**Determining the Effect of Flow Separation on Aerodynamic Forces for Bluff and Aerodynamic Bodies**

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**Abstract**

**Introduction and Methods**

The objective of this lab was to use a wind tunnel to experimentally determine the effect of flow separation on aerodynamic forces for both bluff and aerodynamic bodies. This report will explain common trends in values such as coefficients in lift and drag, and Reynolds number, and compare those trends with published theoretical, empirical, and computational results. These kinds of experiments and results are of interest because wind tunnels are used a lot for testing models of proposed aircraft and race cars. Wind tunnels are also used for flow visualizations, which can be useful to see how the flow of a fluid changes over a specific shape such as an airplane wing.

During these experiments, an object was placed inside the wind tunnel and differential pressure, axial force, and normal force were measured. The analysis in this report is operating under three assumptions. One, the flow within the wind tunnel may be modeled as steady and constant across all surfaces that are being tested. Two, the fluid can be modeled as an ideal gas. Finally, since flow separation is often increased with the pressure gradient on the body, the effects of large flow separation will be observed when the wind tunnel is reading a large pressure gradient.

This experiment is dealing with 2-dimensional (not 3-dimensional) fluid flow in the wind tunnel. 2D flow has two components, lift and drag. The component in the fluid flow direction is drag, which can have two sources: viscous drag and form drag. Viscous drag is due to viscous shear stresses acting on the solid surface. Pressure drag is due to pressure distribution on the object and the subsequent separation of the boundary layer from the solid surface.

Lift and drag can be represented by their non-dimensional coefficients. The following equations are needed in order to determine the lift and drag effects on the bodies that are being tested. Lift and drag forces can be calculated from the normal and axial forces measured using the wind tunnel readout system. Equations 1 and 2 can be used to calculate these quantities, using Fn as the normal force, Fa as the axial force, and alpha as the angle of attack.

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1. The experiment procedure w/ figure
   1. Test the following at 0 angle of attack:
      1. 1.5” diam sphere, 4” diam sphere with and without turbulent trip, dimpled golf ball
   2. Measure axial force in increments of 5mph from 0-40
   3. Plot Cd vs Re and compare to published values
   4. Test Clark-Y airfoil at free-stream velocity (40 m/s) varying angle of attack in 2 deg increments from -6 to 20 degrees.
2. Theory and equations
3. Consider lift and drag can be represented by their non-dimensional coefficients in which the magnitude of the lift/drag force is non-dimensionalized by a measure of fluid kinetic energy.

The following equations are needed in order to determine the lift and drag effects on the bodies that are being tested.

Where Fl,d is the lift or drag force, rho is the fluid density, V is the average free stream flow speed, and A is either the projected frontal area or the plan-form area.

3. Airfoil Theory: Mathematical explanation for lift on airfoils is that the airfoil shape creates a circulation in the airflow as seen by a still observer, much like that around a baseball thrown with backspin. Both the baseball and the airfoil then experience an upward lift force. Drag is a force that resists the object’s motion. Therefore an airplane with lower drag will be able to fly at faster speeds than a higher-drag airplane with the same amount of power. In addition, lower-drag aircraft will require less power to fly at the same speed.

4. 3D Lift and Pitching Moment Theory:

– For airplane wings, pressure distribution at the wing tips result in trailing vortices with induced downwash.

– The vortices expand and travel downwards

**For Rectangular wing planforms:**

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**Results and Discussion**

**Conclusions**

**References**

1. Lab handout

2. 3D lift theory document