Continuum Mechanics And Transport Phenomena
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Lecture – 13
Visualization of Flow Patterns: Streakline

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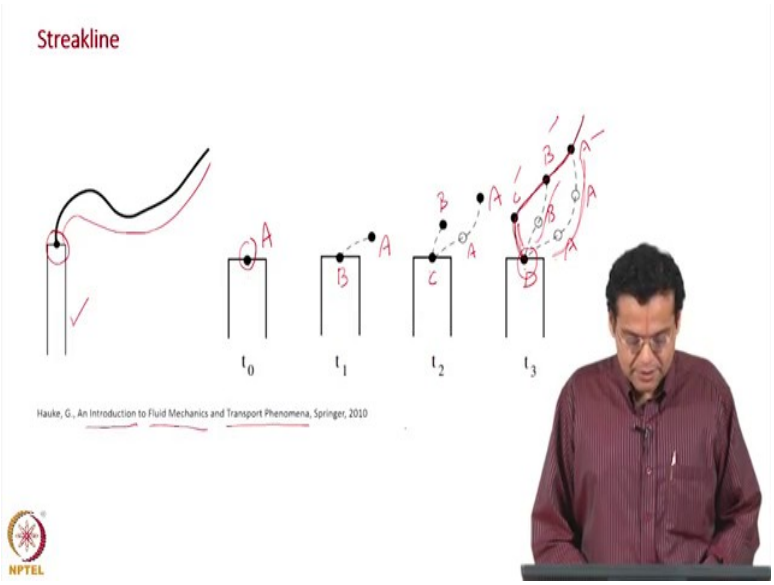

So let us move on to streakline. So, a very excellent representation of streakline, thanks to the book by Hauke G, in fact, the title of the book and the title of this course are almost same. It is introductory course; the book title is introduction. Of course, restrict to fluid mechanics, we are going to discuss both fluid and solid mechanics analogously. It also has a transfer phenomena component in it. So, in that way it is very good representation the title of the book and the title of course go hand in hand. Thanks to the author for this representation which gives a very clear picture of streakline.

The way in which I start as of course, indicating that streaklines are slightly difficult compared to streamlines and path lines. So, let us discuss that. What is shown in the figure is something like a chimney and then smoke coming out of it. Smoke coming out of chimneys is an example for a streakline, or if you have a region inject dye and then that is also example for a streakline. What is shown in the figure is a particle, let us call particle A, in this particle and this is our point of focus. And the particle A is at initial position at time t_0. At the next

time t_1, the particle has moved to next position which was at the initial location has moved, and then another particle B enters at the same location.

Now, sometime later the particle A was moved to some other location of course, initially it was at initial position, now it has come to the another location. Now, particle B it was at initial position, it has now come to same location of particle A and another particle C is just entering the same initial location. Now, sometime later another particle D is at the initial position. Particle C which was just entered in the previous time instant is now at the location of B and D is just entering. So, now, this particle A has taken one path, B has taken second path, C has taken third path, all depend on the fluid flow happening in that location. I keep repeating this point because we said visualization of flow patterns. So, when we draw a line that should represent the velocity field.

Now, all the paths followed by different particles are path lines because it is for a particular fluid particle. All those are path lines, because we said path line is a path travels by a fluid particle, path line for A, path line for B, path line for C.

Now, what is the streakline? Connect all these end points of the path lines, you will get a streakline. So, the curve is the streakline which is the end point of all the path lines. Other way of putting it is, it tells you the locus of all fluid particles at a particular time, it is a particular time, but it has a time history associated with that, and all these particles have passed through the particular point or initial position. So, it is a very good representation with which you can physically understand streaklines very clearly. Remember when we measure experimentally by injecting a dye or smoke like this, we are measuring streakline only.

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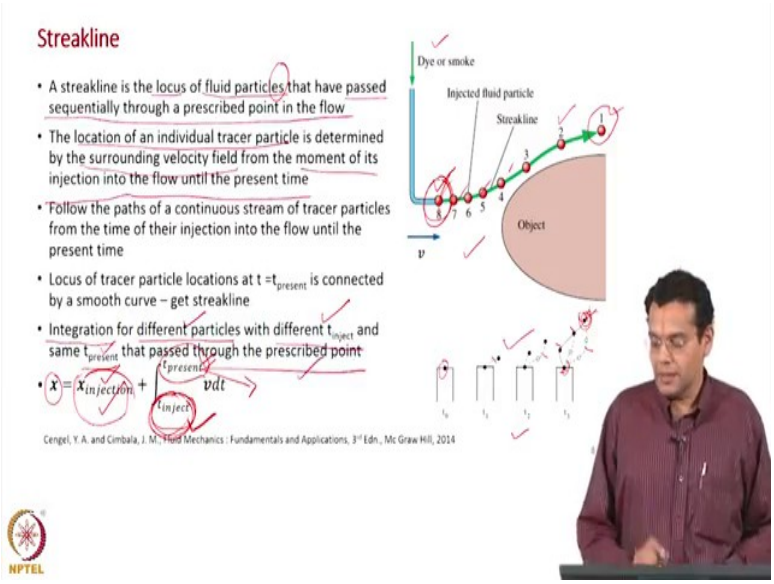

So, let us move on to how to describe in terms of words and in terms of equations. The picture in the above slide image shown is a usual representation for streakline that is my appreciation for this representation of streakline. Clearly it tells what a streakline is, this is also tells very colorfully about a streakline, a better representation of a streakline. What is shown here is as I told you dye or a smoke is injected at a particular point; this point which entered here which was here at the times you are interested corresponds to this particle 1.

So, likewise this particle 1 was at the initial position sometime earlier, now it is moved; particle 2 was at that location, now it is also moved. Likewise particle 8 is just entering. Our particle 8 and this particle are analogous each other. There I took four particles, yes of course, here we have shown for 8 particles.

Now, let us define streakline, a streakline is a locus of fluid particles that have passed sequentially through a prescribed point in the flow. Streakline is a locus, why is it locus, moment we say locus something should be constant. In this particular case, what is constant this point of injection is a constant.

What is common to all this fluid particle, every fluid particle has passed through this point sometime earlier compare to the present time. You wants streakline at a particular time, these particles have passed through this point at some time earlier that's why it says locus. As I told you earlier path line is for one fluid particle; now streaklines are connecting endpoints of several fluid particles, that is why locus of fluid particles that have passed sequentially

through a prescribed point at the flow. What is the prescribed point, in this case wherever injecting the dye.

So, why is that streakline is important what actually measure is a streakline, you will shortly see that for steady state case streaklines also coincide with path line and stream lines. So, it is equivalent to measuring streamline. We may say that we have injecting a dye, I measure a streakline, but you are not messaging directly a streamline. So, in a steady state case because the flow is steady and all these coincide with each other, and you are measuring a streakline actually because the flow is steady so happened that the streakline becomes equivalent to the stream line. So, we can little more casually you can say I measured stream line, but not precisely.

So, the location of individual tracer particle is determined by surrounding velocity field that is what we have seen. As I told you all these path lines, the path line and the location all, the path line does not matter for us, only this location matters for the streakline, for location of an individual tracer particle is determined by the surrounding velocity field from the moment of its injection into the flow until the present time. As we have been saying streakline should represent the flow there. So, the position depends on the flow field from the moment to the particular time instant.

Why is it from the moment?, the velocity field could change also during that time could be a function of time as well that is why it says the depends on the surrounding velocity field which can change from the moment of its entry of injection into the flow until the present time. Of course we are following the paths of a continuous stream of a tracer particles from the time of their injection into the flow until the present time that is what we have done.

Follow the paths of a continuous stream of particles, and we are following the paths, the paths as it does not is not important to us. We are interested in the final position, but the particles follow the path lines. So, follow the paths of a continuous stream of tracer particles from the times of the injection into the flow until the present time.

Locus of treasure particle locations at time $t = t_{present}$. The present time I denote it as $t_{present}$ is connected by a smooth curve to get a streakline. That is what we said all this points are connected by a smooth line to get the streakline. A locus as I explained you because all of them pass through a particular prescribed point in the flow.

Now how do you represent mathematically? Now, integration for different particles with different t_{inject} and same $t_{present}$ that passed to the prescribed point may be let me show in the next equation as well be easier to explain this statement.

$$x = x_{injection} + \int_{t_{injection}}^{t_{present}} v dt$$

Now, remember here also we do integration. We want the current position. In the earlier case x was some initial portion of fluid particle; in this case x is the point of injection. Now, so, $t_{present}$ represents the time at which we want to plot the streakline.

And now t_{inject} keeps changing because different fluids particles are at this prescribe point at different time instance. Let us say the example which we will take let us say we want $t_{present}$ is 2 seconds, t_{inject} will vary from let say 0 second, 0.5 second, 0.1 second, 1.5 second etcetera. In the $x_{injection}$ is same, t_{inject} is different, and so when you do this integration you are doing it for different fluid particles. Why is it, because the fluid particle at the prescribed location at t_{inject} keeps changing at different instance of time, so that is why in the early integration I was very specific the early integration this was the initial position this was the initial time.

And let us say zero and then some given initial portion, we varied the end time and that was our one fluid particle. In this particular case, injection point is of course same, the present time is same, but the time of injection is different because we are doing this integration for when you change t_{inject} represents another fluid particle. We will understand this when we go to the example. So, now let us look at this example this statement integration for different fluid particles unlike the earlier case with the different t inject and same t present that pass through the prescribed point, is it.

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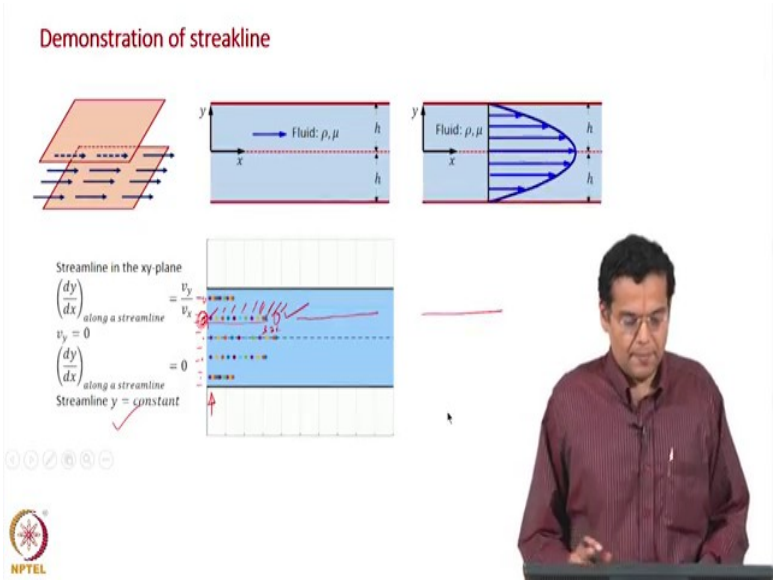

Now, let us have a demonstration for the streakline in the same geometry and same fluid flow conditions. So, let us straight away look at the demonstration of streakline. The way in which you have done is or what you have to focus is, here the simulation is run (watch video for better understanding) such that as if I am injecting a dye here, remember the prescribed point can change. If you want to get an entire flow field, you will have to change the point of injection.

So, the way in which you visualize the simulation is that you have a point of injection is at inlet so, you are injecting a dye at different inlet locations that is how you should visualize. Look at the initial point, focus at that point, you will see particles continuously entering and then flowing through the flow fluid. Now, let us run that simulation, I will also stop in between if you see here particles are continuously entering. And then they move through the flow fluid.

So, what you see here is particle being continuously injected and they follow the flow field. Now, let us stop and see, now what we are seeing here is, let us take this particular location. I have injected dye at inlet position and several fluid particles have passed that particular point over period of time. Let us say I want streakline at the time where I frozen the video. Now, this is the position of the particle which is just entered or just the point of injection, this last one is a first particle which enter the point of injection.

Now, how do we define a streakline? I should join the location of all these points by a smooth line in this case which go up and it is just a straight line, is it? I will repeat again. You have the first particle, second particle, third particle etcetera. And the first particle has followed the path line, right now it is at the end; and second particle followed the path line, right now it is after first particle; likewise third particle etcetera and the last particle which is just entering. We said streakline has one where we join all the present end points of the path lines. Those end points of the path lines are all lying in the same horizontal line; for this case and you get the straight horizontal line as a streakline.

And we already seen that the streamline is also horizontal line passing through that y location the path line is also same. So, for a steady state flow, streaklines, path lines and streamlines are all the same. Good demonstration to show how in this particular case the steady state field, velocity field, the streamlines are the horizontal lines, path lines are also horizontal, streaklines are also horizontal. Of course, as I told you the streamlines along this at this y location coincide with the path line with this as initial position, coincide with the streakline taking this as a point of injection. Though we generally say streaklines path lines and streamlines are all same, but this point which are considering should be kept in mind.

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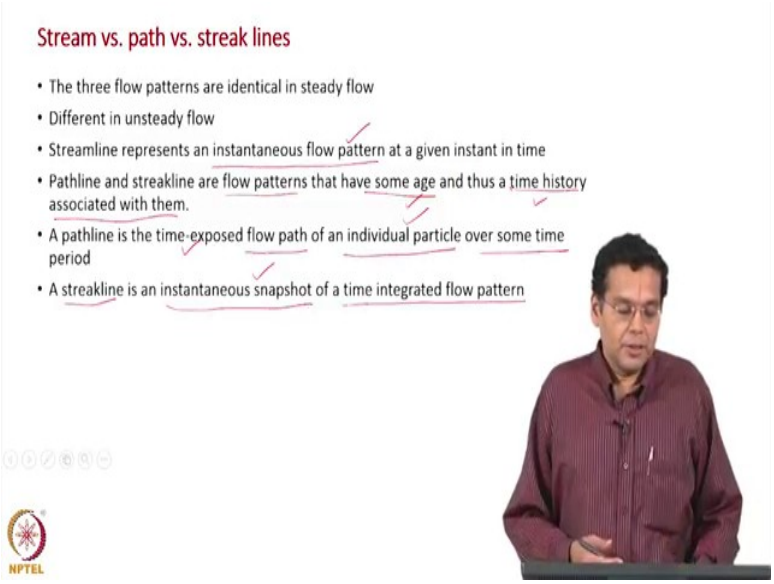

Just a comparison of stream versus path versus streaklines, we have discussed most of the concepts just like a summary. The three flow patterns, now I think we are kind of convinced why they are flow patterns; they represent the flow field. Three flow patterns are identical in

steady flow we have also demonstrated that; they are different in unsteady flow. I have two examples one for a steady flow; one for a unsteady flow. We will also see how these lines are different for a unsteady flow condition.

Streamline represents an instantaneous flow pattern at a given instant in time. We are saying that instantaneous flow pattern at a given instant in time. Path line and streaklines or flow patterns that have some age we talked about some integration of the time for both of them that is why a flow patterns that have some age or time and that does a time history associated with them. For streakline there has no integration, but both for path lines and streaklines, we did some integration. How does they differ, you will see in example that is why have some age and does a time history associated with them.

A path line is the time exposed flow path of an individual particle over sometime period. So, that is a flow path over some time period of an individual particle. And as I told you we use a videography to measure this. A streakline is instantaneous snapshot because in our case example was $t_{present}$ at $t_{present}$ what is the streakline, for example, 2 seconds. At 2 seconds what are the, what is a streakline. So, streakline is instantaneous a snapshot and that is why we can measure streakline just using a camera. You do not require a videography, just a snapshot, take a photograph, then you can measure, that is why specifically want you to pay attention to videography and then photography. Just take a photo, you can take a snapshot of steak line, but path line will have to follow it and hence require a video.

So, instantaneous snapshot of a time integrated flow pattern. So, quick summary or a good summary of that how they represent flow pattern and how do they different, one is an instantaneous flow pattern, others two have time history, individual particle, and it is a time expose that's why require a video, instantaneous snapshot just a camera, and it represents final position different fluid particles.