Chapter 7
Aerodynamic Force Measurements Using Blower Balance Tunnel at Low Reynolds Number

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ABSTRACT

This chapter describes the basic concepts of aerodynamics, evolution of lift and drag, types of drag, reduction of wing tip vortices, non-planar wing concepts for increased aerodynamic efficiency, various methods for determination of aerodynamic forces of an airplane, classification of wind tunnels, blower balance tunnels, and a case study report on aerodynamic force measurement of the non-planar wing systems. To increase the aerodynamic efficiency of the monoplane configuration, the 'C-wing' configuration is presented in this chapter. The aim is to prove, at all angles of attack, C-wing produces a higher (L/D) ratio than straight wing for the same wetted surface area. The aerodynamic characteristics of three different wing models with NACA-64215 aerofoil such as straight wing, C-wing, and inverted C-wing at different angles of attack and low Reynolds number are shown. The inverted C-wing created more lift but produced more vibration, which may lead to lesser structural integrity.

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INTRODUCTION

Fluid mechanics is the branch of physics deals with the mechanics of fluids (liquids, gases, and plasmas) and the forces on them. It can be divided into fluid statics, the study of fluids at rest; and fluid dynamics, the study of the effect of forces on fluid motion.

Properties of Fluid

Any characteristic of a system is called *property*. It may either be *intensive* (mass independent) or *extensive* (that depends on size of system). The state of a system is described by its properties. The number of properties required to fix the state of the system is given by *state postulates*. Most common properties of the fluid are:

- **Pressure (p)**: It is the normal force exerted by a fluid per unit area. In SI system the unit and dimension of pressure can be written as, N/m^2 and $M\ L^{-1}\ T^{-2}$, respectively.
- **Density (ρ)**: The density of a substance is the quantity of matter contained in unit volume of the substance. For mass density; Unit: kg/m3, Dimension: M L-3.
- **Temperature (T)**: It is the measure of hotness and coldness of a system. In thermodynamic sense, it is the measure of internal energy of a system. Many a times, the temperature is expressed in centigrade scale (degree Celsius) where the freezing and boiling point of water is taken as 0 degree Celsius and 100 degree Celsius, respectively. In SI system, the temperature is expressed in terms of absolute value in Kelvin scale (K = degree Celsius + 273).
- **Viscosity (μ)**: When two solid bodies in contact, move relative to each other, a friction force develops at the contact surface in the direction opposite to motion. The situation is similar when a fluid moves relative to a solid or when two fluids move relative to each other. The property that represents the internal resistance of a fluid to motion (i.e. *fluidity*) is called as *viscosity*.
- **Specific Weight (υ)**: In fluid mechanics, specific weight represents the force exerted by gravity on a unit volume of a fluid. For this reason, units are expressed as force per unit volume (e.g., N/m^3 or lbf/ft^3). Specific weight can be used as a characteristic property of a fluid.

Classifications of Fluid Flows

Some of the general categories of fluid flow problems are as follows:

1. **Viscous and Inviscid flow**: The fluid flow in which frictional effects become signification, are treated as viscous flow. When two fluid layers move relatively to each other, frictional force develops between them which is quantified by the fluid property 'viscosity'. Boundary layer flows are the example viscous flow. Neglecting the viscous terms in the governing equation, the flow can be treated as inviscid flow.
2. **Internal and External flow:** The flow of an unbounded fluid over a surface is treated as 'external flow' and if the fluid is completely bounded by the surface, then it is called as 'internal flow'. For example, flow over a flat plate is considered as external flow and flow through a pipe/duct is internal flow. However, in special cases, if the duct is partially filled and there is free surface, then

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