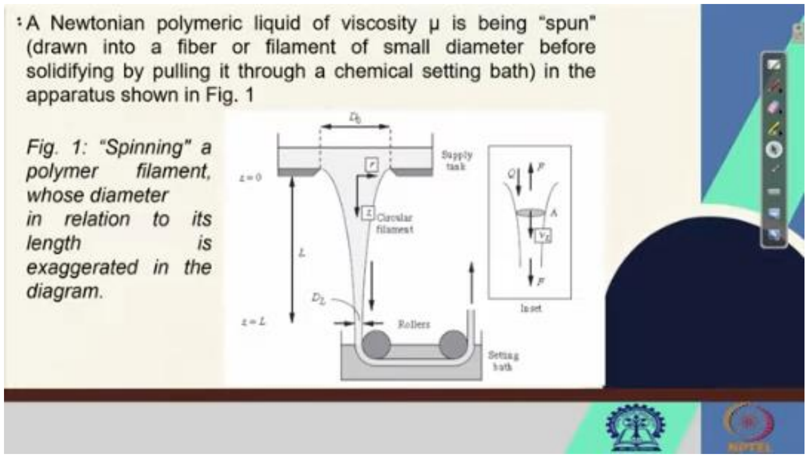
IMPACT OF FLOW OF FLUIDS IN FOOD PROCESSING AND PRESERVATION

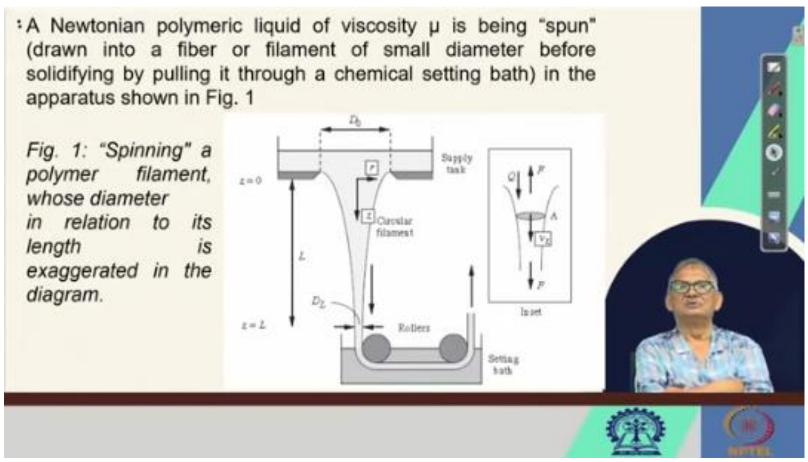
Lecture31

LECTURE 31 : PROBLEMS AND SOLUTIONS ON SPINNING

Good evening, my dear students and friends. We are handling with moving systems, normally not done, right? Yeah, it is becoming a little definitely harder, but I do not want to restrict only to that which is said by most of us. So, again like a spinning, spinning a polymeric fiber that I would like to address.

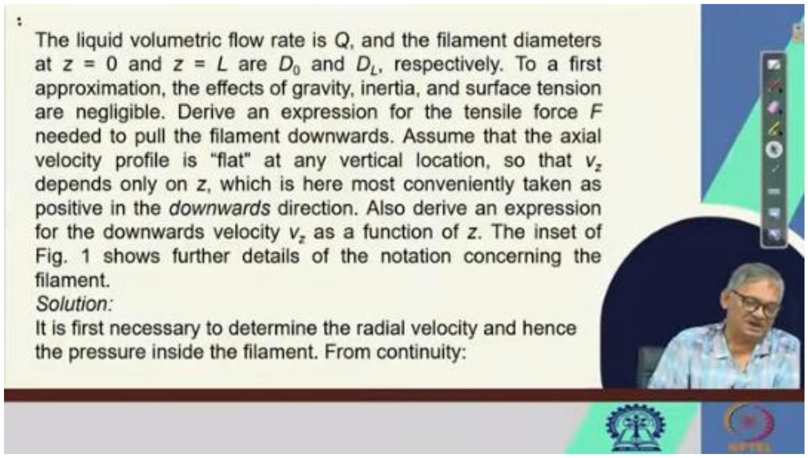
So, if we look at, you see Here we are assuming that again Newtonian polymeric liquid. I tell you we are not handling with non-Newtonian because non-Newtonian part will be taken care of by my co or teacher right who is Konishka Bhuya, he will take the non-linear I mean non-Newtonian part right. So, here we say Newtonian polymeric liquid of viscosity mu is being spun





that is drawn into a fiber of filament of small diameter before solidifying by pulling it through chemical setting, but in the apparatus as it is shown ok. Now, as it is shown means this is the figure. it says that spinning a polymer filament whose diameter in relation to its length is exaggerated in the diagram right like this ok. So, here you see that is supply tank that has a diameter height is L at z is equal to 0, it starts and at z is equal to L it ends with the height L. There is a circular filament, there are rollers by which it is being drawn.

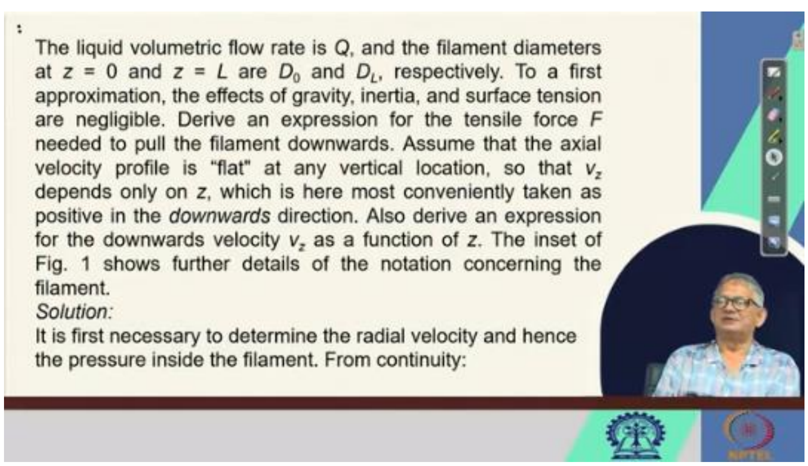
It has a supply tank, and it looks like this is the setting bath, and it looks like this, OK. Q is flowing like this, and F is going out like that, OK. Now, the liquid volume flow rate is Q. And the filament diameters at z equal to 0 and z equal to L are shown as D_O and D_L or D_0 and D_L, respectively. To a first approximation, the effects of gravity, inertia, and surface tension are negligible.



So, derive an expression for the tensile force F needed to pull the filament downward. Assume that the axial velocity profile is flat at any vertical location. So that v_z depends only on z, which is here most conveniently taken as positive in the downward direction. Also, derive an expression for the downward direction for flow. Also, derive an expression for the downward velocity v_z as a function of z, right?

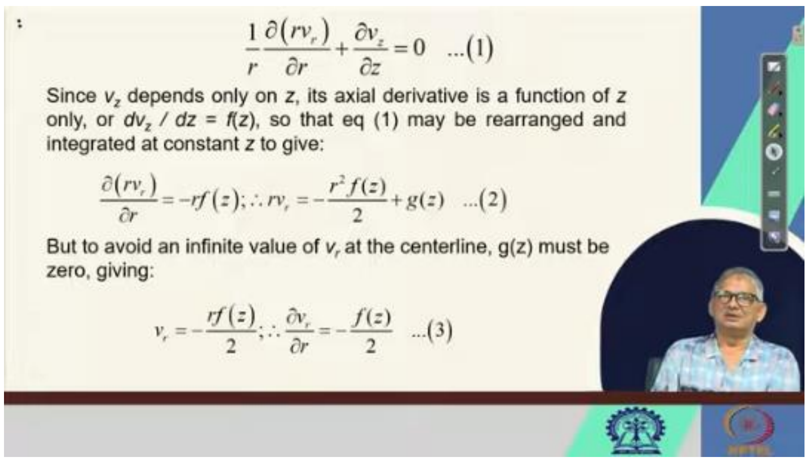
The inset of the figure, which we have already shown earlier, is this one, right? The inset of the figure shows further details of the notation concerning the filament. Right. Again, a new problem, obviously, a solution will also be very interesting.

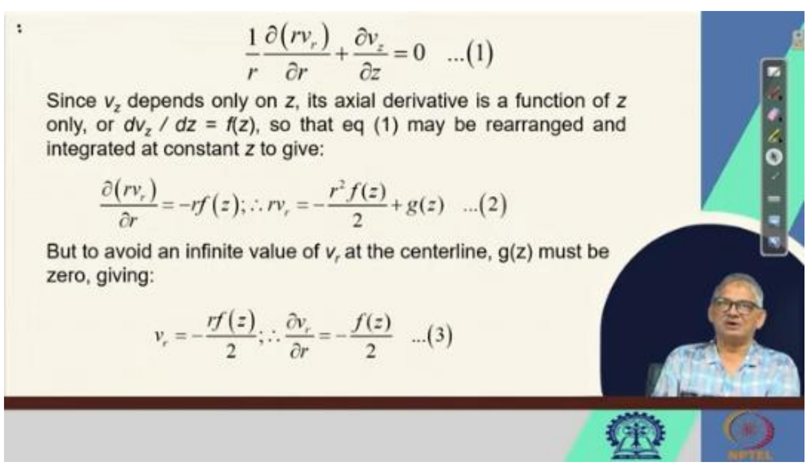
So, let us see the problem again. The problem says the liquid volume flow rate is Q, and the filament diameters at z equals 0 and z equals L. R, D_O and D_L respectively. To a first approximation, the effects of gravity, inertia, and surface tension are negligible. So, derive an expression for the tensile force F needed to pull the filament downwards.



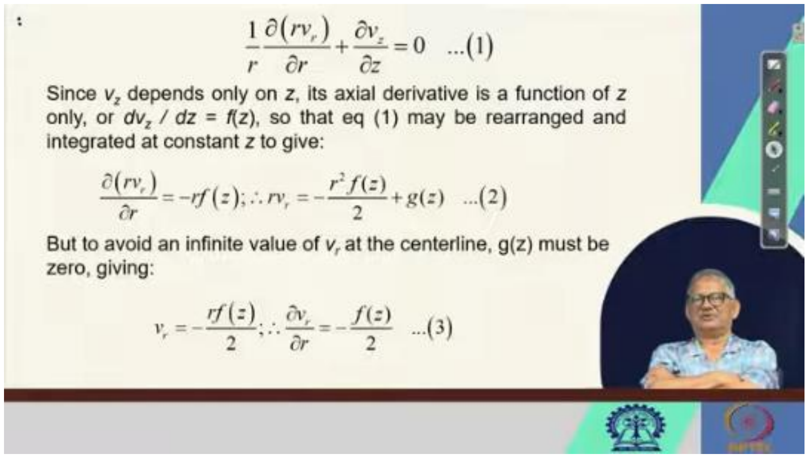
Assume that the axial velocity profile is flat at any vertical location, so that v_z depends only on z, which is here most conveniently taken as positive in the downwards direction. Also derive an expression for the downward velocity v_z as a function of z. The insert of this figure, that is what we have shown, tells further details of the notation concerning the filament which we have already discussed. Now it is first necessary to determine the radial velocity and hence the pressure inside the filament.

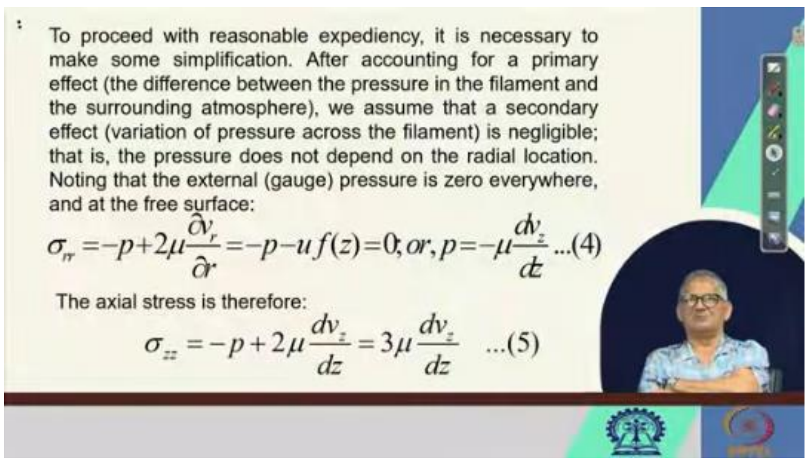
Then from the continuity equation, we can write 1 by r. del del r of r v_r plus del v_z / del z is equal to 0. Since v_z depends only on z, its axial derivative is a function of z only. or d v_z / dz is a function of z. So, that we can write this equation one may be rearranged and integrated at constant z to give del del r of r v_r is equal to minus r which has a function of z. Therefore, r v_r is equal to minus r square by 2 function of z plus g_z. But to avoid an infinite value of v_r,





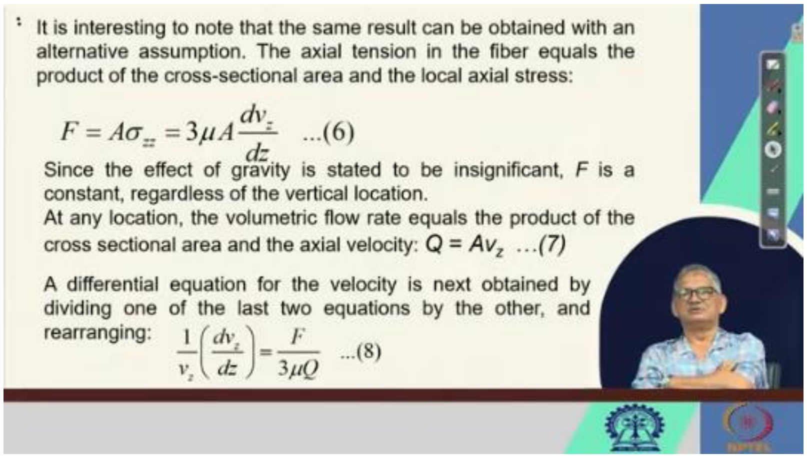
At the center line, g_z must be 0, giving v_r is equal to r function of z over 2 minus, of course, minus r function of z over 2 and therefore, del v_r / del r is equal to a function minus function of z over 2 and we name it as equation number 3. To proceed with reasonable approximation or reasonable expediency, it is necessary to make some implication. Some simplification is required. After accounting for a primary effect, That is the difference between the pressure in the filament and the surrounding atmosphere.





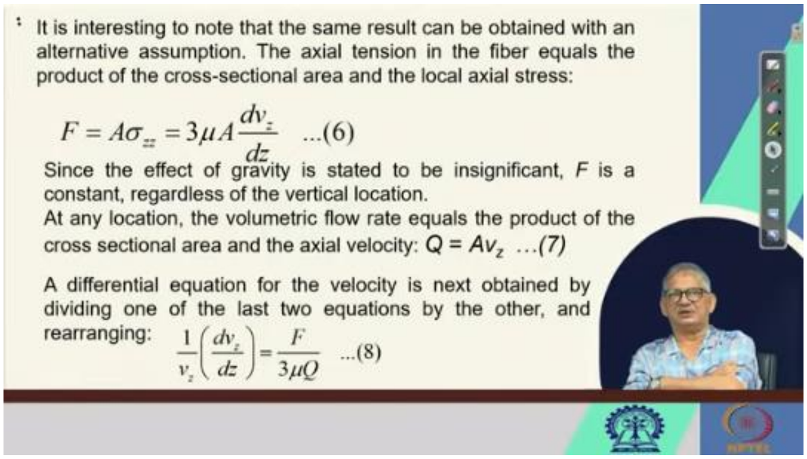
We assume that a secondary effect that is the variation of pressure across the filament is negligible. That is, the pressure does not depend on the radial location. So, we can note that The external that is gauge pressure is 0 everywhere. And at the free surface, we can write sigmarr is equal to minus P plus 2 mu del v_r / del r.

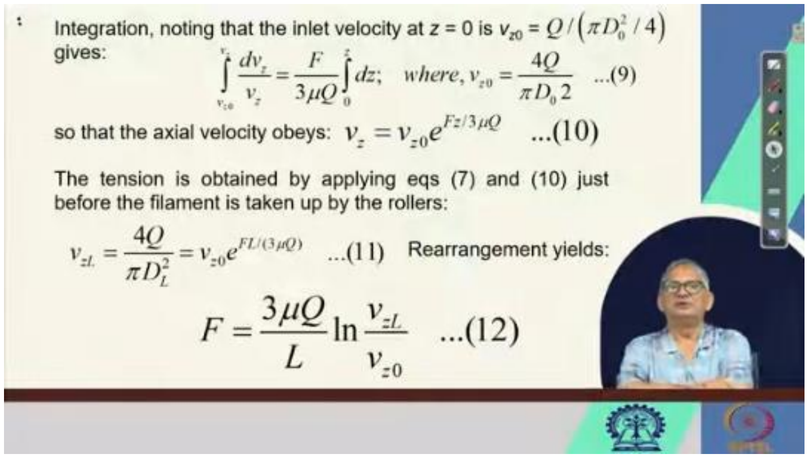
And this is equal to minus p minus u as a function of z which is equal to 0 or p can be written as minus mu d v_z / dz which we give a name of equation 4. The axial stress is therefore, $sigma_{zz}$ equal to minus p plus 2 mu d v_z / dz, that is, 3 mu d v_z / dz. This we term as equation number 5. So, it is interesting to note that the same result can be obtained with an alternative assumption.



What is that? The axial tension in the fiber equals the product of the cross-section area and the local axial stress. So, F is equal to A into sigma$_z$, z is equal to 3 mu A into d v_z / dz, which we can give equation number 6. Since the effect of gravity is stated to be significant, F is a constant.

Regardless of the vertical location, at any location, the volumetric flow rate equals the product of the cross-sectional area and the axial velocity Q is equal to A v_z. A differential equation for velocity is next obtained by dividing one of the last two equations by the other and rearranging it as 1 by v_z d v_z / d z equals F by 3 mu Q right. So, integrating this and noting that the inlet velocity at z equals to 0 is v_z 0 equals to Q over pi d square by 4. or pi D_o square or D_0 square by 4.

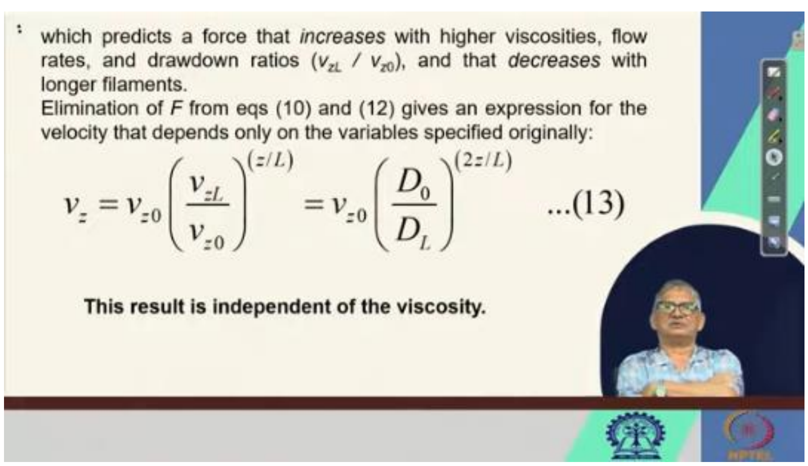




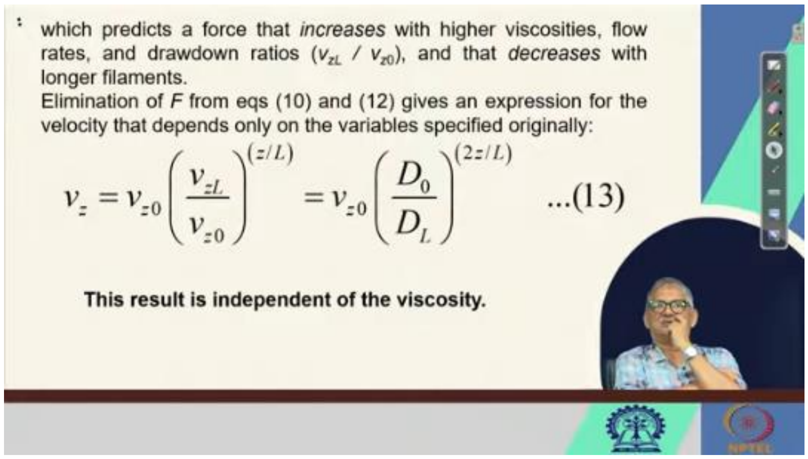
And this gives integration of d v_z v_z over v_z equals 0 to v_z equals to capital F by 3 mu Q d z over 0 to z where v_{z0} equals to 4 cube by pi D_o square, Now, pi D_o into 2 not square. So, the axial velocity obeys v_z equals to v_{z0} e to the power F_z over 3 mu Q. It will give a name of equation number 10.

The tension is obtained by applying equation number 7 and equation number 10 just before the filament is taken up by the rollers. So, v_{zL} equals 4Q by pi D_L square, which is equal to v_{z0} multiplied by e to the power F_L by 3 mu Q. Let us name it as equation number 11. So, arranging it gives F equals 3 mu Q by L multiplied by ln of v_{zL} over v_{z0}.

So, let us assign it as equation number 12. So, this predicts a force that increases with higher viscosities, flow rates, and drawdown ratios. So, we can write v_{zL} over v_{z0}, and that decreases with longer filaments. Now, the elimination of F from equation number 10 and 12 gives an expression for the velocity that depends only on the variables specified originally as

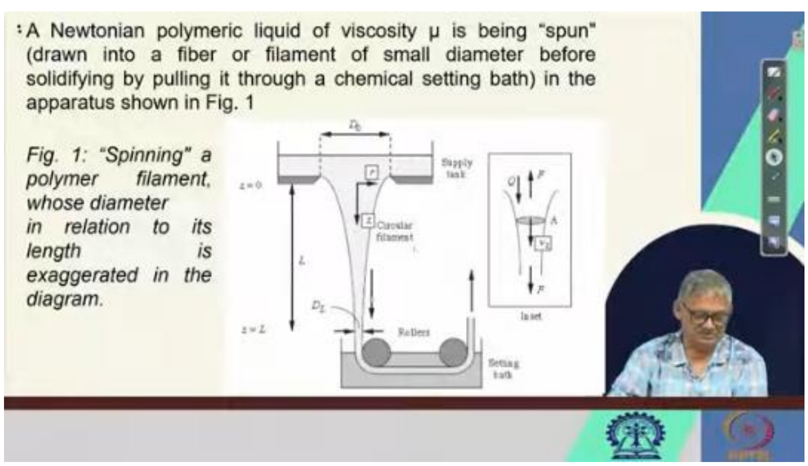


v_z equals v_{z0} multiplied by v_{zL} over v_{z0} to the power z by L, which is equal to v_{z0} times D_0 over D_L to the power 2z by L. So, let us name it as equation number 13. So, this result is independent of the viscosity, right? So, with this, we come very close to the end of the class, but We would like to highlight one more thing here: while spinning is being done in this way, the same may not be true for many other things.

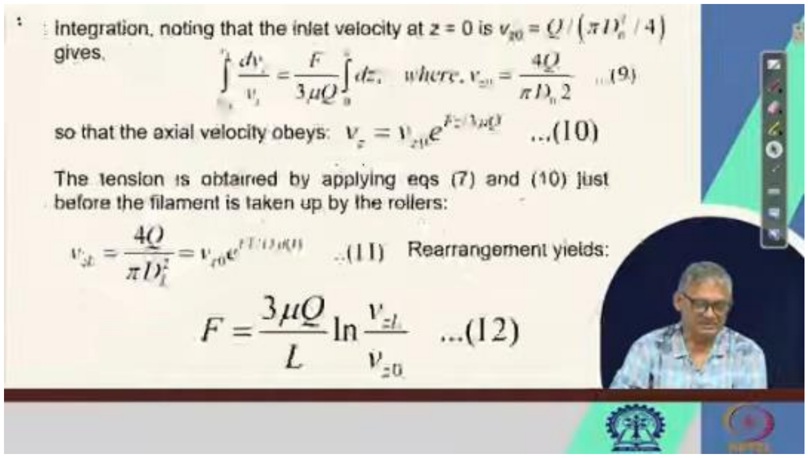


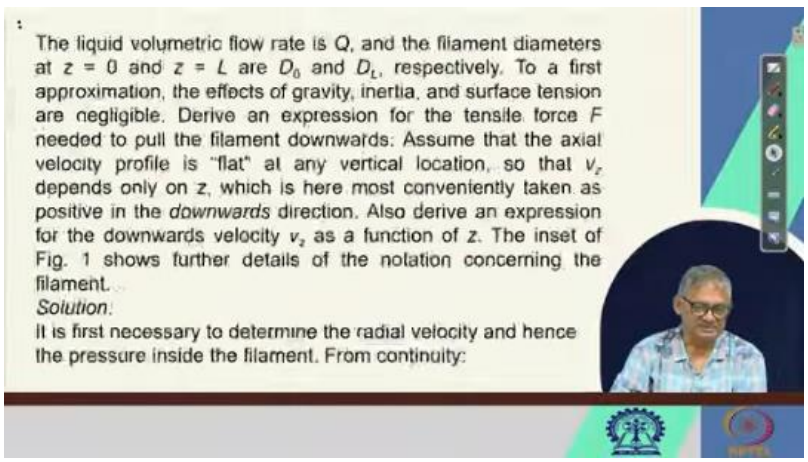
The equations which we have developed, that is v_z or v_{z0}, these are specified variables. This v_z is like we said v_{z0}, v_{zL} to v_{z0}. I hope we remembered the original pictorial view. The original pictorial view was, we gave, The original pictorial view was, we gave a pictorial view, where the top was z is 0 and the bottom was z is L, right.

So, if we look at that here, z is 0, and this was the supply tank; it is z is 0 and z is L. Right. Similarly, D_L, D_O, these things also we identified, and the quantum of flow Q and the force F which are applied. Of course, there are in set we can see that. It is both ways the force is acting.



Here, that is why the next we have arrived at this. Where is that? Oh, before this. Right? So, we have arrived earlier that there is a back flow and a forward flow.





So, those things are also taken care of. So, we see that we have come again to this spinning as a new technique for chemical setting or some other. Right, but in the food industry, its use is not that effective as of now, okay. So, we thank you all for your careful listening.

So, we thank you again.

Thank you.