EXPERIMENTAL ANALYSIS OF LIFT FORCE ON SYMMETRIC AEROFOIL IN THE AIRFLOW TUNNEL

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Abstract
In this paper we will be discussing about the airflow tunnels and the results of experiments conducted in an open airflow tunnel on the aerofoils. These tests were carried at low speed keeping artefact stationary and allowing the air to pass through it, the air will be blown on the experimental profile with the help of an efficient fan. The aerofoils were designed in a computer drawing tool named solidworks. Distinct aerofoils were selected for experimentation and the results were recorded and studied at various angle of attack and speed. The airflow tunnel tests of one from the selected aerofoils at various angles of attack and at a constant speed is outlined in this paper. The pressure distribution over the profile of the aerofoil surface was obtained; lift force and related lift coefficients were calculated. The conclusions derived from the scrutinization of the results will be used in the future to carry out further research and development.

Keywords: Low speed airflow tunnel, lift force, lift coefficient.

Introduction
Aerodynamic examination has been the primary way of verification of aerodynamic models. All the objects that encounter fluid have to experience forces, for instance lift force, drag force which can be determined in a device named airflow tunnel easily. Airflow tunnel enables to determine the aerodynamic characteristic which affects the performance of the object. The obtained values of Aerodynamic forces are used to develop and modify the object to give a better output. Airflow tunnel testing is being widely used by many industries such as aviation industry, automotive industry, construction industry as several artefacts such as space vehicles, aeroplanes, buildings, and automobiles can be tested in this manner.

Objective
- To study the influence of angle of attack and the velocity of air on the existing aerofoil designs.
- Study the surface pressure distribution and evaluate the lift force acting on the aerofoil and determining the respective lift coefficient.

Airflow tunnels
An airflow tunnel is a device used to determine the aerodynamic parameters acting on the objects. In the tunnel scaled objects are kept in the test section and the air is permitted to flow through it. The airflow tunnels are designed and developed for special purposes according to the construction and speed range, airflow tunnels are classified as: -
Based on construction:
- Open airflow tunnel
- Close airflow tunnel

Based on speed range:

- Subsonic (Low speed), M<1
- Transonic, M =1
- Supersonic, M >1
- Hypersonic, M >5

As per the requirement of applications the airflow tunnel instruments are available today. In an open airflow tunnel the air is extracted from outside atmosphere and expelled to the same medium again. In closed airflow tunnels, the air is circulated with the help of a power unit continuously. Intermittently, a small amount of air is exchanged with the atmosphere to increase the air quality and have some temperature control. According to the requirement of the speed, airflow tunnel design varies on account to boundary layer formed and effect of compressibility by the enclosure. For the experiment we required the air density to remain constant that can be achieved by subsonic type (low speed) of airflow tunnel. In low speed airflow tunnel the density of fluid remains nearly constant. As shown in the Fig.1 according to the law of conservation of mass and Bernoulli's equation as the cross-sectional area increases the velocity decreases causing the pressure to increase. In a similar manner as the cross-sectional area decreases the flow velocity increases causing pressure to decrease. The test section is placed after the contraction section and before the diffuser in case of this analysis of low speed airflow tunnel. From the knowledge of conservation of mass and Bernoulli's equation the test section can be designed to get required Mach number since velocity is outcome of the cross-sectional area for low speed airflow tunnel. Mach number for low speed airflow tunnel is less than 1.

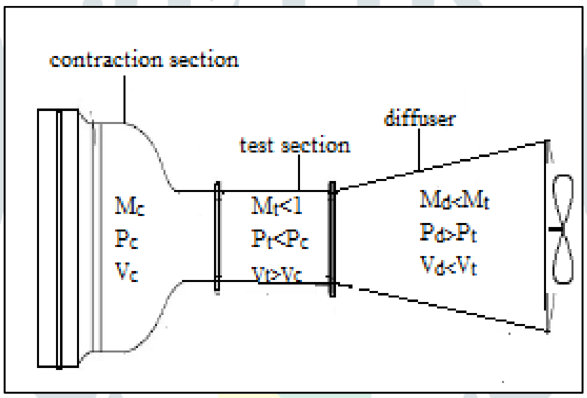


Fig.1: Mach no. in low speed airflow tunnel

Aerofoils

The geometrical configuration of aeroplane wings and propeller are made as such to generate higher lift value and lower drag value. Aerofoil surface coincides with the streamlines i.e. it's a streamlined body; it has rounded leading edge and given a consistent curvature in the flow direction as shown in Fig.2. It is designed in such a way that the separation occurs at the extreme rear end of the body producing a small wake and consequently small pressure drag. The flow becomes laminar to turbulent but doesn't separate at the rear edge. Even for the high value of Reynolds number pressure drag is very small comparatively to the skin friction drag which makes a major contribution to the total drag in case of aerofoil. The resulting force is perpendicular to the direction of flow. The lift force and the moment acting on the aerofoil are mainly due to pressure distribution.

Elements of the aerofoil:

Chord length

It's an imaginary straight line drawn from the leading edge of an aerofoil to its trailing edge.

Angle of attack (α)

It’s an acute angle between the chord length and the direction of wind blowing.

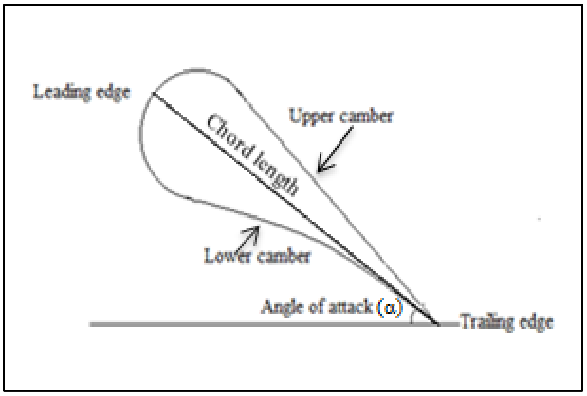


Fig.2: Elements of Aerofoil

Camber

It is the curvature of aerofoil from the leading edge to the trailing edge which is divided into three categories; Upper camber which refers to curvature of upper surface, lower camber signifies the lower surface and the mean camber line that is equidistant from the points between upper and lower surface.

Designing and testing of aerofoil profiles in the airflow tunnel

The analysis of the experiment contemplates the use of rapid prototyping methods to create geometric models for airflow tunnel testing. The CAD aerofoil geometry models were wall mounted in the test section of the airflow tunnel. The aerofoils were designed using computer aided software called Solidworks as shown in Fig.3. The design of aerofoils pivoted on determining different shapes of these aerofoils. The aerofoils chosen for the present work are symmetric. Ultimately, the following types of aerofoils were selected for the examination, given their variety and popularity:

- NACA 0012
- NACA 0024

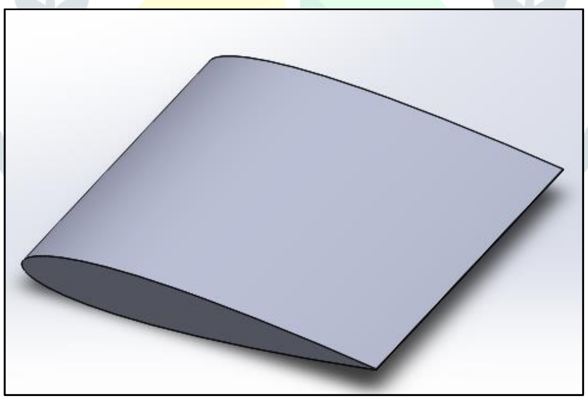


Fig.3: CAD model of symmetric aerofoil NACA 0012

In order to measure the pressure distribution on the aerofoil surface pressure taps were provided on each and every hole provided on the aerofoil section, shown in Fig.4. Aerofoil was wall mounted in the test section. With the help of round protector, the desired angle of attack for the aerofoil was set. The aerofoil was held at a particular angle using screw mechanism. Measurements of the surface pressure distribution were carried out with the help of water manometers to which all the tapings were connected.

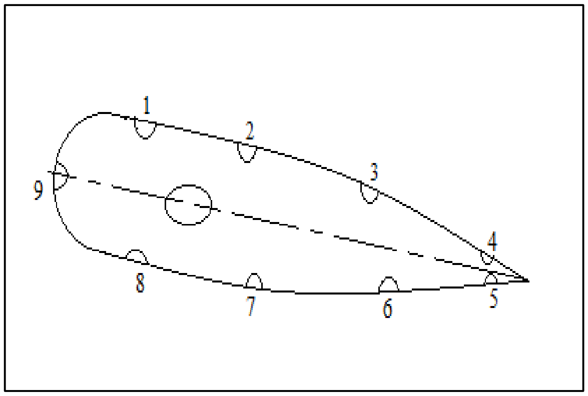


Fig.4: Tapings provided to measure pressure distribution

Experimental procedure

The pressure readings were recorded with the help of a U tube manometer having water as a manometric fluid and the velocity of air is measured by a Digital anemometer. The analysis of the forces was performed at free stream velocity of 6m/s and 10 m/s. The artefact was held in the test section at the required angle of attack as shown in Fig.5. The desired velocity was set with the help of speed controlling knob. The pressure readings were measured. The experiment was performed at different angles and air velocity.


Fig.5: Experimental setup with wall mounted aerofoil

Calculations:

Pressure (P) in Pa (at each point of aerofoil) = r×g×h

r = Density of water (1000kg/m^3),

g= acceleration due to gravity (9.81 m/s^2),

h= height of manometric liquid (m),

Pressure force on the pressure points of aerofoil,

F_L =L × w × P× cos α (N),

L= Span length (m),

w= width of the aerofoil (m),

ρ = density of fluid (air) 1.18 kg/m^3 (23°C),

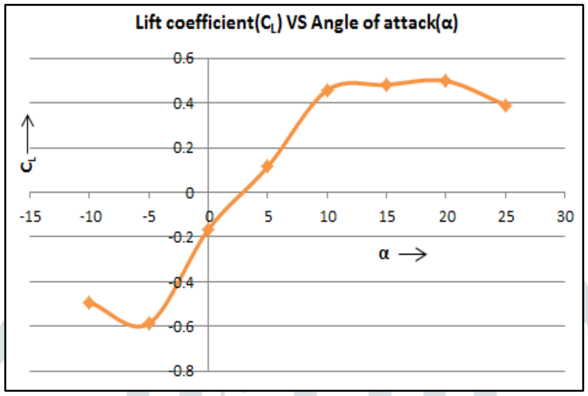
A (Area of the aerofoil) = L× w (m^2),

Lift coefficient (C_L) = F_L/ (0.5× ρ ×V^2×A)

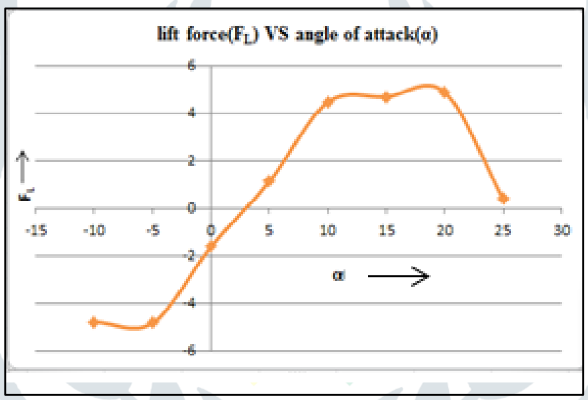
V= velocity of air (m/s)

Result and Conclusion

One from the selected aerofoils (NACA 0012) results are discussed here at 10m/s, from graph 1 we can see that, as the angle of attack increases the value of lift coefficient increases. At 0° the lift coefficient is almost equal to zero. From graph 2, it can be observed that lift force starts decreasing after a certain point. This is due to boundary layer separation happening somewhere around at the top surface of the aerofoil as shown in the Fig.6. Therefore, it can be concluded that increasing angle of attack increases the lift force up-to certain limit.



Graph 1: Lift coefficient VS Angle of attack



Graph 2: Lift force VS Angle of attack

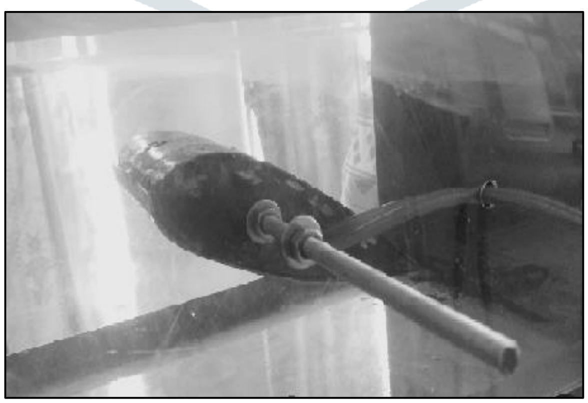


Fig .6: Boundary layer separation at 50˚ angle of attack

References

- Advanced Topics in Aerodynamics- Airflow Tunnel and Experimental Aerodynamics.
- P. Bradshaw and R. D. Mehta, "Design Rules for Small Low Speed Wind Tunnels," The Aeronautical Journal of the Royal Aeronautical Society, pp. 443-49, 1979.
- Fluid dynamics - Equation of continuity and Bernoulli's principle. Lecture 4 Dr. Julia Bryant.
- Hirata K., Kawakita M., Iijima T., Koga M., Kihia M., Funaki J.: Numerical and experimental study on aerodynamic characteristics of basic airfoils at low Reynolds numbers. Transactions of the Japan Society of Mechanical Engineers, 77(776), 2011, 1111-1126.
- J.B.Barlow ,W.H.Rae,A.Pope,Low Speed Wind Tunnel Testing,Third Ed,John wiley,New York,1999,P360,374.
- Reference book- unique publication, by Senjal Cimbala for aerofoil design.
- The Royal Aeronautical Society. Wind tunnels and wind tunnel test techniques, Royal Aeronautical Society London, (1992).
- V.B Bhandari, Design of Machine Elements.