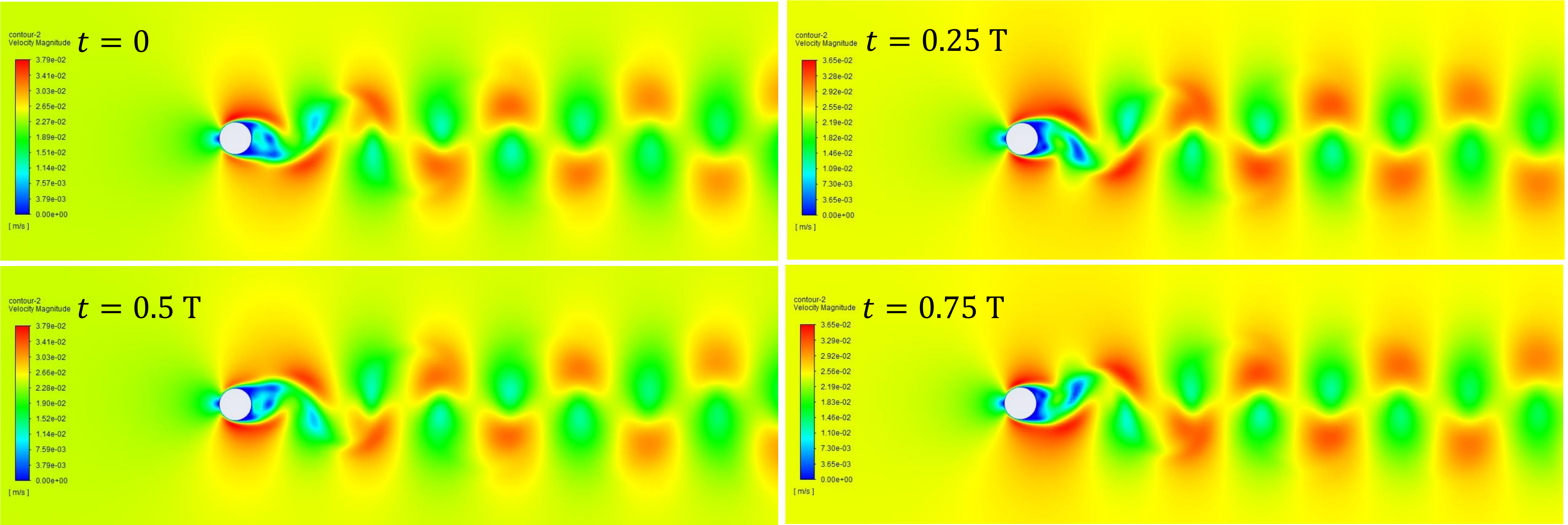
Unsteady Flow Over a Cylinder

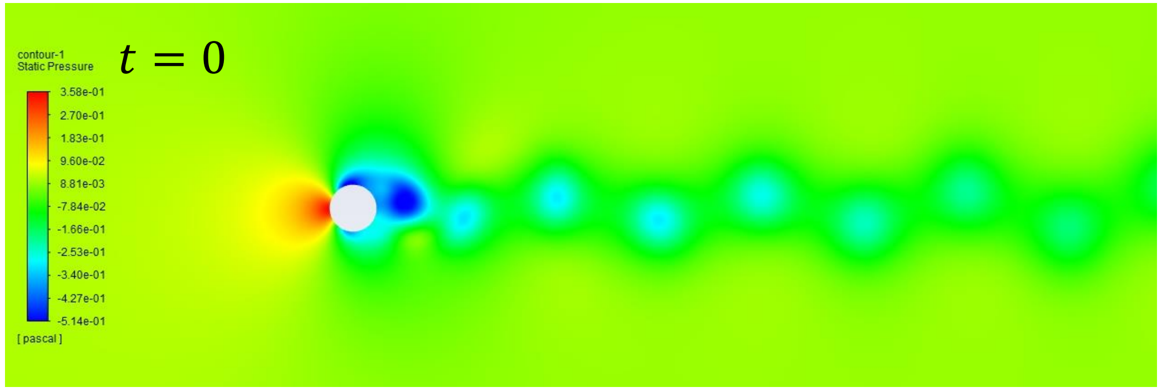
Results – Velocity Magnitude

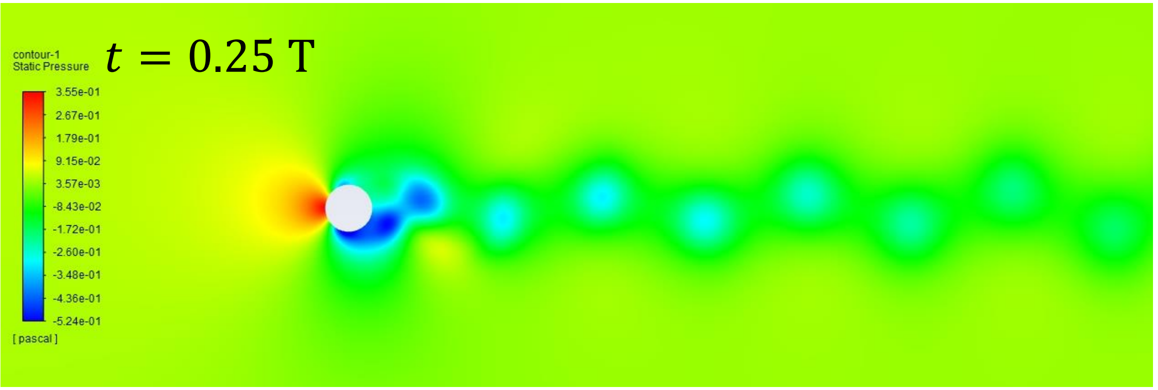
- The vortex shedding takes place when the water flows past the cylinder at a certain range of Reynolds Numbers.
- In this example, the global Reynolds Number ($Re_D = \rho V D / \mu$) is approximately 250, corresponding to periodic unsteady vortex shedding flow regime.
- Vortices are formed behind the cylinder and detach periodically from either side. Then the alternating vortices travel along with the main flow towards the downstream region, forming a von Kármán vortex street.

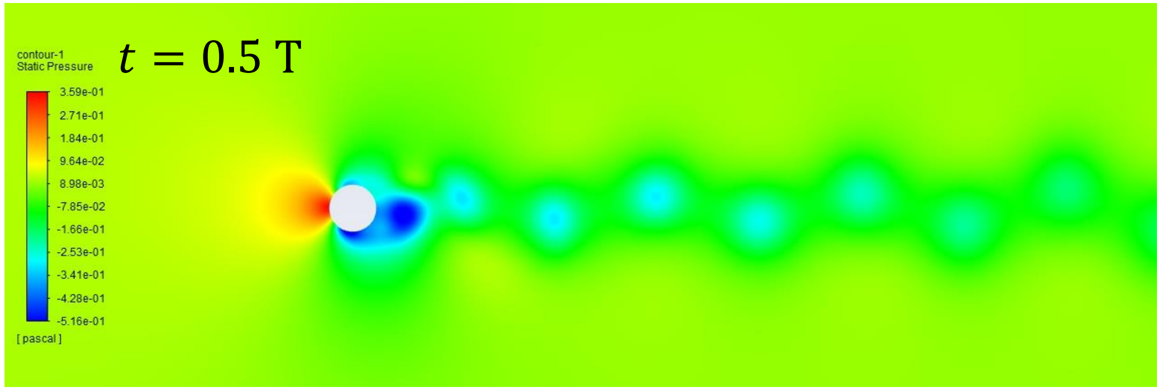


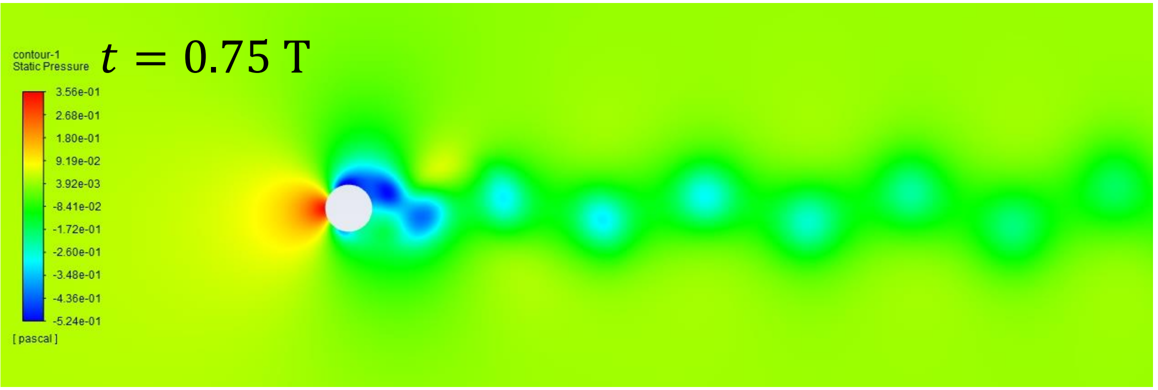
Results – Static Pressure

- Vortices, characterized by low pressures at their cores, propagate downstream with the flow.
- The periodic alternation of high and low pressures at either side of the cylinder results in periodic forces acting on the cylinder in both the horizontal (drag force) and vertical (lift force) directions.



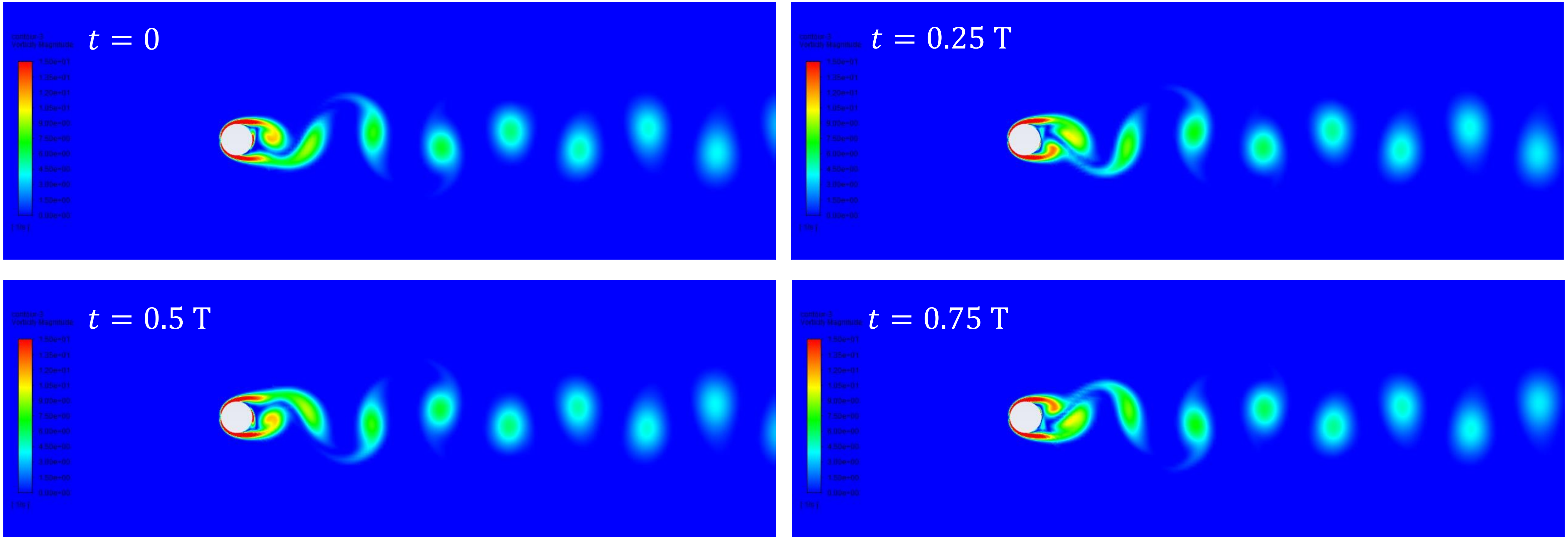






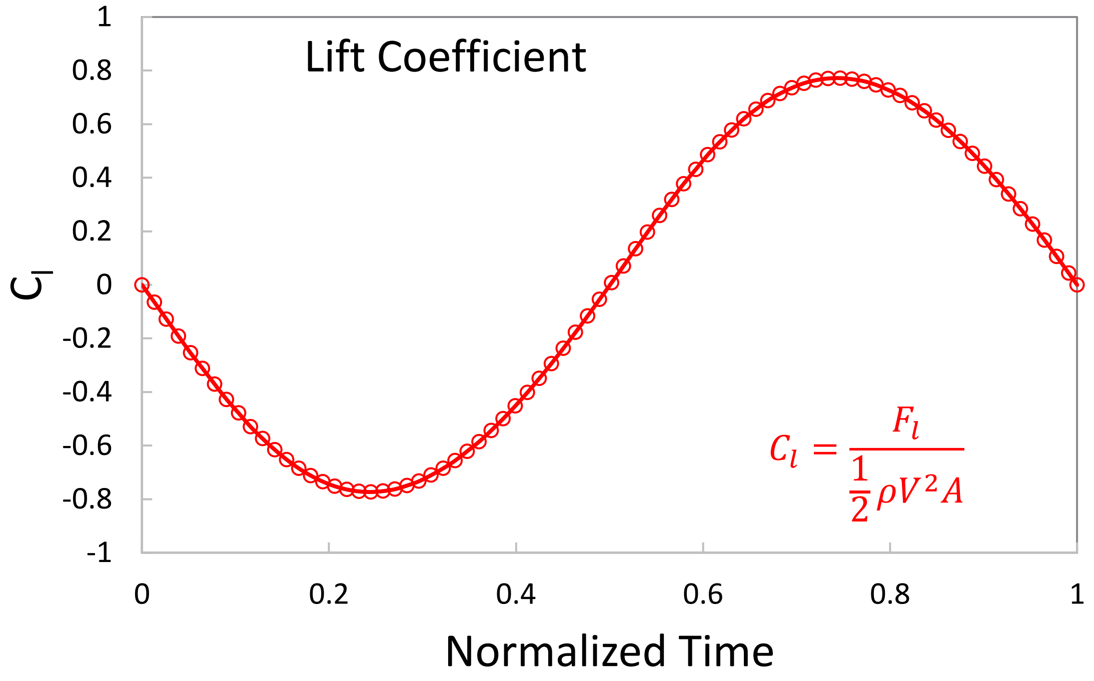
Results – Vorticity Magnitude

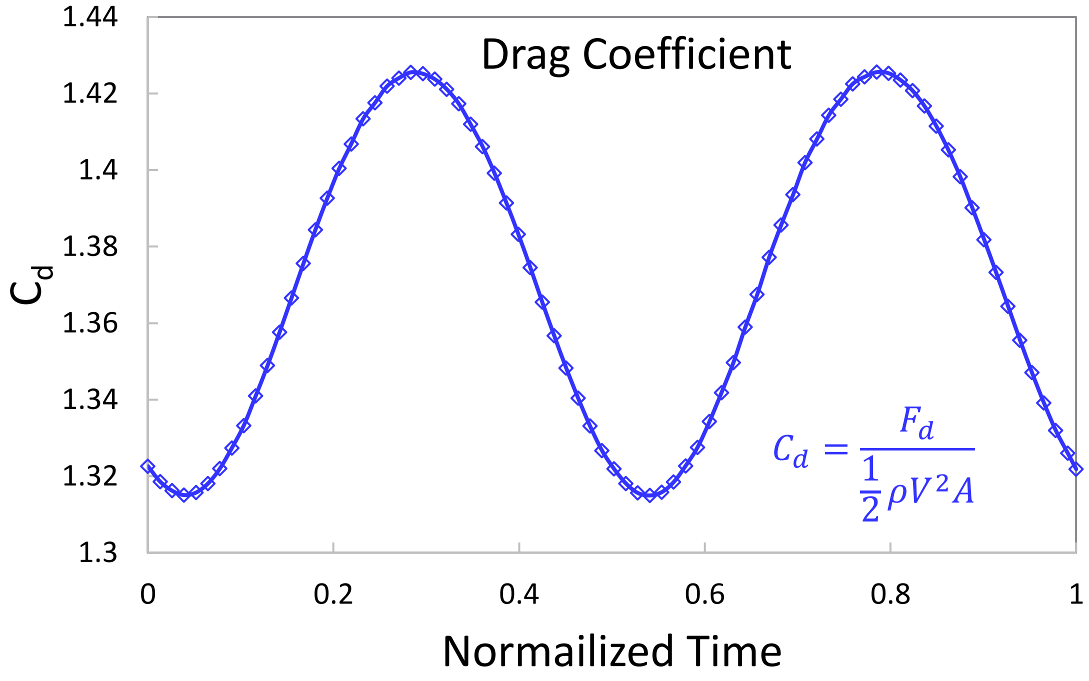
- The vorticity can be considered as a local measure of the spinning motion of a fluid, which is often used to visualize the vortices or eddies.
- As shown, the vorticity exhibits periodic patterns due to the periodicity of vortex shedding.



Results – Lift and Drag Coefficients

- Both the lift and drag coefficients fluctuate periodically with time. Because the vortex shedding alternates on either side of the cylinder, the lift force (represented by the lift coefficient in the plot below) varies between positive and negative peaks in a sinusoidal manner. The positive peak corresponds to the vortex shed on the upper side, and the negative peak – to the vortex shed on the lower side. The period equals to the time between vortex shedding on the same side.
- The drag force (represented by its coefficient) oscillated at half the period of the lift force, as both vortices shed from the top and bottom induce the drag force in the same direction. Unlike lift, the drag force is always positive.





Appendix

Unsteady Flow Over a Cylinder

Model Setup Notes

- A rectangular region, with diagonal start point (0.005, -0.05) and end point (0.32, 0.05,) behind the cylinder is marked as a cell register for patching a non-zero y-velocity to speed-up the onset of the unsteady vortex shedding.
- Zero-shear wall condition is applied to the "sidewall1" and "sidewall2" that bound the flow but avoid the formation of the viscous boundary layers along these walls.
- Ansys Fluent uses the numbers in Reference Values to normalize force coefficients. The reference area is set to the frontal area of the cylinder ($0.01\ m^2$). The reference density and viscosity correspond to those of water. The inlet velocity (0.025 m/s) is used as the reference velocity.
- The "Laminar" viscous model is chosen because the global Reynolds number $Re = 250$ is in the laminar regime.
- Solution methods and controls:
  - The "Coupled" scheme is applied so that the momentum and continuity equations are solved in a closely coupled manner.
  - Second order implicit transient formulation generates less numerical diffusion than the first order.
  - Relaxation factors of momentum and pressure are set to 1 to accelerate solution convergence within the sub-iterative loop.
- Calculation:
  - The time step size of 0.025 s provides sufficient temporal resolution corresponding to the flow Courant number of about 1. (Note the implicit time discretization is unconditionally stable and can handle Courant numbers greater than 1).
  - 10 Max Iterations/Time Step is sufficient for adequate solution convergence within each time step.
  - 800 time steps ensure a fully developed periodic flow field.
  - Three solution animations are created to record the variations of pressure, velocity and vorticity versus time.

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