BioMEMS and Microfluidics
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Lecture - 41
Review Lecture of 26, 27 and 28

Hello and welcome to this review lecture on lectures 26 to 28 of the course NPTEL course BioMEMS and Micro Fluidics. So, here we actually start looking at the continuum mechanic parts of the fluid mechanics by first investigating this different representational way of means like time lines, path lines, street lines and stream lines.

So, as we already have discussed if the number of fluid particles in a flow are marked at a given instance of time, and they formulate a line in the fluid at that particular instance and with time, there is a shift in that particular line, so the line formulated by such examples of sub particles with respect to time is known as the time line.

In the similar manner, we talked about path lines which is a path of trajectories traced out by a moving fluid particle on the fluid streak lines which is basically you identify a space or a location inside the fluid, and let all the particles travel. Then, the particles which have travelled from that particular point, you try to create an array and that formulates these streak lines and then finally, the stream lines which are major, you know majorly used and representational tool in identifying a lot of fluid behaviour and these are lines drawn in the flow field, so that at the given instance, they are tangent to the direction of flow at every point in the flow field.

In respect to that, we learnt how to independently compute all these time lines, path lines, streak lines and stream lines by looking at a problem, example and after clarification of that, we again categorise them into steady state and unsteady flows. We really found out that all these steady flow processes would have all the path lines, stream lines and streak lines to be identical whereas, only when we talk about unsteady flows, there is the difference between all these different representations of flow fields. We also talked about different, you know flow fields like stress field for example, where you know you are talking about surface stresses and body stresses. We also discussed how gravitational force acting on a fluid element would formulate a body force whereas, forces on an element of a fluid which is actually either parallel to an area or perpendicular to an area would compute or would result in something called normal stress and shear stress, ok.

So, we had a limiting approximation, where we defined with respect to an area vector how the force vector would be manipulated to be considered to as a shear stress field or a normal stress field. Then, we talked about what happens in a rectangular co-ordinate system. So, you would have in a particular coordinate system, three different planes, principle planes and all these principle planes, each of them would have one normal stress, ok.

In the positive n1, in the negative direction of course, and another pair of at least two shear stresses which would be related in a way through the force direction and the area vector direction. So, therefore, we categorise in a very nice manner. What would happen to let say a cuboidal, a small cuboidal element or a cubical element within in the fluid in terms of all these principle and shear stresses in that particular thing. Then, we represented the matrix of stresses, the stress matrix in such a domain of the fluid flow.

We discussed about viscosity at length, where we were looking at how the velocity change in the y direction in a circumstance, where there is a fixed plate boundary and a moving plate boundary would create a shear stress which can be proportional to the rate of change of velocity with respect to y direction, and we derived a formulation where in we finally arrived at the famous Newton's law, where the shear stress would be proportional to du/dy. This would be equal to a constant mu with respect to you know fluids which are also known as Newtonian fluids. However, if mu would vary, there would be different aspects associated with the flow behaviour and we would categorise them into the non-Newtonian fluid modes.

So, in one case we took the shear stress $\tau_{yx}=k\left(\frac{du}{dy}\right)^{n-1}\frac{du}{dy}$ to, and that varied the index n in a manner, so that in one case, it would be pseudo plastics where particularly n would be less than 1 and in another case, it would be a dilatant when it is greater than 1. Then finally, Bingham plastic where this τ_{xy} could be represented as a constant stress plus a variable stress with time, ok. So, in this consideration, we actually plotted this shear stress versus deformation rate in all the cases, particularly the pseudo plastic case, the dilettante case, the Newtonian case and then the Bingham plastic case, and also considered some fluids where there is a decrease in the n value, the index value with respect to time under shear stress and those classes of fluid were categorized as the traffic fluids. So, in a way these different behaviours of fluids flows with respect to the shear stress as opposed to the rate of change of velocity was in detailed manner looked into in this particular lecture.

We then started with trying to derive the Navier stokes equation by looking at a small cubical element again within the flow and then, we considered the Newton's laws of motion, where the acceleration because of rotation as well as linear translation would be coupled into one domain and then finally, derived the very famous Navier stokes equations-The conservation of momentum equation. That process we also looked at the conservation of mass by looking at again a small volume element and seeing how the fluid flow across that volume element would necessitate that there is no creation of mass as such within that volume.

So, these two equations we derived in details and then, also represented them in an indexed manner across this particular lecture, and we just started working on how to scale down those equations in these lectures 26 to 28.