Aerodynamics

Bluff Bodies

- Flows with large wakes (comparable to the typical dimension of the body) and significant changes when compared to the ideal fluid model (large $\delta$) originating an high pressure (form) drag force.

Masters of Mechanical Engineering
Aerodynamics

Bluff Bodies

• Large wake is related to the body shape (cylinder, sphere) and/or with the orientation of the incoming flow (flat plate, foil)
Aerodynamics

Bluff Bodies

• Near wake has small velocities and an approximately constant pressure smaller than the undisturbed pressure

• Far wake exhibits vortices of symmetric strength aligned along two parallel lines and shifted half wavelength “von Kármán street”

• Vortex shedding leads to an unsteady flow and problems of induced vibrations
Aerodynamics

Bluff Bodies

• Examples of vortex shedding for flows around cylinders and foils

http://www.youtube.com/watch?v=_AJgEa2dbJU
http://www.youtube.com/watch?v=PdaChF24Jj8&feature=related
http://www.youtube.com/watch?v=J-xxCkebdZs&feature=related
http://www.youtube.com/watch?v=SJ3w4bg5Tx8&feature=related
http://www.youtube.com/watch?v=vQHXIHpvcvU&feature=related
http://www.youtube.com/watch?v=6UlsArvbTeo&feature=related
Aerodynamics

Bluff Bodies

• Significant experimental and numerical investigation has been performed for cylinders
Aerodynamics

Bluff Bodies

- Flow around a cylinder at small Reynolds numbers is steady

\[ Re = 9.6 \]
Aerodynamics

Bluff Bodies

- Flow around a cylinder at small Reynolds numbers is steady

\[ R_e = 13.1 \]
Aerodynamics

Bluff Bodies

• Flow around a cylinder at small Reynolds numbers is steady

\[ R_e = 26 \]
Aerodynamics

Bluff Bodies

• Flow around a cylinder at small Reynolds numbers is steady

\[ R_e = 30.2 \]
Aerodynamics

Bluff Bodies

- Flow around a cylinder at small Reynolds numbers is steady

$$R_e = 41$$
Aerodynamics

Bluff Bodies

• The wake becomes unstable with the increase of the Reynolds number
Aerodynamics

Bluff Bodies

• The wake becomes unstable with the increase of the Reynolds number
Aerodynamics

Bluff Bodies

• The wake becomes unstable with the increase of the Reynolds number
Aerodynamics

Bluff Bodies

• The wake becomes unstable with the increase of the Reynolds number \( R_e = 2000 \)
Aerodynamics

Bluff Bodies

• The wake becomes unstable with the increase of the Reynolds number $R_e = 10000$
Aerodynamics

Bluff Bodies

- Near wake exhibits very low velocities and an approximately constant (base) pressure smaller than the pressure of the undisturbed incoming flow (at infinity)

\[
\begin{align*}
|\vec{U}_b| & \approx 0 \\
p_b & \approx \text{const.} < p_\infty
\end{align*}
\]
Aerodynamics

Bluff Bodies

- Vortex shedding dominates far wake

- Vortex shedding is originated by instabilities in the near wake
Aerodynamics

Bluff Bodies

- Vortex shedding may lead to vibration problems. Shedding frequency, \( f \), is defined by the Strouhal number, \( S \)

\[
S = \frac{fd}{V_\infty} = F\left(\frac{|V_\infty|d}{v}\right) = F(R_e)
\]

Masters of Mechanical Engineering
Aerodynamics

Bluff Bodies

• The influence of the Reynolds number on the drag coefficient, \( C_D \), (drag crisis) and Strouhal number, \( S \), is related to transition to turbulent flow upstream of flow separation.

\[ C_p \] distribution on a circular cylinder at different Reynolds numbers

Masters of Mechanical Engineering
Aerodynamics

Bluff Bodies

- Vortex shedding originates periodic lift and drag forces that may induce vibrations

Instantaneous pressure distribution, $\tilde{c}_p$, on a circular cylinder shifted half period
Aerodynamics

Bluff Bodies
Aerodynamics

Bluff Bodies

Masters of Mechanical Engineering
Aerodynamics

Bluff Bodies

Masters of Mechanical Engineering
Aerodynamics

Bluff Bodies

Masters of Mechanical Engineering
Aerodynamics

Bluff Bodies

Masters of Mechanical Engineering
Aerodynamics

Bluff Bodies

Masters of Mechanical Engineering
Aerodynamics

Bluff Bodies

• Physical models to study problems related to vortex shedding
Aerodynamics

Bluff Bodies

• Mathematical models (numerical solutions) to study problems related to vortex shedding

Masters of Mechanical Engineering
Aerodynamics

Bluff Bodies

- Devices to avoid problems due to vortex shedding

a) Cylindrical chimney

b) Model of TV antenna tested in wind tunnel

Masters of Mechanical Engineering
Aerodynamics

Bluff Bodies

• Devices to avoid problems due to vortex shedding

Devices for submarine cables