Modeling of Tundish Steelmaking Process in Continuous Casting

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Lecture – 36
Intermixing in Tundish

Welcome to the lecture on Intermixing in Tundish. So, when we talk about the tundish flow, so in the plants the tundish will be used as a buffer reservoir and the ladle will be pouring in the liquid steel into the tundish and from the tundish, the metal will be continuously delivering be delivered to the respective molds.

So, the you know, so once the one of the ladle which is bringing the liquid steel from the steel melting soap, so that once that you know finishes in that case you will have the another ladle waiting in line and the one ladle will be you know leaving that spot and another ladle will be pouring in the liquid metal. So, it will start pouring.

Now, there is a time lag between these two processes and that is why that results into certain downgrading of the steel that is known as the intermixing, so that is intermixed grade. So, you know during ladle changeover process, new grade intermixing to old grade it will be mixing to the old grade

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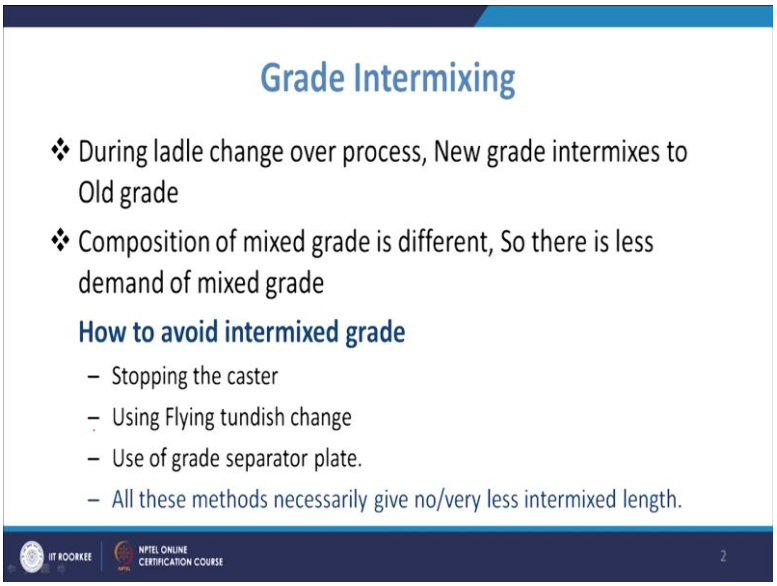

So, you know that can be understood by you know.

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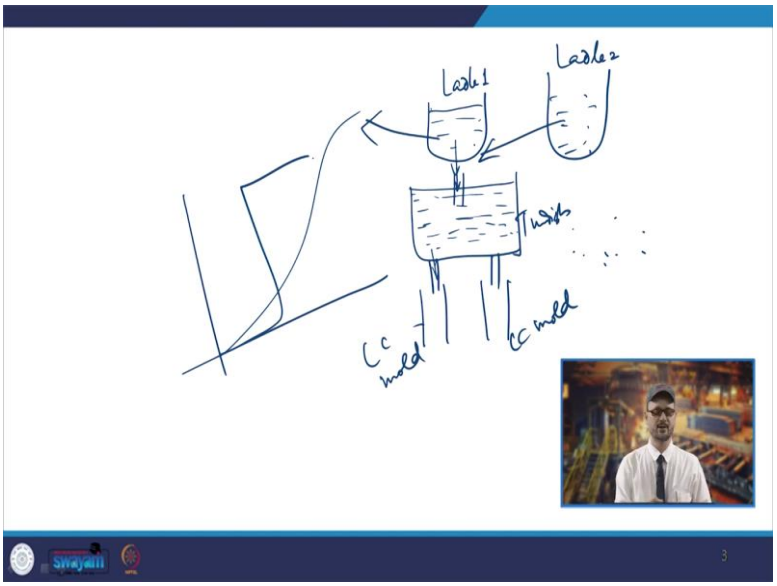

So, you will have the tundish and you will have the inlet here. So, one of the ladle; so this is ladle you know 1 and another ladle will be ladle 2, so that will be waiting. So, it gets you know it will be pouring in the liquid steel to the tundish and tundish from here it is going to the different you know mold. So, this is your continuous casting mold.

Now, the thing is that when this is gets over, so this has to be taken away and this is brought here. So, it has the liquid steel. Now, what happens that there may be change of the grades from here to you know in this case from, so between these two steel. Thing is that normally when you are casting the similar grades in those cases, when you are casting those similar grades in that case there is no such problem, however there may be variation in the grades.

Now, when that varies in that case you know normally your tundish operates at a constant level because the free surface area of the tundish is very high and you know the level of difference is small. Although that also you know has effect and that is your residual volume which is there inside the tundish, so that there will be change that is expected in that case.

Now, the thing is that when suppose it has gone up to certain you know height and then, you have brought in the another steel, so this is steel which is going inside it will be mixed with. So, it will be going and it will be mixing with the steel which is already there of this ladle inside the tundish. So, it will be mixing and now this new grade of steel, the steel which will be coming out it will be of neither this composition or this composition, but it

will be in between them because there will be some amount of this steel and stand. There will be so large amount of this initially of this ladle and a smaller amount from this ladle.

And slowly you know its composition, the steel which was already there, it will be depleting and then you have the new ladle steel which will be replacing that old ladle steel. So, in this case this is known as the, now what you get the steel in between for that time that is known as the intermixed grade steel and its composition will be neither of the ladle 1 nor of the ladle 2. So, many a times this is considered to be a downgraded steel and its value will be normally smaller than the normal you know steel.

So, what is done is you know in the industry? So, as we see that composition of this mixed grade is different, so there is less demand of this mixed grade and that is process. This process is known as Grade Intermixing or they are intermixing with each other, they are mixing among each other. So, how to you know avoid these intermixing intermixed grades? There are certain ways by which basically you can avoid these intermixed grades.

So, one is the stopping the caster and then you will have the. So, stopping the custard means you completely stop the caster, so you and then further you use it. So, in that case you can completely stop the formation of intermixed grades, but then you will have your continuity is over you do not have the you know continuous process of casting. So, and then because there is a large amount of you know involvement of the energy and all that, there are many bottlenecks when you start. So, all these are there when you do this take this process.

Then you can have the flying tundish change, so that is also another way by which you can change that and then you can start the work. There is another also way that is you know use of great separator plate. So, there will be a plate which will be separating that grade. So, the older grade will be allowed to leave first and then, you remove that plate and then you allow the next grade to go. So, these are basically and the way, but they are not practical keeping the continuity of the process in mind. These processes are not you know viable, they cannot be think of a practical you know substitute.

So, the thing is that in the industries you will have to continue and also, you will have you know not much of the control on changing other parameters like maybe the control in the flow rate or maybe the residual volume amount of the steel which was there in the tundish already. So, these you know things are the may be they may be thought of and that is why

in normal case we go for the normal ladle changeover. So, you just change the ladle and then, the liquid steel will come and it will start pouring the liquid steel into the tundish.

Now, this process is expected to give you the maximum amount of intermixing grade steel, but you can certainly reduce by either by altering the flow field or by controlling other parameters like residual volume which is there or maybe that you change the flow rate you know ingoing or out going. So, that may have the effect on the intermixed amount volume.

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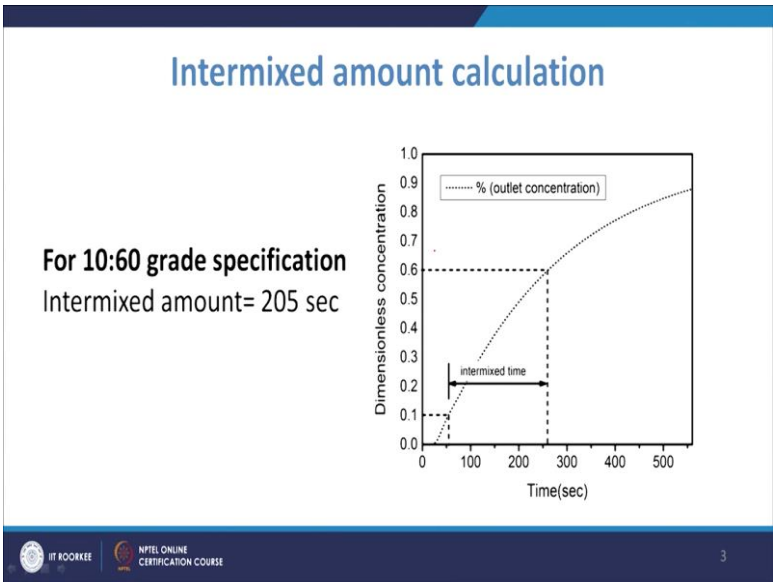

So, what we do is this is how the intermixed amount is calculated. Now, this is how you get this graph. So, we have talked about the you know getting the RTD curve. So, that is that you solve these the continuity equation, the restore equation and then after that you solve the you know concentration equation in the transient manner. So, that is what we have already studied.

Now, in the case of the when you solve the concentration equation, so we use the tracer. And tracer for tracer we can use many things like you used dye or you can have you know NaCl or so the salt or dye, all these things are used as the tracer in the you know water modeling. And we while we talk about the RTD you know curve that is your C curve, so that is basically because of the pulse inputs. So, there you allow the that input for some time and otherwise the flow is going on.

So, in that case you get C type of curve, the RTD curve. What we do is we normally take that new grade steel as tracer itself, so that you know replaces the old grade. So, your concentration you know means whole liquid. So, that will be stopped and next will be the tracer amount only.

Now, that will go into the tundish and slowly in that case it will go on, so it has to increase you know continuously because the now the old steel is not going into the tundish. Only the new grade steel is going into the tundish. So, slowly you know after some time, it will start appearing and then slowly it is increasing and as you see at some amount of time the this concentration is reaching close to 1. So, you know 1 means its it has this is the concentration of the new you know grade.

Now, the there are grade specification that is 10 is to 60 what I mean to say because if you say that if the new steel is you know has more than 10 percent and less than 60 percent, so in between when you have the mixing, so the old steel should not be more than 10 percent and new steel should not be less than 60 percent like that. So, there may be different criterias, you have stringent lenient criterias and all that. So, based on that you can have a you know amount of calculation.

So, basically the thing is that in that time whatever amount of steel is coming out that may be you know a downgraded quality of steel and that needs to be rejected. So, what you do is that by plotting this graph you see that for how much of the time which can be measured on these ordinate axis. So, that will be multiplied with the flow rate. So, that will be giving you the amount of the steel which is going to be of the intermediate grade and that may be removed

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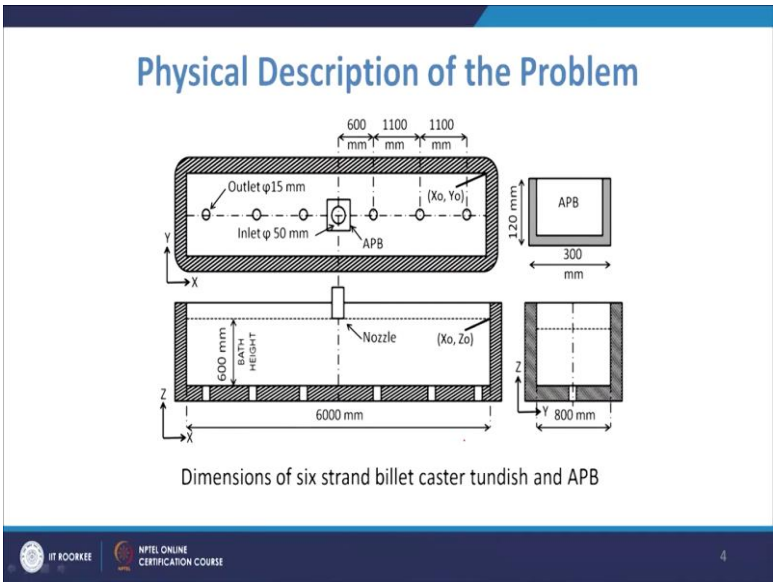

So, that is why you know now we have done certain work that you can refer and you can also see that you have a tundish, you have in one inlet and you have three outlets and you use the advance put in box are there the flow modifier, this nozzle bath height and all that are there.

So, even experimental work can be done. So, and then accordingly you can have the you know see you can you can see that how they are you know behaving, how these things are captured, how the measurement is being done.

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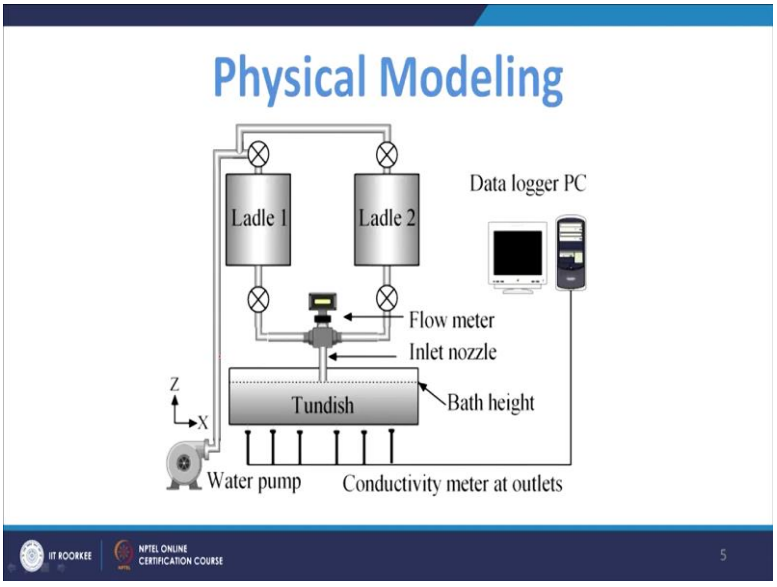

So, if you try to do the modeling physically what you have to do is, you have to have two ladles and you have a flow meter and then, you have the inlet nozzle here. So, you allow these liquid steel to allow, so you will have the two type of fluid and one you can you know color and another you can be it can be white or so or different color.

So, normally we one is water and another is the tracer that is salted solution or the dye, then we allow this and once it is reaching up to certain height, both height. So, at steady state it will be the flow will be going on and then what you do is you stop this part and allow the liquid you know watered may be allowed to be this part. So, and you have the conductivity meters which is fit at these outlets and that they are basically measured with the help of this data logger. So, you have a conductivity meters by that you measure the outlet and that is being you know measured.So, that is how this concentration comes.

So, at our different outlets you will have different lines. So, at the near outlet it will start maybe somewhere slow and at the far outlets which is far from the inlet and that may appear little late, so that you mean see. And then from all the outlets you can measure, so what is the intermixed amount being calculated and that can be you know accordingly you can have the decisions the plant may have decisions what to do with that kind of intermediate grade of steels.

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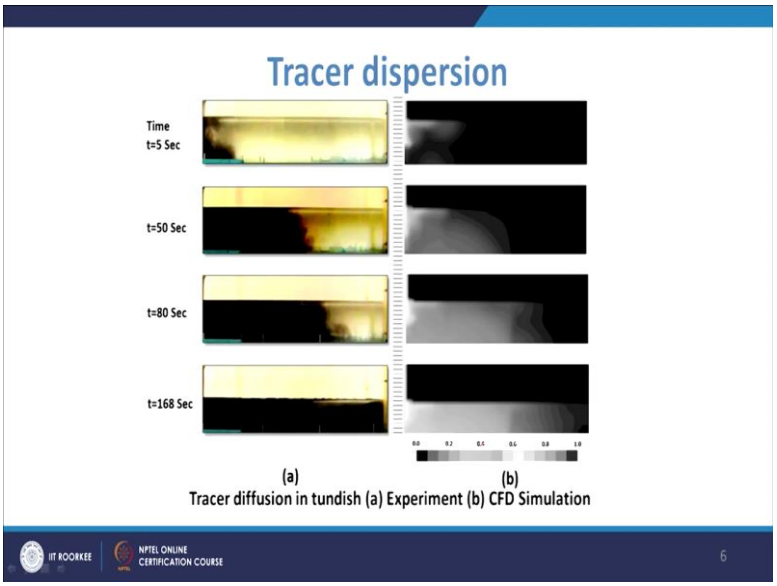

So, this is just showing one example of these Tracer dispersion and what you can see that this is the experiment. So, you gave the you know this is how the flow is going on with

water and then you started, you giving tracer. So, what you see that after you know after some time when you put that tracer continuously, so it is taking and it is all going and taking that in 168 seconds and you know that can be even understood with the help of the expiry of the simulation also. So, that is seen that how it is progressing, how the tracer has to proceed and in how much time it is how going. So, that can be seen using the CFD simulation also.

So, that tells you that when you do the physical modeling it will be giving you a sense that how the tracer is going to due to diffusion, how with their concentration will be going to change.

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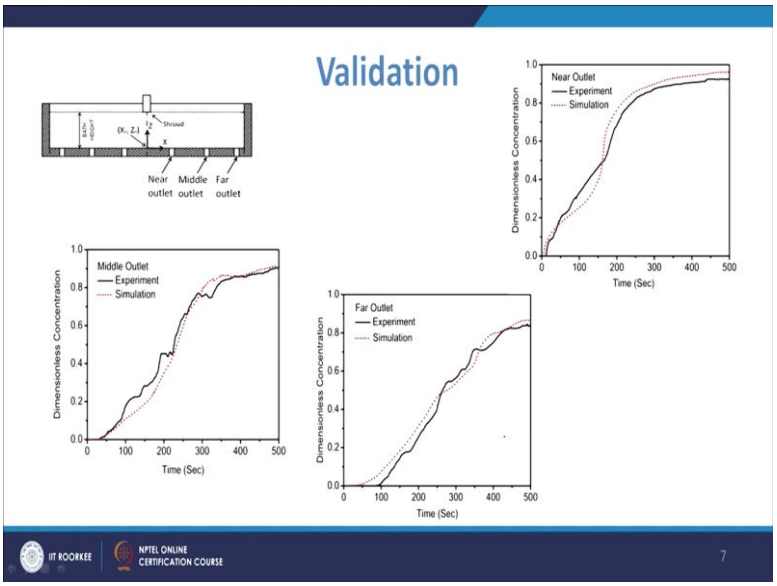

Now, this is how the validation work is done and what validation means you got the work from the you know from the experiment and similarly you got the work from the you know the from your work that is simulation and on from the experiment.

So, what you see normally that this is how there will be some matching and mismatching between these experiments, but they say you know for these two near and as well as the middle you see that the there is a match at which it starts and then finally, you will have also in between you will be so having some matching and then that is how it is showing. So, this way you can do the validation also by controlling all these parameters and having different conditions.

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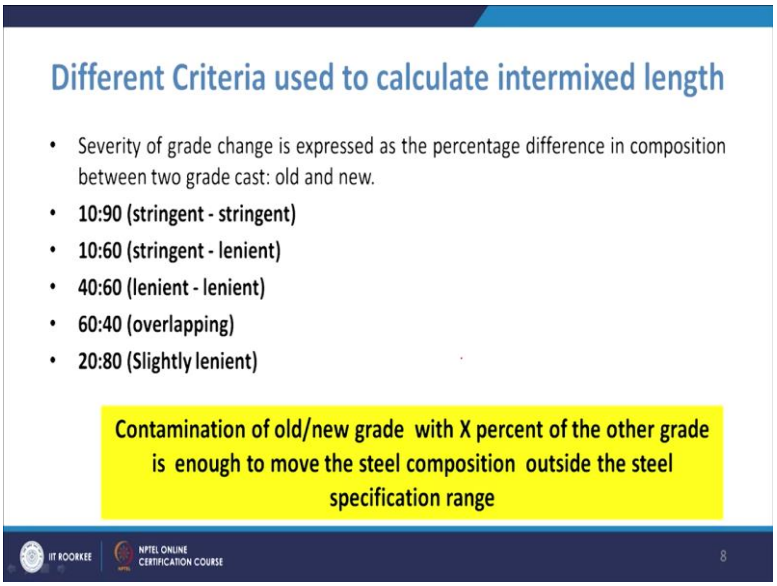

Now, as I told you that there may be different criteria's which may be used to calculate that intermixed length. So, you know you because in the in the plants there may be situations when you will have the possibility of casting two grades which are very much different from each other. And many a times you will have those situations when they are not very much different from each other. So, you will have the stringent requirements you know and on both the sides you have stringent requirements that suppose 10:90 means any you know of any one if it is more than 10 percent, then that case it is rejected like that so 10:90.

So, similarly you have different you know requirements which needs to be fulfilled to minimize those intermixed grades. So, that needs to be kept in mind while calculating that intermixed amount. So, you know so depending upon that; that is what it is said that how much it is being contaminated by old or new grades. Based on that you know you will have those two points on the F curve and then you have to take that time you know duration and for that whatever is you know getting flowing that needs to be removed.

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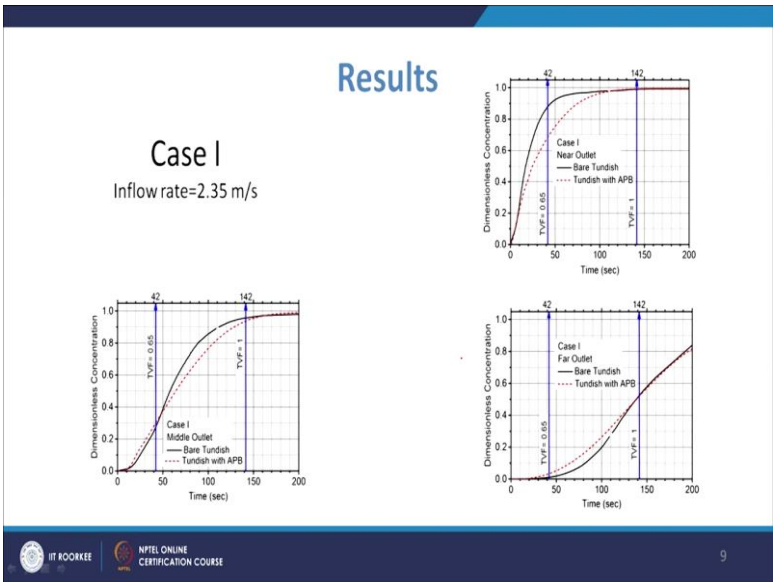

So, there has been you know certain results for the different cases like inflow rate was changed.

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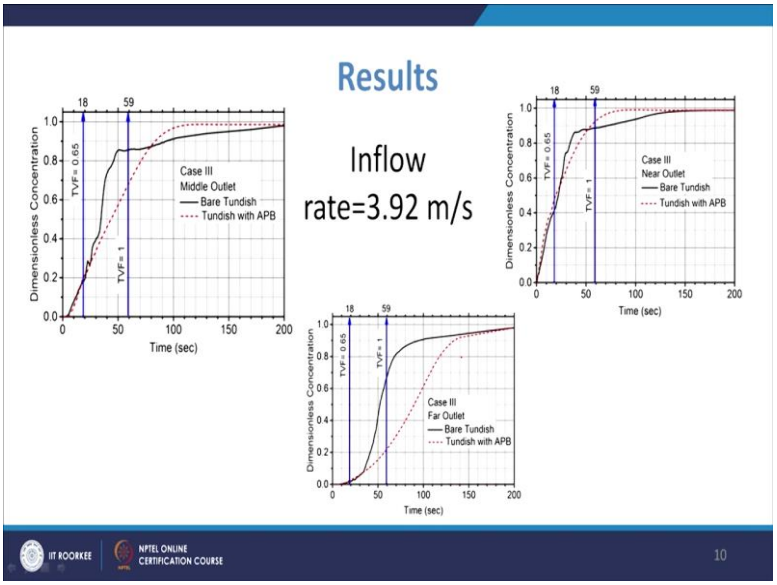

So, now what was seen that inflow rate if you change from 2.35 meter per second to say 3.92 meter per second. So, how you know these you know how these amount intermixed? Amount is changing, how the graph is changing? Suppose this is your near outlet and in this case also you have this is a near outlet.

So, if you look at these two curves you see the difference with the change in the inflow rate. And also with the bare tundish and also tundish with APB when you use the advanced pouring boxes in those cases what will be the change. So, that also can be you know calculated you know in such cases.

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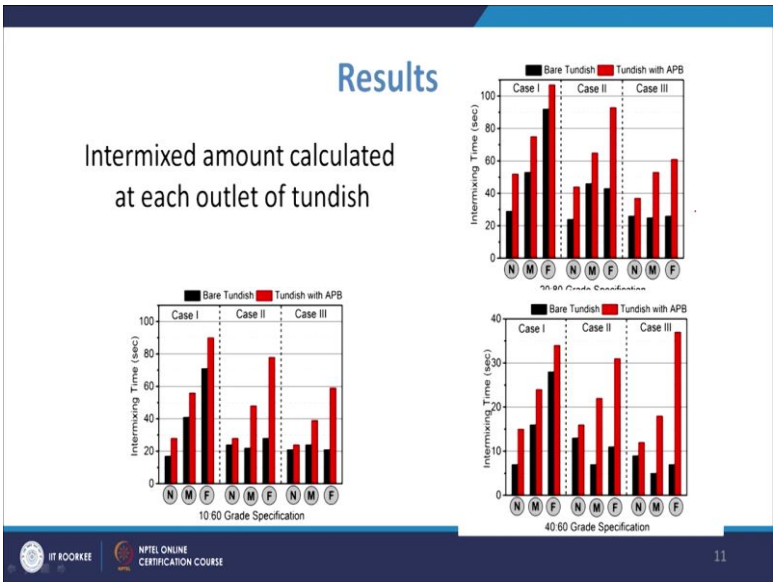

So, that can be calculated. So, once you you know calculate for a particular kind of grade specification suppose for 10:60 for 20:80 or 40:60 grade specification, these data's can be you know calculated and they tell that if you go for case 1, you know where the you know flow of the velocity was same and in this case flow was you know increase in case 2. Case 3 was you know further increased.

So, in those cases what is going to happen? So, you know as you see in this case you will have the bare tundish is this one and you will have tundish with APB. So, in the bare case as you see for 10:60 grade specification as it can be seen here for the near outlet. As you have this case once you use the advance, put in box advance the intermixing amount is increasing.

So, what do you see that if you use these APBs, your inter mixing time is basically increasing does not help much the intermixed amount. It is basically because of the sense that when you use these boxes you know otherwise it will go there will not be any mixing. So, what you expected that if you use you know the if you go for the normal tundish, so the old steel will be flushed first and then the new steel will come.

Whereas, if you use this flow modifiers, both will mixed first and in that case you are intermixed amount will go on increasing. So, that is what is evident you know at each of the outlet in the bare tundish and the tundish with the APBs. And as you see that when you take these different cases, in those cases you are like in 10:60, you get the maximum of these in intermixing amount, you know in this case of the near outlet like that. So, that will be your values of, now in this case it is this itself is a smaller one, so it is minimum in this case. This is the linear ladle grade, it is you know hardly it is about 7 or so and in this case it is close to 16 or so.

So, what you see that this is being a you know somewhat this 10 is stringent to 1. So, that is why your amount is higher in this case 20:80 as you see in this case we say it is quite higher. So, that is going up to maybe close to 30 and close to 50, so in the case of the APBs. So, that is the result which is observed when you use the advanced putting boxes type of flow modifiers. So, that increases basically the intermixed amount.

So, and also what you see that when you go from case 1 to 2, 2 to 3 in that case the intermixed amount also is seen to you know decrease in this case when you take the 10 is to 60. So, basically it all depends upon you know the kind of profile which you get the F curve which you are getting you know when you do the mathematical modeling, when you get the concentration you know which is they are monitored at the outlet.

So, how it is changing? Basically in normal case you know you as we have seen in normal case you expect that it should move like this. So, this means that there will be no intermixing and as you know as the this will be smaller and smaller in that case your amount of intermixing will be increasing because same thing will take large amount of time.

So, the thing is that you know depending upon the type of curve you know that amount of intermixing will be changing and there may be many analysis based on the you know F curve, you can analyze whether it is going to be ah you know decreasing the you know the intermixed amount or the intermixed amount will be increasing. So, all these things can be you know found out.

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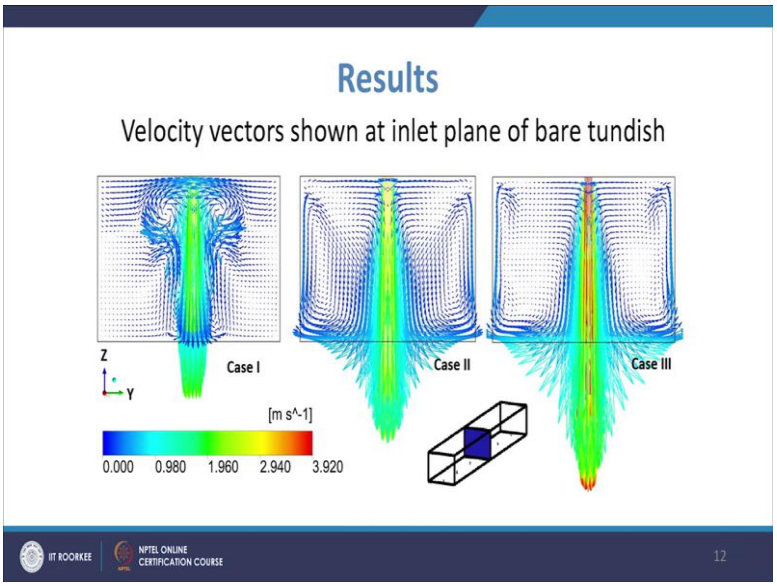

This is the velocity vector which is you know showing that how you are increasing the you know velocity for the three cases. In one case it is about 1.78, then it is increasing accordingly.

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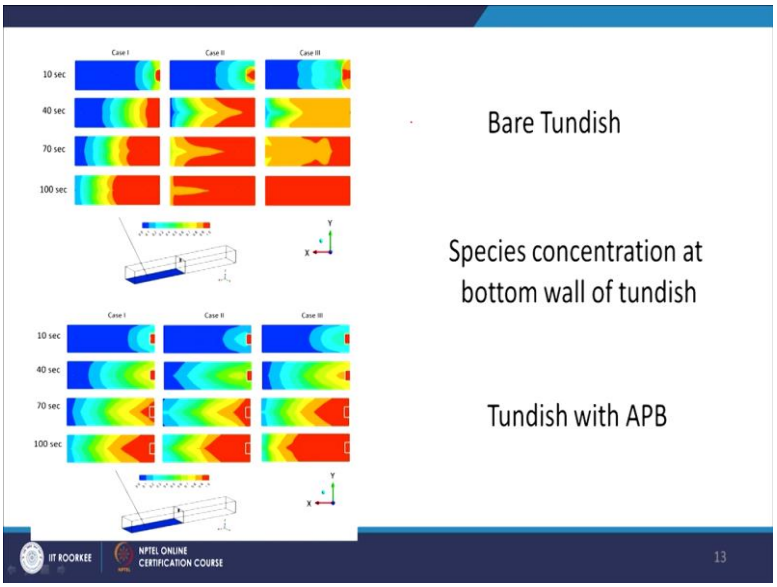

So, this is about the species concentration that you can draw and you can see that with time how your you know concentration is increasing. So, from inlet it is increasing towards the. So, as the time is increasing how this tracer concentration is going to change after at the time is progressing and you can see that if you increase the flow, then that case how it is

changing. So, with APB and without APB as you see here it is there is changing that tracer concentration which is observed.

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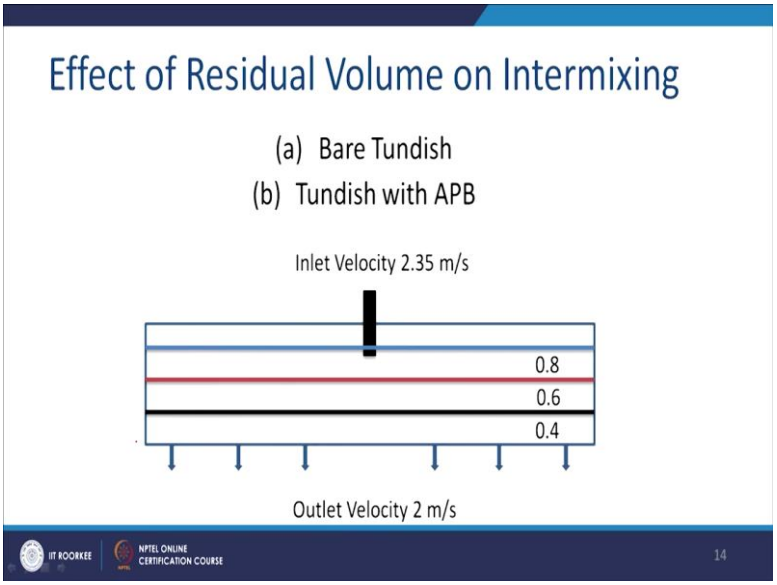

Another study may be which has been done is you know on the residual volume of intermixing. So, as we discussed that whatever amount is left over in the tundish that is a residual volume. So, what is that amount and what is that its effect on the intermixed amount? So, that may be kept smaller, it may be at a higher you know height and what is the inlet velocity which you are maintaining, so that you can have the velocities value is already there which is you know measured.

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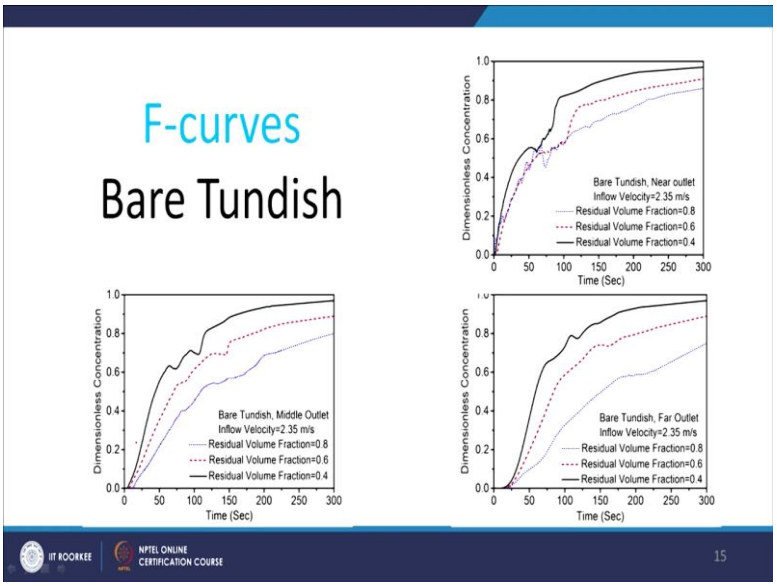

So, if you what is that effect on the residual you know volume and the ones having the residual volume means when the height is remaining at that particular volume fraction of 0.4 then you allow. In that case, when it is 0.6, then you allow or when it is at 0.8 of height then you allow means when you are allowing the new grade of steel to fall at that time, what is the height of the steel of that old component in the tundish.

So, that is what the residual volume fraction is and this way the curve looks like when you will have the if you look at these velocities and these are the you know F curves for the you know a middle outlet, near outlet and the far outlet when inflow velocity was point 2.35 meter per second. And the residual volume fractions are you know change, what you see that when your residual volume fraction is minimum, in that case the slope is maximum and when your slope is maximum in that case the chances of the intermixed amount will be minimum.

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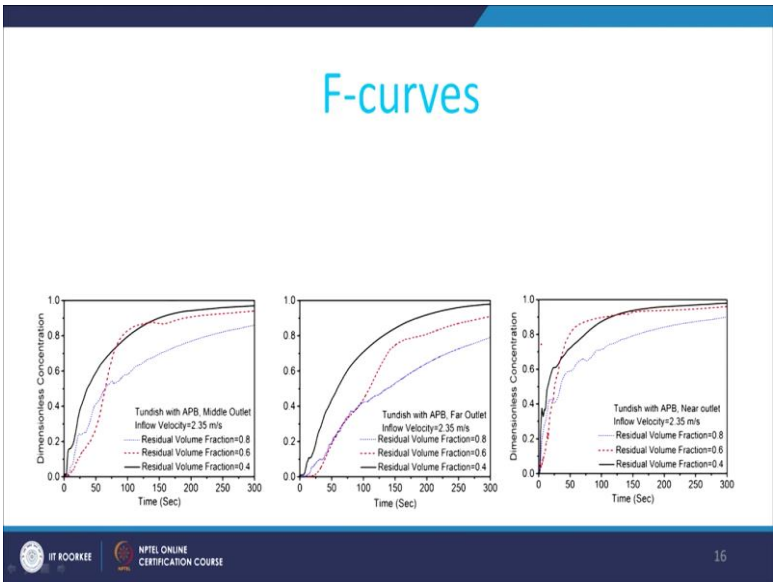

So, residual volume fraction if it is a smaller than a smaller that will be leading to the lower value of the intermixed amounts, that is what is seen you know even with the use of APBs also you can have that feeling.

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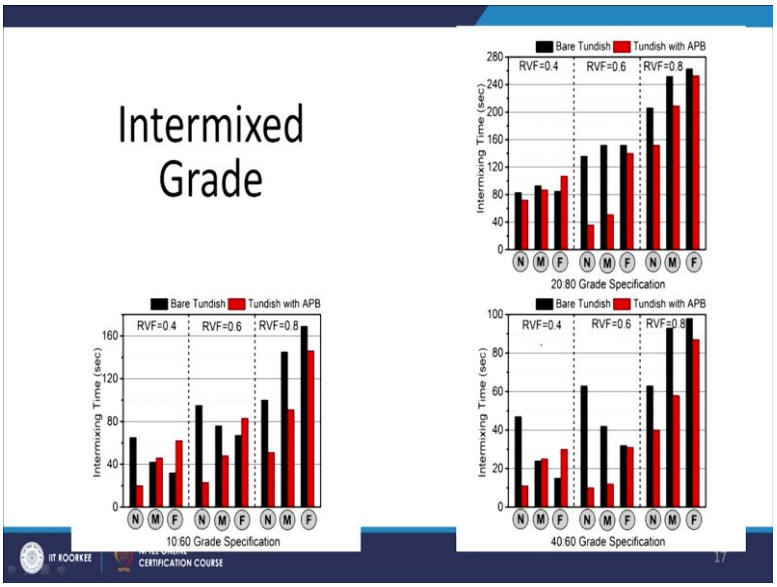

Then that amount calculation also as you see it is smallest when your residual volume fraction is less. So, in those cases you are likely to have the minimum of the intermixed amount.

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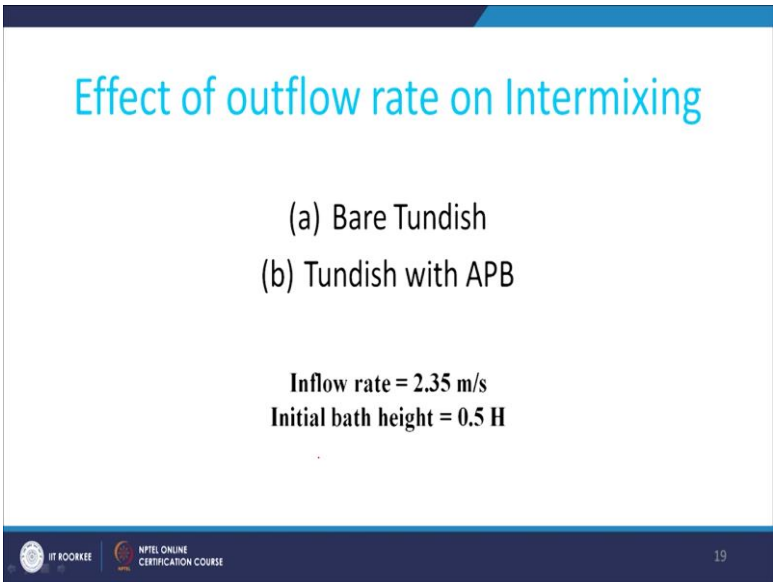

So, this is again the residual. In those cases the concentration at the bottom wall of the tundish which is shown and one is again the effect of outflow rate on the intermixing.

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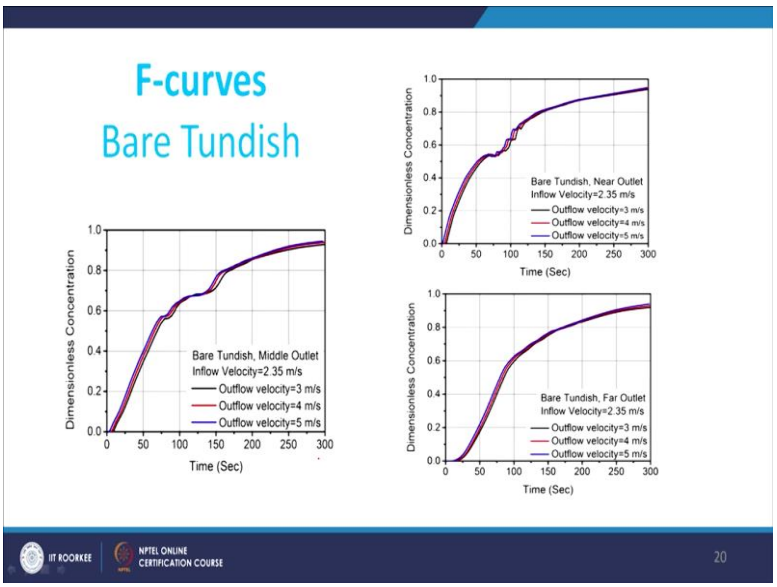

So, that way you know if you look at the inflow velocity that is a 2.35 meter that is constant and your outflow velocity when you are changing two different values like 3, 4 and 5 meter per second. So, in that case there may be change.

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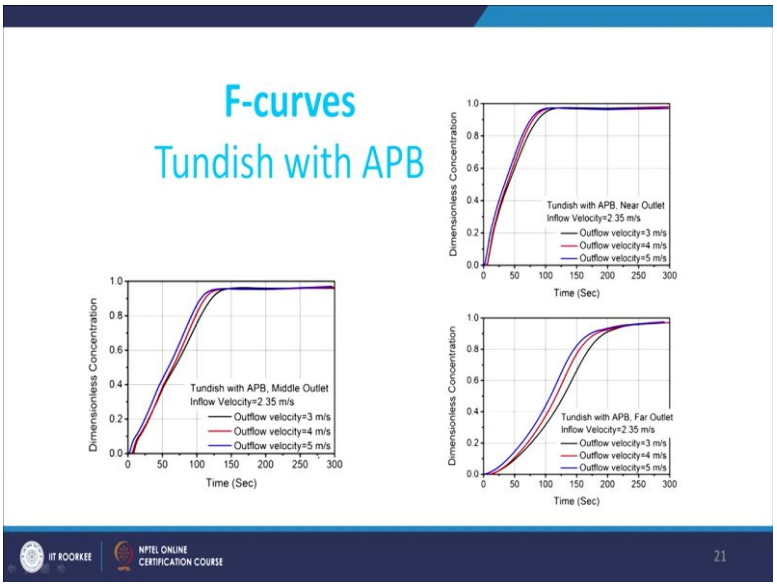

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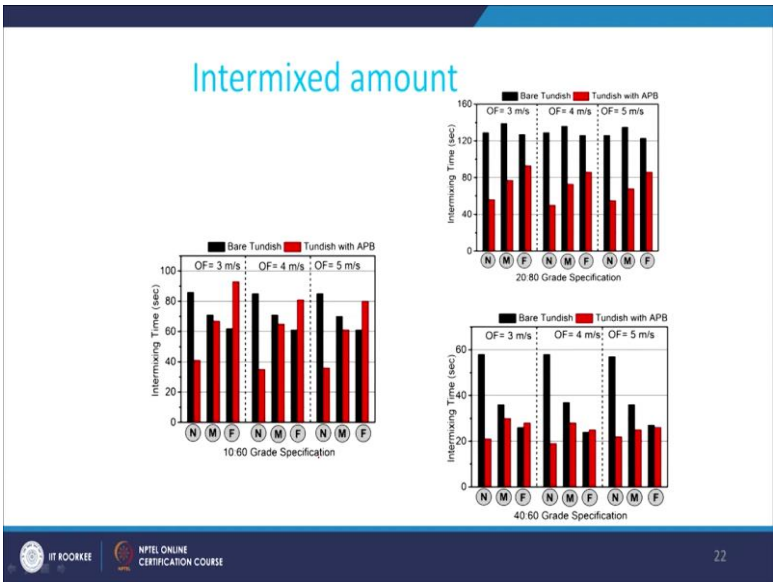

So, basically thing is that you can have the different parameters changed and accordingly you can calculate the intermixed amount. And you can suggest in the plant that if you maintain this flow rate or if you have the proper selection of these of process parameters, in those cases you are likely to have the minimum of the intermixed amount. And the decrease in the value of intermixed amount will basically increase the productivity of the plant.

So, this study can be done you can you can work on this, you can have the you know results and you can analyze them, you can even analyze based on the F curves because you have you know as you see your typical F curve goes like this and it may go like this, it may go like you know it may go like this.

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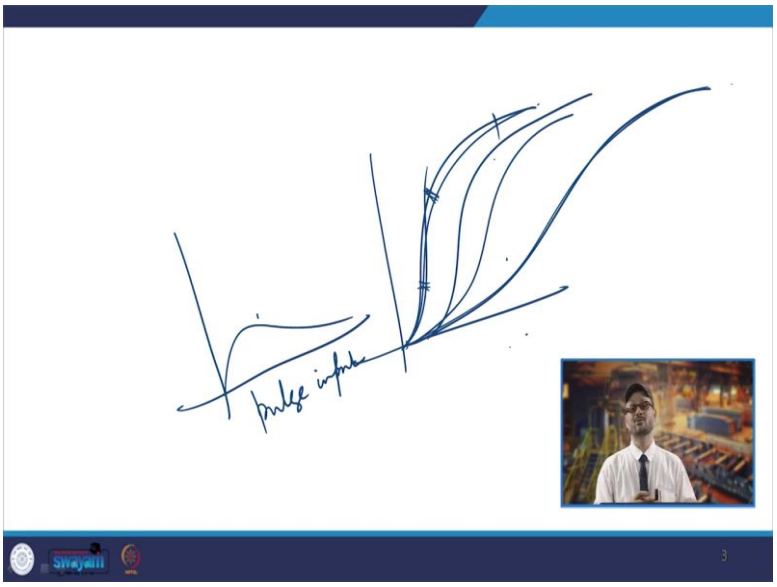

Now, you see in all these cases you can be looking at this may go like this. By looking at the curve itself you can have the idea in which case there will be maximum of the intermixing. So, basically your you know slope higher that you see that will give you mix from intermixed amount.

You see you might recall that when your slope will be smaller and this way when this is pulse input now, in that case you tell that mixing is higher. In this case, when the slope is higher in that case, you say that inter mixing will be minimum basically in that case intermixing minimum, this will be intermixing will be maximum.

So, these studies depending upon even you can have the study based on the you know depending upon the criteria and you can have the different zones and you can discuss about the slope values in the different zones and you can analyze the amount of intermixed you know intermixed amount formation. So, these studies can be calculated can be done to have the analysis of the inter mixing process and you can do it.

Thank you very much.