Flume Demo Energy Equation

SPEAKER Bob Holmes: Okay. In this lecture, Lecture 6, we're going to be doing a flume demonstration of the concepts that we've talked about in Lecture 6. Now, remember, when we've talked about the energy equation in Lecture 4, we've talked about an ideal fluid. In this particular lecture, we're going to talk about a real fluid, and we're going to look at energy losses.

Now, when we talk about things from a fluid mechanic standpoint and when one talks about energy, we're talking about three types of energy, remember? We have potential energy, which basically is the distance , or elevation, between the bed surface and a common datum and we're using the table for the common datum to the bed of the channel. And so that would be our potential energy. Now, our pressure potential would be that depth of water that we have above of the bed. Now, if we look at the downstream end of things here, we can see that that value is about this distance here. We're looking at the bed of the channel to the water surface on the downstream end. If I look at upstream, you can see that my pressure potential is much higher because I've got higher depth. So I'm looking at the bed of the channel to the water surface. And then lastly, we have that concept of kinetic energy, which is due to the velocity of the stream at that particular location. And we'll zoom in here a little bit, and we will talk about that.

Now, when we talk about an ideal fluid, everything is frictionless, and so we don't have any kind of problem with energy losses. But that's not the real world. So we're going to talk about real fluids, which you're going to encounter out there in the rivers and streams that you're working in. And so in that we have energy losses.

Now, we have a couple of types of energy losses. One is due to the friction. Just basically what happens with the boundary and how we lose energy due to the frictional resistance. So, as we have water flowing from the upstream end to the downstream end, especially as we go over the OG spillway where we increase our velocities by quite a bit, we get high velocities. You would think that we'd have more frictional resistance and more energy loss due to friction in this particular section as opposed to up in here in the upstream of the OG where the water is more tranquil and slower so you'd have less energy loss due to the friction. Now, we're going to look at the frictional losses, and we're going to zoom in here in a second and look at those pitometers, those pito tubes that are measuring the total energy by converting that velocity head into an

elevation force, but we're also going to look at additional losses that are due to other concepts besides friction. And that's what we're going to talk about next, and we'll show a little closer view of that in a second.

But this here is what we call a hydraulic jump. We go through a system where the channel of the bed is fairly flat, but as we come over the OG spillway, you can see that we go and we go from a more tranquil flow down into a very rapid flow. And as it hits this channel down here, we're going to be looking at a much faster velocity. But all of a sudden, the flow says, "You know what? I'm not on a slope that I can maintain this high velocity." And so we go through this hydraulic jump in order to keep the flow and energy balance. And so this hydraulic jump that you're seeing in front of you is very inefficient, and it losses a lot of energy through it, and so we're going to look at that. So let's go for a tight-end shot of the OG spillway.

Okay. So we've got--you can see here a pitometer on the downstream end of this OG spillway, and right here is our elevation pitometer. And you can see that we've got a little bit of dancing up and down. And that's due to the unsteadiness of the flow. Remember, the pitometer elevation here, this distance between the water surface down here and up here at our pitometer location, that's dependent upon the velocity of the flow in that particular location. Well, as that velocity and the flow is very turbulent, that velocity is changing through time. And so you're seeing with that bouncing up and down in that meniscus in the pitometer, you're seeing the evidence of that unsteadiness. Now, if we look upstream, you can see that we've got a very nice tranquil flow here. even though the flow is unsteady, it's turbulent, you're not having the degree of dancing up and down that you see on the downstream end.

Now, if I measure the total elevation of the energy grade line, I'm looking at adding up the potential energy plus this pressure potential, which is basically from the bottom of the channel to the water surface profile here or the water surface elevation, and then I've got the kinetic energy,

which is basically due to the velocity that is at the height of the meniscus above the water surface. So if I add those three together, that gives me the total energy.

Now, if I look at that elevation and I contrast that with the elevation of the meniscus at the downstream end, the difference between those two is going to be my energy loss due to what? It's going to be due to the friction and only the friction because right now what we've got is the water coming over a OG spillway drop with the cross-sectional remains the same. Therefore everything you are losing in terms of energy is due to the friction.

Now, if we pop back up for a wider shot, you can see that in this particular case we're going to look here and we're going to look at our hydraulic jump. Again, we've got the flow coming over the OG spillway and we still got a very, very shallow flow here and very rapid. All of a sudden, the flow says, "Hey, I'm on a slope that's not steep enough to maintain this particular velocity," and so it goes to this hydraulic jump, which, again, as I've already said, is very, very inefficient and a good way to dissipate a lot of energy. And so if we look--let's go in with a tight shot, and we can see here on the downstream end, you can look--again, we've got that meniscus. And you can see it's bouncing up and down. And if you contrast that with what we see upstream--now, remember, when I contrasted above the OG spillway that meniscus line you saw, it was fairly steady. Look downstream inside that rapid flow that was super critical, you saw it bounced quite a bit, that meniscus, in relation to the upstream of the OG.

Now, look at the--compare and contrast the difference between what we have upstream here and what's going on downstream in that hydraulic jump. Now, I've moved the pitometers in a little closer, just so we can get a tight shot and you can see the total thing to get the concept. And you can see that there's a tremendous amount of unsteadiness inside this hydraulic jump just downstream.

Now, the other thing is--remember, that if I look at the elevation of that meniscus, the elevation from the bed or the total distance from the bed or the datum of the table all the way to the bed and then the bed all the way to the meniscus, that is the combination. That is the total energy. Okay? Now, look, this is the total energy at this location upstream of the hydraulic jump. If I look

downstream to the hydraulic jump, I can see that if I average out those, that bouncing up and down on the bottom here, and you can see that I've got about this much drop and so that is my

total energy loss in the space of a few centimeters there. So you can see that the total energy loss due to these non-fictional induced mechanisms, like a hydraulic jump, are much greater than what we would see for the friction.

Later on in other lectures, we're going to look at like contractions and expansions, and we'll see the losses that are due to those as well. That concludes this particular flume demonstration for Lecture 6.