Spanwise Blowing On Swept Back Wing to Generate High Vortex Lift

Bhoomika A.H.[1], Arpitha V.V.[2], Mohammed Aaqil Nawaz[3], Ramprasad Kadam[4], Ramesh Kumar[5]
[1,2,3,4] Student, Department of Aeronautical engineering, SIT, Mangaluru
[5]Professor, Department of Aeronautical engineering, SIT, Mangaluru

Abstract- **An investigation has been conducted to evaluate the aerodynamic effects associated with spanwise blowing over a swept back wing's upper surface in a direction parallel to leading edge. Experimental pressure and force data were obtained on the wing having sweep angle of 30 degree and showed that span wise blowing aids in the formation and control of leading edge vortex and hence significantly improves the aerodynamic characteristics at higher angle of attack. Full vortex section lift is achieved at inboard span station with a small blowing rate, but successively higher blowing rates are necessary to attain the full vortex level at increased span distances. Span wise blowing generates large increase in lift at high angles of attack, improves the induced drag polar, delayed wing stall to higher angles of attack and extends the linear pitching moment to high lifts.**

Span wise blowing is a method used for increasing the lift of a wing or other aerodynamic lifting surface. The span wise blowing is given more preference for producing lift than the high lift devices that is the different types of flaps. The use of high lift devices will produce more lift along with the increased drag but the span wise blowing of a wing would produce increase in lift with reduced amount of drag that is the amount of drag produced may be negligible when compared to total lift.

Introducing this concept in the fighter aircraft design offers the possibility of increasing excess power for manoeuvring at high load factors (during high rate of angular rotation).

The conclusion is the span wise blowing helps in reattaching the flow and establishing a healthy leading edge vortex on the upper surface of the wing and therefore increasing the lift.

Index Terms- **Span-wise blowing, increasing lift, increasing stalling angle.**

I. INTRODUCTION

Spanwise blowing originated in 1967 from the studies performed at Aerospace Science Research Laboratory of the Lockheed Georgia Company at a time when vortex phenomena was investigated. Since then the lift augmentation by means of spanwise blowing is dependent on several factors.

The fluid community is continuously searching for methods to reduce drag and also to improve aerodynamic efficiency. Drag reduction has proved to be a challenge but there are chances for more improvements. By looking at various ongoing research works it is obvious that modification can increase the aerodynamic performance. These types of researches involve the study of different kinds of modification in order to ensure that there is reduction in the total drag. The modifications energize the flow by producing the vortices, which results in delaying the boundary layer separation due to attached flow and this type of flow has the potential to be more efficient than the conventional boundary layer control methods.

At present it is very difficult to predict for a given incidence, sweep angle, leading edge shape and Reynolds number whether the flow around a wing will remain attached or separated either from the upper surface as a bubble or from leading edge as a vortex sheet which rolls up above the wing.

The objective of vortex studies is to gain a better understanding of vortex phenomenon and find means of controlling the vortex to produce high lift or to control drag. Accordingly, the present investigation was initiated to evaluate the spa.nwise development of an augmented leading edge vortex .This was accomplished by measuring surface pressure distributions on a moderately swept wing with spanwise blowing from the fuselage and by analysing the experimental results with appropriate aerodynamic theory.

In a commercial airplane the implementation of the spanwise blowing on swept wing can be done by providing a ducting between the compressor and the wing for spanwise blowing.The intake air from the compressor is about 20% is diverted for spanwise blowing of the wing, which produces vortex lift.Therefore the lift produced by the wing is high and the drag produced is negligible compared to the total lift.

Aerodynamic characterstic usually increase at higher angles of attack. Spanwise blowing generates the significant increase in lift at high angles of attack. It also improves the drag polar and extends the linear pitching moment to high lifts. The idea of integration of spanwise blowing concept into fighter aircraft design offers possibility of increasing the specific excess power which is available for manuevering at high load factor.

A promising technique for enhancing the leading egde vortex and effectively delaying vortex breakdown to high angles of attack is by spanwise blowing. This concept consists of blowing a discrete jet spanwise over the wings upper surface in a direction essentially parallel to leading edge. The interaction of jet flow with leading edge results in formation and control of leading edge vortex with subsequent increase in lift.

First wind tunnel investigation obtained using surface pressure distribution on trapezoidal wing with leading edge sweep angle of 44 degree. Lift ,drag and pitching moment were measured in second test program on delta wing planform having 30 degree and 45 degree. The tests were conducted at mach number of about 0.2 with spanwise blowing from fuselage only no ductings on the wings. Data were aquired for range of angle of attack and jet thrust co efficient.

The method employs a jet of air that is blown spanwise along the upper surface of the wing essentially parallel to the leading edge along the wing span, approximately at the quarter chord line.

It was determined that a high speed jet could provide the necessary suction by means of its entrainment, acts like a line sink carries away the flow which has separated from leading edge and causes the flow to reattach after portion of wing downstream of jet therefore leading to the formation of the vortex .

II. DESIGN, FBRICATION AND TESTING

The fabrication of the NACA 4412 airfoil for span wise blowing is done on the basis of the design of the airfoil through plotting x and y coordinates and fabrication followed the procedure as: designing, wood cutting, tapping and finishing. The coordinates were marked and the fabrication was proceeded.

Figure 1. Fabricated 3D wing model

All the experiments and tests conducted on the swept wing model having aerofoil NACA4412 are done in the subsonic wind tunnel. The test section size of the wind tunnel is 600*600*2000mm with removable side windows. It is an open cycle, suction type wind tunnel which makes use of compressed air provided by the compressor. It has maximum speed of 50m/s. The inlet section of the wind tunnel is bell-mouth type. The resulting flow is represented in Figure 4.11 and Figure 4.12 for normal and spanwise blowing respectively.

Figure 2. Smoke flow over the wing without spanwise blowing

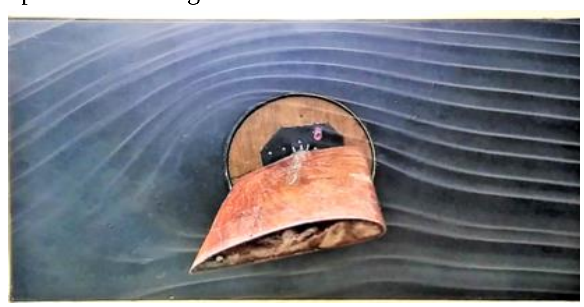

Figure 3. Smoke flow visualization of wing with spanwise blowing

III. RESULTS AND DISCUSSION

A swept back wing with and without span-wise blowing had been tested in the wind tunnel where the experimental results are shown in the tables below , which contain the Co-efficient of Lift , Co-efficient of Drag and Lift to Drag ratio from angle of attack 0 to 20◦ for a streamline velocity of 15 m/s.

Table 1: Wind tunnel testing of Normal and spanwise blowing on sweptback wing at chord 12.5

Angle of Attack (Degrees)	Co-efficient of Lift (C_l) for normal	Co-efficient of Lift (C_l) for spanwise blowing	Lift to Drag ratio for normal	Lift to Drag ratio for Spanwise blowing
0	0.030769	0.030769	-	-
5	0.46	0.3	11.23338	11.4504
10	0.49	0.45	5.721938	5.58276
15	0.44	0.53	3.676471	4.14264
20	0.26	0.48	2.745881	2.6178

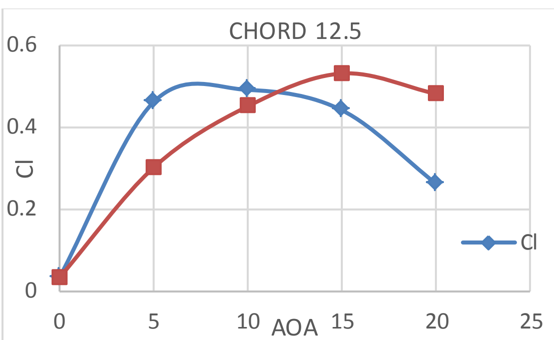

Figure 4: Co-efficient of Lift for Normal and spanwise blowing on sweptback wing

The Figure 4 shows that for small angle of attack, there is no significant increase in the C_l value, which indirectly indicates that during cruising, where the angle of attack is small spanwise blowing need not be used. During landing phase, where the angle of attack is high and at lower speed, if blowing is done over the wing leading edge higher life coefficient is obtained.

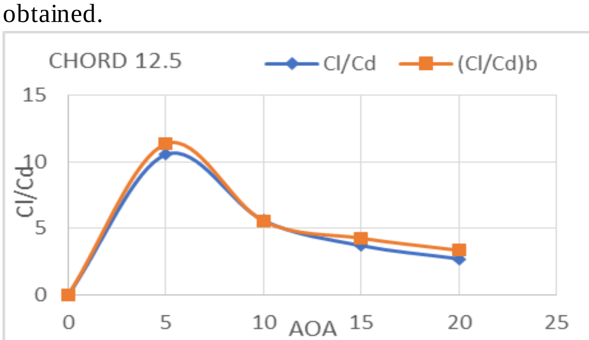

Figure 5: Lift to Drag ratio for Normal and spanwise blowing on sweptback wing

The Figure 5 shows that lift to drag ratio of spanwise blowing is greater throughout the range of angle of attack than without blowing. Where (Cl/Cd)b and (Cl/Cd) lift to drag ratio of spanwise blowing and without blowing respectively.

Table 2: Wind tunnel testing of Normal and spanwise blowing on sweptback wing at chord 11

Angle of Attack (Degrees)	Co-efficient of Lift (C_l) for normal	Co-efficient of Lift (C_l) for spanwise blowing	Lift to Drag ratio for normal	Lift to Drag ratio for Spanwise blowing
0	0.108423	0.108423	-	-
5	0.49	0.3	11.23338	11.45038
10	0.47	0.57	5.721938	5.582762
15	0.53	0.51	3.676471	4.142637
20	0.22	0.2	2.745881	2.617801

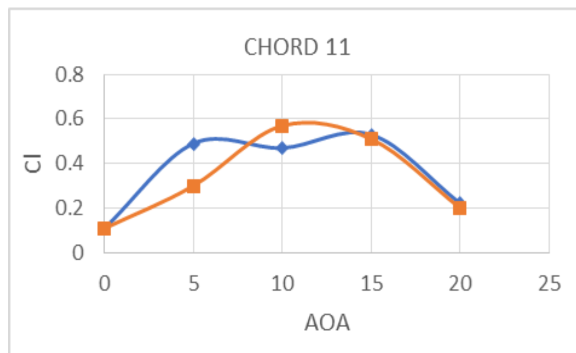

Figure 6: Co-efficient of Lift for Normal and spanwise blowing on sweptback wingThe Figure 6 which is similar to C_l versus angle of attack graph of chord 12.5. Here both C_l and stalling angle are increasing for spanwise blowing. This shows that leading-edge vortex breakdown is reduced and boundary layer separation is delayed than without spanwise blowing.

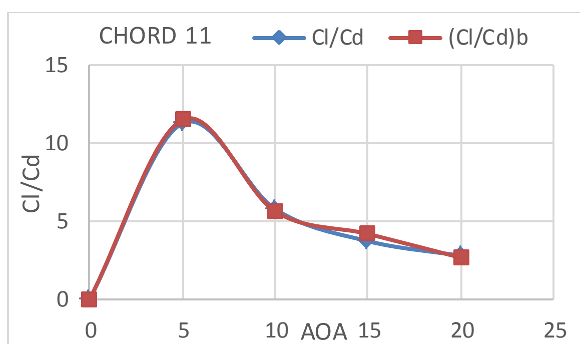

Figure 7: Lift to Drag ratio for Normal and spanwise blowing on sweptback wing

From the Figure 7, the spanwise blowing and without the $C_{l/Cd}$ is not increasing. This means with blowing higher lift is produced with increase in drag also. This is advantageous during landing. Hence separate flap actuation systems (which increase the weigh) can be replaced by spanwise blowing system.

Table 3: Wind tunnel testing of Normal and spanwise blowing on sweptback wing at chord 9

Angle of Attack (Degrees)	Co-efficient of Lift (C_l) for normal	Co-efficient of Lift (C_l) for spanwise blowing	Lift to Drag ratio for normal	Lift to Drag ratio for Spanwise blowing
0	0.216154	0.216154	-	-
5	0.39	0.26	11.327	11.30926
10	0.45	0.62	5.553088	5.893536
15	0.42	0.63	5.553088	5.609973
20	0.22	0.44	2.718063	3.218256

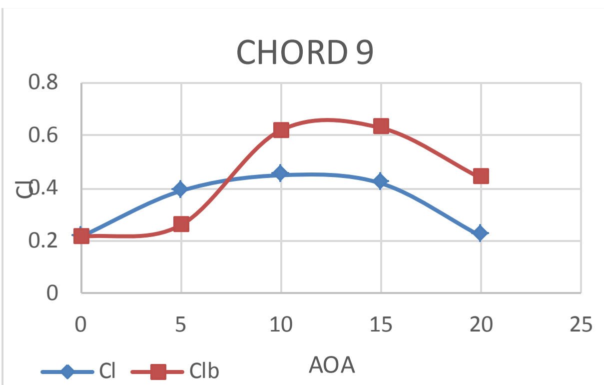

Figure 8: Co-efficient of Lift for Normal and spanwise blowing on sweptback wing

For a blowing velocity of 15 m/s, Figure 8 shows higher lift than the wing without blowing.

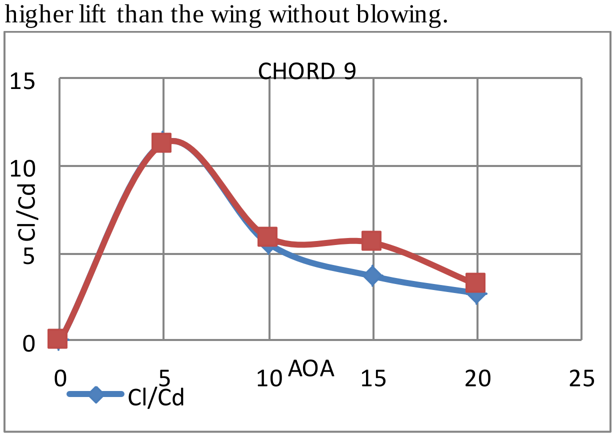

Figure 9: Lift to Drag ratio for Normal and spanwise blowing on sweptback wing

The experimental analysis show that the spanwise blowing has lower co-efficient of lift than the normal when it is at angle of attack 5 degree, but as the angle of attack increases the spanwise blowing shows an improvement in C_l with respect to normal as the spanwise blowing not only keeps the flow energized but also delays the boundary layer separation. This is why it can be clearly be seen that the spanwise blowing can still generate lift for higher angle attack.

IV. CONCLUSION

To find the maximum performance of the wing, it should be tested in a wind tunnel at different angles of attack. From the above discussion Lift and Drag coefficients are taken from the wind tunnel by performing certain calculations.

The present investigations was conducted to measure the effects of spanwise blowing on the pressure of 30^o sweptback wing. Wind-tunnel data were obtained at free-stream mach number of 0.04 for a range of model angel of attack and optimized jet velocity and nozzle chord-wise location of 9.8m/s and 3.6cm(from root leading edge) respectively.

- Spanwise blowing delays the vortex breakdown to larger span distance and hence increases the lifting pressures.
- The flow gradients resulting from blowing are favourable for the formation and control of the leading-edge vortex and thereby increasing overall vortex lift at higher angle of attack.
- It is seen that stalling angle and co-efficient of lift of spanwise blowing is more when compared with spanwise blowing, hence better landing can be attained.
- In todays practice aircrafts use high-lift devices such as flaps, slats and boundary layer suction to increase Cl during takeoff and landing. High-lift devices increase Cl, as well as simultaneous drag. Since they have moving parts, they also increase complexity. Whereas spanwise blowing reduces the complexity and overall weight of the aircraft.

V. SCOPE FOR FUTURE WORK

Theoretical program as per reference [12] can be done to generate vortex lift.

To better interpret these experimental result theoretical estimates of section lift characteristics can be made by using leading edge suction analogy developed by polhamus[12].

Introducing this concept in the fighter aircraft design offers the possibility of increasing excess power for manoeuvring at high load factors (during high rate of angular rotation).

REFERENCES

[1] Polhamus, Edward c.: A Concept of the Vortex Lift of Sharp-Edge Delta Wings Based on a Leading-Edge-Suction Analogy. NASA TN D-3767, 1996.

[2] Polhamus, Edward c.: Application of the Leading-Edge-Suction Analogy of Vortex Lift to the Drag Due to Lift of Sharp-Edge Delta Wings. NASA TN D-4739, 1968

[3] Wentz, William H., Jr.; and Kohlman, David L.: Wind Tunnel Investigations of Vortex Breakdown on Slender Sharp-Edged Wings. Rep. FRL 68-013 (Grant NGR-17-002-043), Univ. Of Kansas Center for Research, Inc., Nov. 27, 1969. (Available as NASA CR-98737.)

[4] Cornish, J. J., III: High Lift Applications of Spanwise Blowing. ICAS paper No. 70-09, Sept. 1970.

[5] Dixon, C. J.: Lift augmentation by Lateral Blowing over a Lifting Surface. AIAA Paper No. 69-193, Feb. 1969.

[6] Dixon, C. J.: Lift and Control Augmentation by Spanwise Blowing Over Trailing Edge Flaps and Control Surfaces. AIAA Paper No. 72-781, Aug. 1972.

[7] Erickson, Gary E.; and Campbell, James F,: Augmentation of Maneuver Performance by Spanwise Blowing. NASA TM X-73998, 1977.

[8] Campbell, James F.: Effects of Spanwise Blowing on the Pressure Field and Vortex-Lift Characteristics of a 44^{O} Swept Trapezoidal Wing. NASA TN D-7907, 1975.

[9] Polhamus, E.C., Predictions of vortex lift characteristics by a leading edge suction analogy, journal of aircraft, vol.8,no.4,april 1971,pp.193-199.

[10] Bradley, R. G.,S mith, C.W., and Wray ,W.O., An experimental investigation on leading edge vortex augmentation by blowing, CR-132415,April 1974,NASA.

[11] Erickson, G.E, and Campbell, J.F., Flow visualization of leading edge vortex enhancement by spanwise blowing, TM X-72702, July 1975, NASA.

[12] Bradley, R.G., and Wray, W.O., A conceptual study of leading edge vortex enhancement by blowing, Journal of aircraft, Vol.11, no.1, Jan.19744, pp. 34-38.