Metal Casting

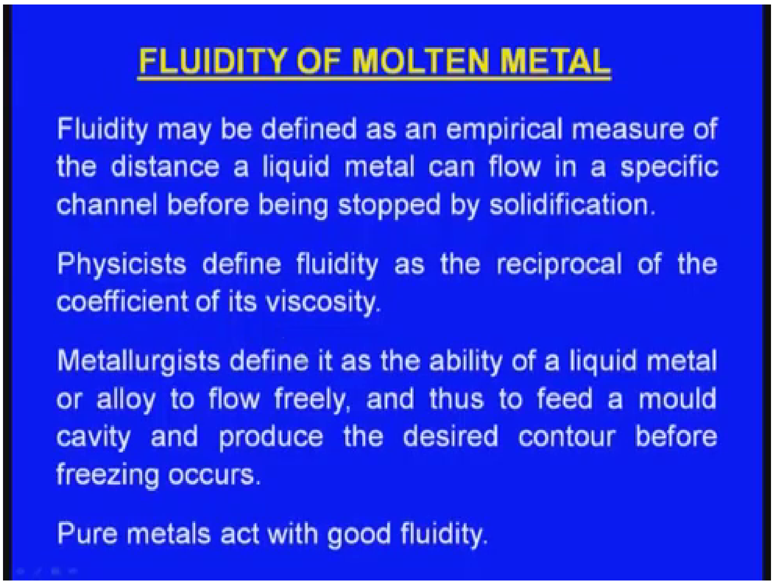
Dr. D. B. Karunakar
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Module – 03
Melting, Fluidity and Solidification
Lecture – 03
Fluidity of Molten Metal

Welcome friends, in the previous class we have been learning about Melting the charge and also how to treat the Molten Metal. Now in this lecture let us see the Fluidity of Molten Metal. The fluidity of molten metal is very important because we may melt the metal, we may treat the metal, but after all it is going to occupy the cavity and it has to fill the entire cavity, it has to fill the entire thin sections of the mould cavity. If the molten metal does not possess enough fluidity then the molten metal cannot fill the entire cavity. May be it may partly fill the cavity, but it may not fill the thin sections or the complex sections that is why the fluidity of the molten metal has highest importance.

Let us see in this lecture, let us learn about the factors that are governing the fluidity of the molten metal and how to improve the fluidity, before that let us see the definition for the fluidity.

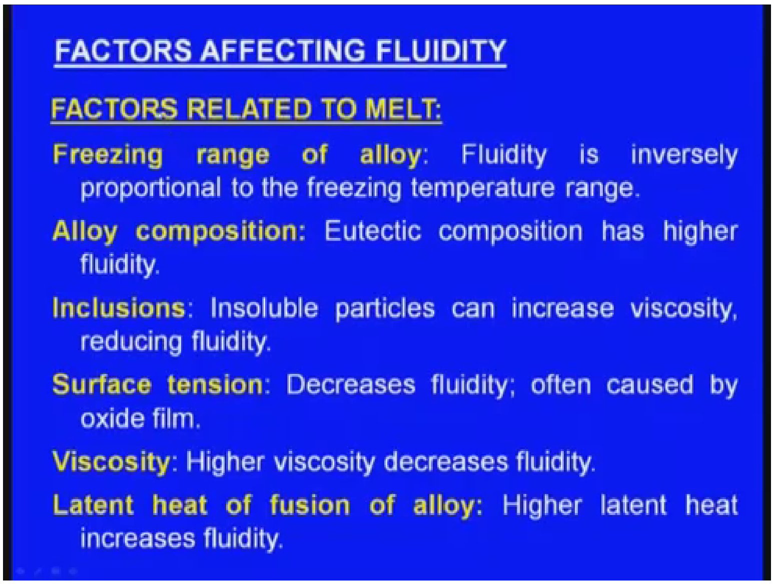
(Refer Slide Time: 01:34)



Fluidity may be defined as an empirical measure of the distance a liquid metal can flow in a specific channel before being stopped by solidification. So, this is the definition for fluidity. Again physicists define fluidity as the reciprocal of the coefficient of its viscosity. Viscosity and fluidity these will be always inversely proportional if the viscosity is higher fluidity will be lesser, if the viscosity is lesser fluidity will be higher.

Again metallurgists define it as the ability of the liquid metal or alloy to flow freely and thus to feed a mould cavity and produce the desired contour before freezing occurs. So, this is the definition given by the metallurgists. Now most important thing is pure metals act with good fluidity. Now, let us see the factors affecting the fluidity.

(Refer Slide Time: 02:47)

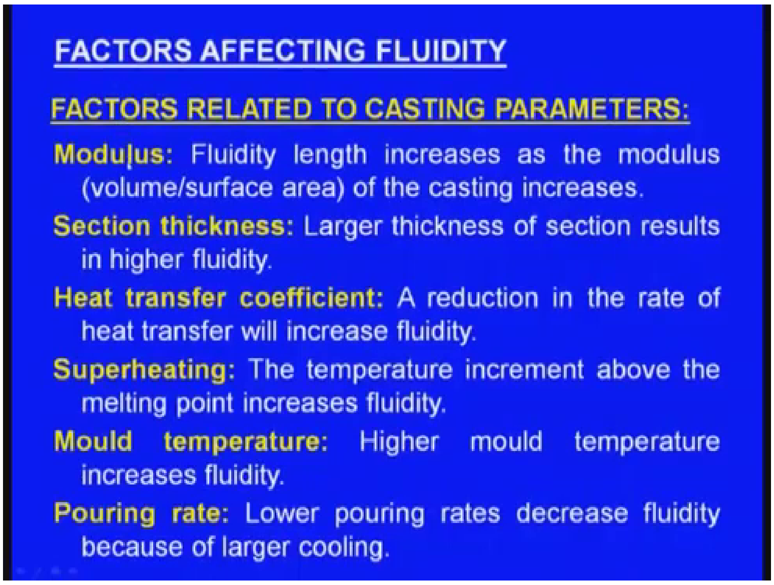


Now there are 2 categories one is the factors relating to the melt and the other category is the factors relating to the casting parameters. First let us see the casting, the factors related to the melt. First one is the freezing range of alloy: Fluidity is inversely proportional to the freezing temperature range right in some alloys the freezing temperature range will be longer in some alloys the freezing temperature will be shorter. For example, let us take the magnesium aluminum alloy, the aluminums melting temperature of the freezing temperature is 660 centigrade, whereas the freezing temperature of magnesium is only 650 degree centigrade. The difference is only 10 degree centigrade so that is a short freezing range alloy.

Whereas if we consider aluminum and tin, alloy, aluminum freezes at 660 degree centigrade and tin freezes at 232 degree centigrade. Here the freezing range is longer than 400 degree centigrade so that is a long freezing alloy. Now the question is the fluidity is inversely proportional to the freezing temperature range means longer the freezing range the shorter will be the fluidity or shorter the freezing range higher will be the fluidity.

Next one Alloy composition: Eutectic composition has higher fluidity. In any alloy system there will be at a particular composition there will be eutectic composition where there is no mushy zone. So, that particular composition has the highest fluidity or the higher fluidity. Next one inclusions insoluble particles can increase viscosity and reduce fluidity when there are insoluble inclusions what happens they increase the viscosity and also they reduced the fluidity. Next one Surface tension it decreases the fluidity and often caused by oxide films. Next one viscosity higher the viscosity lesser the fluidity this we have already seen. Next one latent heat of fusion of alloy what is this latent heat of fusion? When a alloy is freezing heat is liberated during the phase transformation. Now higher the latent heat of fusion higher will be the fluidity. Now all these we will be analyzing and discussing later.

(Refer Slide Time: 05:23)



Next one there is another set of what say parameters these are the factors related to the casting parameters. Now first one is the Modulus: Fluidity length increases as the modulus of the casting increases. Now what is Modulus? Modulus is the ratio of volume to surface area, now as the modulus is increasing fluidity is also increasing. What does it mean? When the what say this modulus is increasing the surface area is decreasing that is the meaning when the surface area is decreasing less heat is dissipated to the mould wall, when less heat is dissipated to the mould wall it stays in the liquid state for a longer time, then what happens it the fluidity will be increasing.

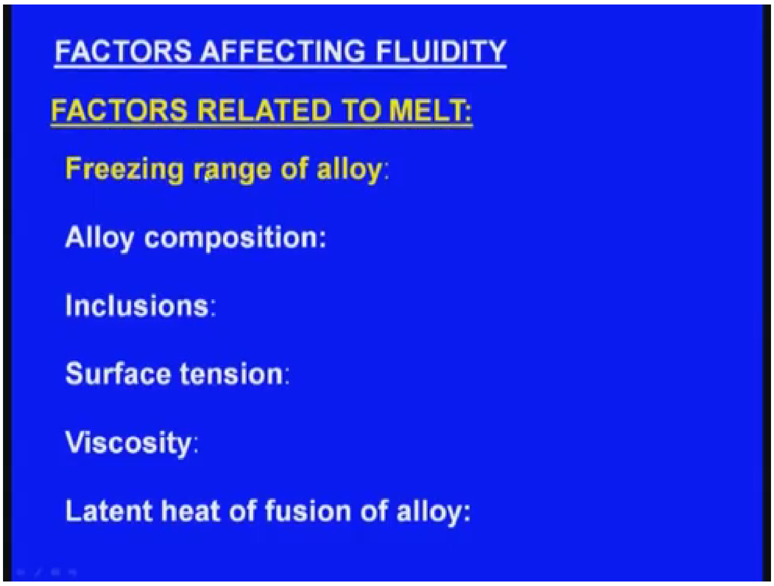
Next one Section thickness: Larger thickness of the section results in higher fluidity, next one heat transfer coefficient a reduction in the rate of heat transfer we will increase the fluidity. What is this heat transfer coefficient it stands for the amount of heat to what say that is a transferred from the casting to the mould wall? Now when this heat transfer coefficient is smaller then what happens less heat is transmitted from the casting to the mould wall then what happens the molten metal will be in liquid state for a longer time that is how its fluidity will be increasing. Next one super heating what is this super heating for example, if an alloy or a metal freeze or melts at a particular temperature

For example, let us take aluminum, pure aluminum melts at 660 degrees centigrade, but we never pour the what say aluminum at 660 degree centigrade we always keep a higher temperature for pouring maybe at 700 or 750 degree centigrade. So, we always pour the alloy or the metal at a temperature higher than its melting point this is known as the pouring temperature.

So, for an casting alloy or a casting metal there are 2 temperatures. One is the pouring temperature another one is the melting temperature. Melting temperature is the temperature at which the alloy or the melted actually melts, whereas pouring temperature is such a temperature it is a somewhat higher temperature at where we will be pouring. Now the super heating is the difference of these 2 temperatures it is the difference between the melting temperature and the pouring temperature. So, as this super heating is increasing what happens the fluidity will be increasing.

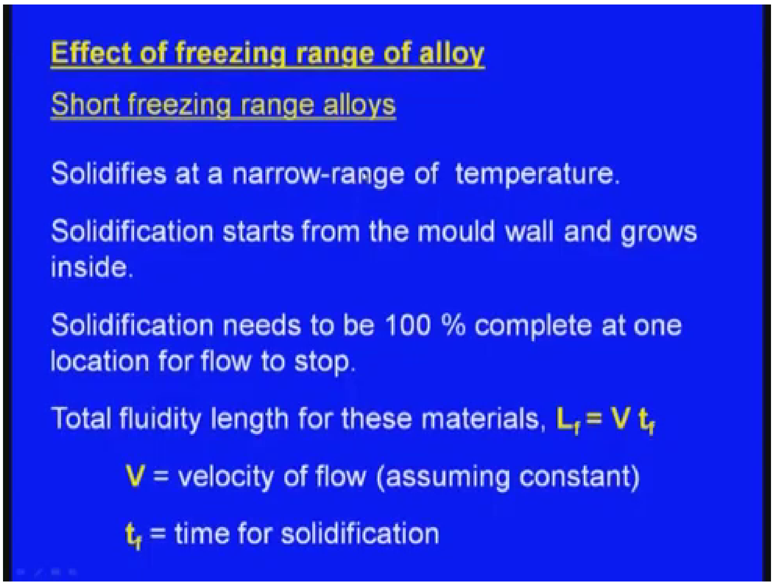
Next one Mould temperature: Higher mould temperature increases fluidity, when the temperature of the mould is higher then what will happen the temperature difference between the molten metal and the mould is lesser the temperature difference means the that is the temperature gradient lesser will be the heat transfer means the molten metal continues to be in the liquid state for a long the time that be the case the fluidity will be increasing. Next one Pouring rate: Lower pouring rates decrease fluidity because of larger cooling.

(Refer Slide Time: 08:48)



Now, let us see the first category of factors these are the factors affecting fluidity related to the melt. First one is the freezing range of alloy.

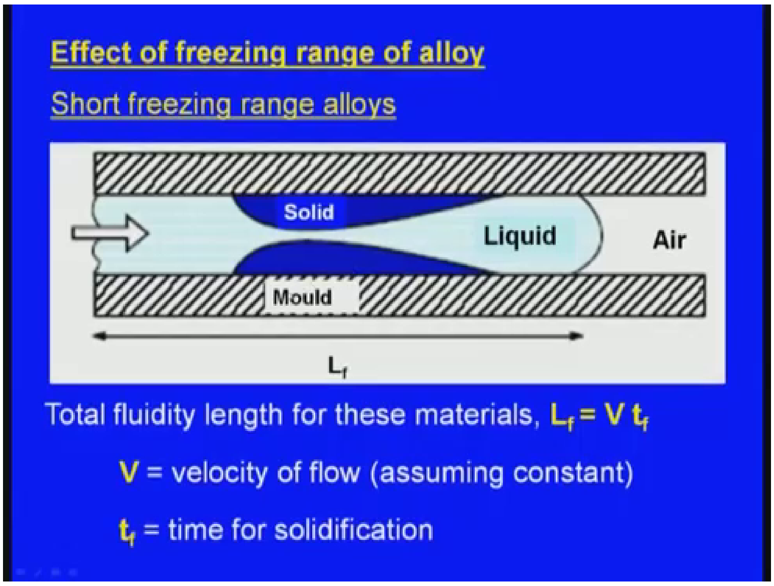
(Refer Slide Time: 08:52)



Now, there are 2 what say alloys primarily, one is the short freezing range alloys and the other one is the long freezing range alloys. Now first let us analyze the short freezing range alloys. These alloys solidify at a narrow range of temperature for example aluminum and magnesium alloy. Aluminum freezes at 660 degree centigrade and magnesium freezes at 650 degrees centigrade only 10 degrees difference in the freezing. So, there is a narrow range of temperature.

Next, one solidification starts from the mould wall and grows inside. Solidification needs to be 100 percent complete at one location for the flow to stop. As long as the solidification is continuing and until and unless the solidification becomes 100 percent the liquid metal continues to flow. Total fluidity length for these materials is equal to is given by L f is equal to V t f, where V is the velocity of flow, most of the times this velocity may not be uniform, but assuming it is the constant then t f is the time for solidification.

(Refer Slide Time: 10:13)

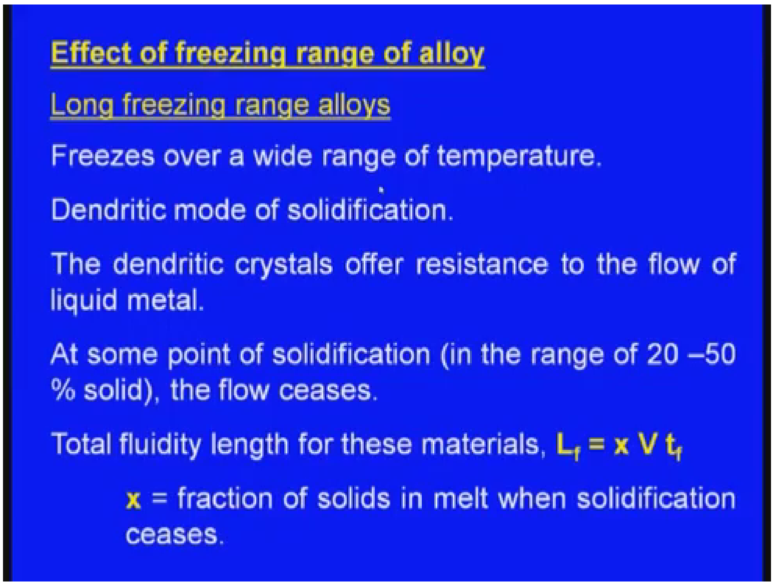


Now, here we can see this is the mould a cylindrical mould and it sees for a short freezing range alloy this is the cylindrical mould and this is the molten metal.

Now, what happens earlier we have discussed the solidification starts from the mould one and it slowly progresses inside, here we can see is this deep blue colored one is the solidified metal. Now the solidification has started here and slowly it is becoming larger and larger like this and here also from this side also the solid starts solidification starts and it is becoming larger and larger. Now what happens till the entire section is blocked by the molten metal, the molten metal will be flowing to the other direction, now that is how we have seen L f is equal to V t f where V is the velocity of flow and t f is the time for solidification.

Now, let us see the long freezing range alloys:-

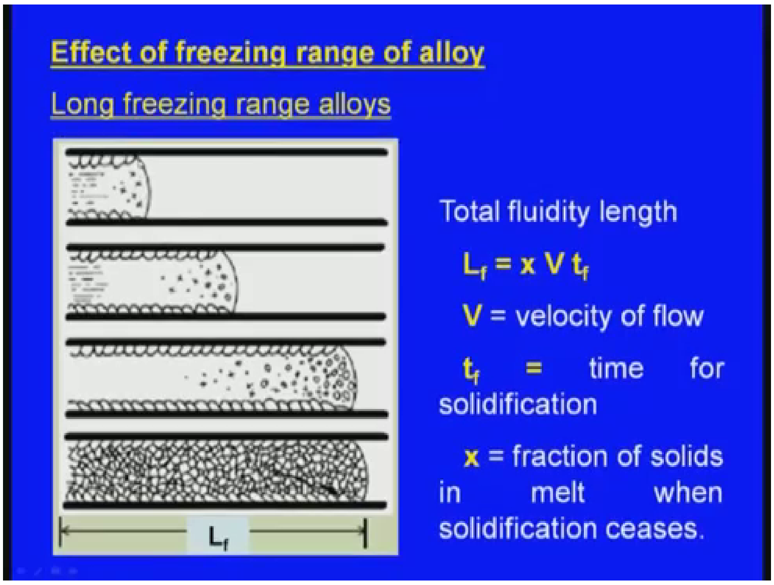
(Refer Slide Time: 11:11)



Freezing over a wide range of temperature means the freezing starts at a particular temperature and freezing continues for a long what say freezing temperature means for example, best thing is aluminum tin, aluminum freezes at what say 660 degree centigrade and tin freezes at 232 degree centigrade, now the freezing range is very long. Next one dendritic mode of solidification during the solidification dendrites will be forming and these will be hindering the flow of molten metal.

Next one the dendritic crystals offer resistance to the flow of liquid metal. Then what happens at some point of solidification in the range of 20 to 50 percent solid, the flow ceases because of the obstruction caused by the dendritic crystals. Again here the total fluidity length for these materials is equal to L f is equal to x V t f, here x is coming additionally when we compare the what say fluidity length for the short freezing range alloys here x is extra. What is this x, x is the fraction of solids in melt when solidification ceases.

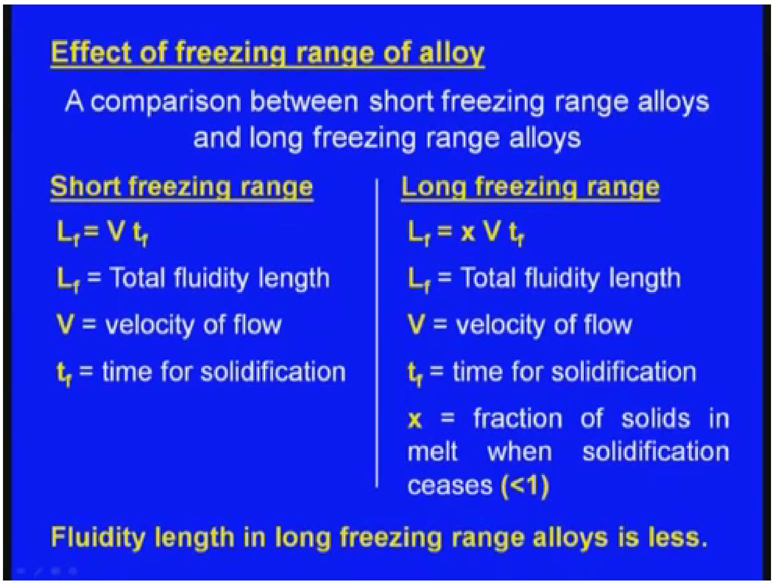
(Refer Slide Time: 12:35)



Now, here you can see this is the what say solidification pattern for a long freezing alloy. Now you can see here this is the initial stage of solidification, as the solidification is advancing and here we can see these are the dendrites and these dendrites will be increasing and at a particular stress they will be causing obstruction to the flow of metal. Now the total fluidity length L f is equal to x V t f, V is the velocity of flow t f is the time for solidification and x is the fraction of solids in melt when the solidification ceases.

Now, we need to consider this x what is the nature of x. Now a comparison between short freezing range alloys and long freezing range alloys.

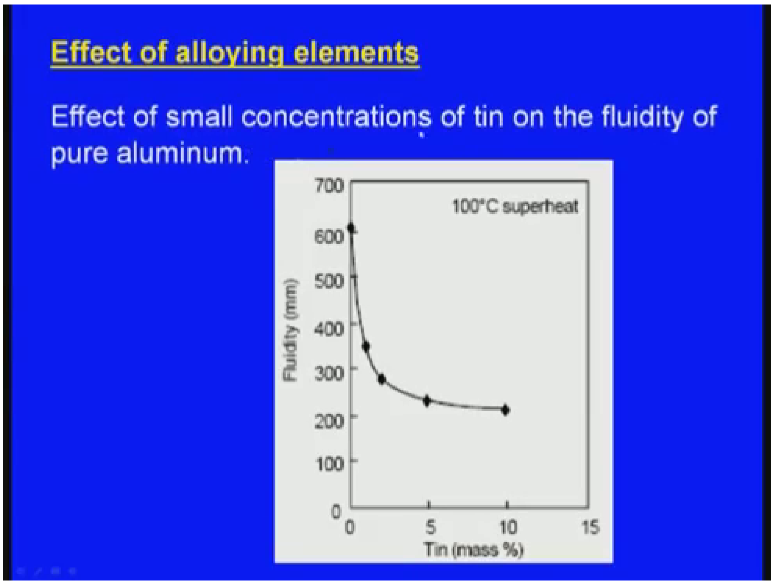
(Refer Slide Time: 13:23)



In the case of the short freezing range alloys L f is equal to V t f, where L f is the total fluidity length, V is the velocity of flow and t f is the time for solidification. And in the case of the long freezing range alloys almost it is same L f is equal to x V t f, this x is coming additionally. Now where L f is the total fluidity length, V is the velocity of flow, t f is the time for solidification and x is the fraction of solids in the melt, when the solidification ceases and it is always less than 1. Then what happens in which case the fluidity will be longer naturally because this x is less than 1 the fluidity long freezing range alloys will be lesser than that of the fluidity in short freezing range alloys. Thus, the fluidity length in long freezing range alloys is always less.

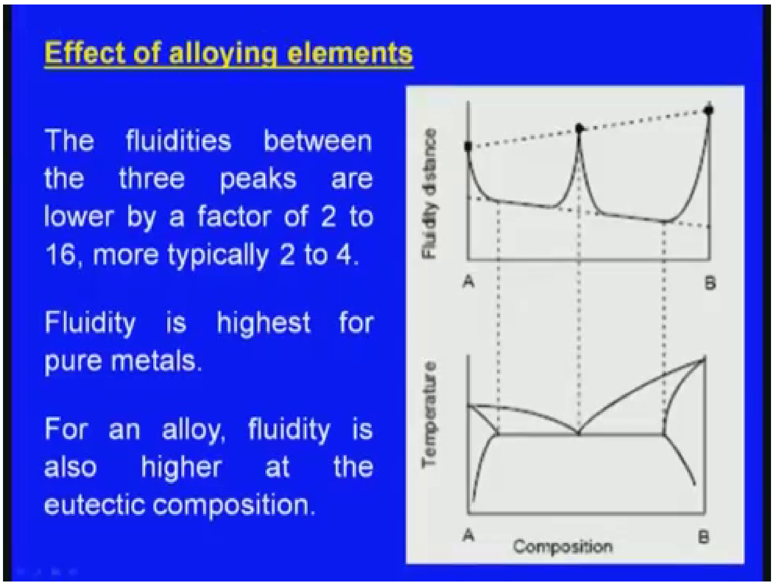
Now, what is our conclusion, longer freezing range of an alloy what say reduces the fluidity. Next one let us consider the next factor that is the alloy composition.

(Refer Slide Time: 14:41)



Effect of alloying elements: Effect of small concentrations of tin on the fluidity of pure aluminum. We are considering the fluidity of pure aluminum and when there are small what say traces of tin. Now here this graph should depicts the effect of alloying element on the fluidity. Now here you can see the x axis indicates the what say percentage of tin and the y axis indicates the fluidity. Now as the tin proportion is increasing the fluidity is decreasing what we can see the alloying elements will be reducing the fluidity here we can see another graph right.

(Refer Slide Time: 15:19)



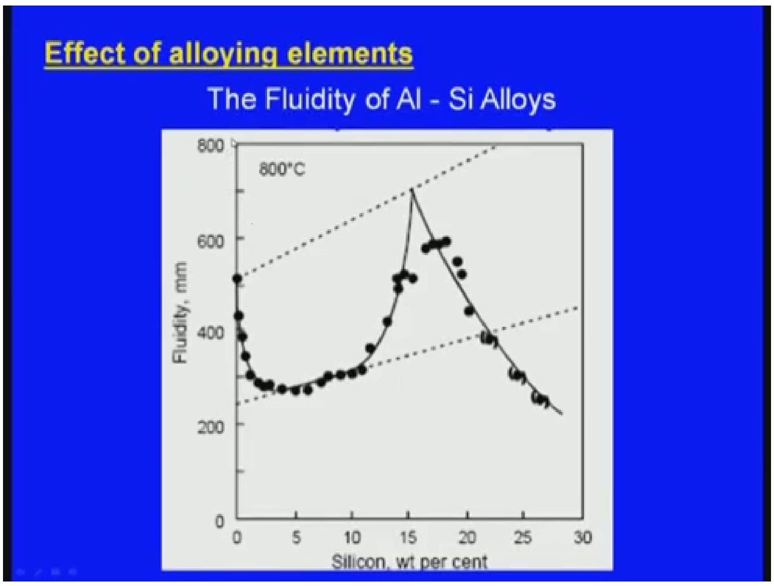
So, this is the phase diagram and here we can see this is metal A and this is metal B, this side it is only pure metal A and this is this side it is pure metal B, in between the what say as we what say progress from left to right the proportion of B metal is increasing gradually starting from 0. Now here we can see this is the phase diagram and here this is the eutectic composition means there is no mushy zone.

Now, here we can see now let us see this is the what say graph which reflects as the fluidity of this alloy system. Now here at the point A it is a pure metal A and 0 of B and 100 percent of A, now what happen fluidity is very high. Let us come to the other side this is metal B, only B and 0 of A you see this fluidity and this axis y axis indicates the fluidity. Fluidity is very high.

Now let us see this is the eutectic point means there is no mushy zone here also fluidity is very high. Now this is what we can what say conclude the fluidities between the 3 peaks are lower by a factor of 2 to 16, more typically 2 to 4. The fluidity between these 3 peaks is lower you see here it is lower and here it is lower.

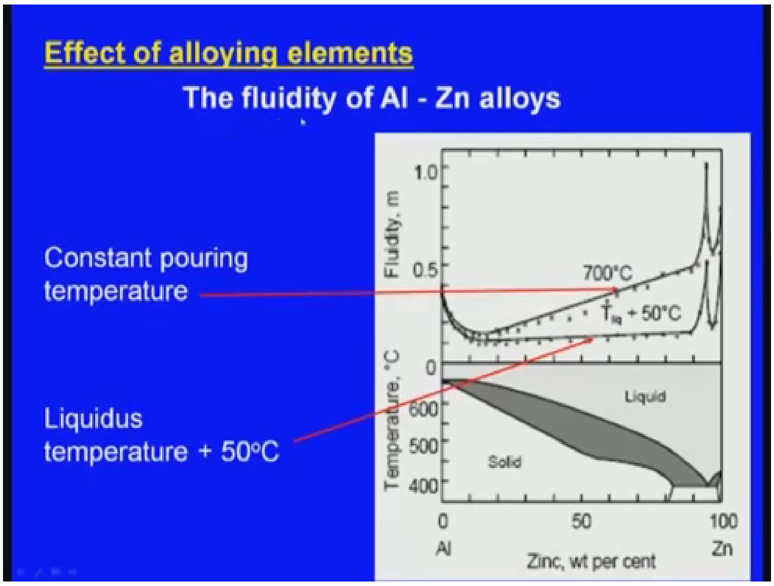
Again what we can conclude the fluidity is highest for pure metals and here it is pure metal a fluidity is very high. Here it is pure metal B here the fluidities very high. Next one for an alloy, the fluidity is also higher at the eutectic composition. So, this is the eutectic point you see here this is the fluidity means at the eutectic point also fluidity is very higher.

(Refer Slide Time: 17:23)



And here the fluidity of Aluminum-Silicon Alloys and here we can see here the fluidity is higher. Next one effect of alloying elements right the fluidity of aluminum zinc alloys let us consider another alloy that is the aluminum zinc alloys.

(Refer Slide Time: 17:34)



Now, this is the phase diagram of aluminum zinc and here we can see this is the solidus means below solidus there is only solid and here we can see this is the liquidus line means above that liquidus there is only liquid between liquidus and solidus there is a mushy zone. So, this is the what say phase diagram and here we can see this is the eutectic point means there is no mushy zone above the eutectic point only liquid and below the eutectic point only solid no mushy zone. Now let us consider how the fluidity will be changing in this system, now let us consider constant pouring temperature that be the case how the fluidity will be.

Now, for example, yes in the same alloy it is what say freezing point is about 650 degree centigrade, if it is pure aluminum 660 degree centigrade. Now generally we add another 50 degrees for super heating maybe at 7010 or at 7025 we start pouring. If it is the constant pouring what happens maybe when the composition is this much when the composition is pure aluminum when the freezing point is 660, we are keeping constant pouring temperature maybe at 700 degree centigrade.

Now as we move to the right side then what happens slowly zincs proportion is increasing as the zincs proportion is increasing what is happening to the melting temperature of the alloy, here it may be some 600 and here it may be some 500 and here it may be some 400 as the zinc proportion is increasing the melting point of that alloy will be decreasing. But the pouring temperature we are keeping constant where that is the 700 degree centigrade. Whether the what say alloy is of a pure metal or whether it zinc is say is some 25 percent or 50 percent the pouring temperature is 700 only.

Then what will happen yes here when it is pure aluminum yes the difference or the difference between the pouring temperature and the melting temperature is only about some 40 degree centigrade, but as the zincs concentration is increasing that difference is also increasing. What is that difference the difference is the superheat, superheat is the difference between the pouring temperature and the melting temperature. As the superheat is increasing fluidity is also increasing we are not altering the pouring temperature, pouring temperature is 700 only. Then what happens here 700 is somewhere here this is the difference, this is the difference, this is the difference.

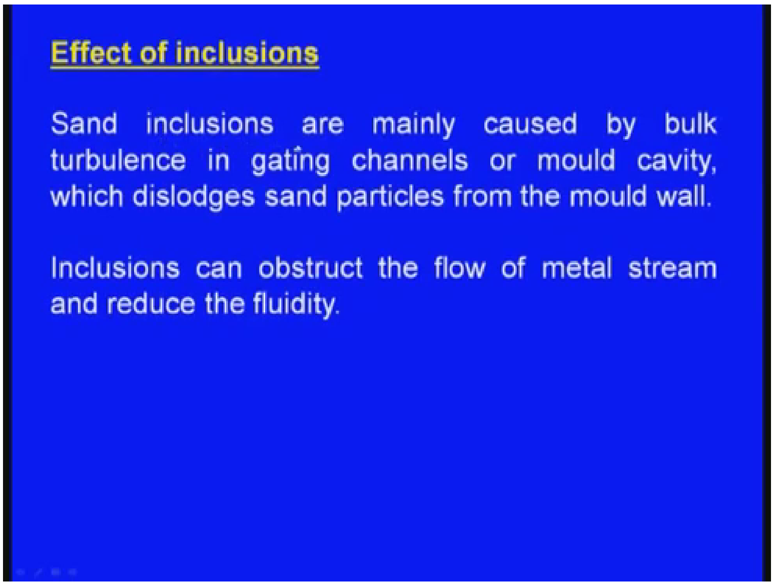
As the zinc concentration is increasing this difference or the superheat is also increasing that is how the fluidity will be increasing at constant pouring temperature. So, this curve indicates the what say fluidity of the system at constant pouring temperature you see as the zinc concentration is increasing at constant pouring temperature the fluidity is increasing. Now this is the eutectic point at eutectic point fluidity is very high.

Now let us consider a what say liquidus temperature plus 50 degrees centigrade. Now we are not considering a constant pouring temperature, constant pouring temperature means we considered 700 degree centigrade constant, whatever be the what say melting temperature or the freezing temperature. Now we are considering we are choosing such a pouring temperature such that the pouring temperature will be liquidus temperature plus 50 degrees centigrade means what is happening the liquidus temperature is slowly coming down as the zinc concentration is increasing.

But we are not what say we are keeping the pouring temperature just 50 degrees above the liquidus temperature whatever it is. Now, may be here it may be say right maybe near 710 degree centigrade and the as the zinc concentration is increasing even the pouring temperature will be just 50 degrees above the liquidus temperature that be the case what happens the superheat will be constant all through then what happens the fluidity also will be constant. Now this line reflects the fluidity when the pouring temperature is just

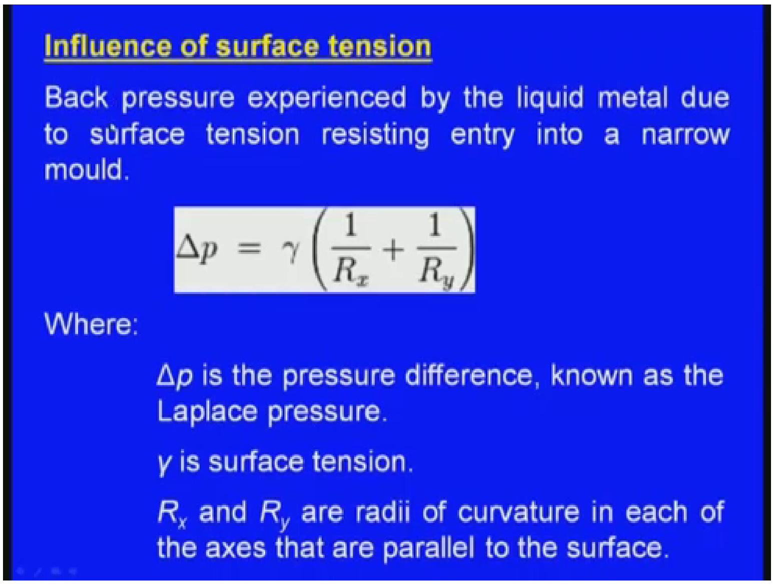
50 degrees plus liquidus temperature the pouring temperature is constant. But however, at the eutectic point again it is very high that is how the fluidity of aluminum and zinc alloy will be changing.

(Refer Slide Time: 22:34)



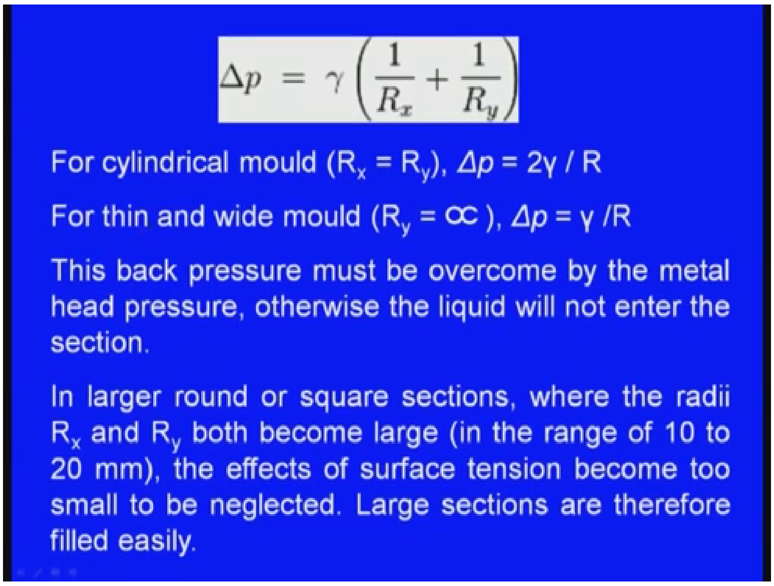
Next one inclusions, Effect of inclusions: Sand inclusions are mainly caused by bulk turbulence in gating channels or mould cavity which dislodges sand particles from the mould wall. Inclusions can obstruct the flow of metal stream and reduce the fluidity once these inclusions coming to picture what happens they can obstruct the fluidity of metal and they can reduce the fluidity. Next one let us see the surface tension.

(Refer Slide Time: 23:07)



What is this surface tension? Back pressure experienced by the liquid metal due to surface tension resisting entry into a narrow mould. Now this here we can see this equation delta p is equal to gamma 1 by R x plus 1 by R y, where delta p is the difference pressure difference, known as the Laplace pressure. Gamma is the surface tension. R x and R y are radii of curvature in each of the axis that are parallel to the surface.

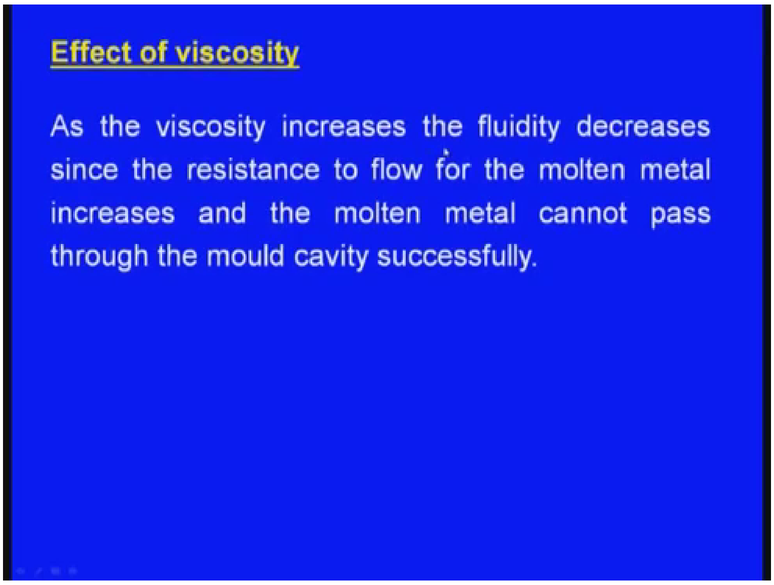
(Refer Slide Time: 23:45)



Now, for cylindrical mould R x is equal to R y that be the case delta p is equal to 2 gamma divided by R and for thin and wide mould R y is equal to infinity that be the case delta p is equal to gamma by R .

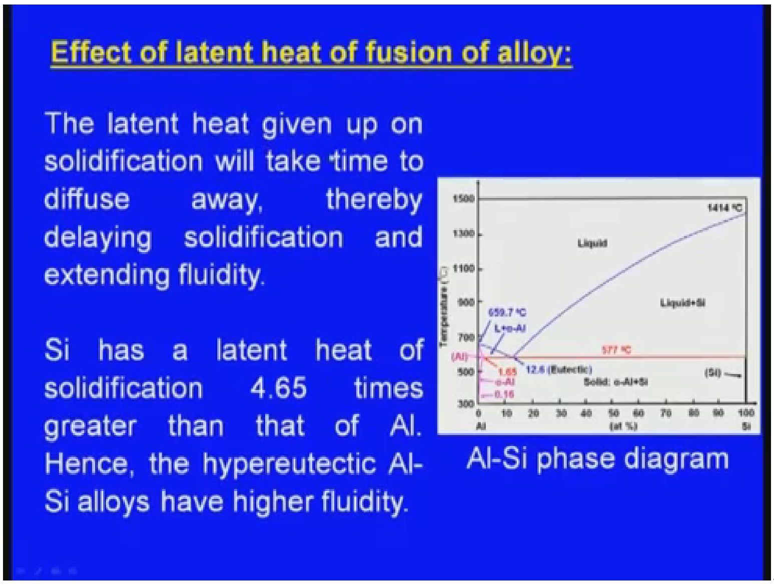
Now, this back pressure must be overcome by the metal head pressure, otherwise the liquid will not enter into the mould. In large amount or square sections where to radii R x and R y both become large in the range of 10 to 20 mm, the effects of surface tension become too small to be neglected. Large sections are therefore filled easily.

(Refer Slide Time: 24:36)



Next one let us consider the effect of viscosity as the viscosity increases the fluidity decreases. Since the resistance to flow for the molten metal increases and the molten metal cannot pass through the mould cavity successfully. So, this is a what say fundamental fact as the viscosity is increasing what happens the molten metal what say becomes thicker and thicker then what happens its fluidity will become smaller and smaller.

(Refer Slide Time: 25:08)

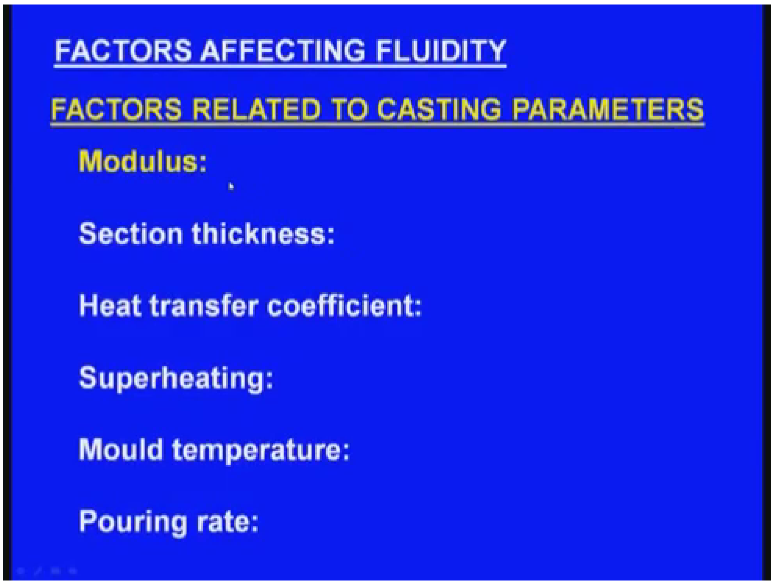


Next one let us see the latent heat of fusion of the alloy. The latent heat given up on solidification we will take time to diffuse away thereby delaying solidification and extending the fluidity. What is this every alloy or every metal during freezing releases latent heat right, now what happens this latent heat causes the metal to be in liquid state for a longer time. Now what happens silicon has a latent heat of solidification 4 to 65 times greater than that of pure aluminum that is why the hyper eutectic aluminum silicon alloys have higher fluidity.

Now, here we can see this is the aluminum silicon phase diagram and here we can see this is the eutectic point means above the eutectic point only liquid and below the eutectic point only solid no mushy zone and this side means to the left of this eutectic point is the hypo eutectic alloy system and to the right of this eutectic point is the hyper eutectic alloy systems. Now what happens in this case as in the hyper eutectic alloys what happens the silicon content is increasing because of the higher silicon content during freezing what happens this silicon releases much what say heat that is the latent heat of solidification because of that the fluidity will be increasing.

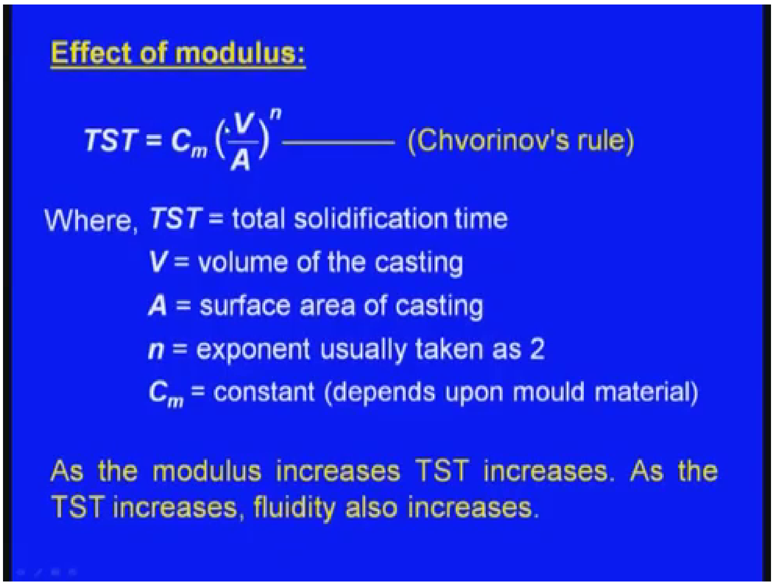
Now let us see the other category of factors these are the factors affecting fluidity related to casting parameters.

(Refer Slide Time: 26:50)



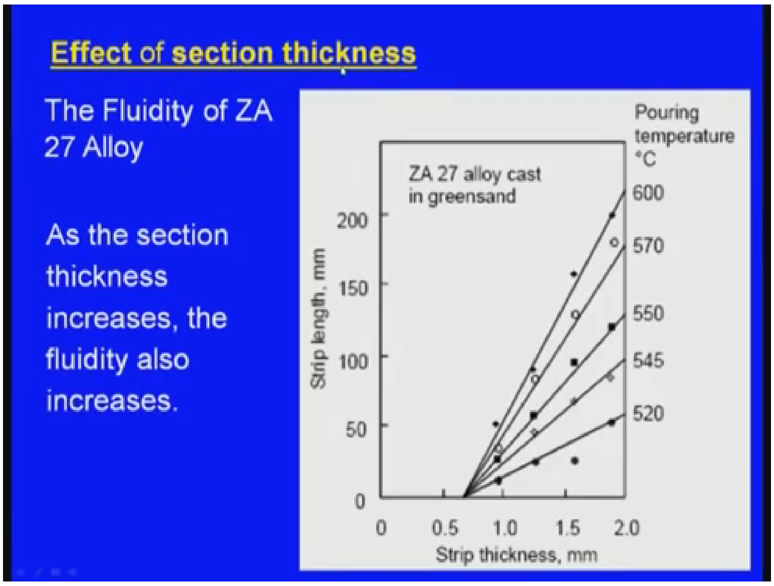
Among them first one is the modulus. What is Modulus? Modulus is the ratio of volume to surface area of the casting that is the modulus.

(Refer Slide Time: 26:55)



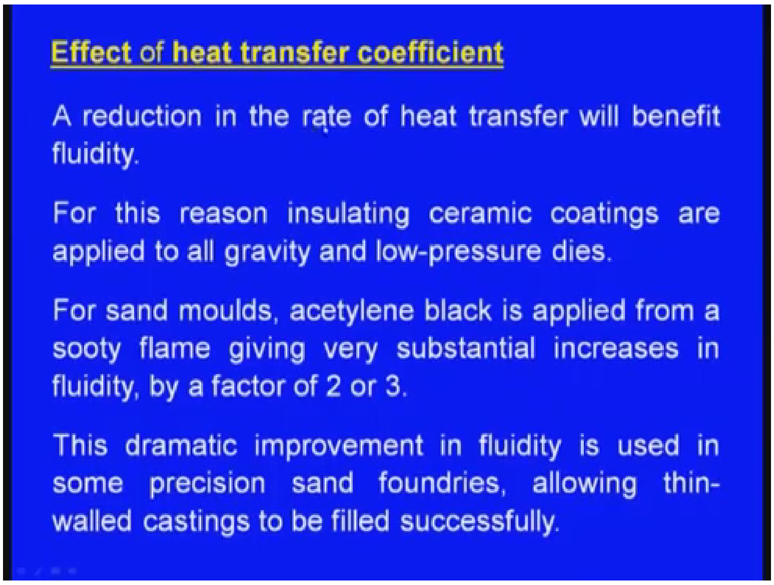
Now this is the Chvorinov's rule. Chvorinov's rules states that TST is equal to C m multiplied by V by A to the power of n, where TST is the total solidification time, A is the surface area of the casting, V is the volume of the casting, n is the exponent. Usually, it is 2 and C m is the constant it say mould constant and it depends upon the mould material. Now as the modulus increases, what happens total solidification time also increases, if the total solidification time increases what will happen the fluidity also increases.

(Refer Slide Time: 27:45)



Next one the section thickness effect of section thickness. Let us consider the fluidity of ZA 27 Alloy. In this case an exponent has been conducted now this x axis indicates the strip thickness and the y axis indicates the strip length means the fluidity length right. Now what happens these are all the pouring temperatures is at 520, 545, 550 570 and 600 degrees centigrade. Now in all these cases as the section thickness increases the fluidity also increases, whatever be the pouring temperature when the section thickness is increasing it right the fluidity is also increasing. Next one heat transfer coefficient.

(Refer Slide Time: 28:32)

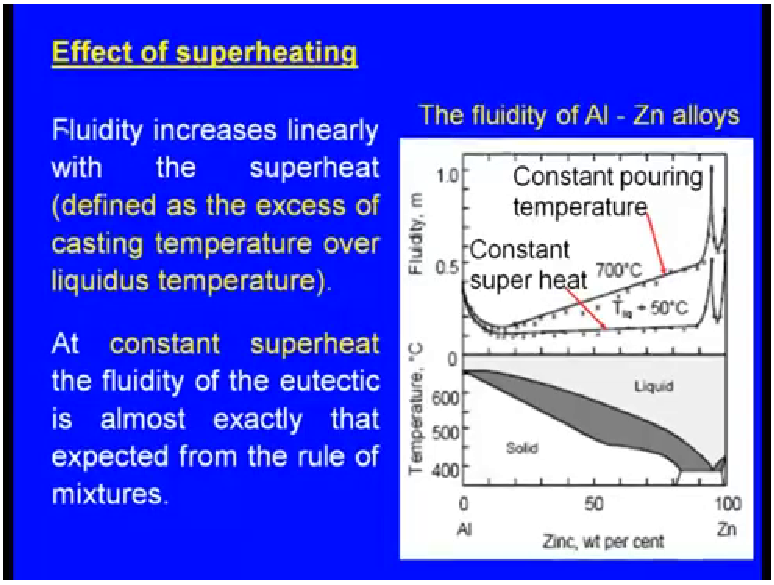


A reduction in the rate of heat transfer will benefit the fluidity right this coefficient of heat transfer reflects the amount of heat transferred from the casting to the mould wall. If the heat transfer coefficient is smaller less heat will be dissipated from the casting to the mould wall. So, for this reason insulating ceramic coatings are applied to all gravity and low pressure dies. And for sand moulds acetylene black is applied from a sooty flame giving very substantial increase in fluidity by a factor of 2 to 3.

Now a black flame or a black coating is given to the mould what say cavity by a using this acetylene black. What is the purpose? So, that the heat transfer coefficient becomes smaller means less heat will be dissipated from the casting to the mould because of that the fluidity will be increasing. This dramatic improvement in fluidity is used in some precision sand foundries allowing thin walled castings to be filled successfully.

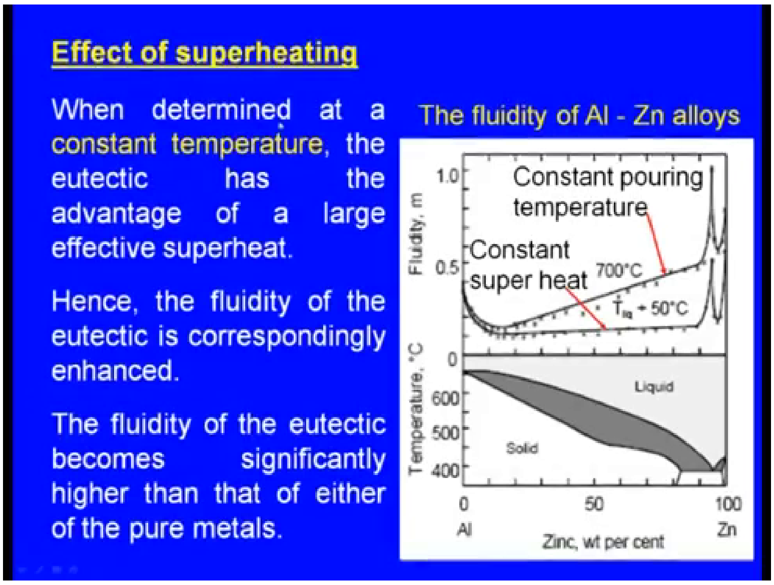
So, when the casting is a having larger thicknesses no problem, but when a casting has very thin sections that time it is very difficult for the molten metal to flow into those thin sections, it is that time we need to take a some measures to improve the fluidity. So, we can decrease the heat transfer coefficient by doing these kind of techniques one is the if it is the die casting right we can always use ceramic coatings or if it is a sand mould we can apply acetylene black coating.

(Refer Slide Time: 30:32)



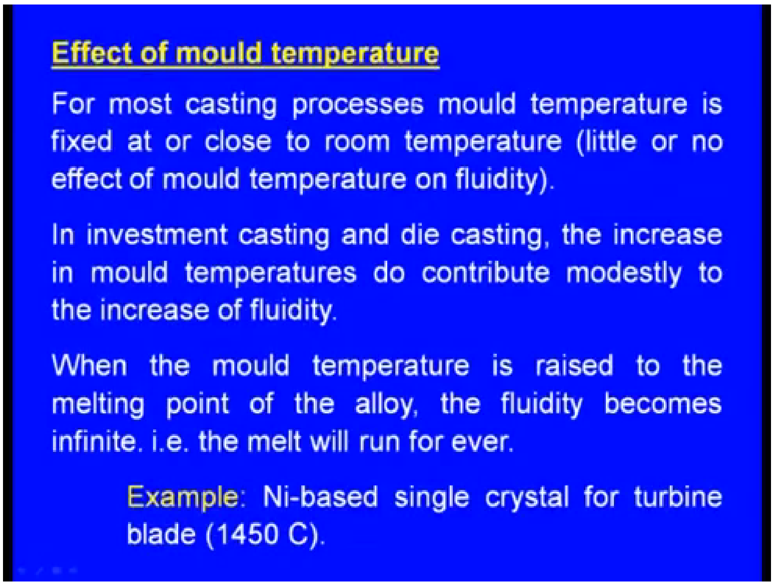
Next we will see the influence of superheating on fluidity. First of all we should know what is meant by superheating. It is defined as the excess of casting temperature over liquid temperature so that is the superheat. So, for example, let us see the aluminum zinc phase diagram here you can see here so this is the liquidus temperature and this is the solidus line and this is the liquidus line means everything above this line is in liquid state and everything below this line is in solid state and this is the mushy zone. Now fluidity increases linearly with the superheat so as the superheat is increasing the fluidity will be increasing. So, at constant superheat the fluidity of the eutectic is almost exactly that expected from the rule of the mixtures.

(Refer Slide Time: 31:23)



Now, when determined at a constant temperature the eutectic has the advantages of a large effective superheat. Hence, the fluidity of the eutectic is correspondingly enhanced the fluidity of the eutectic becomes significantly higher than that of either of the pure metals.

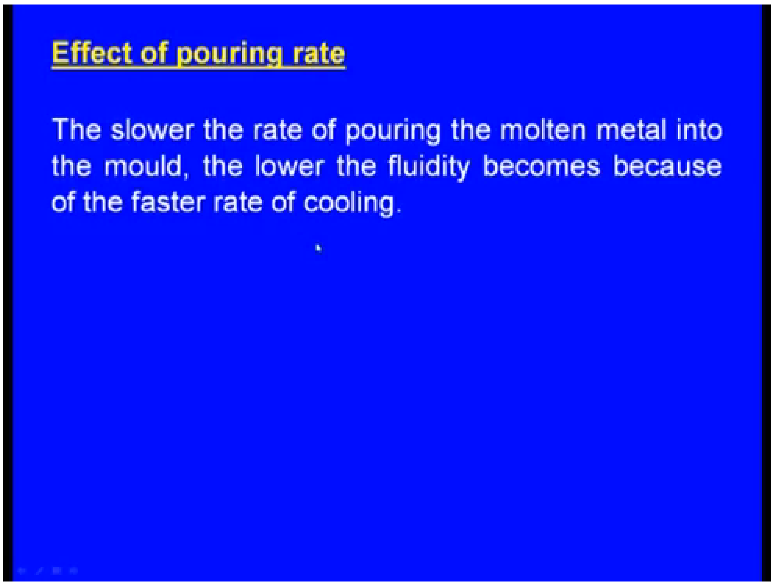
(Refer Slide Time: 31:48)



Next one let us see the effect of mould temperature on the fluidity for the most casting process moulding temperature is fixed at or close to room temperature little or no effect of moulding temperature on fluidity because most of the times the modeling temperature is fixed at the room temperature. But you see in investment casting or die casting the increase in modeling temperatures do contribute modestly to the increase of the fluidity. When the mould temperature is raised to the melting point of the alloy the fluidity becomes infinite means the melt will run forever example nickel based single crystal for the turbine blade. So, here the melting point is 1450 degrees centigrade.

Next let us see the influence of pouring rate on fluidity. The slower the rate of pouring the molten metal into the mould, the lower the fluidity becomes because of the faster rate of cooling.

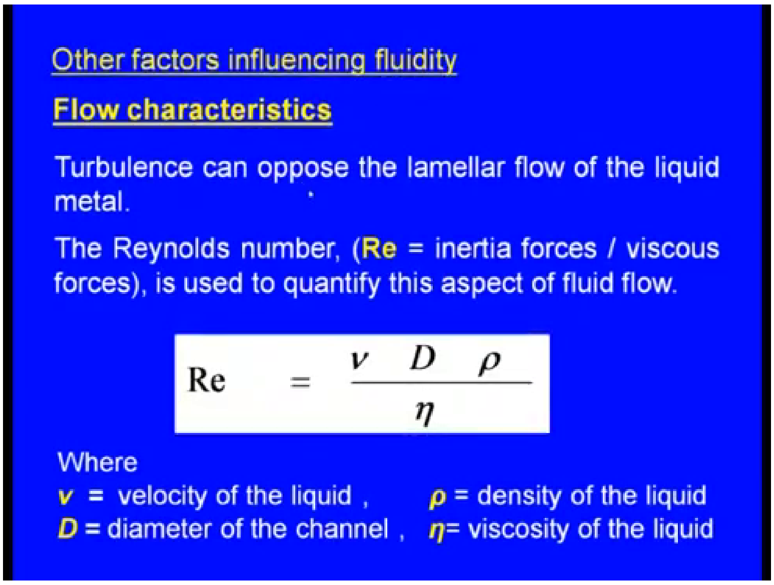
(Refer Slide Time: 32:40)



Now, So far we have completed the effect of the what say effect of the casting parameters. So, under these we have seen the effect of modulus, effect of section thickness, effect of heat transfer coefficient, effect of super heating, effect of mould temperature and finally we have seen the effect of pouring rate on the fluidity.

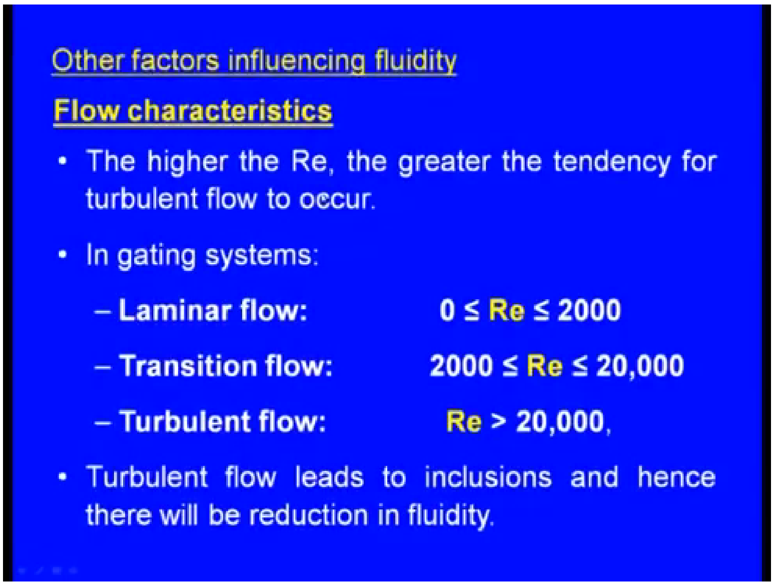
Next let us see other factors influencing the fluidity what are these other factors.

(Refer Slide Time: 33:13)



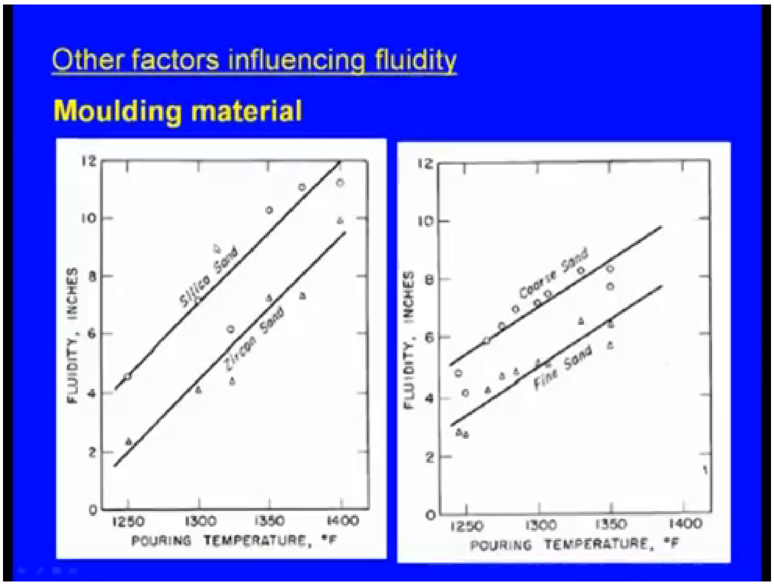
Flow characteristics turbulence can oppose the lamellar flow of the liquid metal. Lamellar flow is very good whereas, turbulence can oppose the lamellar flow of the liquid the Reynolds number R e is equal to inertia forces divided by viscous forces is used to quantify this aspect of the fluid flow. R e is equal to v D rho divided by mu right here v is equal to velocity of the liquid, rho is the density of the liquid, D is the diameter of the channel and the other parameter is the viscosity of the liquid. The higher the R e the Reynolds number the greater the tendency for turbulent flow to occur.

(Refer Slide Time: 33:55)



So, in gating systems lamellar flow we will get when the Reynolds number is between 0 to 2000 and we get transition flow when the Reynolds number is between 2000 and 20000 and we get the turbulent flow when the Reynolds number is more than 20000. Now what happens if there is a turbulent flow, turbulent flow leads to inclusions and hence there will be reduction in fluidity.

(Refer Slide Time: 34:28)

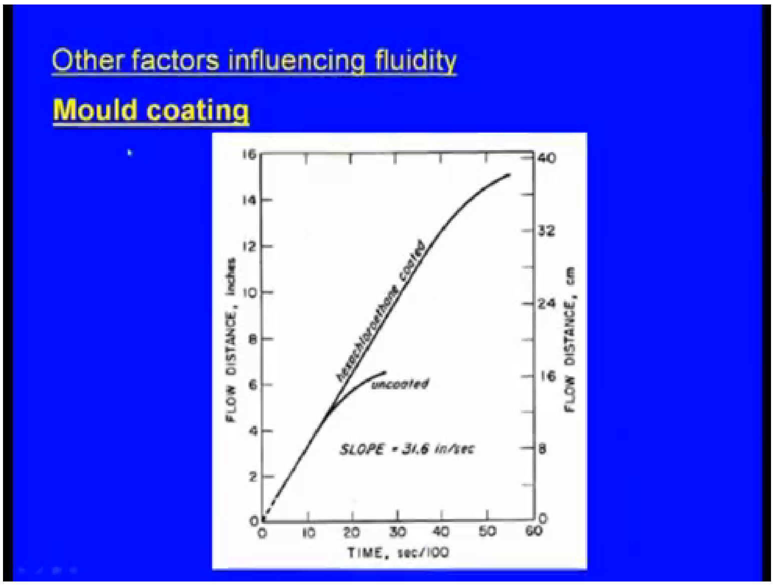


Next to other factor is the Moulding material. Now you see here this is the pouring temperature and this is the zircon sand and this is the silica sand. Now as the pouring temperature is increasing fluidity is also increasing but you see in case of the silica sand the fluidity is higher for the same temperature whereas in zircon sand for the same temperature the fluidity will be less. So, this is another what say factor which will be influencing the fluidity. And again we can see another aspect coming to the moulding material that is whether it is fine sand or the coarse sand for the same what say type of sand whether to you take the silica sand or you take the zircon sand.

So, here we have the 2 types: One is the fine sand we have taken and another thing is we have taken the coarse sand. In which case there will be better fluidity for the same temperature what say coarse sand will have the better fluidity compared to the fine sand why? Because fine sand so many what say particles will be coming in contact with the molten metal because of their what say fineness. So, more what say heat is extracted by these fine sand particles that is how it becomes more viscous as it is flowing that is how the fluidity will be coming down in case of the fine sand.

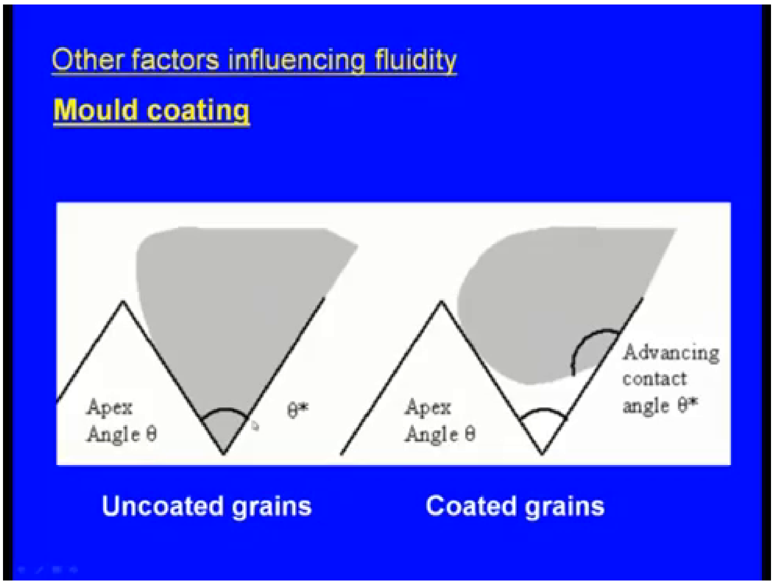
Now next other parameter is the Mould coating.

(Refer Slide Time: 35:50)



Mould coating also influences the fluidity now you see here so this is the time x axis we can see the time and on the y axis we can see the flow distance means the fluidity, fluidity is measured in terms of a in terms of the flow distance in your channel. Now here we can see there are 2 cases in one case there is no coating uncoated means the fluidity will be enhancing and at one stage it will come and it will be stagnating. On the other hand when the moulding material is given you certain coating then what is happening it is the fluidity is increasing.

(Refer Slide Time: 36:36)

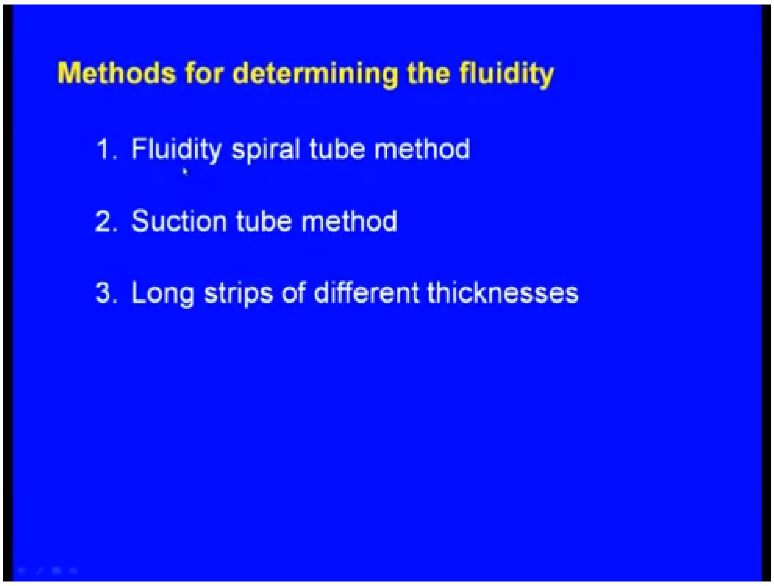


So, we can conclude like this when there is a mould coating the fluidity will be enhanced why it is enhancing you see here we can see this is the what say we can see here there are the uncoated grains and here there are coated grains. Let us examine now what happens when the molten metal is flowing above uncoated grains and also above the coated grains. When it is flowing above the coated grains uncoated grains what is happening it is fully occupying or flowing around the grains so this is the grain and this is a grain. So, it is fully occupying and fully going in contact with the what say grain sand grains then it is flowing, whereas in the case of the what a coated grains the mould what say molten metal is not going in full contact with the sand grains.

Now, what happens in these 2 cases in the case of the uncoated grains because it is going in full contact with the sand grains, it is what say extract liberating more heat or it is dissipating more heat to the sand grains. In the case of the coated grains because it is partly going in contact with the sand grains, it will be dissipating lesser amount of heat to the grains sand grains. So, as it is in the case of the coated grains because it is dissipating lesser amount of heat its fluidity will be enhanced or it will be what say having higher what say this what say lesser viscosity that is how the fluidity will be increased.

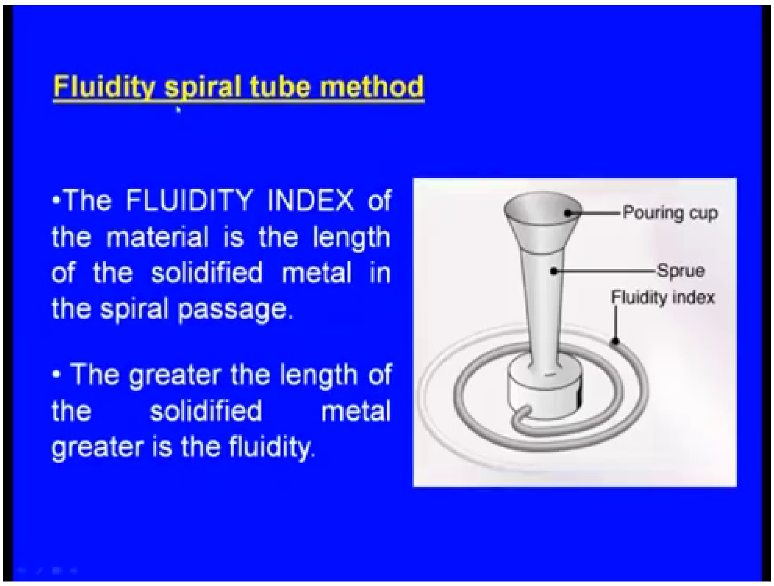
Now we have another topic that is the methods for determining the fluidity. So, far we have seen the importance of fluidity in casting under different parameters that will be influencing the fluidity. Now how to measure the fluidity let us see few methods that are available.

(Refer Slide Time: 38:37)



One method is fluidity spiral tube method, another method is suction tube method and another method is long stripes of different thicknesses. So, these are the 3 methods available for determining the fluidity of a molten metal.

(Refer Slide Time: 38:44)

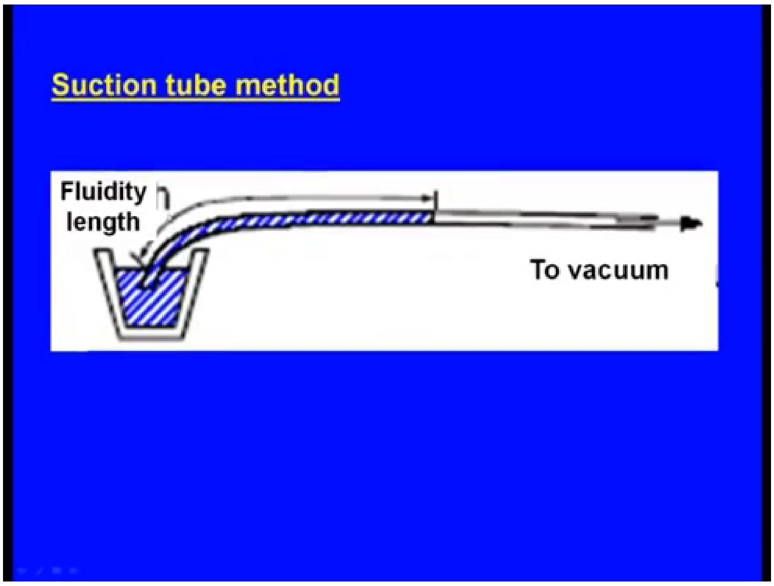


Now, let us see the first one that is the fluidity spiral tube method. The fluidity index of a material is the length of the solidified metal in these spiral passage. Now how does it look like this spiral tube you can see so this is the pouring cup and this is this sprue and at the bottom there is a sprue well, now this is a thin tube a metallic tube that is all about this what say spiral tube, what say apparatus.

Now this is the thin tube this whole apparatus will be kept inside the mould box. Tthe drag then it will be compacted then this will be withdrawn, once it is withdrawn is naturally there will be a what say passage sprue passage then here you can see this is the thin wire spiral wire. So, there also a mould cavity created a spiral cavity will be created then we you put the coke box over that, then you pour the molten metal. Then the molten metal will be flowing like this, it will be flowing then it will be flowing along this spiral passage.

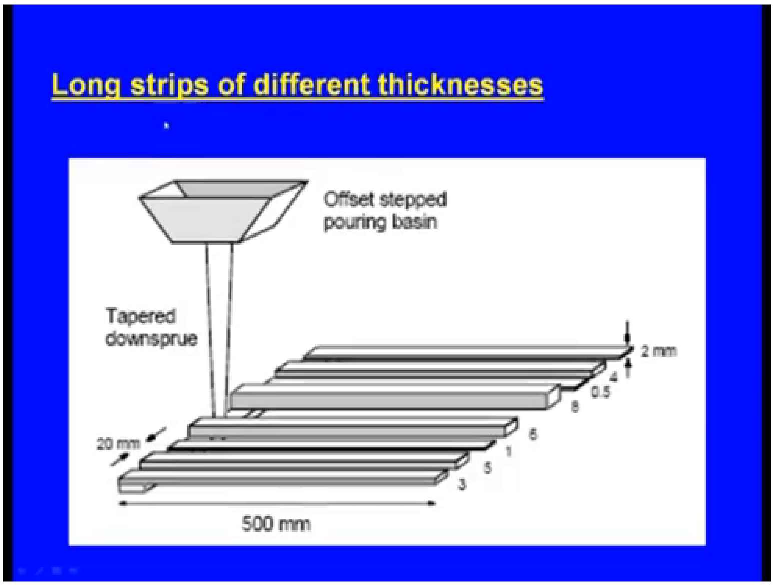
Then as the molten metal is flowing inside it will be flowing and flowing and it all depends upon the fluidity. If the fluidity is more and it will be flowing more distance and if or if the fluidity is less and it will be flowing to a lesser distance. So, now when we stretch it yes we can measure what is the distance it has flown. So, that is how we can measure the fluidity using the spiral tube method. So, the greater the length of the solidified metal greater is the fluidity. Sometimes it may flow for 20 inches or sometimes that is that is a lesser fluidity sometimes it may flow for 30 inches means it is a higher fluidity.

(Refer Slide Time: 40:32)



Next one is the suction tube method. So, it is a based on the application of the vacuum. So, here there is a simple tube is there. So, this tube will be immersed inside the molten metal, so this is the molten metal. Now on the other side the tube will apply vacuum then what happens because of the application of the vacuum the molten metal will be flowing through this tube. Now what will happen depends upon the fluidity of the molten metal it will be flowing inside the tube. If the fluidity of the molten metal is very good it will be flowing to a longer distance maybe it may flow up to even here or if the fluidity is very less it may flow up to here or if the fluidity is moderate it may flow up to here. So, that is how the fluidity of the molten metal can be measured using the suction tube method using the vacuum.

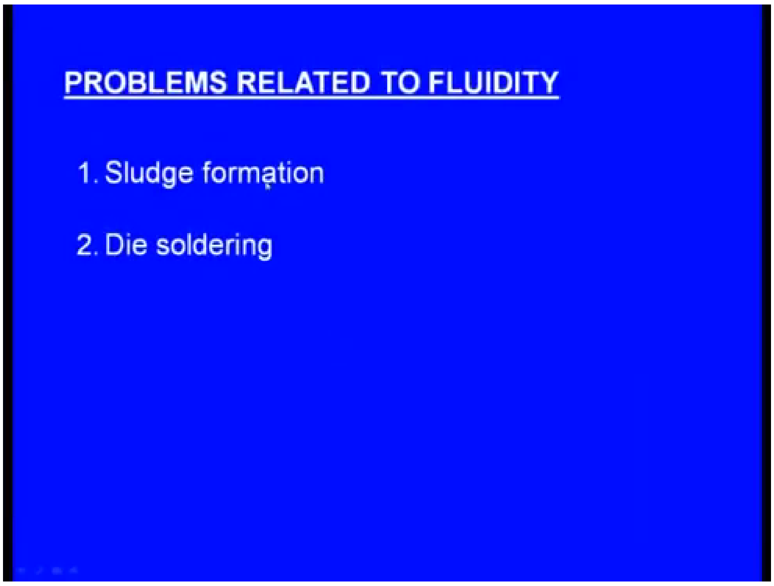
(Refer Slide Time: 41:28)



Next one next method is the long strips of different thicknesses. So, here we can see say this is another what say method which is similar to the what say spiral tube method in the case of the spiral tube method we see a thin spiral wire is there, but here long what say sections are there. So, this is the what says sprue what say pouring cup, and this is this sprue the tapered sprue and this is the runner you can see there is a central runner is there here. Now to this runner different what say sections are attached these sections are what say cross sections of these what say plates is they are rectangle rectangles.

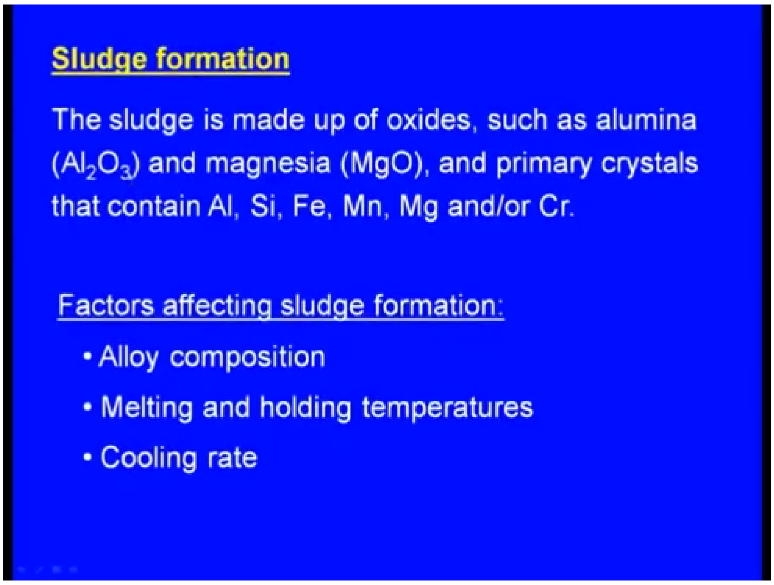
You can see here, here the thickness is more and the here the thickness is moderate and the here the thickness is very less likewise you can see different thicknesses may be one mm here, 5 mm, 3 mm, 6 mm, 8 mm, 0.5 mm you can see 2 mm likewise different thicknesses what say sections will be attached. Now the when you pour the molten metal into this the molten metal will be flowing then it will be flowing into this runner then it will be flowing through different sections and depending upon the fluidity of that molten metal it will be flowing into these different sections and stopping at a particular place.

(Refer Slide Time: 42:53)



Next one let us see the problems related to fluidity. What are the problems associated with the fluidity, one is the sludge formation and another one is the die soldering. What are these?

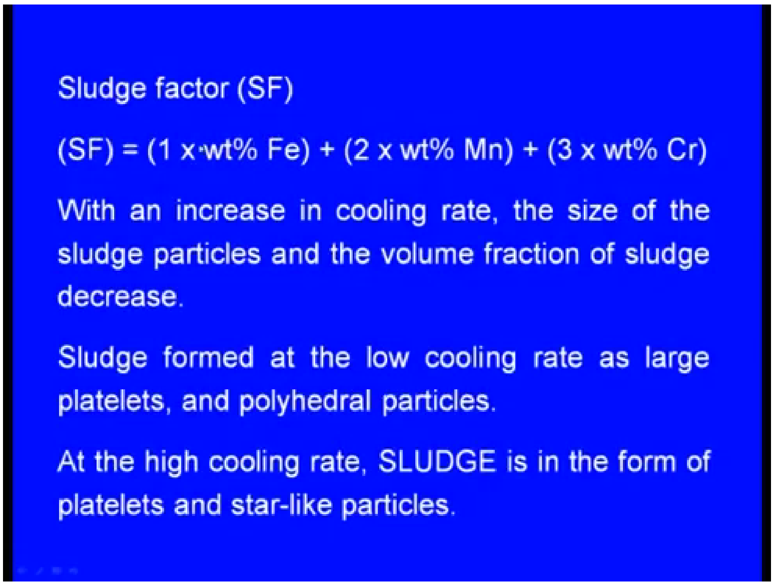
(Refer Slide Time: 43:08)



First let us see the sludge formation, this sludge is made up of oxides such as alumina Al 2 O3 and magnesia MgO, and primary crystals that contain aluminum silicon iron manganese magnesium and or chromium. So, all these together will be forming a sludge. Now this will be affecting the flow of the molten metal sometimes this sludge will be obstructing the flow of the molten metal.

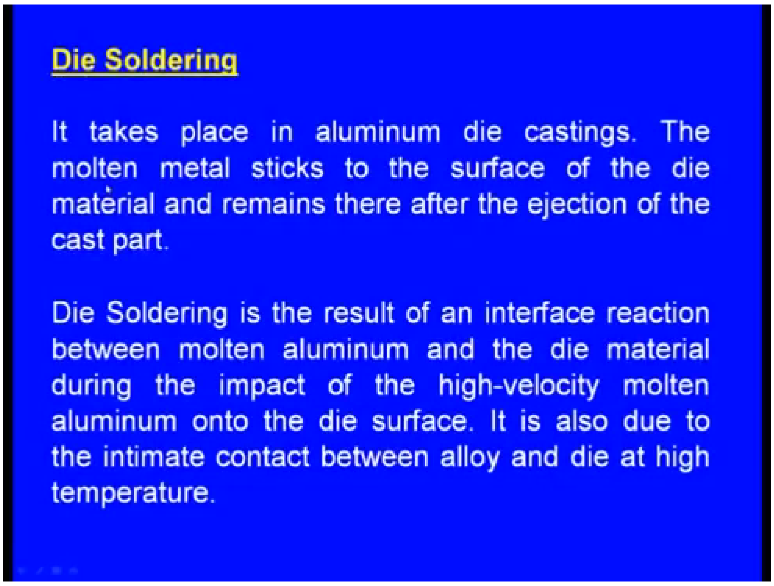
Now, what are the factors affecting sludge formation: One is the alloy composition, second one is the melting and holding temperatures. And the third one is the cooling rate.

(Refer Slide Time: 43:49)



Sludge factor SF is equal to 1 into percentage weight of iron plus 2 into percentage weight of manganese plus 3 into percentage weight of chromium. So, with an increase in cooling rate the size of the sludge particles and the volume fraction of the sludge decreases sludge formed at the low cooling rate as large platelets and polyhedral particles at the high cooling rate sludge is in the form of platelets and star like particles.

(Refer Slide Time: 44:21)

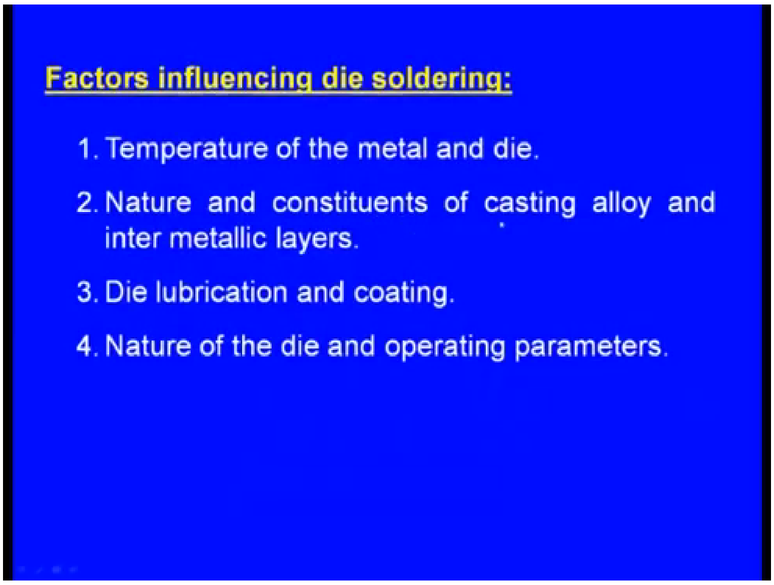


Next problem associated with the fluidity is the die soldering. So, this arises in the case of the die castings, when you are making castings using the die casting process. So, it takes place in aluminum die castings especially the molten metal sticks to the surface of the die what say die material and remains there even after rejection of the casting.

So, this shall die soldering is the result of inter phase reaction between the molten aluminum and the die material during the impact of the high velocity molten metal into the die surface. It is also due to the intimate contact between the alloy and die at high temperature.

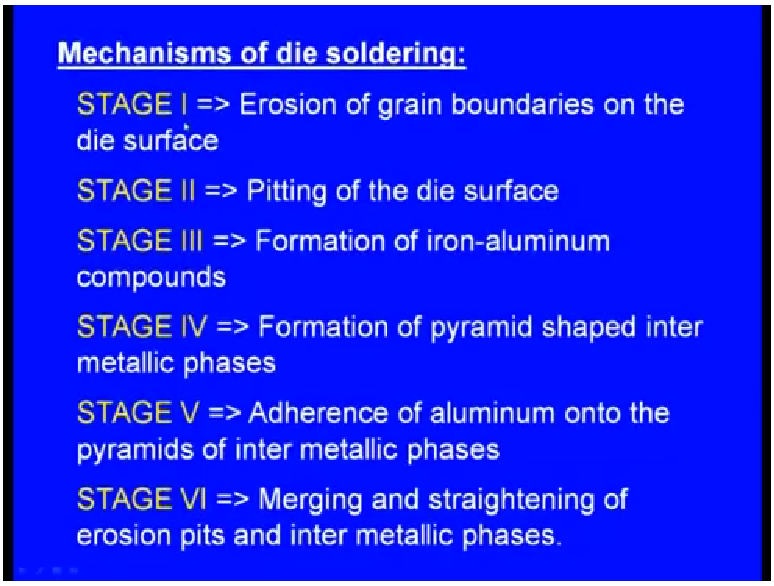
So, what happens in the case of the die casting we inject the molten metal into the metallic dies. Now there inside the metallic dies the molten metal solidifies and the casting has to be taken out. But in this process it can so happen that the molten metal will be sticking to the die material inside the cavity. So, that is how this die soldering problem arises.

(Refer Slide Time: 45:27).



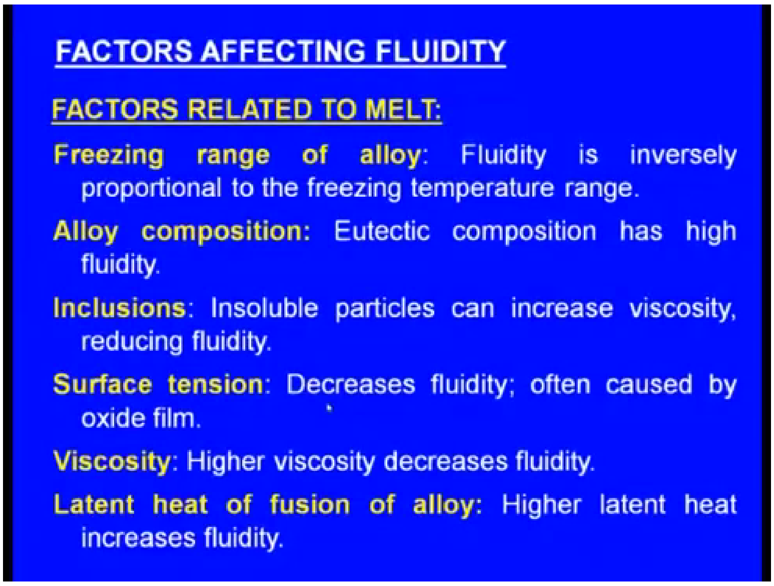
Now, factors influencing the die soldering: One is the temperature of the metal and die, next one nature and constraints of casting alloy and inter metallic layers, next one die lubrication and coating, next one nature of the die and operating parameters.

(Refer Slide Time: 45:49)



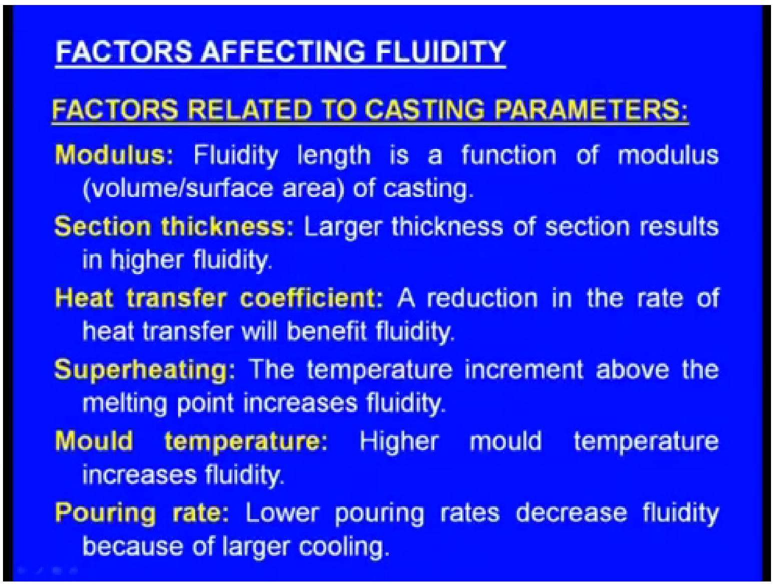
Now, mechanisms of the die soldering let us see the mechanisms of the die soldering we it takes place at 2 different stages. At stage one, erosion of grain boundaries on the die surface, at second stage what happens pitting of the die surface, at the third stage formation of iron-aluminum compounds. Fourth stage formation of pyramid shaped intermetallic phases and at fifth stage adherence of aluminum on to the pyramids of intermetallic phases and finally, merging and straightening of erosion pits and intermetallic phases. So, these are the mechanisms of the die soldering.

(Refer Slide Time: 46:29)



So, friends in this lecture we have seen the fluidity its importance and the factors affecting the fluidity. We have seen that factors related to the melt that affect the fluidity or the freezing range of alloy, alloy composition, inclusions, surface tension, viscosity, latent heat of fusion of the alloy.

(Refer Slide Time: 46:53)



And what are the other factors related to casting parameters they are the modulus, section thickness, heat transfer coefficient, super heating, mould temperature and pouring rate. Now also we have seen the methods for determining the fluidity. Now then we have seen the problems related to the fluidity. So, with this we are completing this lecture and we will meet in the next lecture.

Thank you.