EXPERIMENTAL ANALYSIS OF FLOW OVER SYMMETRICAL AEROFOIL

Mayank Pawar[1], Zankhan Sonara[2]
[1,2]Assistant Professor,Chandubhai S. Patel Institute of Technology, CHARUSAT, Changa, Gujarat, India

Abstract

The present study deals with the study of static pressure distribution over the surface of an aerofoil. Upper surface an aerofoil act as a suction surface and lower surface act as a pressure surface. Due to difference in pressure on the suction and pressure surface of an aerofoil, lift is produced. Lift produced is utilized for generation of power in turbines, compressors and even for movement of an aeroplane. In the present study, experiment is carried out at different angle of attack of an aerofoil and pressure is measured at different points over the surface of an aerofoil. The paper signifies following outcome as, with increase in angle of attack of an aerofoil, flow separation leads towards the leading edge. Further, increase in angle of attack leads to the effect of stall region on an aerofoil and decrease in high pressure region over the surface of an aerofoil which results in decrease of lift.

Keywords: Aerofoil, Suction Surface, Pressure Surface, Lift, Angle of Attack, stall Region.

I. Introduction

The blade sections employed for airplane wings and propellers are of such a geometrical configuration as to produce high lifts and low drag values. This state of affair is possible with the so called lifting vanes which include bodies like kite, aerofoil, hydrofoil and propeller blade. An aerofoil is an streamline body which has a rounded leading edge, is elongated and is given a gradual curvature in the flow direction.

As the fluid passes ove rthe surface of an aerofoil, the centrifugal force of the fluid particles on the upper (convex) side tries to move those fluid particles away from the surface. This reduces the static pressure on this side below the free stream pressure. On account of this "suction effect", the convex surface of blade is known as suction side. The centrifugal force on the lower side presses the fluid harder on the blade surface, thus increasing the pressure above that of free stream. Therefore this side of blade is known as pressure surface.

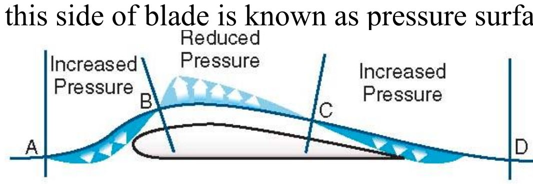

Fig.1 Pressure distribution over aerofoil surface [10]

This pressure difference on the upper and lower side results in lift of an aerofoil which is is a result of pressure differences and depends on angle of attack, airfoil shape, air density, and airspeed.

TERMINOLOGIES

An outline of the symmetrical and asymmetrical aerofoil. A and B denote the leading edge and trailing edge respectively. The leading edge is usually a circular area blended into the main profile and the trailing edge is ideally of zero radius. Chord line: A line joining the leading and trailing edges of the aerofoil. Profile center or camber line: A line joining the mid points of the profile. Angle of attack: Angle between the chord line and the line of undisturbed velocity.

Stall: Beyond a certain value of angle of attack, separation point moves forward towards the leading edge and the lift produced by the aerofoil starts diminishing. The aerofoil is then said to be operating under stalled conditions. The value of the angle of attack at which lift reaches its maximum value is known as the stalling angle.

The angle of attack is the angle between the chord line of an airfoil and the oncoming air. A symmetrical airfoil will generate zero lift at zero angle of attack. But as the angle of attack increases, the air is deflected through a larger angle and the vertical component of the airstream velocity increases, resulting in more lift. For small angles a symmetrical airfoil will generate a lift force roughly proportional to the angle of attack. As the angle of attack grows larger, the lift reaches a maximum at some angle; increasing the angle of attack beyond this critical angle of attack causes the upper-surface flow to separate from the wing; there is less deflection downward so the airfoil generates less lift. The airfoil is said to be stalled.

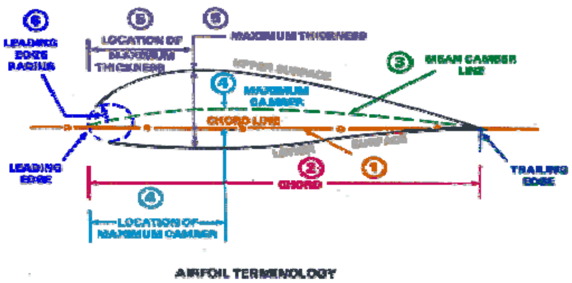

Fig.2 Aerofoil Terminologies

II. Literature Review

Aerodynamic analysis of a symmetrical aerofoil by Narayan Rathod [1] carried out different performance of an aerofoil based on geometry, Reynolds number and co-efficient of lift. He emphasize mainly the parameters such as the distribution of pressure and velocity over a symmetrical aerofoil surface and to obtain the characteristic curves. The experimental approach has been applied to carry out the parametric study and results are being validated with the established results and he compared experimental characteristic graphs with the theoretical graphs of lift versus angle of attack and gave ideas of stall effect. Experimental study of aerofoil with wind tunnel set up by P. Ghosh [2] and his team experimented flow characteristics over a symmetrical airfoil in a low speed wind tunnel. They measured pressure distribution on the airfoil surface, lift and drag forces, mean velocity profiles over the surface. They carried out experiments by varying the angle of attack and changing the ground clearance of the trailing edge from the minimum possible value to free stream velocity region. They found that high values of pressure coefficient are obtained on the lower surface when the airfoil is close to the ground. This region of high pressure extended almost over the entire lower surface for higher angles of attack. As a result, higher values of lift coefficient are obtained when the airfoil is close to the ground. The flow accelerates over the airfoil due to flow diversion from the lower side, and a higher mean velocity is observed near the suction peak location. The pressure distribution on the upper surface did not change significantly with ground clearance for higher angles of attack. The upper surface suction causes an adverse pressure gradient especially for higher angles of attack, resulting in rapid decay of kinetic energy over the upper surface, leading to a thicker wake and higher turbulence level and hence a higher drag.

III. EXPERIMENTAL SET-UP

Experimental set up as shown in fig.4 consists of suction type open circuit wind tunnel with a test section of 30cm*30cm*100 cm length of thick Plexiglas window. 5 kw AC motor with variable frequency drive is used for axial fan. Multi tube manometer is used for measuring pressure readings at different cross section over the symmetrical aerofoil. NACA 0018 aerofoil as shown in fig.3 is with axial chord -16cm and 29cm span with 12 pressure taps is provided to determine pressure distribution over the surface of aerofoil. Material of aerofoil is aluminium. Aerofoil is inclined at different flow angles and variations in pressure on the upper & lower surface of the aerofoil is measured at different angles. These pressure differences will give effect of pressure on both the surfaces of an aerofoil and hence lift and drag produced due to aerofoil.

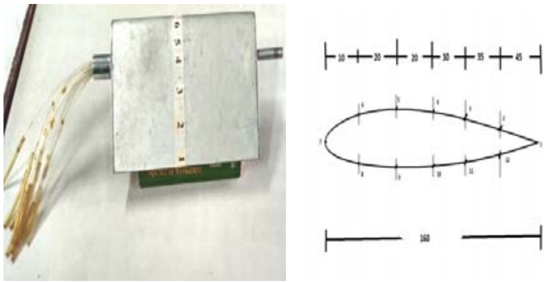

Fig.3 NACA 0018 Aerofoil with pressure tappings

Co efficient of pressure at different locations on the upper and lower side of an aerofoil is obtained by measuring water level in multitube manometerand in u-tube manometer.

The co efficient of pressure is given by,

$$C_p = \frac{P - P_0}{\frac{1}{2}\rho v^2} \qquad (1)$$

Where, P is static pressure at different points and P_0 is atmospheric pressure measured by multitube manometer. Free stream velocity of the flow V, can be measured by using piutot tube and u-tube manometer.

Fig.4 Experimental setup

IV. RESULTS AND DISCUSSION

At an angle of attack equal to 0˚, pressure distribution line is symmetry about each other on both upper and lower surface. But due to the effect of circulation and vortices on the trailing edge of an aerofoil, high pressure region is formed near the trailing edge on the upper surface of an aerofoil.

Increase in angle of attack from 0◦-15◦ results in flow separation leading towards the leading edge of an aerofoil on the upper surface as shown in fig.5 while sudden rise in pressure occurs on the lower side at angle of attack 15◦ which increases the effect of sudden rise in drag on the pressure side.

High pressure region starts increasing on lower surface of an aerofoil as shown in fig.7 as we increase angle of contact. Effective high pressure is obtained from 7.5 degree angle of attack. Maximum high pressure gradient is obtained at 15 degree which is around 0.92 at a distance of 20 mm from the leading edge.

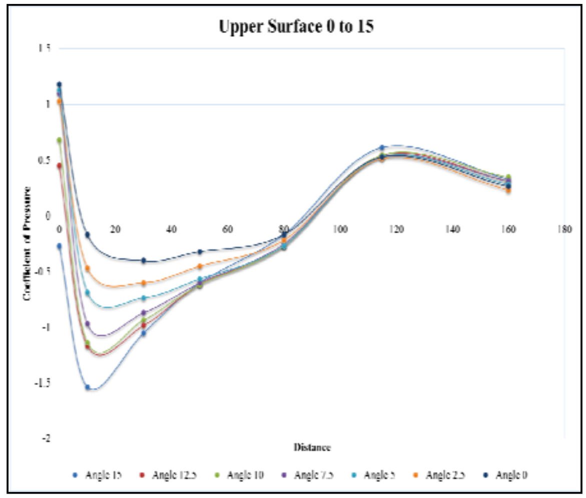

Fig.5 Pressure distribution over upper surface

(angle of attack 0-15 degree)

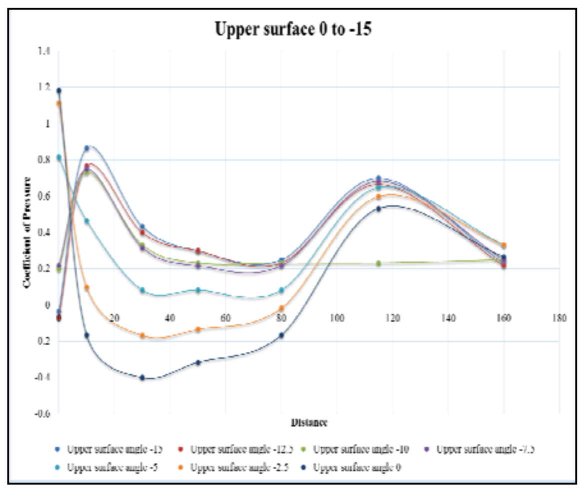

Fig.6 Pressure distribution over upper surface

(angle of attack 0- (-15) degree)

At higher angle of attack, from 7.5. to 15, due to formation of wake region on the upper surface of an aerofoil, pressure towards the leading edge of an aerofoil reduces sharply. Further increase in angle of attack may lead towards stall effect of an aerofoil.

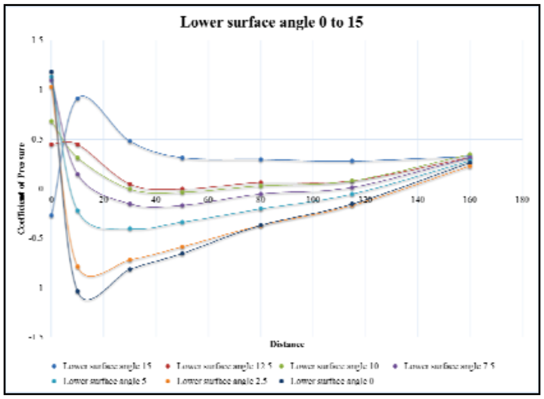

Fig.7 Pressure distribution over lower surface

(angle of attack 0-15 degree)

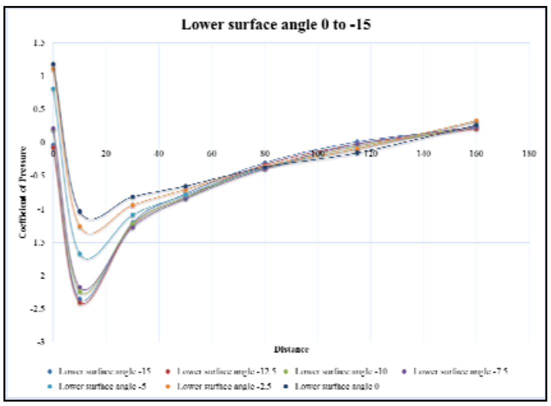

Fig.8 Pressure distribution over lower surface

(angle of attack 0-(-15) degree)

Increase in angle of attack leads the flow separation towards the leading edge of an aerofoil as shown in fig.5. From angle of attack 7.5◦ to 15◦, sudden increase in pressure starts occurring from 20 mm to 12 mm chord length from the leading edge. It shows that flow starts separating and increase in pressure starts occurring very near to the leading edge as increase in angle of attack. Further increase in angle of attack may lead this increase in pressure very near up to 5 mm chord length of an aerofoil.

On the pressure surface as shown in fig.7, at the steep rise in pressure occurs at the angle of attack of 15◦, which increases sudden pressure and results in drag effect on the aerofoil. For higher pressure gradient and obtaining maximum lift, 15˚ angle of contact is sufficient.

For angle of attack from 0◦ to (-15◦) as shown in fig.6 and fig.8, increase in angle of attack increases the effect of pressure on the upper side and as a result, drag effect produces on the upper side. On the pressure side, flow separation and formation of wake region occurs which gives high pressure on the trailing edge of the pressure surface.

V. CONCLUSION

Vortices and flow separation starts forming at the trailing edge of an aerofoil and it starts growing further towards the leading edge as angle of contact increases. This flow separation can lead to increase in pressure at the trailing edge and hence decrease in lift will occur. As angle of attack is increase further, stall may occur on the aerofoil which may lead to decrease in lift or pressure gradient of an aerofoil.

Further, increase in angle of contact 15◦ onwards may lead flow separation towards leading edge of an aerofoil which may results in stall effect of an aerofoil.

Even to reduce the effect of stall and flow separation towards the leading edge, one may do changes and modifications in design of an aerofoil or can use slats and flap on the leading and trailing edge of an aerofoil which generates boundary layer flows.

On the opposite side, decrease in angle of contact leads towards increase in effect of flow resistance which results in effect of drag on the aerofoil.

Acknowledgement

We are very thankful to Charotar University of Science and Technology, CHARUSAT, Changa, Dist: Anand (Gujarat) for providing us facilities for performing experiment in fluid mechanics lab on wind tunnel.

References

[1] Narayan Rathod, Aerodynamic analysis of a symmetrical aerofoil, 2014 IJEDR | Volume 2, Issue 4 | ISSN: 2321-9939.

[2] P. Ghosh*, Akhilesh. K. Dewangan*, Pratik Mitra*& Dr.A.K.Rout Experimental study of aerofoil with wind tunnel set up, Recent Advances in Thermal Engineering (RATE-2014), Bhubaneswar, Volume:OSC-366, January-2014.

[3] D.S.Kumar, Fluid Mechanics and Fluid Power Engineering

[4] Applied Aerodynamics: A digital Text book, version 5, January 2007.

[5] Robert Sheidahl ,Aerodynamic characteristic of seven symmetrical aerofoil sections through 180 degree angle of attack

for use in aerodynamic analysis of vertical axis wind turbines, Sandia National laboratories energy report.
[6] Gene J Bingham, Low speed aerodynamic characteristics of an aerofoil optimized for maximum lift co-efficient, National Aerospace Administration, Washington,D.C. December 1972.
[7] Chih-Min Hsium, Aerodynamic characteristics of a two dimensional aerofoil with ground effect, Journal of Aircraft, Vol 33, No.2, March-April 1996.
[8] Ramesh K Agrawal, 2017, Chod-dominated ground- effect. Aerodynamics of fixed wing UAVs. Advanced UAV aerodynamics, flight stability & control, 201-254.
[9] Mohammad Saeed Seif (2016), A practical method for aerodynamic investigation of WIG. Aircraft Engineering and aerospace technology, 73-81. Online publication date: 4-Jan-2016.
[10] http://www.dynamicflight.com/aerodynamics/airfoils.
[11] http://web.mit.edu/2.972/www/reports/airfoil/airfoil.html
[12] http://aerospaceengineeringblog.com/boundary-layer-separation-and-pressure-drag/
[13] http://www.zenithair.net/high-lift-design/