AME 70634 Flow Control

Fall, 2024

Homework No. 2

Problems

1: A method sometimes used to calibrate hot-wire sensors is to place them in the wake of a circular cylinder where they can detect the vortex shedding. The shedding frequency is related to the velocity through the relation $St = 0.212(1 - 21.2/Re)$ that was shown in Figure 3.4.

1. Based on this approach, determine the number of cylinder diameters that might be needed to allow hot-wire calibration for velocities ranging from 5m/s to 60m/s.
2. How might the calibration be performed?
3. What difficulties might arise in calibrating at the highest velocities?

2: Hot-wire sensors are simply small diameter cylinders that are heated. Velocity is inferred by measuring the heat transfer from the wire, where the governing parameter is the Nusselt number, Nu. An empirical relation used in the calibration of hot-wire sensors is $Nu = C_1 + C_2\sqrt{Re_D}$ where C_1 and C_2 are functions of the Prandtl number. This relation is generally valid for $1 \leq Re_D \leq 1000$.

1. We expect there to be a relation between the heat transfer and the drag coefficient. Use the information in Figure 3.6 to generate a plot of Nu versus C_D for a circular cylinder with $1 \leq Re_D \leq 1000$.

3: Circular cylinders undergo a dramatic drop in drag ("drag crisis"), at $Re_D > 200,000$. The drop in drag is associated with the turbulence onset of the boundary layer which caused the separation location to move further aft along the cylinder surface with the result being a contraction of the wake.

1. Describe three passive methods that could be used to lower the drag on a circular cylinder.
2. Based on Problem 2, what effect would the "drag crisis" have on the heat transfer from the cylinder". Is there a practical application for this?
3. Spheres also undergo a drag crisis at higher Reynolds numbers. List three passive methods that apply to spheres to lower the drag on spheres. Provide practical examples.

4: It has been established that at low Reynolds numbers, the wake undergoes an absolute instability to disturbances with a temporal amplitude that can be described by a Landau equation of the form given in Equation 3.1. This applies near criticality where $Re \simeq Re_{G_c}$.

1. Based on Equation 3.1, plot the amplitude, $B(t)$, as a function of time for $c_1 = c_2$ where (a) both are positive, and (b) where c_1 is positive and c_2 is negative.

2. For the case in which c_2 is positive, determine the saturation amplitude.