Modeling of Tundish Steelmaking Process in Continuous Casting
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Lecture – 32
Boundary Condition

Welcome to the lecture on Boundary Conditions. So, in the last lecture in a approach towards the modeling process we talked about the elements of modeling step. And, we saw that we need to have the you know acquaintance with the 3 steps which we need to follow I mean that is pre-processing, post processing and solving. Now, once you make the geometry then you need to apply the boundary conditions and as it say normally we deal with the cases of mass momentum and heat transfer.

So, you know we need to have the you know knowledge about the different type of boundary conditions which are required which are applied on the boundaries and other conditions other type of boundary conditions, may be they are of different type that we will see in this lecture. And, after that the solution is you know the equations are solved to get the meaningful results. So, if you talk about the boundary conditions. Now, typically when we talk about the boundary conditions, if you typically look at the Tundish geometry; so, you have boundaries as the walls.

So, you have one is your wall boundary condition. So, on the wall you will have a different kind of processes going on. You know like on the wall there is flow, there is shear going on, there may be roughness; so, the roughness that may also be required to be provided in many cases.

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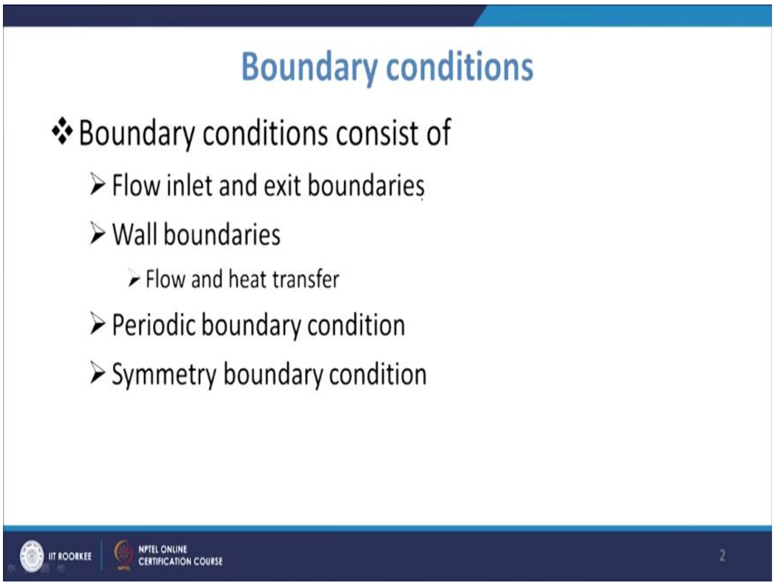

So, you will have wall boundaries. Apart from that you know the inlet is important because through the inlet the material is going inside the domain. So, you have to specify that what are the inlet boundary conditions like you may specify the velocity, you may specify the pressure. So, like that you have a different you know ways to you know to represent these inlet boundary condition. Similarly you have exit boundary condition or outlet boundary condition. So, you there you have to have again the outflow boundary condition or pressure outlet or so.

So, these are the options which are you know available to you this which needs to be applied depending upon the type of problem we are dealing with. Apart from that many a times we need you know we do the computation on a larger domain which is time consuming. When we do the computational you know work, when we do the mathematical modeling or numerical modeling that time we need to be aware that we should approach towards those the methods by which you can reduce the computational time.

So, that is how you know that is one of the parameter which you know is indicative of the efficiency of the computational algorithm or the computational tool or the way you are doing the computation. So, these boundary conditions like periodic boundary conditions or symmetric boundary conditions they help you know to identify, you know those conditions you know and imply them in such a manner that your domain size may be smaller and that will physically give you all the meaningful results or that the same results which you could have done on the full you know geometry. Like if you have a very large you know vessel which is of rectangular shape I know cross section. So, you will have that vessel. So, and if there is simply one inlet coming and there are two outlets in that case.

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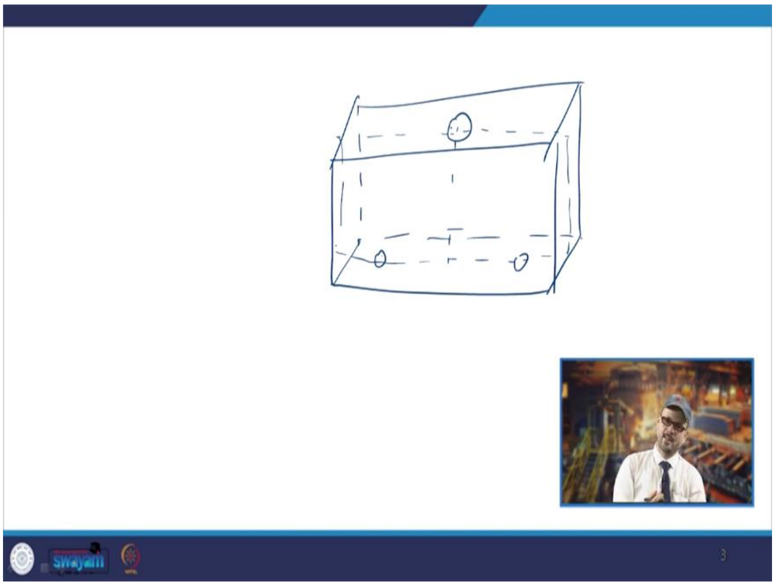

So, if suppose you have a larger you know tundish and if suppose; so, if suppose if this is of a this shape so, suppose here. So, you know and so it is going like this. Now, in this case if suppose there is out outlet which is there in the center in that case and you have two outlet us here at the symmetry you know plane are in the middle. Now in this case what you can see is that you can take half of the tundish half along here and do the you know analysis which will.

So, this line has to be the symmetry on this plane you have to apply the symmetry boundary condition which will tell that there is the similar type of mirror geometry existing on the other side. So, accordingly your computation time will be one half. Again in such kind of geometries even you can have further you know bifurcation from half because again this is the mirror geometry of this part.

So, you can have the solution only for the one fourth of the domain. So, your computational time is normally becoming one fourth of what you are doing and that is helpful when you are doing these you know analysis when you are doing the solution of the you know results when you are solving the equations that time it becomes helpful to locate them.

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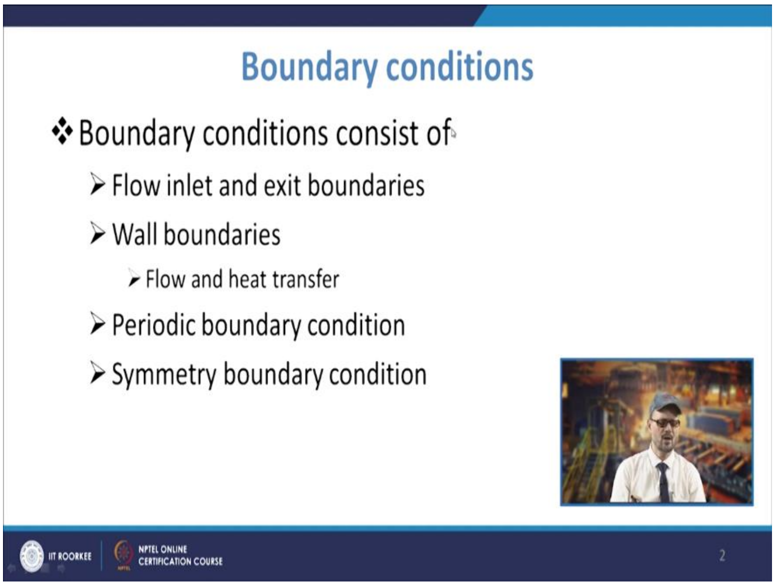

So, you know that time these periodic you know symmetry boundary conditions or periodic boundary conditions are also there where periodically if you have to apply the boundary condition in that case the periodic you know same type of condition if it is applied at regular intervals you know in that case you know you can apply the periodic boundary condition and you can get those results.

So, you will have these are the different types of you know the boundary conditions we will discuss about them one by one.

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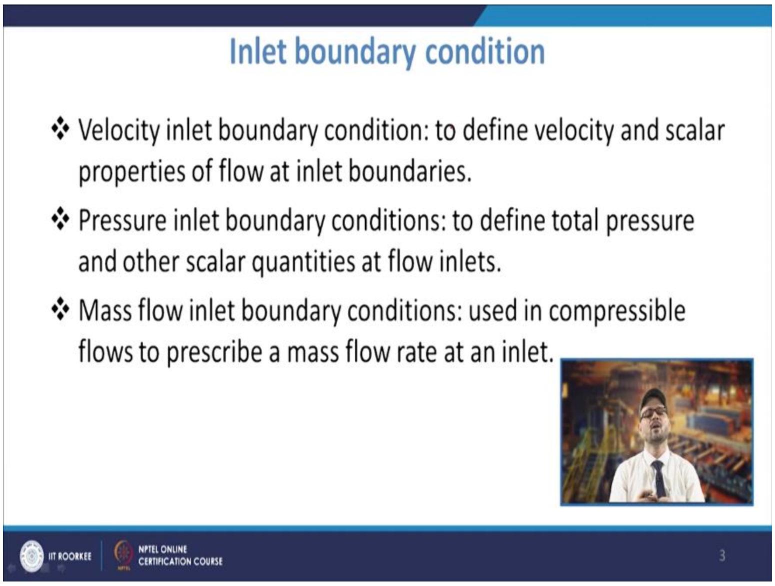

Now, the most important is the or every each one of these are important. So, first we will start with the inlet boundary condition. So, inlet is that place through which the medium you know of flow that will be moving and it will be going into the domain. So, there you need to have the condition. Now, in that you may have to specify a velocity and then you have a scalar properties of flow and the inlet boundaries.

So, you can have velocity you can have the definition of temperature or so. So that is known as the velocity inlet us when you are specifying these velocity then it is known as the velocity inlet condition mostly in case of the in normal case we use these velocity boundary condition especially in the case of incompressible flow where the density is remains constant and throughout it does not vary. So, in that case you know you go for using these velocity inlet boundary conditions. This is not going to be suitable in the case of compressible flows.

So, in compressible flows we normally go for the mass flow inlet boundary conditions. You know because they are the density will be changing. So, that is why you go for the mass flow inlet boundary condition. So, you specify the mass flow you know at the inlet. You have also you know pressure inlet pours. So, sometimes your pressure distribution is known you know the pressure are the inlet us. So, in that case you are total pressure and other scalar quantities you know at the flow inlet is defined.

So, that is known as the pressure inlet boundary condition. So, these are the 3 types of you know inlet you know boundary conditions. When you go to define the inlet boundary condition now when you are dealing with the you know turbulent flow in that case you may have to go for you know defining. So, while discussing the turbulent parameters that there we will also discuss that you will have to give the turbulence parameters also defined at the inlet especially you try to define the intensity many a times and hydraulic dia you know that is also demanded you know required to be specified.

So, you we you go for turbulence intensity many a times and that will be depending upon the you know. These are the assumptions basically so that is taken are at the inlet. So, these are you know the inlet boundary condition. Similarly, if you have the exit boundary condition or outflow boundary condition.

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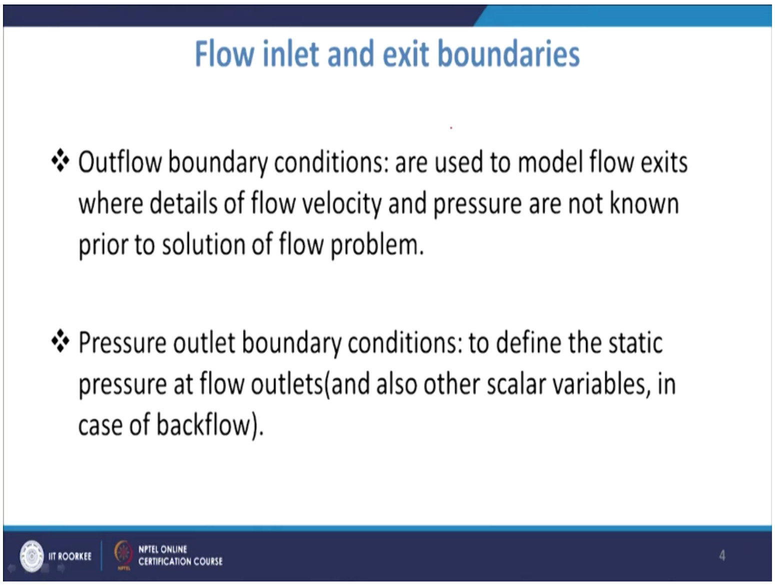

So, the outflow boundary conditions are used to model the flow exits for details of flow velocity and pressure are not known prior to the solution of flow problems. So, basically in normal case when you are defining the inlet velocity you do not know what will be the velocity at the pressure. So, you give the outflow boundary condition and this is the normally by default boundary condition given. So, it will you know take that depending upon the conservation rules.

It will set the you know velocity or the required things at the outlet. So, that is normally the outlet boundary condition. And, apart from that we can know we also should know that there is a on the outlet you have some sometimes the pressure outlet boundary condition which will be defining the static pressure at the flow outlets. So, these are the you know 2 kinds of you know conditions boundary conditions which are applied at the you know outlet.

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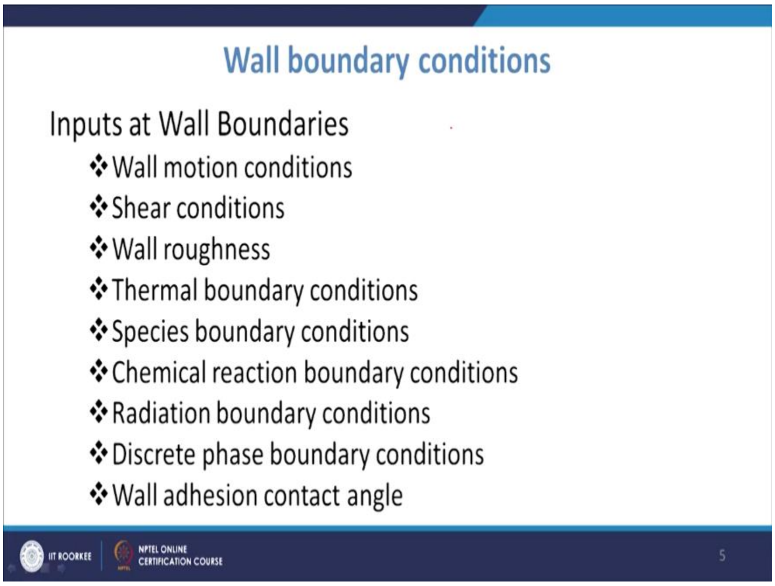

Now you come to the you know wall boundary conditions. So, you have while we talk about the wall boundaries you need to provide you know many kind of conditions, many kind of parameters. And among them you have something like wall motion conditions there may be wall moving. So, you may specify the movement on the wall. There may be shear conditions you may have to provide the wall shear value.

Wall roughness can be provided you may have the thermal boundary conditions at the walls. So, what is the you know heat flux through the wall or whether you are the providing a specific temperature at the wall. So, there will be temperature boundary condition at the wall. So, that way specification will be there then you have species you know boundary conditions also. There you have the chemical reaction boundary conditions, radiation boundary conditions.

So, you have the discrete phase boundary condition and you have the wall adhesion contact angle. So, these are the different kinds of boundary conditions for different cases use. Like in chemical reaction you can have this condition like what is the that condition at the wall also. So, whether the reaction is taking at the wall or you know for the radiation boundary conditions what will be the radiation you know for that wall properties need to be you know set. So, what will be the radiation values.

So, how it will be computed, that you need to specify. Then the discrete phase boundary condition many a times we discuss for the discrete phase particles. So, we talk about the you know behavior of the discrete particle which is there. And, we use many a times the Lagrangian type of a method for that and in that also you give define a condition on the wall that when this particle will be hitting the walls what cut type of conditions should be given that the wall may absorb these particles, the absorbed particle may stick to the wall or the middle be rebounding or reflecting you know.

So, that needs to be specified you know on the wall. So, this is regarding the for the discrete 2 phase kind of studies there you need to provide these conditions wall adhesion contact angles. So, this is also one of the parameter which needs to be looked into. So, this is. So, what do you see that you have the different type of you know wall boundary conditions. And you need to know that what way because suppose if you talk about the you know flow. So, in that case you may have the no slip boundary condition.

So, which is mostly used; so, no slip means you know the layer the wall is you know having no movement the wall and also the fluid layer which will be attached to that it also does not have the movement. So, that way you apply these you know no slip type of condition. So, we will talk about the different types of the these wall boundary conditions. So, you go further we go further. So, if you talk about the wall motion condition you will have it is a study wall you may have a moving wall.

So, on the moving wall also you have elastic conditions for the moving walls you may have that the translational wall motion, rotational wall motion or wall motion based on the velocity components then if you talk about the shear conditions. So, in that you may have the you know no slip condition.

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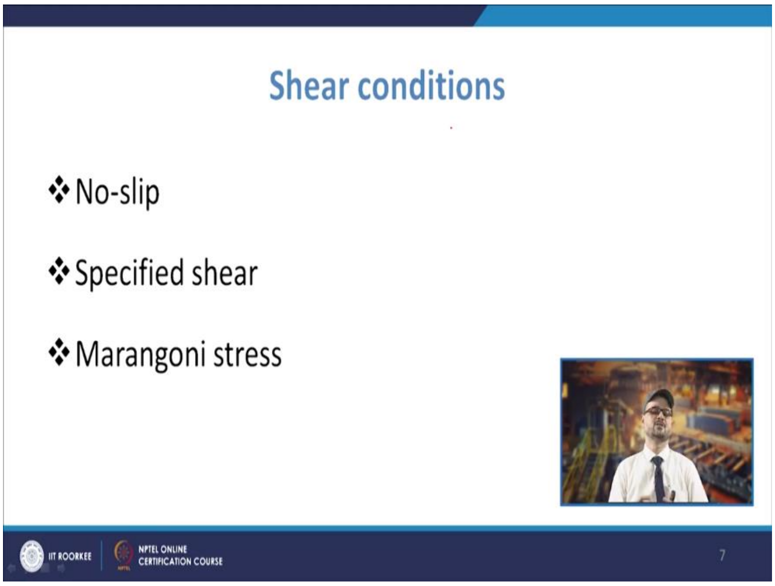

You may have the specified shear and you may have the Marangonis stress that is that stress also. So, that shear you know that condition is also there. So, basically you know if you talk about these you know. So, in the case of you know these the specified shear you defined a certain value of the shear you know that is given. And, in the case of these Marangoni you know stress you may hear you know this is this will allow you to specify the gradient of the surface tension with respect to the temperature at the surface.

So, there this Marangoni type of stress condition or that condition will be there. So, you will be getting that shear stress calculation you know because of these you know gradient of temperature on this surface. So, whether is for a specified surface tension; so, that way it is the this shear you know conditions are used. You have also the wall roughness conditions. So, before that we should know about the roughness parameters also are given.

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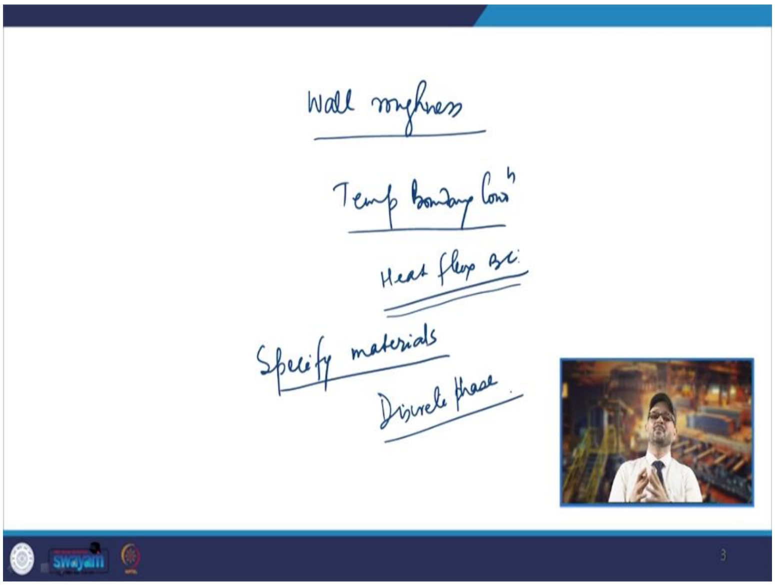

So, you may be you know encountering these terms like wall roughness. So, you know if the roughness is nil then you have the no slip. It is just a plain type of condition, but there may be you know the roughness also provided on the wall. So, that so this roughness will be there. Then you have the temperature boundary conditions as we where discussing. So, you will have the thermal boundary conditions.

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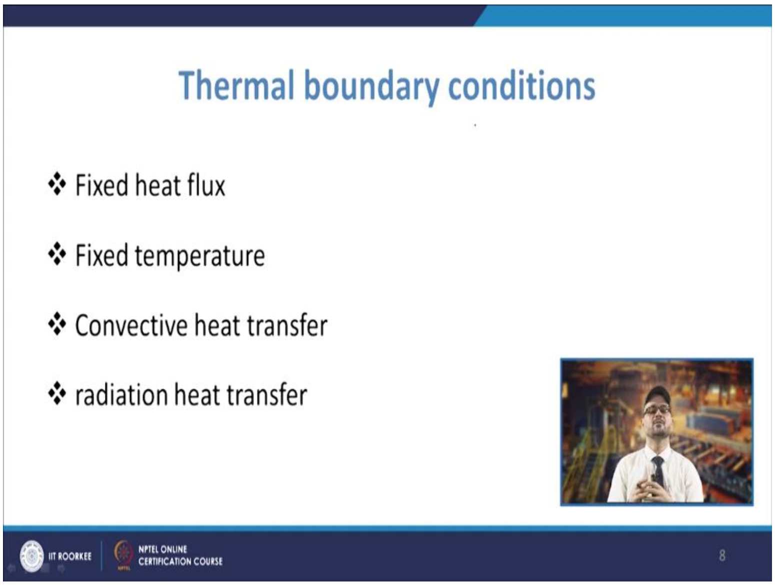

Now, the thermal boundary conditions are important because while dealing with these thermal boundary conditions you need to know that what should be the condition proper condition you should be selected. Like you may go for the fixed temperature kind of condition where, you say that the walls are at a fixed temperature and accordingly because the fluid is there inside the domain and the walls are at a fixed temperature.

So, the heat transfer will take place and since the temperature of the fluid is generally higher than the wall and walls are normally at room temperature or at some specified temperature. So, there will be you know heat transfer taking place you know through the walls and that is to be computed. So, when you have the temperature boundary conditions provided. So, in the case of you know temperature boundary condition which is there. So, in those cases you know you can find the heat transfer and that can be found you know when there is a temperature is fixed at the wall.

So, you can have the use of the heat transfer coefficient. You know that is local heat transfer coefficient will be there on the inner side and based on the you know temperature difference between the wall and the in the fluid which is adjacent to so at that node which is adjacent to the wall inside the you know domain. So, that is being taken out. So, you will be finding that that by multiplying with this you know local heat transfer coefficient and then also if there is any radiation type of heat transfers that can be added. So, what you need to tell you need to tell the proper temperature you know at the boundary or at the wall.

So, that you know the heat transfer value can be calculated. Similarly you may have you have the heat flux you know condition. So, then apart from the temperature boundary condition where you define a temperature at the wall you have the heat flux boundary condition. So, you know this boundary condition in that you are providing it a constant value of heat flux you try to say and from that heat flux which you provide and the solver will try or the model will try to find the temperature and you know.

So, normally you provide these you know heat flux boundary condition and it will depending upon that heat flux. So, dividing it again by the heat transfer coefficient and then and taking into account the that the temperatures you find the value of the you know temperature you know using these heat flux boundary conditions. So, you have this way different type of you know these typically you have heat flux boundary condition or you have the you know the temperature boundary condition. Then you have the convective heat transfer then radiative heat transfer you have the conduction heat transfer. All these you know depending upon the you know formula these things can be applied and you can get you know the you know you can put these boundary conditions into the model.

Now, apart from that and the next type of boundary condition is the symmetry boundary conditions. So, you need to specify as we discussed that you specify the symmetry boundary conditions in the in the domain and that basically decreases the size of the domain. So, that increases the computational you know efficiency that will decrease the computational you know time and so proper you know symmetric boundary conditions needs to be applied and also the periodic boundary condition and that may be for the translational or the you know rotational type.

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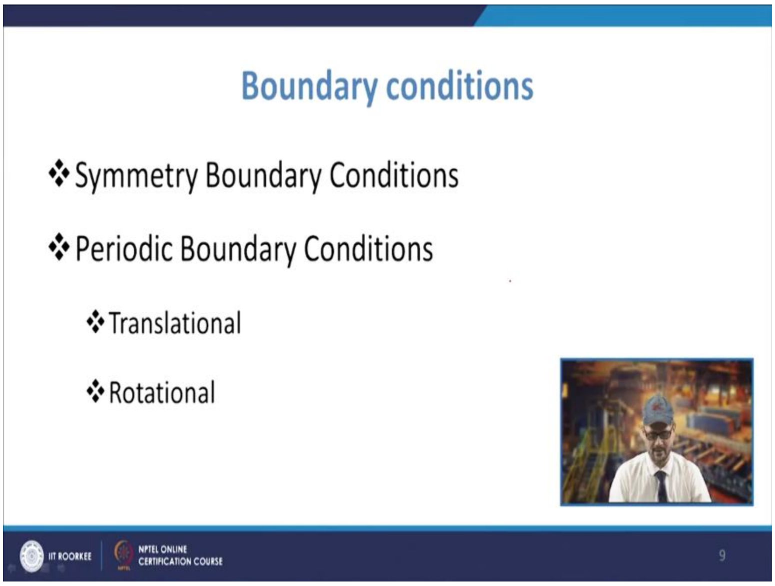

Then you know after that you have you know. So, once you have put these boundary conditions then you need to go for ensuring that what is the, what are the other things you need to know. Like you have to specify the material properties; so in fact, the material properties are specified before we apply the boundary conditions in many kind of models or CFD tools. So, you need to specify you know the material properties. Now as we discussed that when you talk about these boundary conditions so they are also they will also be dependent you must have the proper knowledge about the type of flows which you are dealing with.

So, accordingly the boundary conditions will be varying like for laminar boundary conditions you will have the different conditions and for turbulent boundary conditions you will have the different boundary conditions and all that. So, accordingly you have to see that what kind of boundary conditions you need to apply. So, we further so what we talked is that one of the part of the this you know pre processing is that when you specify the properties especially the material properties. So, when you specify you know the material properties you have materials may be like you have fluid solid or porous.

So, for materials normally you will have its physical properties like density, temperatures you know thermal conductivity, heat capacity you know you know temperature. So, you may have this density or several conductivity or you know the heat capacity. So, this needs to be specified. Now, the issue is that they can be having a constant value or they may be depending upon the temperature. So, you need to specify you know. So, most of the tools have this provision to have you know these properties defined in terms of so that will be varying in terms of temperature. So, they will be temperature varying.

So, what happens is that you know they will be in some form may be there is polynomial relationship is there, for the material property with temperature or they may be you know different you know type of forms. So, that needs to be specified while taking the properties of the material you know. Then that will apply to all the different types of you know properties which is there. Then next thing is which will be is that you must know that what kind of you know you know solution you are heading towards because there is not always only the solution for the heat transfer and fluid flow.

Normally you go for the you know the reaction or the other parameters like the parameters related to the mixing of the fluid you know and it is behavior inside the fluid or you may have to have the conditions related to the discrete phase. So, you will have the species transport you know models. So, you will have to take into account that part. Then you will have the especially the discrete phase type of model will be there.

So, in that you have the a Eulerian Lagrangian type of Lagrangian type of model is normally adopted where for the fluid you have the Eulerian you know you know concept where you get you solve the almost all the equations. You know get the velocity field and all the temperature field everywhere and then you are solving for the discrete phase. So, that will be interacting that will be interacting on the basis of mass I mean the momentum and the heat transfer interaction will be there you know and accordingly you will have the behavior of these particles.

So, especially they are used you know in the case of tundish when we deal with the inclusion you know behavior. So, in those cases these type of models are used and in those cases you have the boundary conditions. Like you have to specify the diameter of these you know particles and their numbers and their densities you know all these things need to be specified as the boundary condition. So, because what happens that when and this is based on the concept that these particles when they are in the in the existing flow field so they will be subjected to certain forces.

So, there will be force balance equation. So, basically it has its own weight and it is subjected to certain forces and also depending upon the flow you know conditions which are available. So, that force balance is done then accordingly you will have acceleration and also velocity of these. So, they will be moving you know in that domain accordingly and they will be floating or they may be going to the walls where on the wall as we had discussed that you will have the condition at the wall like it may be sticking or it may be reflecting there.

So, that so these you know these conditions are need to be specified you know. So, these are also the conditions a boundary conditions will be there for these particles which are required you know to be provided in the case of discrete you know phase. So, discrete you know phase in those cases. Apart from that we will also discuss in the case of a tundish flow one thing is also common is the multi field analysis. So, what happens that you have the presence of the different phases like you may have the gas solid interacting or gas liquid interacting or liquid solid interacting.

So, especially when you talk about the tundish in that case you have the liquid steel in the tundish and then you have slag they are at the top. So, you can do the two phase or multi phase type of analysis and there are different methods for that. So, there also you will have those analysis and there we need to know that how this analysis used to be done and what are the conditions which needs to be given at the interface and how they are computed. Because they are you know especially when we do the free surface analysis or the surface fluctuation or the interaction of the one phase with the other at the interface.

So, these you know there also you need to provide the conditions you know in the case of these multi phase analysis and that you know that. So, appropriate boundary conditions need to be provided in those cases also. So, when we will discuss about that kind of you know analysis there we will study that how the appropriate boundary conditions are provided and you know accordingly you get the proper you know output values.

So in fact, you know we talked about all these kind of possibilities of those models which we need to study and there are boundary conditions which need to be applied you know in the tundish in such cases. So, we will talk about it in our coming lectures.

Thank you very much.