

Modeling of Tundish Steelmaking Process in Continuous Casting
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Lecture – 39
Case Studies in Modeling of Tundish Steelmaking – I

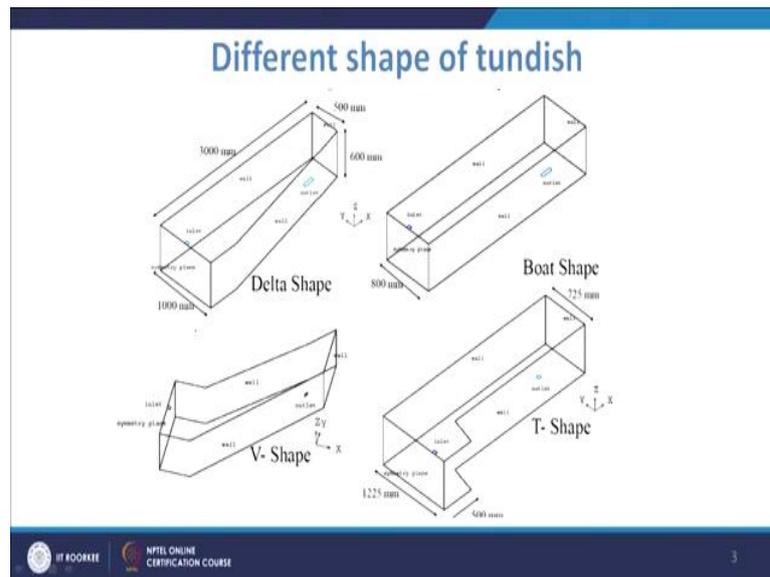
Welcome to the lecture on Case Studies in Modeling of Tundish Steelmaking – I. So, we are going to have the discussion now on the case studies of different type of work which are being carried out in the modeling of tundish steelmaking process. So, in the next lecture also we will talk about the similar type of case studies.

So, in this lecture we are going to have the discussion about some of the parametric analysis and this is the outcome of certain of my research work and you can even see the such kind of work in the literature which has been reported in the you know international journals or conferences.

So, I have tried to analyze and discuss such kind of work which can be thought of you know being tried by the researchers in the industries or in the academia and also this kind of work is still going on. So, we will try to have discussions on certain such kind of work. So, we talked about the mixing as well as the inclusion separation processes which are one of the important you know duty which is performed by the tundish, but here we are going to have the discussion on those aspects for the different configuration of tundish.

So, you know there are different kind of tundish which are reported, different shape of a tundishes, and how they perform, how you do the analysis, how you can have the visualization of the output results so, that can be seen in those task. So, how that we should see them so, that we will see in this lecture.

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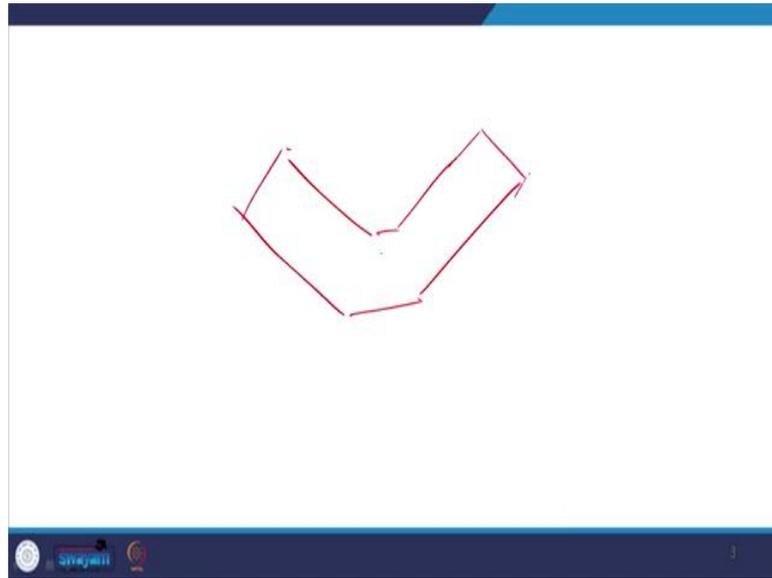


So, we have basically taken you know these four different type of tundishes basically they are the outcome of certain research work which I did for even the ministry that is DST. So, they are the outputs also you know we got similar outputs there. So, we acknowledge the support by the DST also.

So, this is suppose we in that the study was carried out on these four different kind of tundish. So, normally we deal with the two the two kind of tundish that is say delta shape and boat shape. So, this is known as boat shape. So, normal you know this rectangular type of cross section and that is being extended. So, that is your you know boat shaped tundish, but then the here in the case of delta shape you have on the symmetry line, you have the larger you know cross section and then it is smaller towards both the side.

So, this is your symmetry plane it means the similar dimension will be coming on the opposite side also. So, you will have a larger you know tundish. So, the whole turn this is about 6 meter 6000 millimeter and in this case you have this is your V shaped tundish. So, here actually you make a V type of you know shape.

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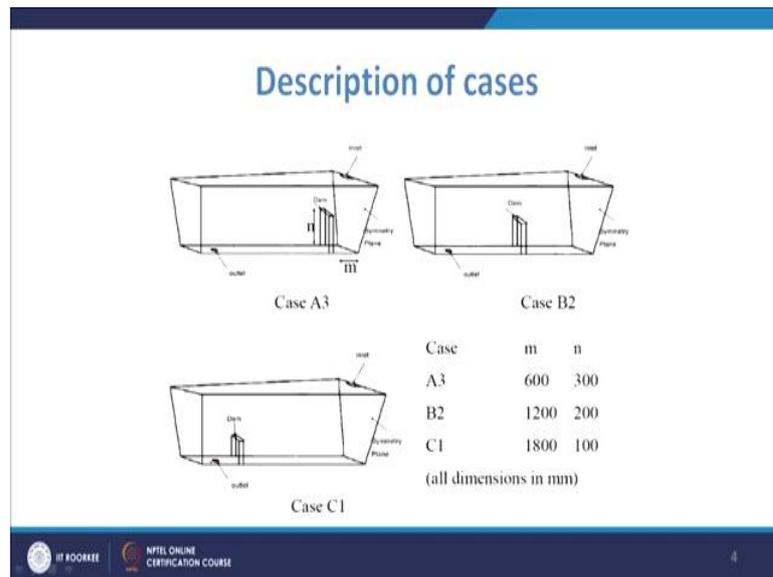


So, it will be like you know this way. So, you will have the this is a 45 degree you know angle. So, that will be your you know this is the type of shape. So, that is what you see this is your that type of shapes this is V shape, this is inlet. So, this way you will have the extension on both the sides.

And, another shape which is also being reported in the literature is T shape. So, in the T shape you have in this case you have the slanting type of slope is there. So, your and in this case your up to certain distance you have the larger you know width and then it becomes smaller. So, that is a T shape of tundish it is known as.

So, as you see these are the four different type of tundishes were taken and it was you know these are the geometrical parameters it was seen that the I mean normally we keep the volume as constant. So, their volumetric flow rate also is kept constant when the inlet size is same. So, that is what the, but now we need to know that when you do the analysis how they perform for the you know main purpose for which the tundish is being used. So, we will talk about it.

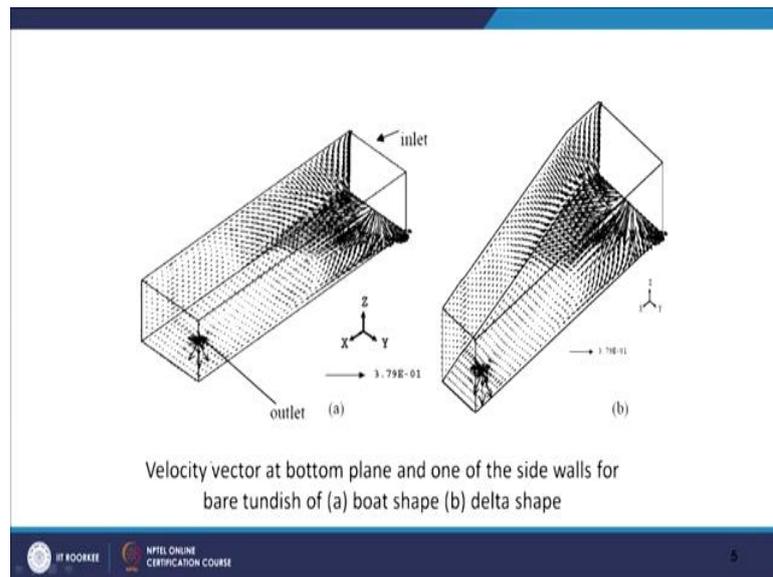
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So, also you know we discussed we will use may be if possible in the this lecture or in the coming lecture we will see that how we can describe the different cases when we use the flow modifiers. So, when you use the flow modifier, flow modifiers will be A1 to A3, B1 to B3 or C1 to C3 and there you know placement will be you know varying so, A or B or C.

So, A is closer to the inlet, B is somewhat you know you know distant and C is quite far near to the outlet. Similarly, you know there the subscript 1, 2 and 3 will be talking about the different heights we are taking. So, height of that flow modifier that is dam specially we have taken so, that its effective will be seen on these parameters.

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So, if you look at so, what we did again it was you know forgetting that you need to solve these equations you treat the you know flow as turbulent. So, you have to solve the appropriate equations even for turbulence also, if you take the case and turbulence model you have to solve these two extra equations for k and epsilon. You can take any other turbulence model and then ultimately you try to you know solve the concentration equation also for the pulse input analysis for the tracer concentration which you get during the pulse input.

And, so first of all when we solve these equations so, in that you are going to have the velocity field steady state velocity field you are getting inside the tundish. So, we will try to have the velocity field which you get in the case of tundishes. So, if you look at the velocity field so, velocity field as is shown on the bottom plane.

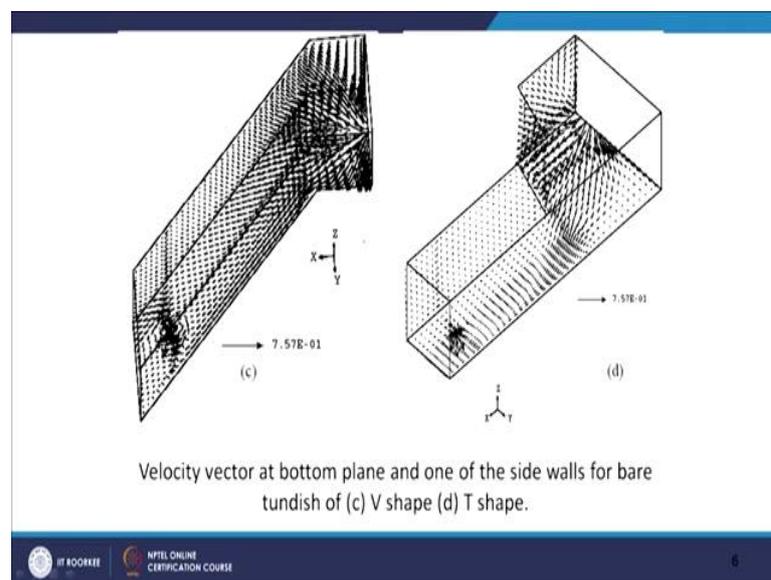
So, this is your bottom plane, these two are the bottom planes as you see and then on one of the side plane also the velocity field has been shown and it is seen that the tundish from the inlet the liquid steel will be going you know down, it will be striking here and then it is moving towards the outlet and since there is no you know flow modifier here.

So, what you see that initially the velocity is very high it will be splashing on all the directions. So, it will be going similarly in the opposite side also. On this side it will be going over the wall. So, that is what it is seen that it is going on over the wall and then it is moving towards the outlet.

So, this way you will your flow will move towards the outlet. You will see the higher velocity then slowly they become lesser because of the you know the stresses which occur because of the wall and all that. So, slowly the velocity will be lesser and then ultimately it will come through the outlet.

So, these are the you know velocity field on the bottom plane and also on the sidewall, one of the sidewall has been shown for clarity. So, that is shown in the case of the boat shape as well as on the delta shape.

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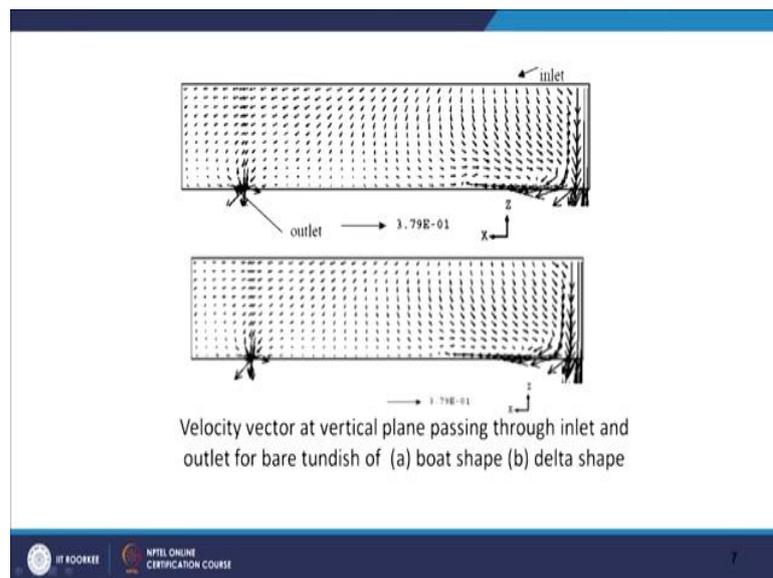


So, if you go to the other kind of you know shape of tundish. So, it is on V shape as you see here. So, you will have if you look at the line you know this is the velocity vector which is showing 0.379, this is 0.379 similarly this is 0.757. So, here if you look at this is here the velocity is quite high and you know this way it will be going and this is your you know T type of tundish.

So, you see the velocity higher it come becomes lower in this range because it is some more distance your inlet is here. So, it will be falling here. So, coming to this side it the velocity will be a smaller, but then this way it will be you will have larger velocity on this side and the smaller velocity on that wall side. So, that is you know being shown in this case and you see the lower velocities on this side where higher velocities on this wall. So, these are the.

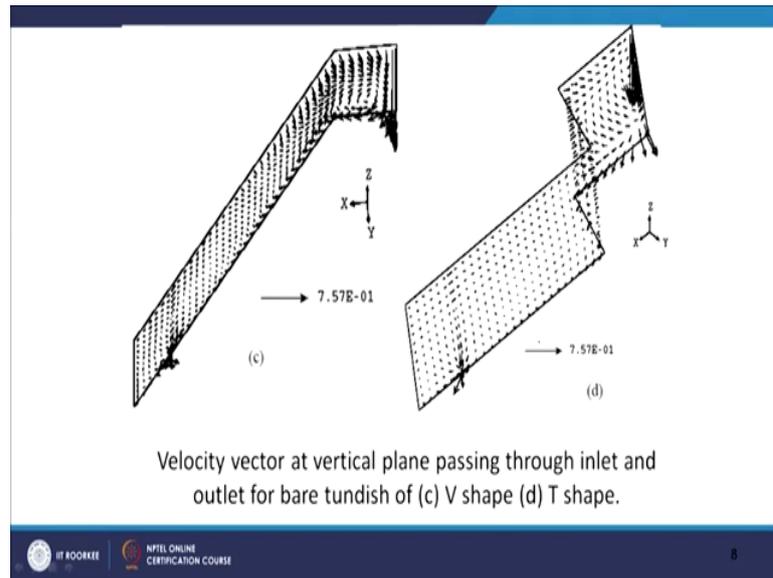
So, this way you can have an idea about the velocity vector which you draw and you should draw the velocity vectors on those surfaces from where you can have the clarity you can draw certain you know inferences, you can draw certain conclusions by looking at those velocity vectors which will tell you that where the velocity field is higher, where the velocity is higher where it is lower. So, which if it is very low it may be like it may likely to have certain dead zones also. So, this is how the velocity vectors are seen.

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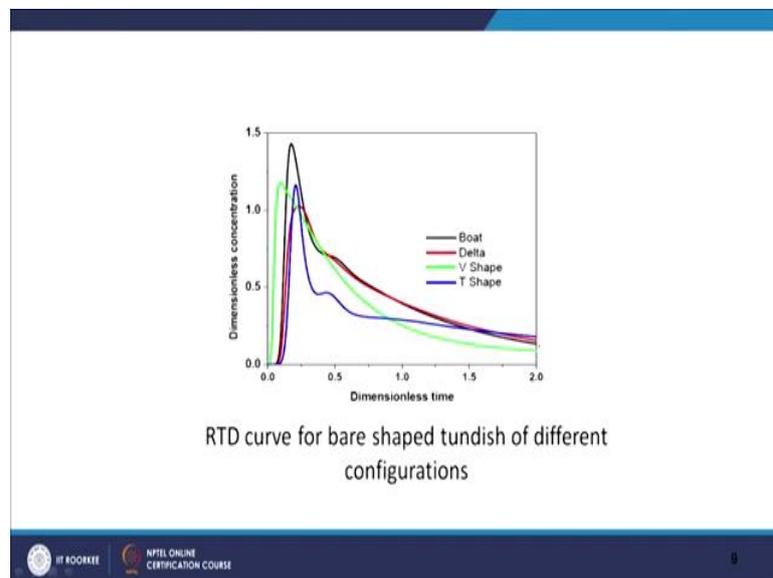
You can have the velocity vector also on the vertical planes passing through the inlet and outlet because we have the inlet and outlet plane that is on a vertical plane. So, for the boat shape it is showing like this is for the you know delta shape you can have this inlet and outlet plane you can have the velocity vector going like that.

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Similarly, on the plane of on the V shape and T shape you can have the you know view of these velocity vectors on those vertical plane where on which the inlet and outlet is you know situated. So, that way you can have the these velocity vectors also.

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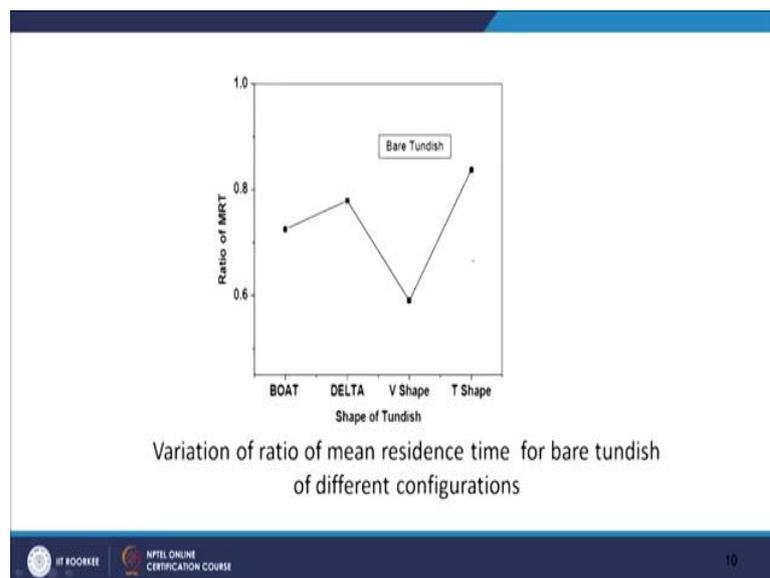


So, ultimately after having the steady state velocity field we are solving for the pulse tracer concentration. So, that is given for a small amount of time as a pulse input and then it is concentration will be measured at the outlet and then it is plotted.

So, what is seen that if you look at these you see that you have a higher peak in the case of the boat shape, but it is coming at a later time maybe not so late the if you see the appearance of the tracer which is there you know delayed for most time that is for the T shape which is indicated by the blue color. And, the V shape what you see is that you have very high very early appearance in the in case of V shape that was seen by if you refer the velocity vector also you can see that the velocity is seen quite high and in that case it reaches the tracer will reach to the tundish outlet early that is the indicative of this line.

So, you know that way and it is going like that and then you will have the it is, but what you see that they are coming slowly and the value is coming smaller on this side. You have the red shape by the delta and you have all these different tundishes will have the RTD curves you can have these and you can then analyze by when you even you look at the it is other parameters like mean residence time or ratio of the mean residence time.

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So, if you find the ratio of the mean residence time that is actual to theoretical. So, that if you look at you will have the minimum for the V shape that is what it is clear that the V shape because you know it has the it is stay in tundishes minimum. So, you know short circuiting is maximum in this case tracer has come and it had directly gone.

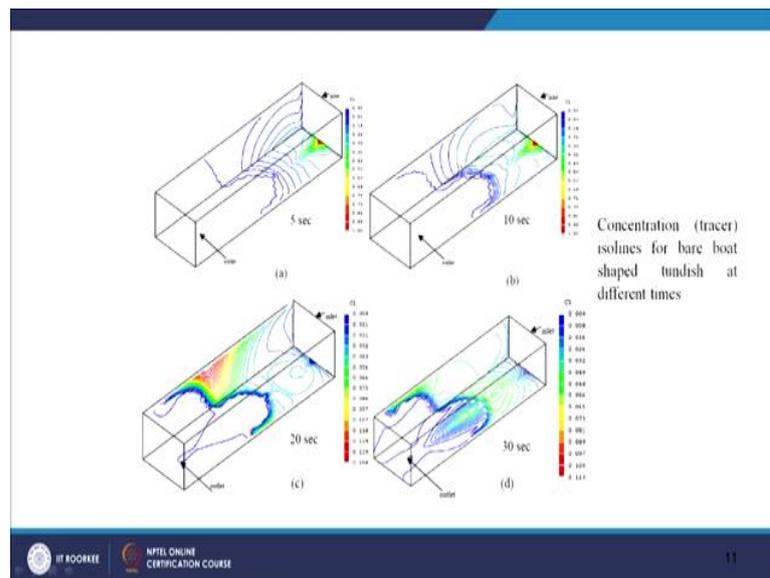
So, the liquid is not able to go you know to every corner it takes a path because of which sort circuit in takes place and your are mixing capability or the way the fluid will go inside, the residence time during which it will be moving inside that is basically minimum for the

V shape and it is maximum for the T shape if you look at the T shape. So, T shape is blue. So, it is coming late.

It is coming you know in the last its appearance is seen you know at the outlet and then it is going and it has and also you see that it is having minimum values also up to this region after that even concentration value becomes less. So,, but then it is going quite you know early. It is going quite late and then at early time it is value also become less and then it is going.

So, that way it tells that the mean residence time for the T shape is maximum and for the V shape it is minimum and then delta shape is seen to be better than boat shape, but not better than the T shape as far as the ratio of mean residence time is concerned.

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And, another thing by which you can have this you know analysis by looking at the concentration isolines. So, you can draw these a concentration isolines you know with time. So, because the when you solve these tracer concentration equation that is basically in a transient manner. So, you are with time variation you are plotting these variation in the concentration at the outlet.

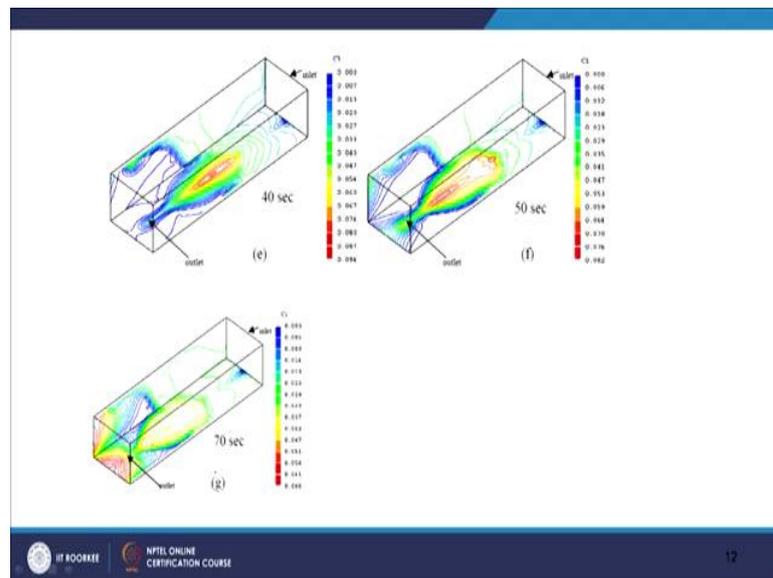
So, what you see that as the time is progressing that tracer will advance towards the outlet. So, at different times if you look at this is in the 5 second if you see the tracer has advanced up to this point and then in the 10 say this is for the boat shape, bare boat shape tundish

and these are the concentration isolines that helps you to understand that how tracer is moving towards the outlet.

So, you see that if you something is some tracer has gone its concentration is maximum at the outlet at the inlet when the at the initial time that is 5 second. And, then as the time progresses you see that the these are going down the value is going down because down tracer is moving. So, if you look at 20 second the tracer is moving more here towards this.

So, concentration is more in on this and then it is coming and appearing through the outlet. So, this is how you see that you know first appearance of the tracer will be somewhere close to 20 second or so in the case of a boat shape and then it moves.

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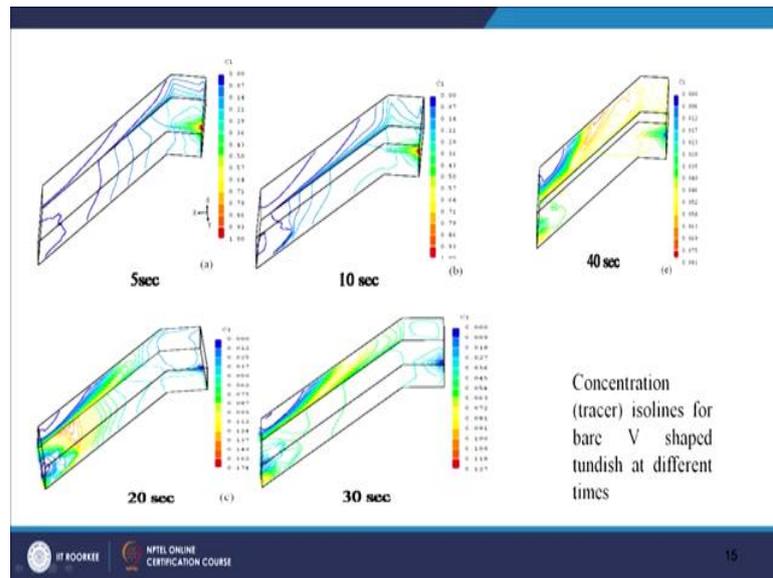


And, further finally, if you look at the 40 second your maximum concentration is here and then it is moving on the towards the outlet. So, it will be moving and going directly this stream will be going towards the outlet. So, as the time is progressing the concentration value also will be decreasing and your tracer concentration if you look at this will be quite small here and then it is increasing on this side.

So, then it has it is coming now through the outlet. So, this is how you now this is basically required to study the movement of tracer how it moves. So, it will basically be going through the as per the velocity field which is existing inside the tundish itself.

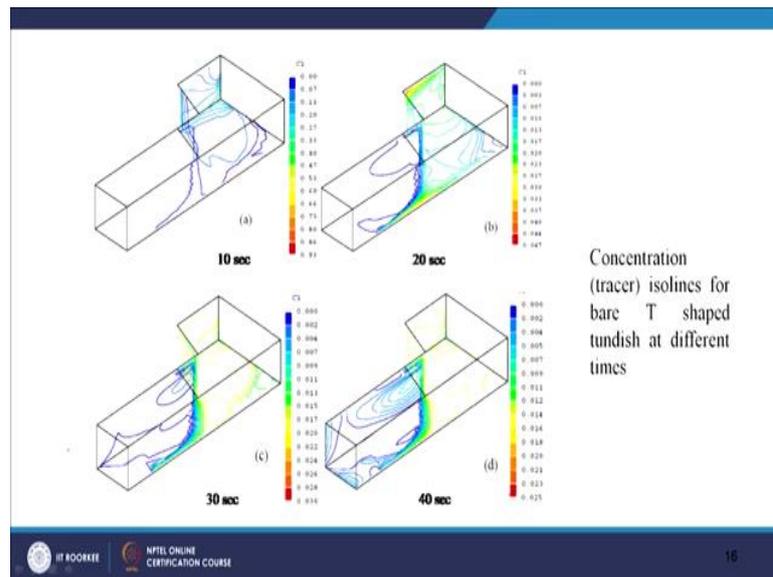
So, as you see that it is going by following the wall and also side wall as well as the bottom wall. So, that way it is moving and going towards the outlet ah. Similar thing can be observed for other kind of tundishes like the this is for the delta shape. So, here also again the same way it is moving and then it is coming out through the outlet.

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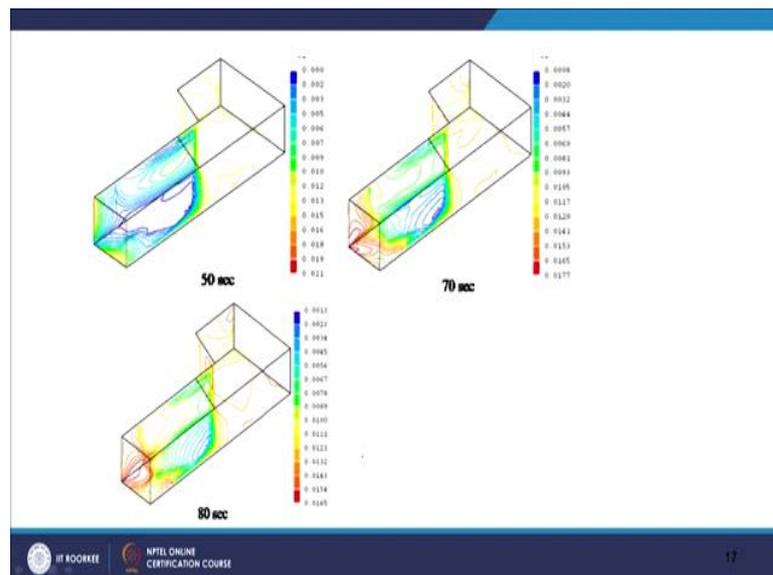
If you look at the this is the V shape tundish so, what you see now in this case you see that quite early it has come basically in 5 in 10 second itself it has come on the outlet. So, that is why you see that in this case basically it quickly comes. So, that is why there is short-circuiting phenomena that can be you know observed here and you know the mixing the mean residence time is basically seems to be is seeming to be quite small as compared to other kind of tundishes.

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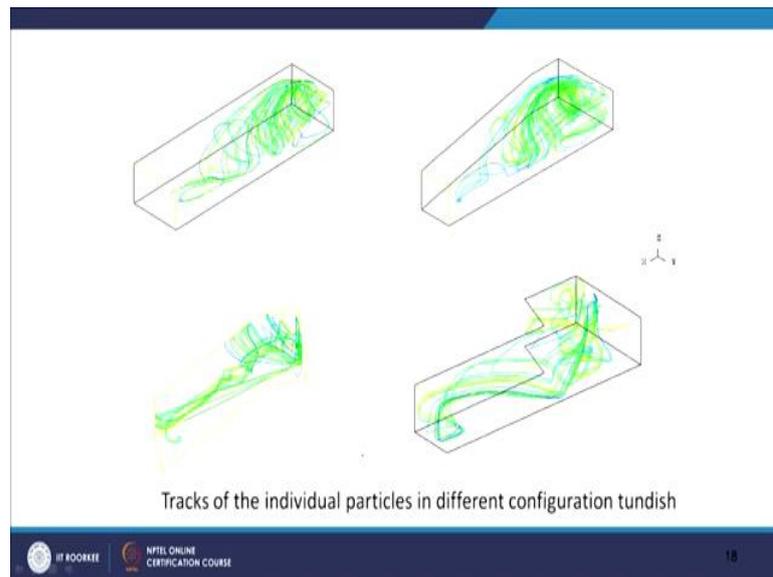
And, if you look at this T shape tundish now, in this case you can have the idea that it is going little late it is going from because it will be going toward this wall, then it is moving and then ultimately after sometime it will be coming towards the outlet. So, that way you know here the appearance is quite delayed and you know that is how you can have certain kind of you know inferences by which you can conclude that white behaves better. So, these are the ways by which you can do these modeling.

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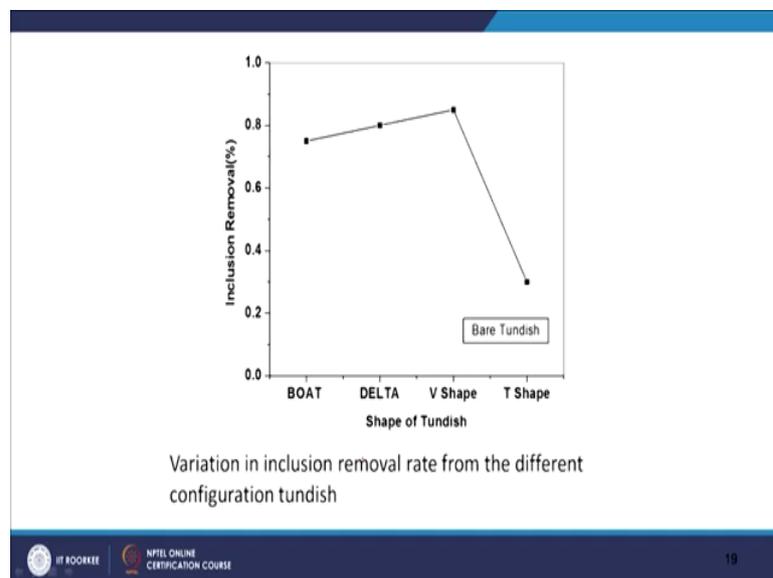
This is the case of T shape tundish.

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You can also do the inclusion studies in the different kind of different shape of tundishes inclusion particle trajectory can be calculated and that can be seen.

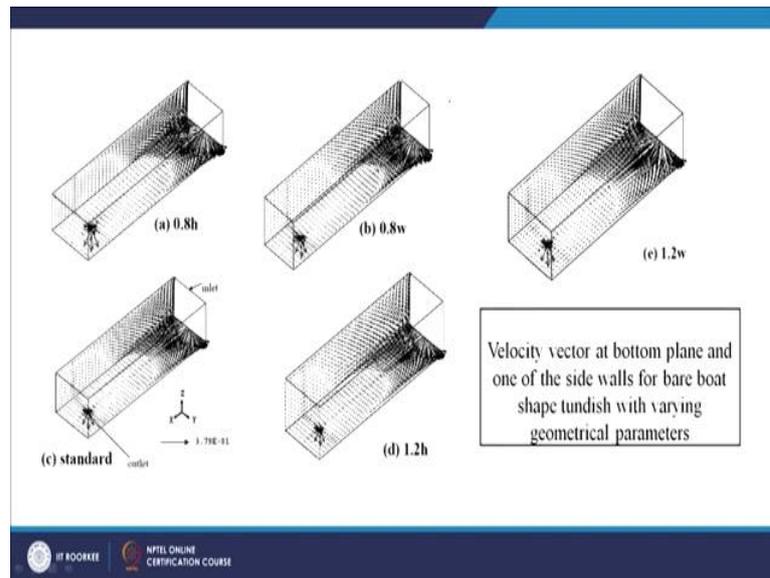
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So, what has been seen was that the inclusion removal was minimum in the case of T shape it was maximum in the case of V shapes. These are the studies which was there, but that can be you know that will be depending upon many parameters and that was one of the result which we got.

Now, another thing which was done was the geometrical parameters of the tundish on mixing and inclusion separation was also studied and that has its bearing because many a times we have shallow tundishes, we have larger tundishes or a smaller tundishes we have a less height or less width or so. So, what will be its effect so, that also can be done.

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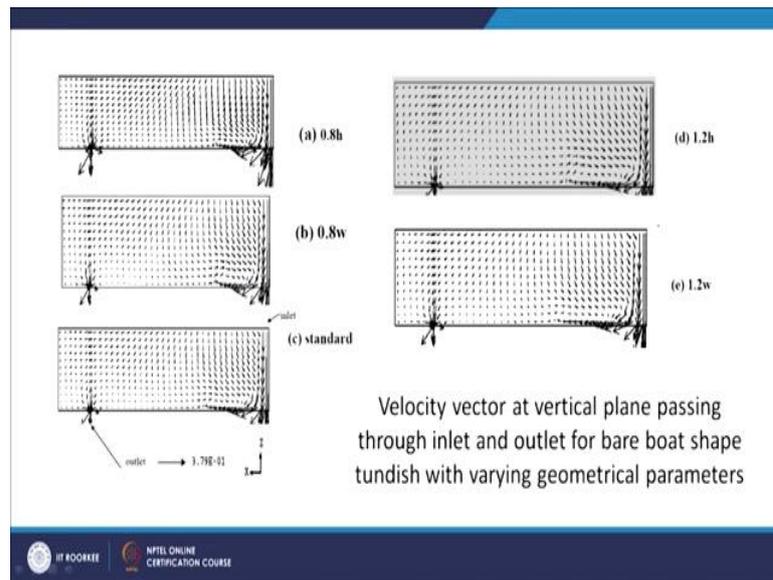


And, in that basically there are you know five cases – one being standard. So, you have other four cases like in one case you are decreasing the height and you have increased the height; similarly you have decreased the width and you have increased the width and one is standard that is h and w.

So, once you do that then you can have the idea that what are the effects of the variation of these geometrical parameters. So, that can be seen any and you can have the analysis of the velocity vectors if you look at when you decrease the you know height or increase the height or you can have the decreased width cases or increased width cases.

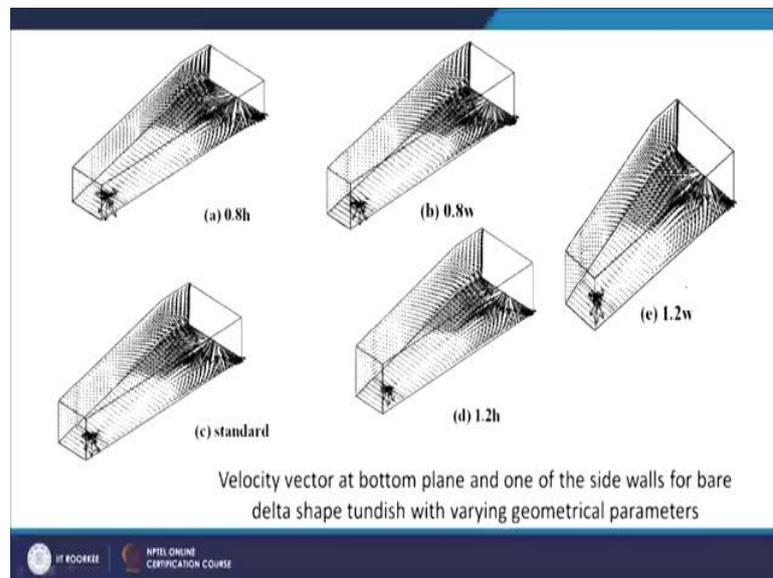
So, you can have a primary field you know that how the velocity vectors are changing because the you know you can see that which is being the width being a smaller it becomes more dense here, height becomes smaller it more become more dense here as compared to the standard or the increased dimensions.

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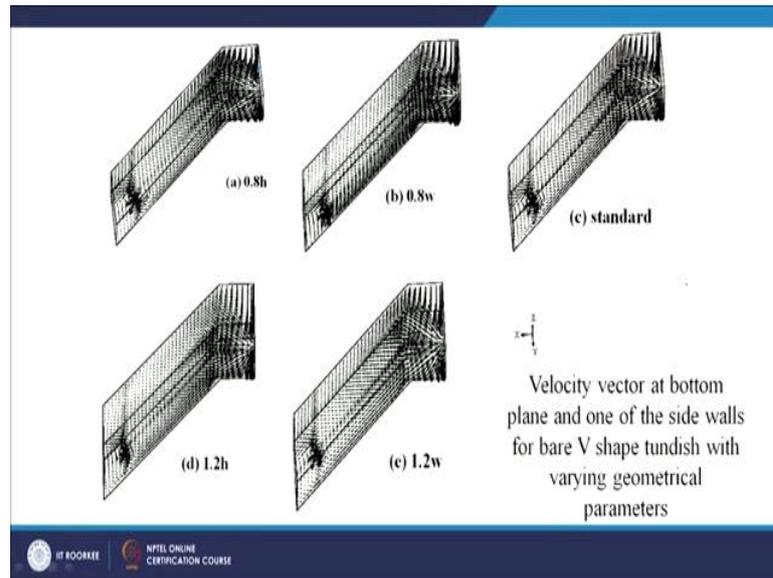
So, you can also analyze these velocity vectors at the you know at the vertical planes for the different you know standard case and then you have the other cases of smaller height or a smaller width or larger height or larger width. So, that way you can have these drawn and see the velocity vectors.

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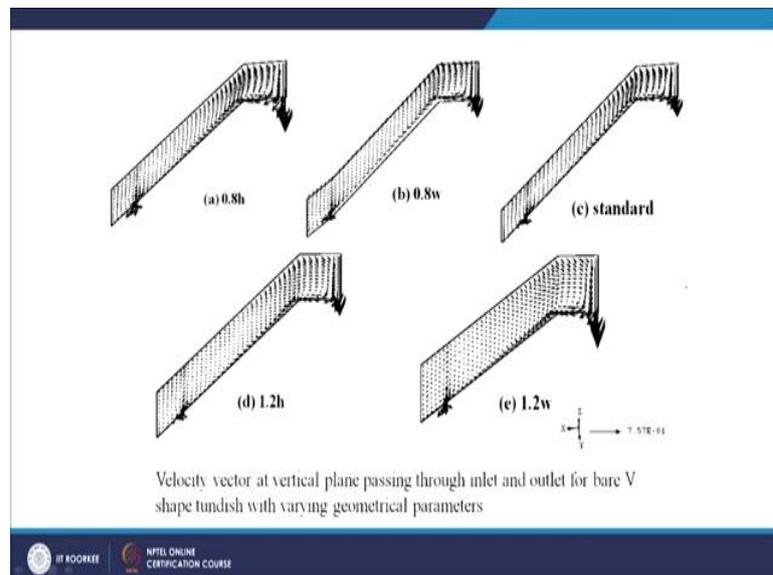
So, that is at the you know this is at the sidewalls also. So, that is shown here.

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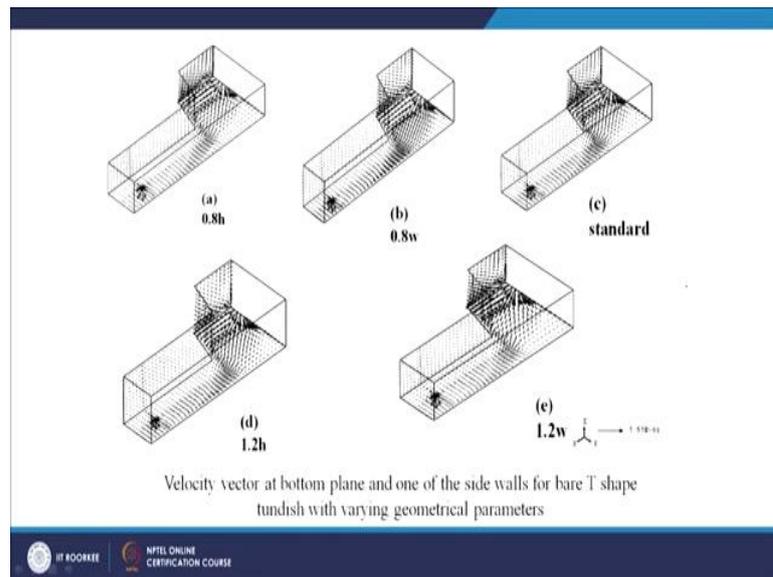


Then, you know this is for the you know this is for the that was for boat shape and this is for delta shape. So, the how delta shape is changing then you have the boat the V shape. So, V shape also you have the different dimensions and then you have the different type of flow vectors.

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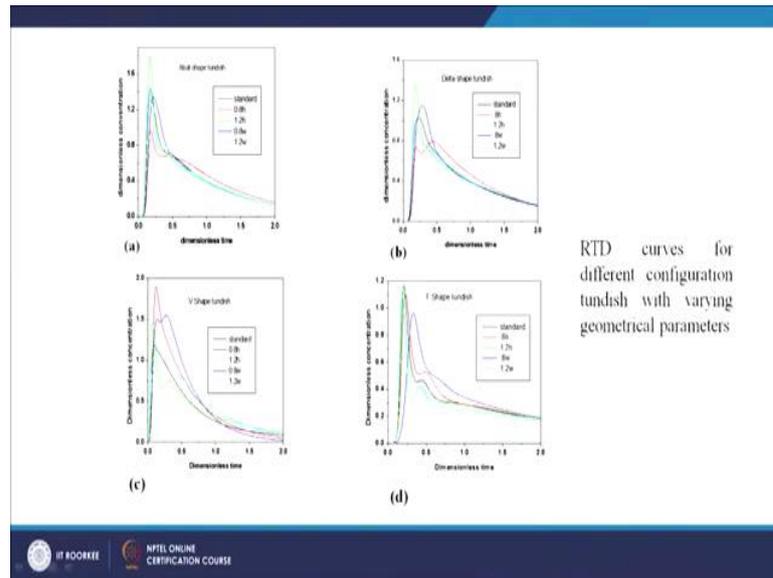
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And, then this is now finally, the T shape. So, in the T shape also we have change these sizes and you can have the you know feel of these velocity vectors at the different you know positions now based on that basically then you can you do the you know the studies of the RTD. And, with the help of RTD you can have the calculation of the mixing parameters and this is again on the vertical plane that is for the T shape tundish.

And, then you draw these you know RTD and based on the RTD you can have the you know analysis and you can see that how they are you know how they these different change in the geometrical parameters they will be affecting these RTDs. So, what you see the if you look at the boat shape tundish so, in the boat shape tundish it is starting here delta shape will be starting here. In the V shape we have already seen that your it will be starting quite early and T shape will be it will be starting the most late way.

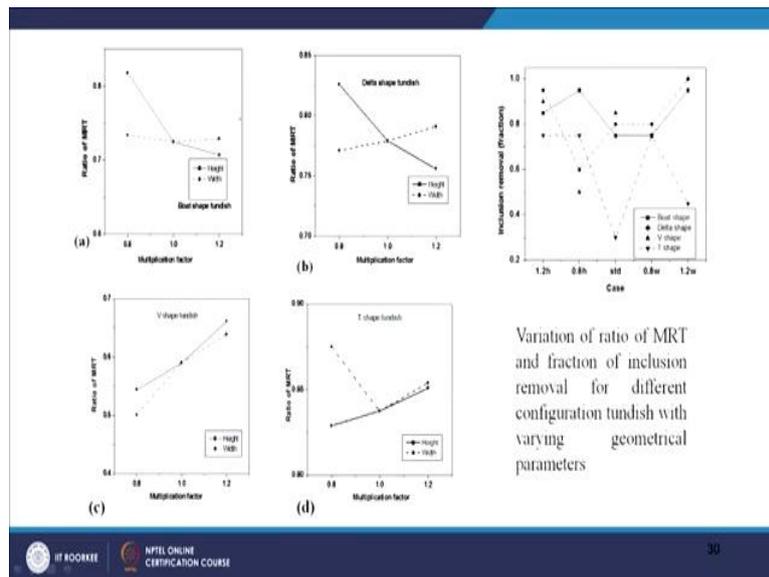
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Now, what you see that this you know red portion is the change in height and your. So, it will be smaller one and smaller width will be blue. So, if you look at the boat shape what you see is that the peak is smaller in the when the height is smaller. Now, that is also seen in the case of delta shape also where you have the peak smaller when you had a height is smaller.

But, that is not seen in the case of V and T shape because in these cases the peak is not small although it is in the case of T shape it is not. So, the highest what in the case of V shape it is highest. So, you know. So, what you see that with the with a smaller height possibly we should get the maximum you know.

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These are parameter if you look at the you know boat shape. So, with the height smaller height if you look at you see that it has maximum ratio of MRT because of this smaller peak. So, that is what is seen that you have that is seen because of the this peak.

Now, again if you look at the width. So, if you see the smaller width case. So, this is again a smaller peak. So, it will be better you know MRT that is being observed, but if you look at these V shape in that case these smaller dimensions are not showing improved results and that can be seen by for the V shape. So, you know in these cases your ratio of MRT is being smaller.

So, a this is good for because in the case of V shape we have already seen that is anyway the MRT is smaller and when you are making a smaller the more quickly the tracer will go through the outlet. So, your short circuiting phenomena is even more aggravated. So, that is why your MRT or the mixing parameter basically the ratio of MRT so, that is decreased for the V shape tundish and for the boat shape it is or delta shape you see that it is somewhat better as compared to the larger height cases.

And, standard we have already analyzed and if you increase these you know height so, this is greener. So, increasing height will be worsening the ratio. So, in the case of delta and boat that is what it is seen from here. So, increasing the height what you see is that normally you do not to have improvement in the case of boat; in the case of delta you can see this is marginal improvement. So, that is one.

Now, in case of V shape as you see the best you know performances by the this you know light blue or that color. So, this is 1.2 width. So, that is showing even better result and that may be seen for the 1.2 width you see that this is quite high 1.2 height also is showing better result. So, that is seen from by looking at those curves.

If you will go for the T shape you see you see the 0.8 width is showing the minimum one and that is why 0.8 you know height this is 0.8 you know height. So, that is showing that maximum one. So, that way what you see that by looking at these graphs you can have one feel that how these you know they these RTDs can be interpreted to have the effect on these parameters like mean residence time or even the mixing parameters.

We also did the you know inclusion behavior and what was seen was that the you know boat shape, delta shape, V shape and T shape so, what was seen that the maximum inclusion removal was with the boat shape that is with this rectangular shaped line and no this is not that this is the you know delta shape is showing the maximum with the height and for this if you look at the V shape.

So, this is triangle one and this is your V shape. So, it is coming down and then it is further going. So, that way it is better for the 1.2 height. So, by looking at this also you can have one feeling that how these you know tundishes are going to perform you know when the geometrical parameters are going to change.

So, this way you know there are different kind of you can have the you know analysis of these results by looking at the papers in the literature and you can have a feel about you know and confidence also interpreting these results and you know justifying a particular shape or size of any tundish for the industrial use if you are working in the industries.

Or you can have a you know model physical model setup also there also you can have these studies and verify them. So, that is about this and we will have a few more case studies in our coming lectures.

Thank you very much.