Velocity Head for Real Fluids

SPEAKER Bob Holmes: In this section, we're going to talk about the difference between an ideal and a real fluid, and we're going to explain why we need this thing called the Coriolis coefficient or the energy coefficient. And so with that, you'll see a slide where we're talking about the ideal and the real fluid. If you'll remember in Lesson 4, we talked about an ideal fluid. There we had no friction between the water particles. Because we had no friction, we had no energy loss. Because we had no energy loss, we have no difference in the velocity between the water surface and the bed of the river. So an ideal fluid, whatever the velocity is at the water surface would be what the velocity is at the bed or near the bed. Now, we know that's not the case, especially if you've made any flow measurements yourself where you measure the water velocity of various points in the water column, you know that the water velocity decreases as you get near the bed. A real fluid has friction. It has resistance, and therefore that velocity changes across the boundary. So the velocity in the middle of the cross-section is vastly different from the edges.

Now, in our energy equation, we always are talking about the mean velocity when we apply that V squared over two G. So if we're going to continue to use that mean velocity, we're going to have to come up with something that would correct for that because we know that the mean velocity, if we consider that as the average, that--because it's a square, and we'll explain that a little bit, that's not going to be a true representation of the kinetic energy. So we'll get a little bit farther into that. When we apply the energy equation, we typically, as I've said, use the cross-sectional velocity to compute it. However, the velocity head is proportional to the velocity squared. Remember? It's V squared over G. So the true average kinetic energy is always greater than the kinetic energy of the parcel moving at the average cross-sectional velocity.

Let me say that again because sometimes it's a little hard to understand. If I have a mean velocity and I just take that verbatim when I square it and divide it by two G. That's going to be vastly different than actual true kinetic energy that if we were able to sum the entire cross-section, that's going to be quite different.

So if we continue to use this average velocity, we need to have a correction factor for the

computation of the kinetic energy. This correction factor is the Greek letter alpha. It's called the kinetic energy coefficient or, as I previously mentioned, the Coriolis coefficient.

Now, how do we compute this value of alpha? Let's just look at a small parcel of a total cross-section. Let's call it A subprime or A subprime-i. Now, the weight of water passing that small parcel is the value of the unit weight of water times the velocity, V sub-i, of that small parcel times the area of that small parcel. Okay? If we compute the total kinetic energy passing through this small section, that's the product of the kinetic energy per pound of flowing water times the weight of the water passing through that per unit time. Okay?

If you look at the slide, you'll kind of understand where I'm going here. So again, gamma, which is the unit weight of the water, times the velocity of that small parcel times the cross-sectional area of that small parcel, that's the weight of water passing through that particular parcel per unit time. If we multiply that times the kinetic energy of that particular parcel, we would get the weight of water passing per unit time. So that'll be the total kinetic energy for that small parcel. If you look on your slide, you can see that that's gamma times Vi cube times this area of that subsection divided by two G. Recall that G is the acceleration of gravity.

Now, that's the kinetic energy delta KE for that small parcel. Now, if you think about how we make a discharge measurement where we make small subsections of the water as we make water velocity measurements as we go across the cross-section, we measure the velocity here, then move over and measure the velocity here, and we also measure the area. So we multiply that area times the velocity and we sum those up going across the cross section. We do the same thing to get the total kinetic energy, KE, and you'll see that on the bottom of your slide. If I sum all those small parcels, the kinetic energy from all the small parcels, I get the summation sign which looks like it's the Greek letter capital sigma. If I sum all of those parcels across and add them up, I get the total kinetic energy that's passing that cross-section per unit time.

Now, let's talk about how we compute that alpha. If we're to compute the total kinetic energy from simply using the mean velocity of the total cross-section, the equation would be as follows. We would calculate the mean velocity, we'd square that again, times the area total divided by two G

and then we multiply by the unit weight of water. Very similar to how we did it earlier. Now, in order to be able to use the average velocity, we have to, as I've said, we have to apply a correction because we know it's not the same. So we can express that as alpha times the unit weight of water times the mean velocity to the cube times the total area divided by two G.

Now, from the previous slide, you'll note that we had when we summed it up all the way across making a true measurement of the total kinetic energy, we have the summation sign of all those small little kinetic energy flows per unit time. So if I set those equal to each other, I can then solve for the alpha because, again, that's our correction factor. And so in order to calculate the alpha, we say we take the sum of all the small velocities as we go across the water column and we cube those times the small area, we sum that all the way across, and then we divide by the average velocity cube times the total area. That is essentially the computation of this kinetic energy coefficient, or the Coriolis coefficient.

Now, because the sum of the cubes of the positive numbers are always greater than the cube of the average, alpha will always be greater than one. Let's say that again. If I have a bunch of individual velocities and I just--let's just say we don't even multiply it by the area. I'm just talking about the velocities here. And I have, say, 10 small velocities all the way across. If I take the cubes of each one of those velocities and sum them up and then I divide it by the average velocity cube, that number will always be greater than one because the cubes of positive numbers individually is always greater than the cube of the average.

You can look at the table in the textbook that you're provided with the class to see typical values of alpha. Now, if we use this sort of value of alpha, our total head energy equation becomes H, which is total head, is equal to alpha times the mean velocity squared divided by two G, that is essentially the velocity head plus the water depth plus the height of the bed above the datum. Again, that height of the bed above the datum plus the total depth is equal to the piezometric head.

That concludes this section.