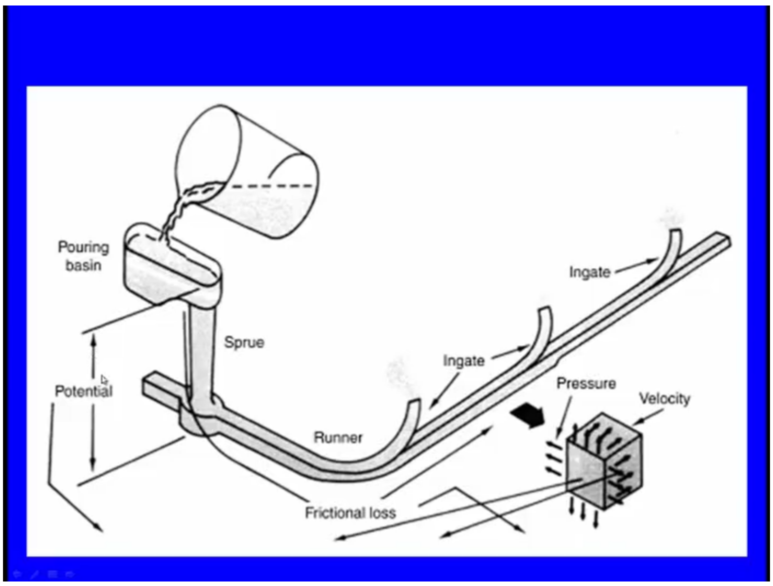

Here we can see the potential energy and here of course, there are frictional losses are there and here we can see the pressure energy and here we can see the what say velocity is there and finally, so these are all what say covered by the Bernoulli's Theorem.

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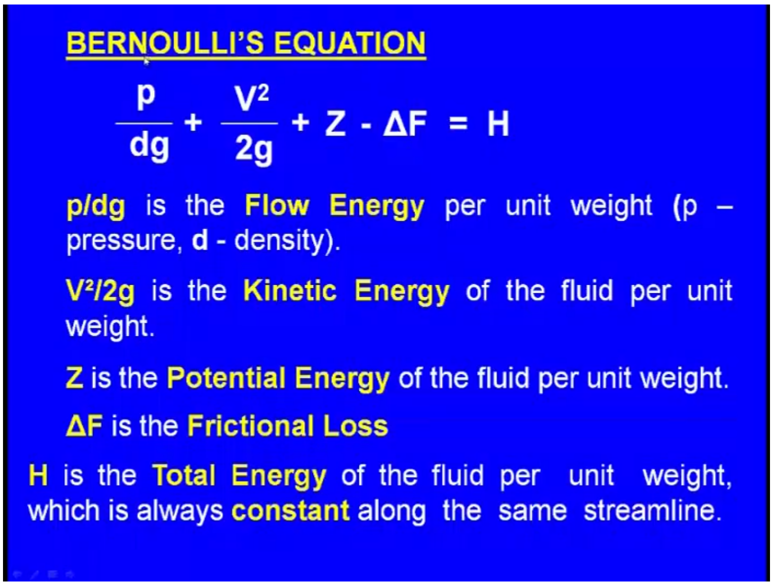

Now, let us see the Bernoulli's equation. It is like this p by dg plus V square by 2 g plus Z minus delta F is equal to H. p by dg is the flow energy per unit weight. Rho is the pressure right and d is the density. p is the pressure. Next one V square by 2 g is the kinetic energy of the fluid per unit weight. Z is the potential energy of the fluid per unit weight. Delta F is the frictional loss and H is the total energy of the fluid per unit weight, which is always constant along the same streamline. So, this is the Bernoulli's equation.

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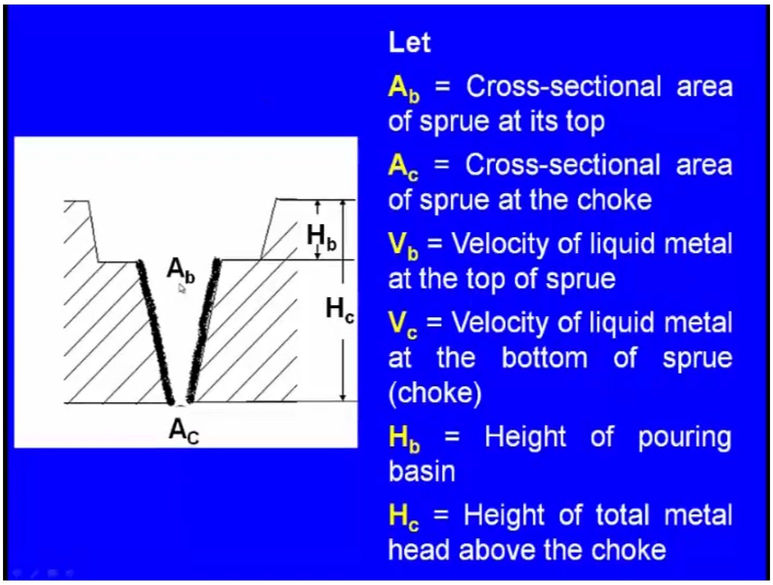

Now let us derive an expression for the whatsay Choke area. This is the Choke. Choke means what say area of cross section at the bottom most portion of the sprue is the choke area. Now we are going to derive an expression for the Choke area. So, here we can see this is the pouring cup and this is the sprue and this is the entrance of the sprue and this is the exit of the sprue right. So, the area of cross section at the entrance of the sprue is A b. The area of cross section at the exit of this sprue that is the choke area is indicated by A c.

Now, the height of the sprue at the entrance is H b, the height of the choke is H c. Let A b is equal to cross sectional area of the sprue at its top, this is the A b. Next one A c, the cross sectional area of the sprue at the choke, next one V b means velocity of the liquid metal at the top of the sprue means here what is the velocity of the liquid metal that is V b. Next one V c is the velocity of the liquid metal at the bottom of the sprue are at the choke that is known as the velocity of the liquid metal at this point to A c is the V c.

Next one H b is the height of the pouring basin. You can see here this is the H b. Next one H c is the height of the total metal head above the choke. So, this is the H c means this the height of the choke.

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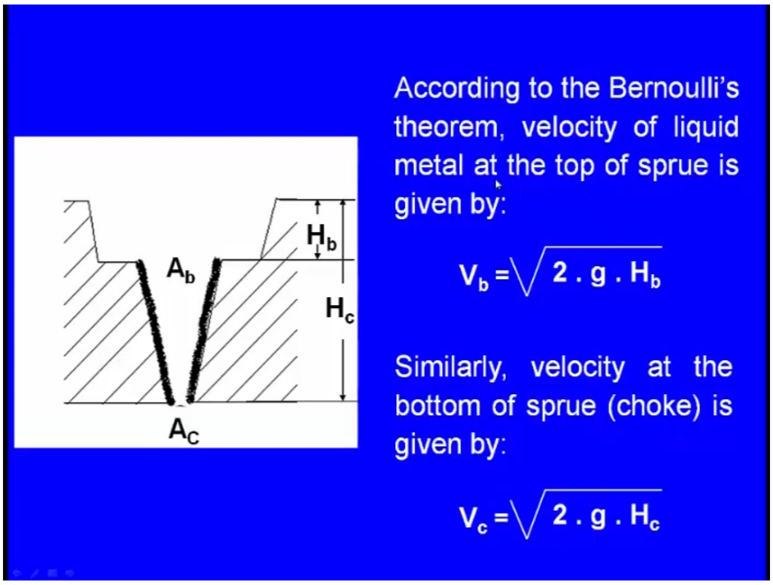

According to the Bernoulli's theorem, velocity of liquid metal at the top of the sprue is given by: V b is equal to square root of 2 into g into H b. This we have already seen earlier. Similarly, velocity at the bottom of the sprue at the choke is given by V c is equal to 2 g H c.

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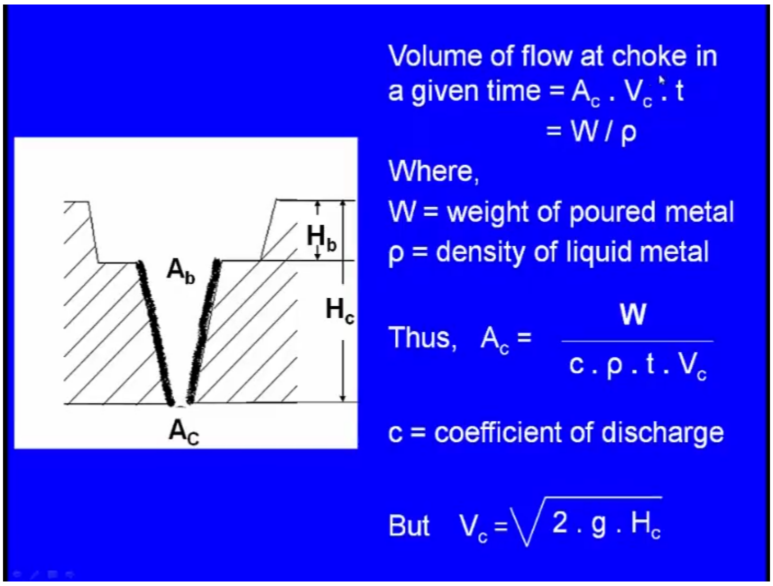

Volume of flow rate flow at choke in a given time is equal to A c into V c into t, that is well known to us volume of flow at choke in a given time is equal to A c into V c multiplied by time. That is also equal to W by rho. Where, W is the weight of the poured metal and rho is the density of the liquid metal. Thus, A c is equal to W by c rho t V c. Here, we come across another term that is the c that is the coefficient of discharge.

Now, V c we have already derived the expression earlier. V c is equal to root of 2 g H c. So, this 2 g H c we will substitute here.

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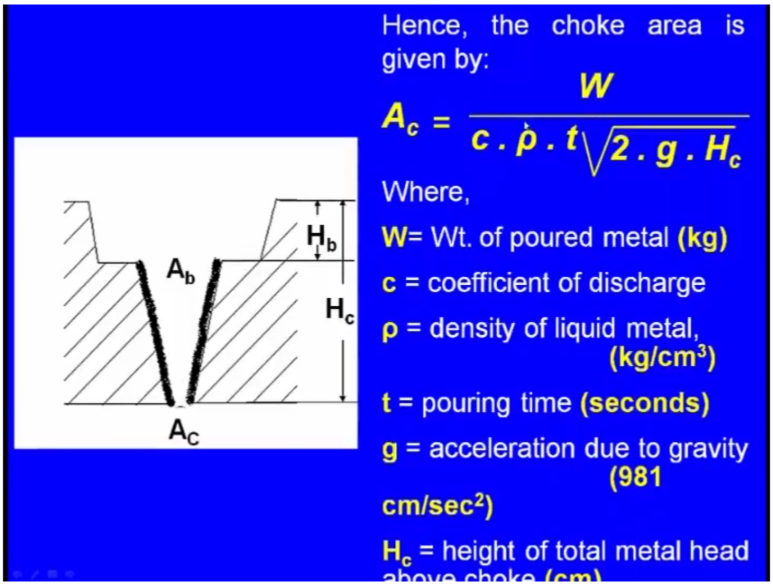

Hence the choke area is given by A c is equal to W divided by c rho t square root of 2 g H c. Where, W is the weight of the poured metal in kgs kilograms, c is the coefficient of discharge because there is a friction we always have to what say take this friction into account that is why, there is a c coefficient of discharge. It will be between 0.7 to 0.9 and for an ideal fluid it will be 1. But such case will not arise right; generally, the coefficient of discharge will be 0.7 to 0.9. Rho is the density of the liquid metal that is kg per cubic centimeter.

Next one t is equal to that is the pouring time in seconds; g is the acceleration due to gravity that is equal to 981 centimeter per second square. Next one H c is the height of the total metal head above the choke in centimeters. So, this is the H c. Now this is the expression we have derived for the whatsay choke area A c. So, for we have seen the elements of the gating system and we have learnt about the pouring cup and this sprue. Now let us see about the sprue well.

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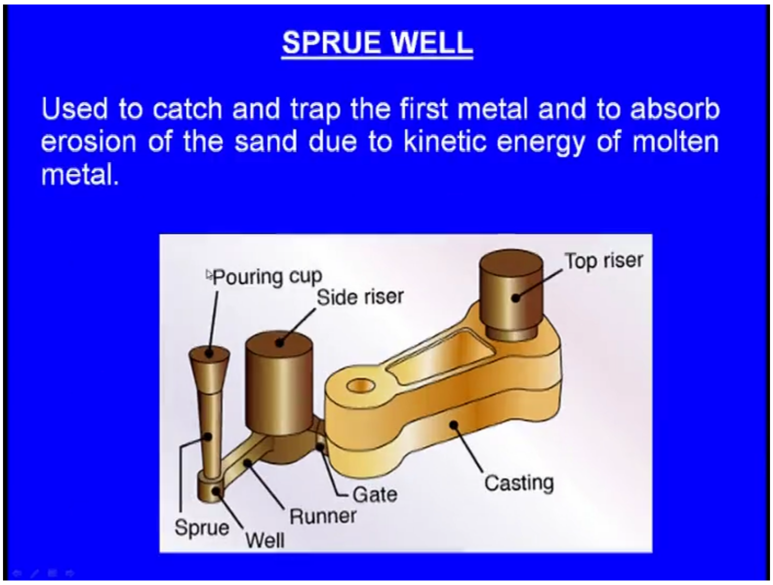

So, this is the sprue well and it is used to catch and trap the first metal and to absorb erosion of the sand due to kinetic energy of molten metal. Now we pour the molten metal in the pouring cup and it will be passing through the sprue. Then, what happens? By the time, it reaches the choke. Its kinetic energy will be too much now straight away it fit falls on the runner, what will happen? It will erode the molding wall inside the runner. We do not want such thing to happen. That is why we are keeping a sprue well here because of this sprue well contains sufficient amount of the liquid metal and the molten metal flows into this sprue well first, that is why there is no erosion of the molding sand. Then, after this sprue well is filled, then the molten metal fills into this sprue well, then it flows into the runner.

So, to prevent the whatsay erosion of the molding wall and to catch the whatsay first metal and to observe the erosion of the sand due to kinetic energy, we keep this sprue well here. So, that is the purpose of the sprue well rules for design of the sprue well.

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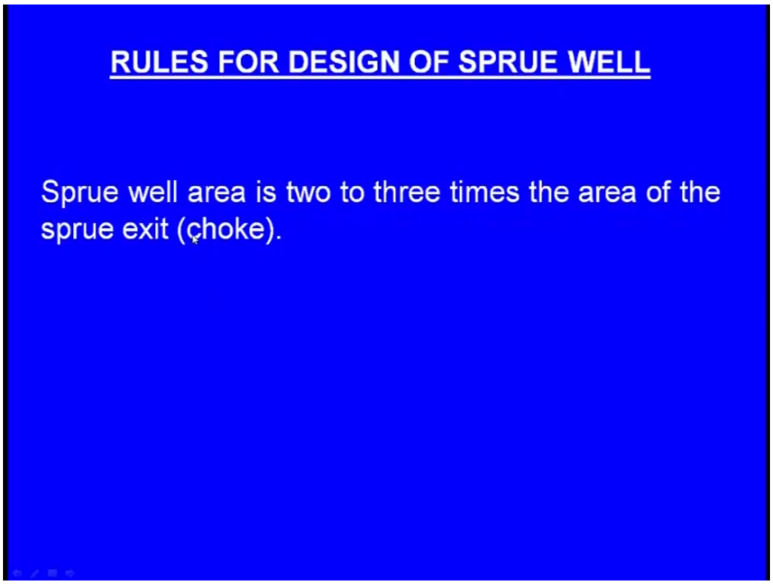

The sprue well area is two to three times the area of the sprue at exit that is the choke means what is the choke area, we have to calculate and the sprue well area what say cross sectional area should be 2 to 3 times the cross sectional area of the choke. Next let us see about the Runner and here this is the gating system.

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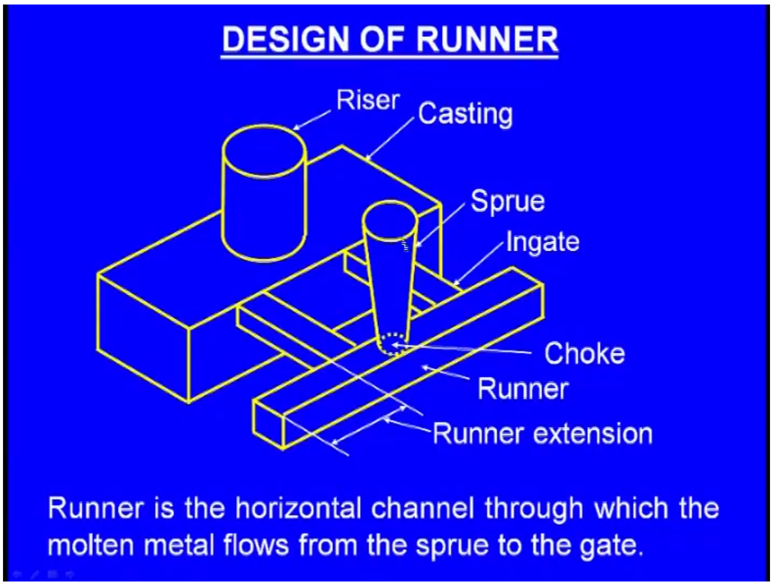

And here we can see this is the whatsay sprue the molten metal passes through the sprue, then it enters into the runner, then it enters into the runner, then it flows through the ingates like this it flows through the ingates. Runner is the horizontal channel through which the molten metal flows from the sprue to the ingate right. It is the horizontal process.

So, this is the runner, this much is the runner. Rules for runner design. Typical cross section of your runner is a square.

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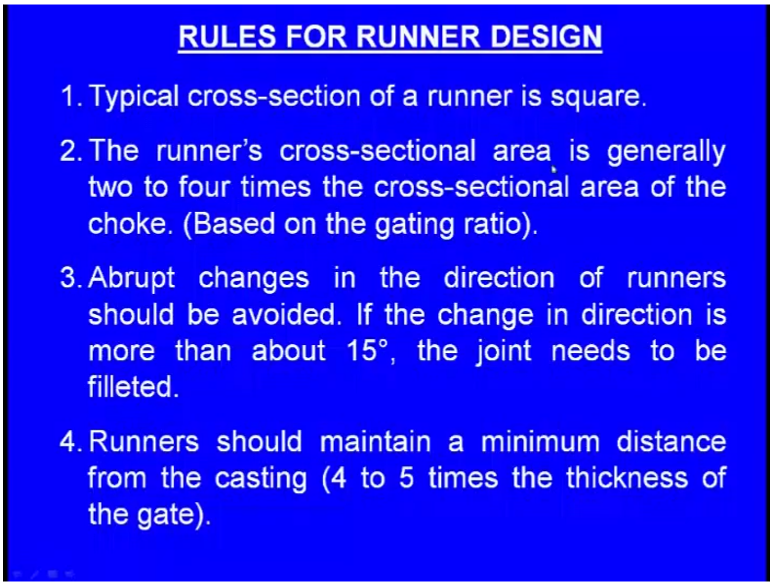

The runners cross sectional area is generally 2 to 4 times the cross sectional area of the choke. Again it depends upon the gating ratio, soon we will be learning about a Gating ratio. So, based on the gating ratio this whatsay cross sectional area of the runner depends. Abrupt changes in the direction of the runners should be avoided. If the change in direction is more than about 15 degrees, then the joint needs to be filleted. If the whatsay change in direction is more than 15 degrees then, instead of keeping a sharp corner there should be a fillet corner.

Next one runners should maintain a minimum distance from the casting 4 to 5 times the thickness of the gate or the ingate. There should be some distance from the casting to the runner, the runner should not be too close to the casting. Then how far it should be from the casting 4 to 5 times the thickness of the ingate. Next one let us see the runner extension.

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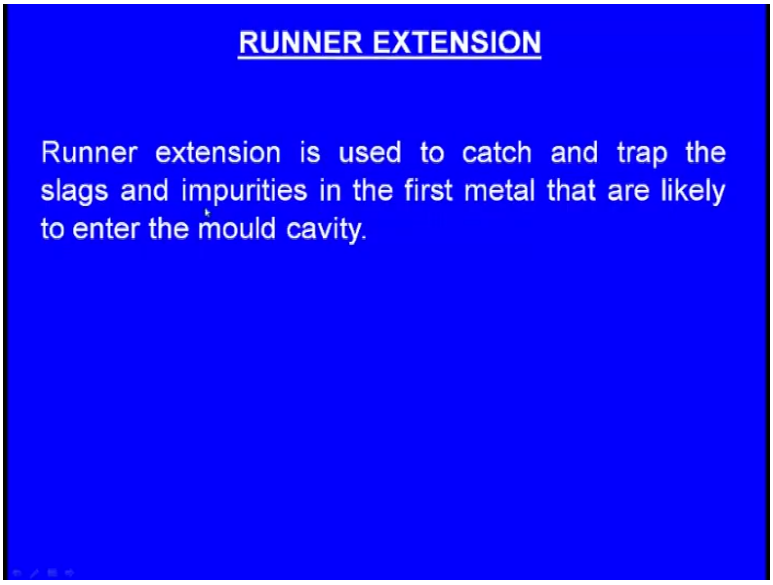
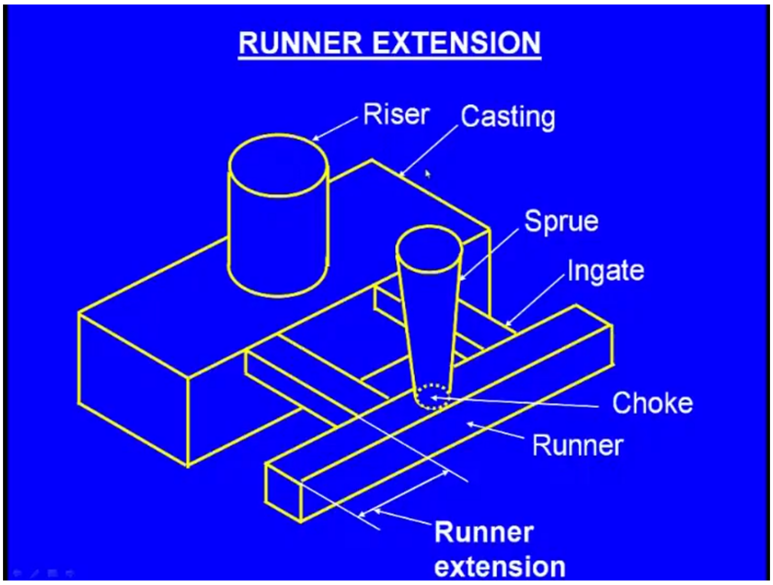


Runner extension is used to catch and trap the slags and impurities in the first metal that are likely to enter into the mould cavity that is the purpose of the runner extension. (Refer Slide Time: 34:35)



Here we can see, this is the gating system and yes this is the sprue the molten metal of course, above the sprue there is a pouring cup which is not shown here. The pour what say molten metal is poured into the pouring cup and it passes through the sprue and this is the choke, the bottom most cross section of the sprue. Then it falls a what say flows into the runner you see here.

Now the first metal may contain some slags and impurities. So, now, our task is that this first metal which contains slags and impurities must not enter into the mould cavity. Somehow, we have to divert them so that they will not enter into the mould cavity. So, for that purpose, what we are doing? We are keeping the runner extension, you see here, from here to here there is no point in keeping this strictly speaking and here you see this is the runner extension and this is also is the runner extension.

Now, what will happen when we pour the molten metal? It what say it comes into the sprue and it passes through this choke right and it enters into the runner. Then first it straight away go straight, this side also, it straight away go straight. Now it is occupied by the first metal which contains the impurities and slags of the molten metal. After the runner extension is filled with the whatsay first metal which includes the, which contains the whatsay slags and impurities, then, the fresh metal continues. Now the fresh metal cannot fill this because this portion is already filled with the first metal, which contains the slags and impurities. Now the fresh metal enters through the ingates like this, like this. So, that is the purpose of the runner extension.

Next one ingates or they are also known as gates.

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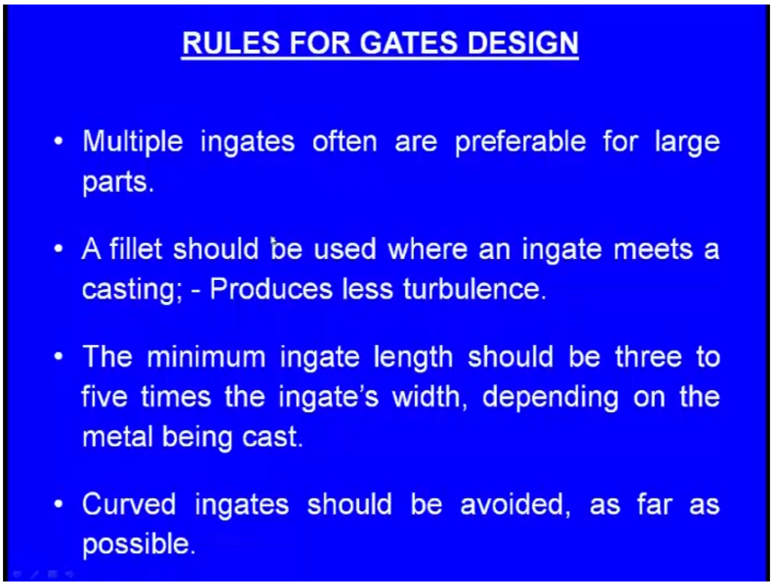

Rules for gates design or the design of the ingates: Multiple ingates often are preferable for large castings. A fillet should be used where an ingate meets a casting right because we use the fillet; it what say causes less turbulence. The minimum ingate length should be three to five times the ingates width. What should be the length of the ingate? That should be three to five times the ingates width. Again, it depends on the metal being cast.

Curved ingates should be avoided as far as possible. Friends, in this lecture, we have seen the elements of the Gating system right. So, these are the elements of the Gating system: pouring cup, sprue, sprue well, runner, runner extension, ingates and the riser is also considered as the part of the Gating system right. Initially, we pour the molten metal into the pouring cup. So, this is the pouring cup, next it passes through the sprue, next here it what say falls into the sprue well, next one it enters through the runner. Next one yes it fills the side riser, next one it passes through the gate or the ingate. Then, it flows through the mould cavity and it fills the mould cavity after filling the mould cavity it raises through the riser

So, these are the different elements of the gating system, we have seen and how to design the pouring cup, how to design the what say sprue what say cross sectional area at the bottom, we called it as the choke. The bottom cross sectional area of the sprue is known as the Choke. We have seen how to design the choke area and we have seen and how to design the runner, runner extension and the ingates. We will continue this in the next lecture.

Thank you.