

Lecture F11 Mud: Vorticity, Strain, Circulation

(41 respondents)

1. **Can you explain the 2nd figure in the notes more?** (1 student)

This shows the fluid element at two successive times, t and $t + \Delta t$. Differences in velocity at two nodes will cause the nodes to not move in unison, resulting in tilting of the edges. Try re-reading the notes and Anderson.

2. **How are $\Delta\theta_1$ and $\Delta\theta_2$ defined?** (1 student)

These are angles that the edges rotate, or tilt, during the time interval Δt . For convenience, we draw the initial element to be aligned with the x and y axes, so the angles can be conveniently measured from those axes.

3. **What does $\Delta\dot{\theta}$ mean?** (1 student)

This is the same as $d(\Delta\theta)/dt$, or the rotation rate of the edge.

4. **In the definition of ω_z , Where did the $\partial u/\partial y$ and $\partial v/\partial x$ come from?** (1 student)

These velocity derivatives are equal to $-\Delta\dot{\theta}_1$ and $\Delta\dot{\theta}_2$ as obtained from the element edge tilting analysis.

5. **Where did the 1/2 factor in the strain just go away?** (1 student)

It's just a matter of convention in how you define ε_{xy} . Anderson doesn't use the 1/2. Other fluids books keep the 1/2. Either way is OK, as long as you're consistent with the definition when using it later on.

6. **What's the squiggly vorticity symbol?** (3 students)

This is the Greek letter ξ (or "xi"). Uppercase version is Ξ , and even harder to write.

7. **What's the difference between vorticity and rotation?** (3 students)

None, really. Vorticity is just twice the rotation rate of the fluid element.

$$\vec{\xi} = 2\vec{\omega}$$

This just gets rid of the annoying factor of 1/2 in the $\vec{\omega}$ definition. It also gives a simpler relationship between the velocity and vorticity:

$$\vec{\xi} = \nabla \times \vec{V}$$

again without a factor of 2 or 1/2.

8. **What does vorticity of a fluid element describe?** (1 student)

Vorticity is uniquely determined from the velocity field $\vec{V}(x, y, z)$ using the curl operation (see above). Nonzero curl at a point means that a fluid element at a point is rotating.

9. **What's the (math) interpretation of curl?** (1 student)

The physical interpretation of twice fluid element rotation rate is easier to see I think.

10. **When is a flow rotational or irrotational?** (1 student)

Aerodynamic flows which are uniform upstream, as most often occurs, are irrotational everywhere downstream, outside the boundary layers. The fluid elements outside the boundary layers do not rotate, even though they might take highly-curved paths when going around the body.

11. **What does circulation do to a fluid element?** (1 student)

Circulation is not defined for a point or infinitesimal fluid element, but rather it's defined for a finite-size loop or circuit. Vorticity, on the other hand, is defined for a point. Circulation is in effect the integrated or cumulative contribution of all vorticity inside the loop:

$$\Gamma = - \iint \xi dA$$

12. **What happens to Γ if the loop is right on the airfoil?** (1 student)

Γ is nonzero and has the same value for any loop enclosing the lifting airfoil, provided the loop stays outside the boundary layer. Γ is zero for any loop not enclosing the airfoil, provided again that the loop stays outside the boundary layer.

13. **Can you review 18.02 material which is used in UE Fluids?** (3 students)

Yes, but this would have to be scheduled off hours. I can't steal time from lectures or recitations. Please give the grad TA's possible times on your schedule.

14. **No mud** (16 students)