**ME4/560 Assignment#2 Fall 2016**

**Due: Oct 31, 2016 12 noon deadline (This is a Monday – no “tricks” allowed))**

Here we are going to look at the lift forces that can be generated by “moving” the stagnation points that occur in a flow around an object. In other words we generate asymmetry in the flow over the object and we get a net force, in this case normal to the flow (lift). One way to do this is to have the body rotate, as in a rotating cylinder that is described in the text and in class. Assume a 2D steady potential flow in air for a cylinder diameter of 0.2 m; the air pressure far from the object can be taken as 101 kPa. For this assignment use the steps given below and your write-up should clearly identify your response for each numbered step. You results should make plots (if needed) and discuss trends for each step.

1. Determine the equations for the streamfunction and velocity potential for flow around a rotating cylinder. Define all of the terms used in these equations.
2. Plot lines of constant streamfunction and velocity potential for a single cylinder rotating with an approaching flow of U = 10 m/s (along the x axis) on the same graph for a rotation rate equal to 0.6 (60%) of the maximum rotation allowed that just keeps the stagnation points on the cylinder surface.
3. For a range of values of U (4 through 15 m/s) determine and plot the maximum rotation rates of the cylinder so that the stagnation points just come together on the surface of the cylinder. In doing this show the derivation of the relationship that you use.
4. Derive the equation for the pressure on the surface of the rotating cylinder. Start from the most general form of the Bernoulli equation and indicate all of the assumed conditions.
5. Determine and plot the surface pressure on the cylinder for U = 4 through 15 m/s for two rotation rates, one where the stagnation points are at 45o from the x axis and the other at 90o from the x axis.
6. Calculate the total lift force on the rotating cylinders using numerical integration around the cylinder and compare this to the analytical value for rotation rates corresponding to part 5.
7. In a real viscous flow there is a lift and drag force acting that should be taken into account. White’s text gives a plot of lift and drag coefficient for a rotating cylinder (shown below) with “a” being the cylinder radius, and  the rotation rate in radians per second. Compare these “real” lift results for the range of velocities (4 through 15 m/s) to those found in part 6 and also plot the ratio of real lift to drag force.

 *from Tokumaro and Dimotakis given in White p 550 7th ed.*

*Assume valid for all Re values used in this problem.*