Application of Bernoulli's principle in airplane wings

[1] S.Bhuvaneswari, [2] M.Abitha

[1]Head of the department, [2]M.phil., scholar
[1]Department of Mathematics,
[1]Kamban College of arts and science for womens, Tiruvannamalai, India.

Abstract : Aerodynamics is a branch of dynamics concerned with studying the motion of air, particularly when it interacts with a moving object. It plays an important role in performance of airplane during flight as well as during takeoff and landing. Using Bernoulli's stated that velocity of a fluid increase, its pressures decreases. Concerning flight, Bernoulli's principle applies to the shape of an airplane wing.

IndexTerms - Bernoulli's principle, airfoils, lift and drag

I. INTRODUCTION

Aerodynamics plays an important role in the performance of an Airplane during flight as well as during take-off and landing. For this the wings of an airplane must be properly designed to have a smooth and steady flight. An Airplane having well designed wings according to the aerodynamic modification will have a very good performance at variable atmospheric conditions How is it that today's airplanes, some of which have a maximum take off weight of a million pounds or more, are able to get off the ground in the first place, let alone fly between continents? Surprisingly, with today's technological advances, airplanes use the same principles of aerodynamics used by the Wright brothers in 1903. In order to gain an understanding of flight, it is important to understand the forces of flight (lift, weight, drag, and thrust), the Bernoulli Principle, and Newton's first and third laws of motion. Although the activities in this lesson primarily focus on the role the Bernoulli Principle plays in the ability of aircraft to achieve lift.

II. THE FORCES OF FLIGHT

At any given time, there are four forces acting upon an aircraft. These forces are lift, weight (or gravity), drag and thrust. Lift is the key aerodynamic force that keeps objects in the air. It is the force that opposes weight; thus, lift helps to keep an aircraft in the air. Weight is the force that works vertically by pulling all objects, including aircraft, toward the center of the Earth. In order to fly an aircraft, something (lift) needs to press it in the opposite direction of gravity. The weight of an object controls how strong the pressure (lift) will need to be. Lift is that pressure. Drag is a mechanical force generated by the interaction and contract of a solid body, such as an airplane, with a fluid (liquid or gas). Finally, the thrust is the force that is generated by the engines of an aircraft in order for the aircraft to move forward.

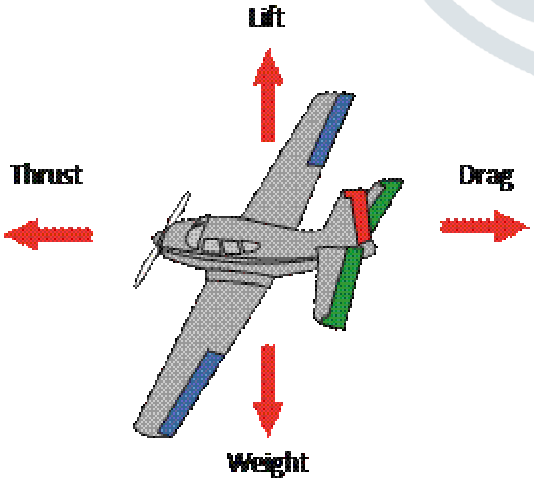


Fig. 1 Four forces of flight

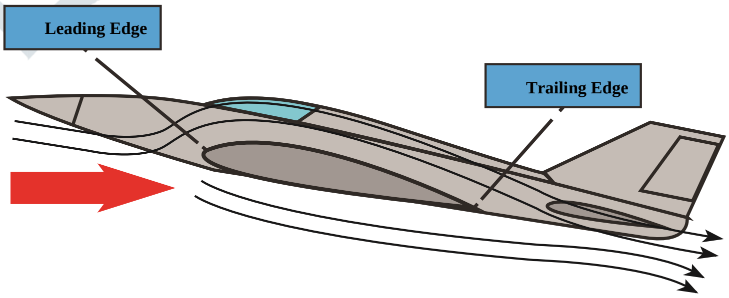


Fig. 2 Airfoil

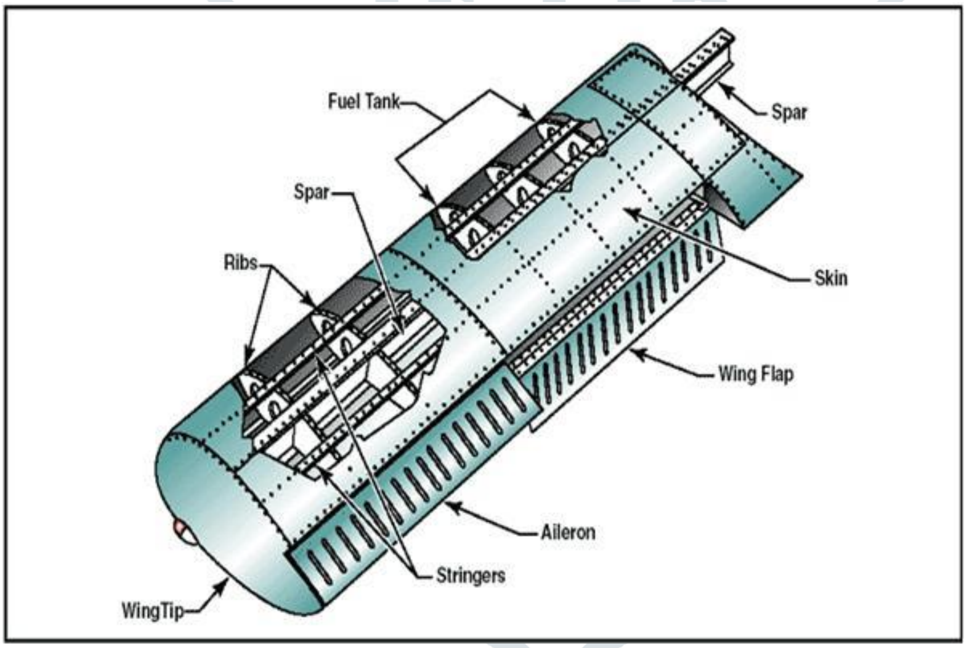
III. PRINCIPLES OF FLIGHT

We are able to explain how lift is generated for an airplane by gaining an understanding of the forces at work on an airplane and Fi.What principles guide those forces. First, it takes thrust to get the airplane moving - Newton's first law at work. This law states that an object at rest remains at rest while an object in motion remains in motion, unless acted Then because of the shape of an airplane's wing, called an airfoil, the air into which the airplane flies is split at the wing's leading edge, passing above and below the wing at different speeds so that the air will reach the same endpoint along the trailing edge of the wing at the same time. In general, the wing's upper surface is curved so that the air rushing over the top of the wing speeds up and stretches out, which decreases the air pressure above the wing. In contrast, the air flowing below the wing moves in a straighter line, thus its speed and pressure remain about the same. Since high pressure always moves toward low pressure, the air below the wing pushes upward toward the air above the wing. The wing, in the middle, is then "lifted" by the force of the air perpendicular to the wing. The faster an airplane moves, the more lift there is. When the force of lift is greater than the force of gravity, the airplane is able to fly, and because of thrust, the airplane is able to move forward in flight.

IV. STRUCTURE OF AN AIRPLANE WING:

A rounded leading edge cross-section.A sharp trailing edge cross-section.Leading edge devices such as Slats or extensions.Trailing edge devices such as Flaps or Flaperons.

Ailerons to roll the airplane clockwise or anticlockwise about its long axis.Spoilers on the upper surface to disrupt the lift and to provide additional traction to an airplane that hasjust landed but is still moving.Dihedral, or a positive wing angle to the horizontal. This gives inherent stability in the roll direction. Anhedral , a negative wing angle to the horizontal, has a destabilizing effect.Winglets to keep wingtip vortices from increasing drag and decreasing lift.



.

V. OPERATION

The chord of the slat is typically only a few percent of the wing chord. The slats may extend over the outer third of the wing, or they may cover the entire leading edge. In reality, the slat does not give the air in the slot high velocity (it actually reduces its velocity) and also it cannot be called high-energy air since all the air outside the actual boundary layers has the same total head. The actual effects of the slat are:

The slat effect: The velocities at the leading edge of the downstream element (main airfoil) are reduced due to the circulation of the upstream element (slat) thus reducing the pressure peaks of the downstream element.

The circulation effect: The circulation of the downstream element increases the circulation of the upstream element thus improving its aerodynamic performance.

The dumping effect: The discharge velocity at the trailing edge of the slat is increased due to the circulation of the main airfoil thus alleviating separation problems or increasing lift.

The pressure variations of flowing air is best represented by Bernoulli's equation. It was derived by Daniel Bernoulli, a Swiss mathematician, to explain the variation in pressure exerted by flowing streams of water. The Bernoulli equation is written as:

$$P + \frac{1}{2}\rho V^2 = \text{constant}$$

where:

P = pressure (force exerted divided by area exerted on)

rho = density of the fluid

V = velocity of the moving object or fluid

To understand the Bernoulli equation, one must first understand another important principle of physical science, the continuity equation. It simply states that in any given flow, the density (rho) times the cross-sectional area (A) of the flow, times the velocity (V) is constant. The continuity equation is written as:

$$\rho \times A \times V = \text{constant}$$

Bernoulli's Equation

$$P_1 + \frac{1}{2}\rho V_1{}^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho V_2{}^2 + \rho g h_2$$

Where (in SI units)

P= static pressure of fluid at the cross section

ρ= density of the flowing fluid

g= acceleration due to gravity;

v= mean velocity of fluid flow at the cross section

h= elevation head of the center of the cross section with respect to a datum.

The Bernoulli's equation says

$$P_1 + 1/2\,\rho v_1{}^2 + \rho g y_1 = P_2 + 1/2\,\rho v_2{}^2 + \rho g y_2$$

But the pressure at the two points is the same; it's atmospheric pressure at both places. We can measure the potential energy from ground level, so the potential energy term goes away on the left side, and the kinetic energy term is zero on the right hand side. This reduces the equation to:

$$1/2\,\rho v_1{}^2 = \rho g y_2$$

The density cancels out, leaving

$$1/2\, v_1{}^2 = g y_2$$

REFERENCES

[1] Ülgen Gülçat, "Fundamentals of Modern Unsteady Aerodynamics", Springer-Verlag Berlin Heidelberg, pp. 4, 2010.

[2] D. Anderson and S. Eberhardt, "How Airplanes Fly: Physical Description of Lift", The Aviation History Online Museum, 2010.

[3] K. Cummings and P. Laws, Understanding Physics, Wiley, 2004

[4] R.M. James, "The theory and design of two-airfoil lifting systems", Computer Methods in Applied Mechanics and Engineering, vol. 10, pp. 13-43, 1997.

[5] M.T. Nguyen, M.T. Pham, M.C.Vu and D.A. Nguyen, "Design wireless control system for aircraft model", Proceeding of International Conference on Engineering Mechanics and Automation, pp. 283-286, Hanoi, 2014.