Theory of Production Processes

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Lecture - 05
Fluidity of Liquid Metals

Welcome to the lecture on fluidity of liquid metals. So, in this lecture we will discuss about the fluidity, which is required for liquid metals when we cast it. So, in the previous lectures we discussed about solidification. So, before solidification you have to ensure that the liquid metal must go into the every portion of the cavity. So, first of all the liquid metal when it is poured from the basically pouring basin and through the gating system it enters into the cavity, you have to see that it should go into all the cavities it into all the intricate details of the mold cavity.

So, the ease with which it goes into the cavity and in the even remote corners of the cavity, that is possible by this property that is fluidity. If the fluidity is more than with ease this liquid metal will go into all the pockets small pockets; if the fluidity is less in that case the metal will not be able liquid metal will not be able to go into the cavity. So, that way fluidity is important. So, let us go to the standard definition of fluidity, it is defined as quality of the liquid metal, which enables it to flow through mold passages and to fill all the interstitials of the mold providing sharp outlines and faithful production reproduction of design details.

So, as we discussed that you know when the liquid metal is poured into it, then as it comes in contact with the mold walls then the temperature comes down. So, and the immediate solidification may be at many point starts very minutely, but suppose we directly put into the cavity. So, as it goes into the cavity and it moves from one place to other so, from the walls certainly, it gets certain resistance. But a thing is that suppose there is a long channel through which you are passing the liquid metal. So, what will happen slowly the solidification will start from the sides?

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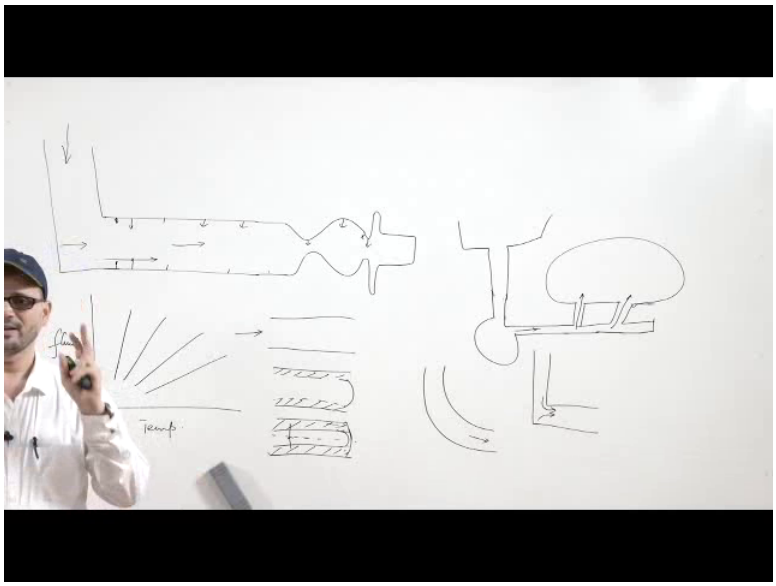

Now, how it happens, suppose you have a channel and you are pouring the liquid metal into it, and the channel and liquid metal goes all throughout.

So, what happens in case of pure metals once you go with time, the solidification will start at this surface as well as at this surface. So, what will happen the advancing front will grow either in this direction, I mean both either in this direction as well as in this direction now the liquid metal which has got certain head. So, due to that head so, suppose it is connected from here, and liquid metal is coming from this side. So, that will go in this direction the thing is that as it goes along this direction. Now how easily and suppose in the way you have different kind of maybe projections or so, so it may be like that suppose.

Now what happens that when the liquid metal goes through this, it will be experiencing certain resistance maybe because of the mold walls or so. Now, the ease with which it goes into this cavity or it fills into these portions and then fills maybe it is extending further into some other geometrical geometry form or so. The thing is that it will go on moving, but the solidification front will move maybe from here and here. So, if it is infinitely long which is quite large, after some time you will see that it will be blocked because the advancing front will come and then ultimately it will be blocked. So, the care which a foundry man has to have that the time during which, this advancing front from both the sides come and join and close this channel so, that there is no further entry of liquid metal, your all liquid must go into the cavity otherwise this will be blocked.

Now for that the metal has to have enough fluid. If the metal becomes solid, in that case there will not be any entry further because the channel will be blocked. So, that is what I mean you must have a fluid life for that metal; if the fluid life of the metal is high in that case even if it takes little more time, you can ensure that liquid metal will move and it will go and fill all the details of the casting. So, that is why fluidity is important. Now the thing is that you may must have either you will hear it and may be that you must have studied about different types of casting defects in the earlier classes.

And many are related to the improper fluidity of the liquid material. So, what happens if this is the case that liquid metal is not able to go to the distance the one where it should go in that case there may be defects like mis run or so, because it may not fill the whole cavity the thing is that as we know that there are many factors which are controlling this fluidity. So, it is not a single physical property, because it will depend upon many factors like as we discussed when we pour the liquid metal into it. It will depend that what is the temperature of the liquid metal. So, normally when the temperature of the liquid metal is higher the fluidity will be higher. Because if you have given large superheat to the liquid metal, first of all the liquid metal loses it is superheat, then after losing it is superheat it comes to it is freezing temperature. Once it comes to the freezing temperature in that case. So, the I mean till it has not come to the temperature of the freezing temperature it is having super heat in that case there is no chance of getting solidified.

So, if the temperature is higher if the superheat given to the material is higher, it will try to go in the path with least resistance. So, one is that the temperature, similarly the we are using normally the sand mold now the fluidity is nothing, but the ease with which it flows. So, as we know that when something is flowing, you have the relative velocity between this surface and the liquid metal which is flowing.

So, there will be a resistance occurring on the mold wall and the surface which is in between the I mean in the first layer of the liquid and the mold wall. Now this will depend upon. So, this resistance will be upon the type of surface the smoothness of the surface. So, if the surface is not smooth, if the surface has rough finish like if you are using the coarse grains at the top layer I mean at the layer which is in contact with the liquid metal, in that case it will experience more resistance.

So, in that case the result may be that that the liquid metal will be experiencing more resistance, and then it will go and stop at a small distance. So, there will you will have either you will have to have other conditions favorable so, that the liquid metal goes into all the cavities. Then there are other factors like the design of the gating system. So, if the design of the gating system is not proper, in that case the flow will not be streamlined; there may be corners where there will be pressure differentials the points which will have the pressure pockets, and in those cases also that affects the fluidity. So, there are many properties, we will discuss that how these properties basically are important when we discuss about the fluidity. So, fluidity is very important for the liquid metals to be studied. So, that you know you ensure that it goes into all the intricate, it fills all the intricate details of the casting.

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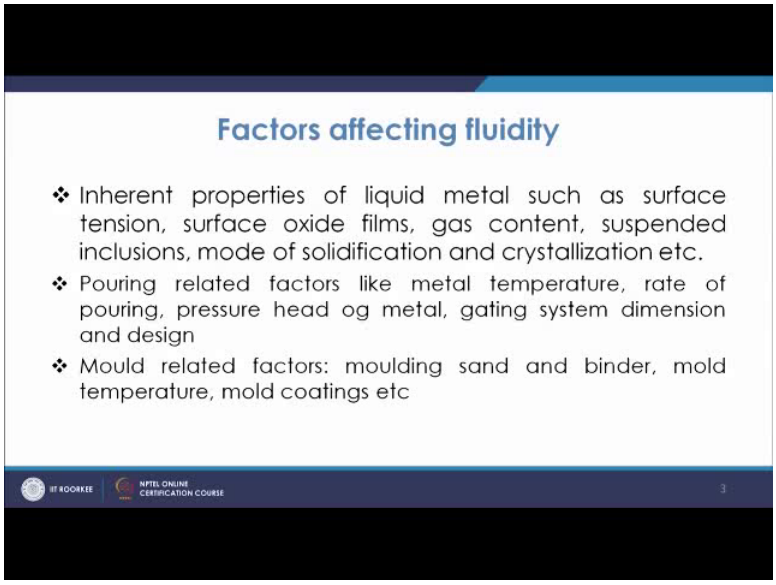

Factors affecting fluidity; so, as we discussed that you have a number of factors which affect the fluidity and the properties are like inherent properties of liquid metal, like surface tension. So, surface tension as we know if the surface tension will be higher or lower, it will be affecting the fluidity of the material, because it is anyway it is the force or which is working. So, surface tension based on that definition, you can it will be clear that how it will affect the fluidity. Surface oxide films; if the surface oxide films are as you know made, then that will also affect the fluidity. Gas content suspended inclusions mode of solidification, crystallization all these are the inherent properties of the liquid metal and basically because when you have any metal which is you are casting,, it will have certain surface tension properties.

It will have the properties whether it makes oxide films, what is the gas content of the liquid metal because at higher temperature large amount of gases are dissolved into the liquid metal. So, that will affect the fluidity, similarly you have inclusions which are suspended into the liquid metal, how it is getting solidified what is the mode of solidification. So, that these are the factors which affect the fluidity similarly pouring related factors like metal temperature as we discussed. So, the temperature will be higher or lower that will affect the fluidity. Rate of pouring pressure head of metal gating system dimension and design, all these are basically the factors which are required to be understood. So, then we have pouring related factors like metal temperature, rate of pouring, pressure head of metal and then getting system dimension and design, these are also the factors which affect the fluidity and further your mould related factors like moulding sand and binder, mold temperature mold coating e t c so.

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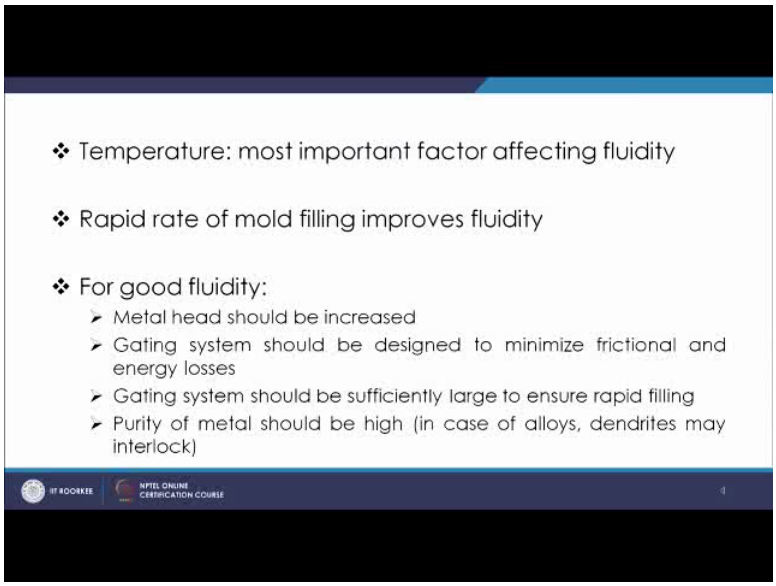

Let us go to the factors first of all the temperature; this is the most important factor which affect the fluidity. If the temperature is higher, the fluidity will be higher. As we discussed that if you have the temperature which is higher then fluidity will be higher. So, if the temperature is larger for different materials, you have different kind of fluidity graphs we will discuss that how fluidity is measured. Basically fluidity is measured by some length distance may be I in inches or in centimeter, and it is basically quantified in terms of the distance which the liquid metal traverses in a spiral twist normally a spiral fluidity test is carried out that we will discuss.

So, in that what we do is we give the liquid metal at one portion, and then the liquid metal is allowed to go along the spiral case, and it is seen that how far it is traversing along the spiral path. So, the distance which it is basically traversing, in inches that is basically measured as that is termed as fluidity that is in inches. So, if the fluidity is higher, the metal will be able to go up to larger distance. So, the temperature is the most important factor affecting fluidity. If the temperature becomes smaller then fluidity will be smaller. In most of the cases when the liquid metal is losing the heat; if the liquid metal will be losing heat in the while traversing through the mold or through the gating system, in that case as the temperature comes down the fluidity will be smaller and smaller.

So, if you maintain some more superheat or if the temperature is higher, the fluidity will be always higher. So, that way temperature is one of the most important factors, which affects the fluidity. Next factor is the rapid rate of mold filling. So, basically this rapid rate of mold filling will improve the fully fluidity. Rapid rate of mold filling will be ensured by basically many ways like you must have proper gating system; you should have quite a large the vessel or the pouring basin which should provide you the liquid metal. So, rapid rate means that you are basically pouring the liquid metal at a fast rate. Now in that case it will take less time to fill the mold.

So, we will see we will study further, that when we are taking less time to fill the mold. In that case the mold is filled in quickly and then solidification has to start. The thing is that when the solidification has to start, you should ensure that your whole cavity is filled. Somewhere you know the solidification will start from this sieve this place, as well as from this place as well as from this place, it will always start from here here here or and all these places the solidification will start at this place it will start, and this place it will start, and this place it will start or so. Now if you look at in this cavity, you have to ensure that this portion should not get solidified. If this gets solidified before it enters into all the portions, in that case this part will not be filled and it will be a defect.

So, you have to see that when it enters into the cavity, more quickly it should go and fill the cavities. So, for that if the fluidity is higher, in that case you can ensure if the temperature is quite high you will be having this confidence that your metal will not solidify here and get it choked. So, for that one is temperature; the second thing is that if even if the temperature is higher, but if you are pouring in a very slow manner in that case temperature will come down. So, pouring must be fast. So, that in less time it will goes and fill it, and once it fills the cavity then the cavity will be solidified. So, then there is not much of the problem. So, for that rapid rate of mold filling is required which will improve the fluidity.

So, for good fluidity the metal head should be increased; getting system should be designed to minimize fictional and energy loses. So, we will discuss about the gating system and you must have heard about the gating system, in the early courses of manufacturing process. The gating system basically consists of that system of network. So, you have the pouring basin and then it will come and it will come to a spruewell and then from here, it will go to the runners and then it will go into the cavities. So, like that. So, you will have the cavity; now in the gating system. So, in that case you have this entries of the point of the entries and then it will go into the cavity.

The thing is that gating system is very important, the flow is basically fluid flow; the liquid metal is flowing through the channel and at every point, if the surface you have basically energy losses you have frictional losses you must minimize it, because of these frictional losses the velocity will be decreased. And in that case if the velocity is in decreased that case rate of pouring will be affected because rate of pouring is nothing, but wherever it is entering if the velocity becomes small and area is same in that case pouring will be affected because area of pouring rate will be area into velocity. So, now, that depends upon the frictional losses now this frictional losses will depend upon the type of surface type of mold surface.

So, this type of mold surface this surface must be made smoother so, that you have minimum frictional loss. So, for that basically we use surface in such a manner, that you have minimum friction like you may use if the sand grain, you should use the mold wash you should use the fine grain sand or so, so that you have minimum frictional losses similarly you have energy losses you may see at many points you have the abrupt section changes. So, whenever you have abrupt section changes. So, here you will have the formation of vena contracta, you will have the formation of zones where there will be adverse pressure gradient.

Now at these places or at the these bends or so, if you have more and more bends you have energy losses. So, you should see that there is no there is minimum of the number of bends or even if there is a bend you should have the streamlining. So, for that you should do these design changes. So, that will basically reduce the energy losses. So, this basically once the energy is lost is less once the frictional amount is less in that case the fluidity can be maintained at a higher value and you can ensure that in certain time the liquid metal will fill the cavity.

Second point is that gating system should be sufficiently large to ensure the rapid filling. So, you must have the sufficient large capacity so, that you ensure the rapid filling purity of metals should be high. What happens that, when you have you may have metals one in one case it is pure in another case it is not pure. So, if the purity is not high in that also the fluidity is affected. In case of pure metals as you know the freezing is by advancing front the by advancing that because you have the plain front solidification. So, what will happen if you have the channel and the liquid metal comes. So, so slowly after some time the solidification will. So, you will have surfaces here and here solidified and this will be your surface like that. So, after some time further you will have this and this. So, this is this portion is solidified this portion is solidified and then your advancing front moves like that.

So, you have this much portion solidified and then when it is basically both are matching at this point then this basically is choked. So, that way it will stop whereas when you have basically the dendritic structure, in that case there will be dendritic interlocking. And in the dendritic interlocking will effect the fluidity will basically break in some case in some sense the movement of the liquid metal because the dendrites will be coming and the generalities arms may interlock and that will affect the velocity of the liquid metal which has to go. So, here you have smooth flow of liquid metal through this passages, but if you have the dendritic formation in the region, ahead of this front as we discussed in the case of concessional under cooling, in that case that will be basically a resistance in the path of liquid flow.

So, that affects the fluidity. So, fluidity becomes less. Other factors like mould related factors we discussed earlier that you have molding sand and binder. So, molding sand which is used you must have the fine sand, which is decreasing the resistance I mean which will give less resistance to the metal which is flowing. So, in that case similarly you have the sometimes we give the mold wash. So, that you have the smooth surface on the molding sand. So, the which is in contact with a liquid metal, and that provides less resistance to the metal. Then you have mold temperature as we discussed that if the mold temperature is high because if the temperature is mold temperature is high, in that case because most of the superheat is arrested when the liquid metal touches the mold and mold is normally at room temperature.

So, if you are giving some temperature to the mold, in that case you ensure that the superheat is not lost quickly. So, the mold temperature will be higher sometimes many a times we increase the mold temperature, because that reduces the chilling effect the temperature which comes down quickly that is not experienced. So, in that case the fluidity will be higher. So, these are the different factors which affect the fluidity of the material apart from that you have certain effects like gas pressure effects, many a times when we are pouring the liquid metal into the gating system, and if there is gases entrapped and these gases are not able to come out. So, as you know that if the gases are there, when sometimes the gases are also formed inside the cavity there may be gases formed because the water metal is going at higher temperature there may be formation of gases and that has to come out.

So, basically if it has to come out you must have proper permeability in the molding material. So, if the molding materials permeability is not adequate, then many a times the liquid metal which is moving that basically gets the pressure from the gases. So, what will happen if the liquid metal is moving in that, and if there is gas is trapped here and if the gas is not able to go out if the id if the fluidity is there fluidity is anywhere there, but if there is the gases, which are here in the last and by the time it goes or the gases are not able to escape out then then these will have a back pressure and this will ensure that this liquid metal will not be able to reach the end point.

So, that is another factor in the case of I mean which affects the fluidity. It has been seen that as the for the metals which solidify at a constant temperature for either pure metals or metals with eutectic composition they have higher fluidity. So, when the fluidity test was carried out if suppose you have the 2 phase diagram like this.

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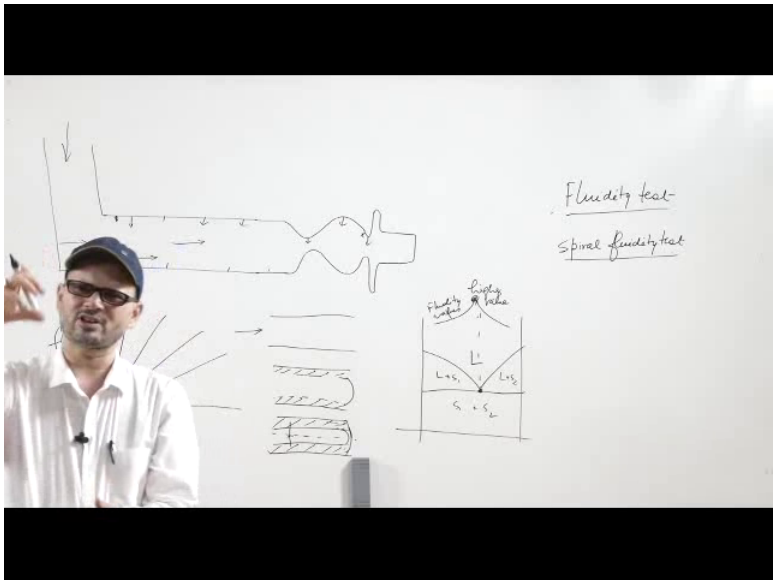

So, at this this is known as the eutectic point where this is liquid and this is liquid plus solid 1, liquid plus solid 2 and this is solid one plus solid 2. So, in that case if you see the fluidity will be here, the fluidity will be higher. So, this value this will be fluidity values this is at this point at this point of eutectics you will have higher value.

So, this is how we scroll back that is why in case of metals, you will have larger fluidity when you have the freezing range of material the fluidity will be affected. So, that is normally seen and that is why we say that it is difficult to fit, we discussed about the CFR or the feeding resistance or so. It has something to do with that kind of structure because, when we talk about those materials which have the large freezing ranges there in those cases because of the dendritic structures formulation, the metal which has to move liquid metal which has to move and go to the different portions their movement is restricted their movement is obstructed, and that is how it affects the fluidity of the material.

So, that is why the composition will affect the fluidity; now let us see the fluidity test. So, you have standard fluidity test which is carried out, fluidity test now fluidity test is the test which talks about that what should be what is the fluidity. Now that is basically quantified in terms of a distance up to which the liquid metal should move.

So, there are there were different tests like you have a straight channel, you have other type of channels, but the most popular among these tests is the spiral fluidity test. So, in the spiral fluidity test you have a spiral type of geometry, and it has certain cross section and then liquid metal will be poured and the liquid metal will basically depending because the temperature is higher. So, this liquid metal will go along this spiral path and it will; it is seen that how much far it traverses. So, depending upon the distance it traverses that is basically said to be the fluidity of the material. So, the test looks like this here.

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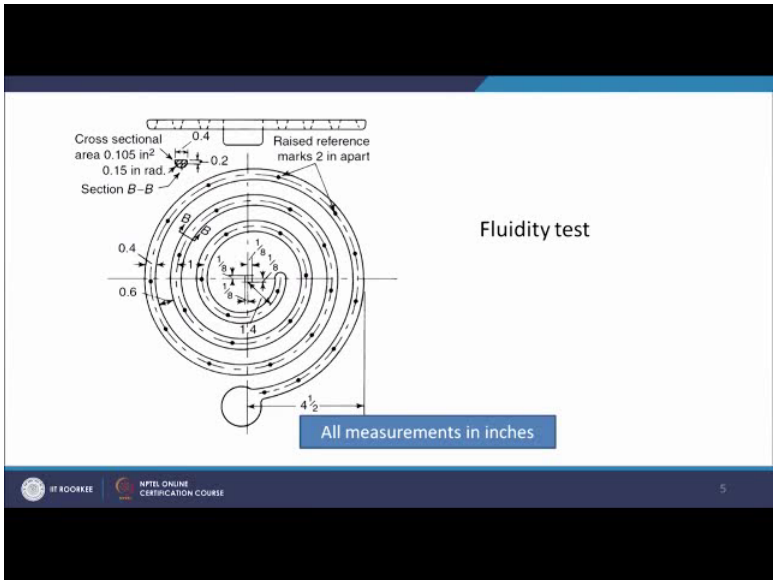

This is a typical fluidity test that is on a spiral test. So, if you can see here you have this is the cross section of the at this section. So, you have this is the cross section you have point four inches. So, it will be something close to 9 centimeter or so.

And then 9 millimeter and the accordingly you have the different dimensions, and you have different points marked here you see that you have different points mark. So, liquid metal will move to different places and you it is to be seen that, how much it how much distance it covers.

So, depending upon the stay standard condition is you know set, and it will be seen that how much distance the liquid metal traverses. If it reverses a larger distance means the fluidity is quite high. If it distance traverses small distance it means the fluidity of the liquid metal is low.

So, then again the fluidity depends upon many factors as we discussed like the compositional factors, you have the surface tension properties are there you have the pro where it has the surface oxide film we which is made.

So, there are different kind of properties which basically drive the this property. So, based on that you can ascertain or you can find this fluidity test. So, when you cast any material you can have the fluidity test and see, whether you have adequate fluidity. So, once you have a adequate fluidity, you can ensure that this liquid metal when it is poured into the cavity at this temperature. So, it will be done at a particular temperature at this temperature it will have adequate fluidity. So, it will go into all the corners and fill the all the details of the cavity. So, this is how the fluidity test is carried out.

Thank you very much.