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Enhancement of Lift to Drag Ratio of an Airfoil by Using Continuous Normal Suction

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Abstract- *An experimental work of continuous normal suction from the wing upper surface effects on the aerodynamic forces is carried out in this thesis. The effect of normal suction slot channels location and the mass flow rate sucked strength are also involved in this study. The wing model with NACA-0015 has been made to achieve normal suction from the wing upper surface by means of four slot channels. Suction is done by using vacuum pump. The tests are to be done for incompressible flow over wing with and without a continuous normal suction for five different angle of attack 0, 4, 8, 12 and 16 degree and for three different Reynolds numbers* 3.9×10^5, 4.58×10^5 *and* 5.25×10^5. *The results showed that the continuous normal suction can significantly increase the lift to drag force ratio.*

Keywords: Airfoil, Suction, Injection, Aerodynamics

1. INTRODUCTION

An airfoil is the shape of a wing, blade or sail [4]. An airfoil-shaped body moved through air produces an aerodynamic force. The component of this force perpendicular to the direction of motion is called lift [1]. The component parallel to the direction of motion is called drag [1]. The lift on an airfoil is primarily the result of its angle of attack and shape. When oriented at a suitable angle, the airfoil deflects the oncoming air resulting in a force on the airfoil in the direction opposite to the deflection. This force is known as aerodynamic force [2]. The NACA airfoils are airfoil shapes for aircraft wings developed by the National Advisory Committee for Aeronautics (NACA). The shape of the NACA airfoils is described using a series of digits following the word "NACA" [5]. The parameters in the numerical code can be entered into equations to precisely generate the cross-section of the airfoil and calculate its properties [3]. The NACA 0015 airfoil is symmetrical, the 00 indicating that it has no camber. The 15 indicates that the airfoil has a 15% thickness to chord length ratio [4][6][7]. NACA 0015 is one of the most common four digits and broadly used as aerodynamic shape. The shape is extensively used for various kind of applications including turbine blade, aircraft wing and so on [8][9]. In this thesis report experimental operation will be done to enhance the lift-drag ratio by using continuous normal suction.The use of continuous wall-normal suction and blowing from upper and lower surface of the airfoil, respectively, is an effective idea to prevent or delay the flow separation and enhance airfoil wake flow structure[10]. In this work, an experimental investigation has been done to study the continuous normal suction effect of air flow from the upper surface of wing on the lift and drag coefficients and their ratio.

2. EXPERIMENTAL SETUP AND PROCEDURE

In this work, an experimental investigation has been done to study the continuous normal suction effect of air flow from the upper surface of wing on the lift and drag coefficients and their ratio. All tests have been done, using a subsonic wind tunnel in the department of mechanical engineering, Khulna University of Engineering and Technology. The wooden wing model (airfoil NACA-0015) with wing spans 95mm and chord of 200mm. This wing was made to achieve normal suction from the wing upper surface by means of four slot channels.The pressure tubes were used to measure the surface pressure of the wing, which was attached to the sensors.

Fig 1: Experimental setup for measuring surface pressure on wind tunnel.

Fig 2: Experimental setup for measuring surface pressure on wind tunnel.

In this experiment subsonic wind tunnel and pressure measuring instruments were used as required apparatus. The constructed model was placed in the testing section of the wind tunnel. The upper surface of the model was drilled through 1.5 mm and small diameter tubes were placed on those drill. The tubes were connected to the sensor and aero lab measurement system. Then for different motor speed with respect to different angle of attack the value of static pressure on the upper surface were taken.

Fig-3 : Mini vacuum pump for continuous normal suction operation.

Lift and drag coefficient can be obtained as follows:

$$C_L = \frac{1}{C}\int_0^C (C_{p,l} - C_{p,u})\,dx \quad [5][6][9]$$

$$C_D = \frac{1}{C}\int_0^C \left(C_{p,l}\frac{dy}{dx} - C_{p,u}\frac{dy}{dx}\right) \quad [5][6][9]$$

Pressure coefficient is defined as:

$$C_P = \frac{P - P\alpha}{\frac{1}{2}\rho v^2} \quad [5][6][9]$$

3. CAD MODEL

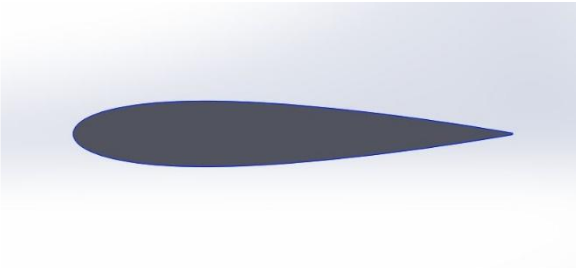

Fig 4: Model of NACA 0015.

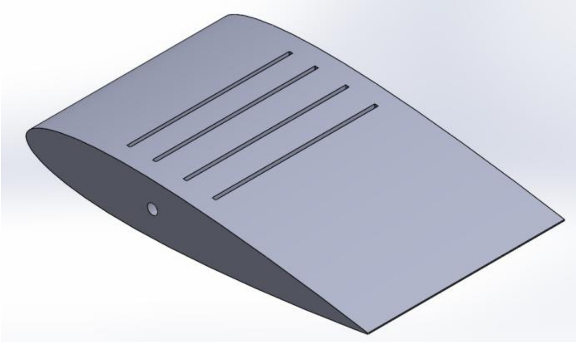

Fig 5: 3D model of NACA 0015.

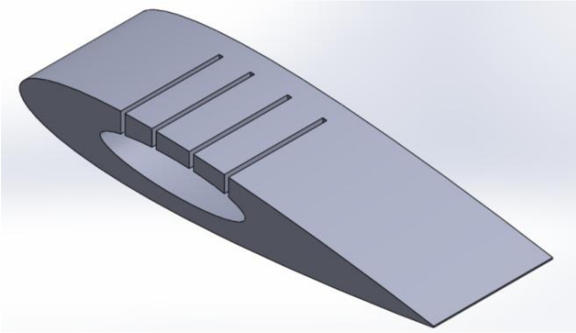

Fig 6: Cross section of NACA 0015.

4. RESULT AND DISCUSSION

4.1. Pressure Distribution at Different Angle of attack without Normal suction

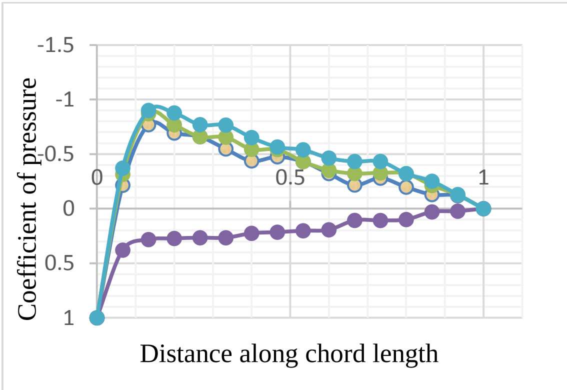

Fig 7: Pressure distribution at 0 degree angle of attack without suction.

This figure shows the relationship of pressure distribution along the chord length for different Reynolds number as 3.9×10^5, 4.58×10^5 and 5.25×10^5. The coefficient of pressure were found to be almost constant for different Reynolds number.

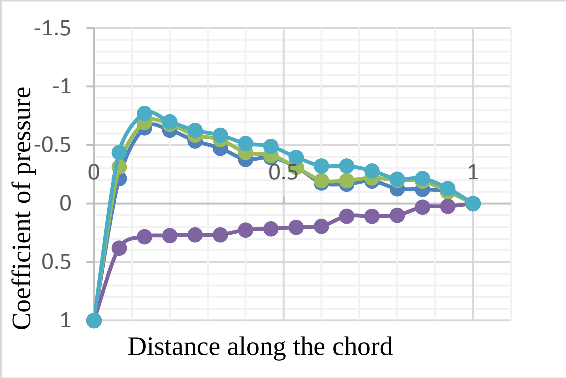

Fig 8: Pressure distribution at 8 degree angle of attack without suction.

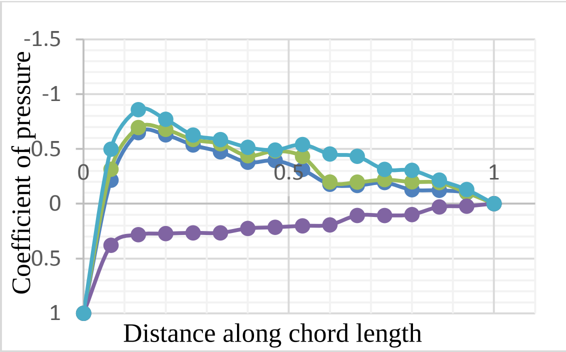

Fig 9: Pressure distribution at 12 degree angle of attack without suction

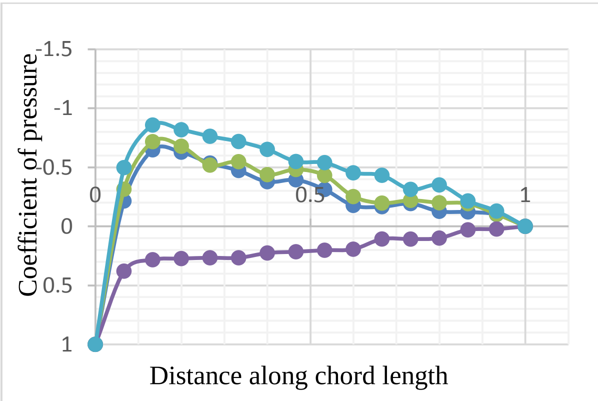

Fig 10: Pressure distribution at 16 degree angle of attack without suction.

The coefficient of lift is increased as the increase of angle of attack. The above results were found for different angle of attack and different Reynolds number for without continuous normal suction. For these same parameters the reults for continuous normal suction are as follows:

4.2. Pressure Distribution at different Angle of attack with Normal suction

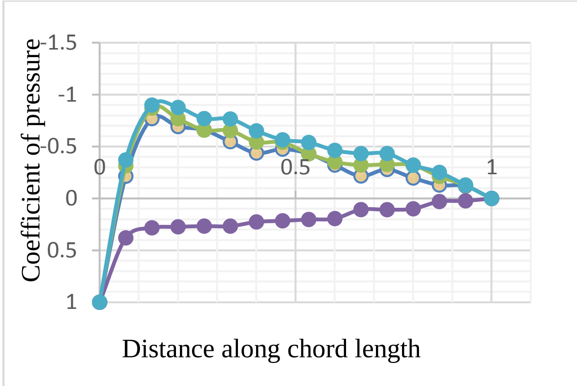

Fig 11: Pressure distribution at 0 degree angle of attack with suction.

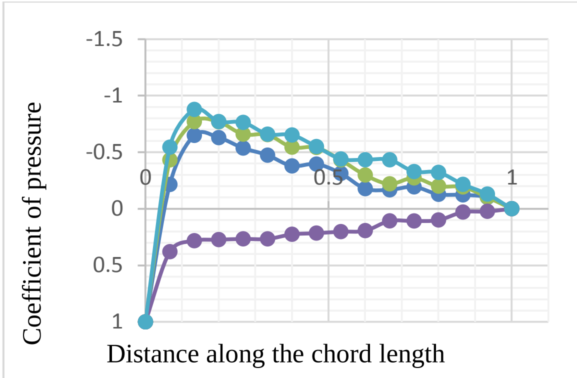

Fig 12: Pressure distribution at 8 degree angle of attack with suction.

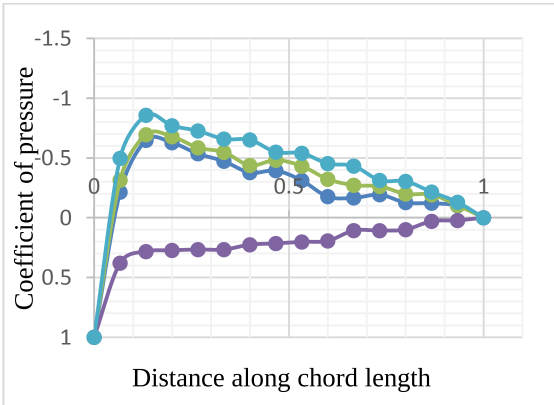

Fig 13: Pressure distribution at 12 degree angle of attack with suction.

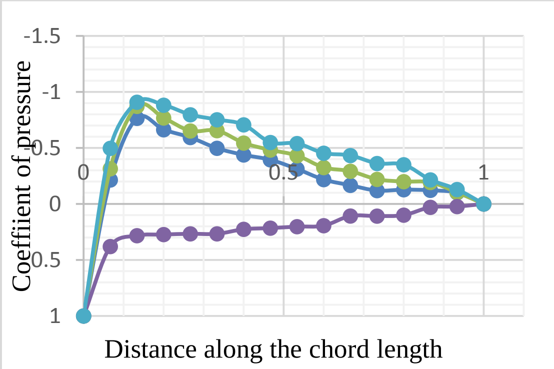

Fig 14: Pressure distribution at 16 degree angle of attack with suction.

4.3. Coefficient of Lift with Reynolds Number at different Angle of attack with and without Normal suction

Now the variations of coefficient of lift along with the Reynolds numbers for with and without continuous normal suction are shown as follows:

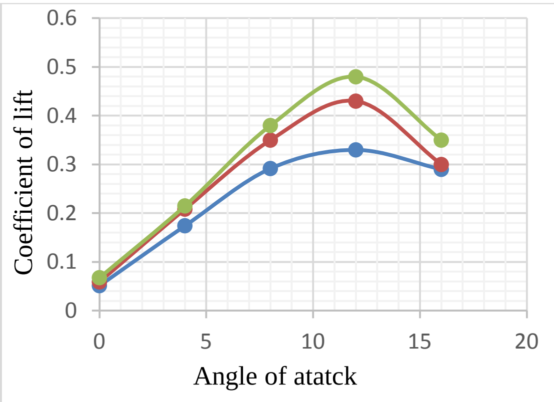

Fig 15: Coefficient of lift vs angle of attack for different Reynolds number at without normal suction

As the Reynolds number increases the magnitude of coefficient of lift is also increased. Reynolds number has a positive effect on coefficient of lift.

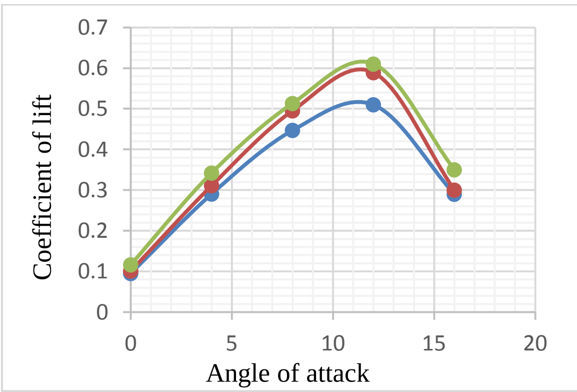

Fig 16: Coefficient of lift vs angle of attack for different Reynolds number with continuous normal suction.

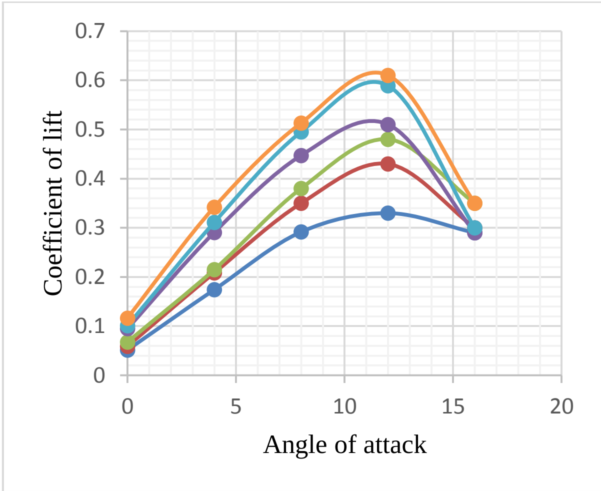

Fig 17: Comparison of coefficient of lift vs angle of attack for with and without continuous normal suction.

In the figure the upper three coefficient of lift curves are found for with normal suction and the rest of the curves are found for without suction. It has been found that by using continuous normal suction the coefficient of lift curve increases more rather than without normal suction.

4.4. Coefficient of Drag with Reynolds Number at different Angle of attack with and without Normal suction

Now the effect of Reynolds number on the drag coefficient is shown below:

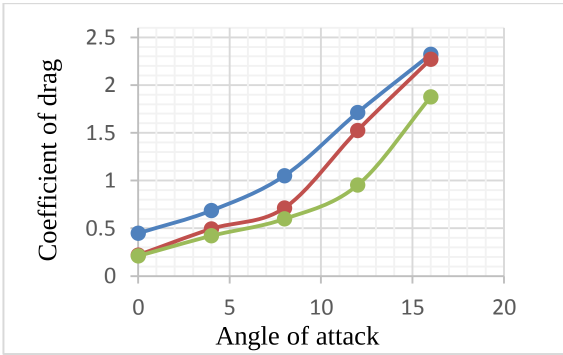

Fig 18: Coefficient of drag vs angle of attack for different Reynolds number at without normal suction.

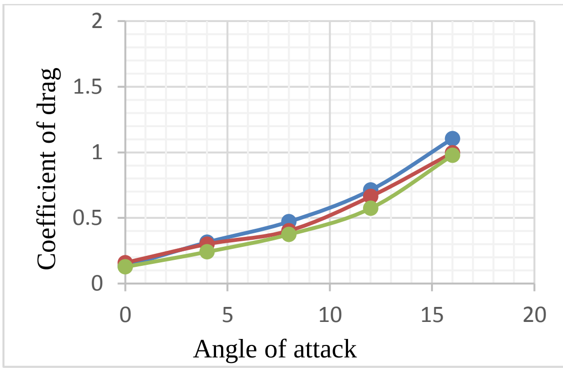

Fig 19: Coefficient of drag vs angle of attack for different Reynolds number with normal suction.

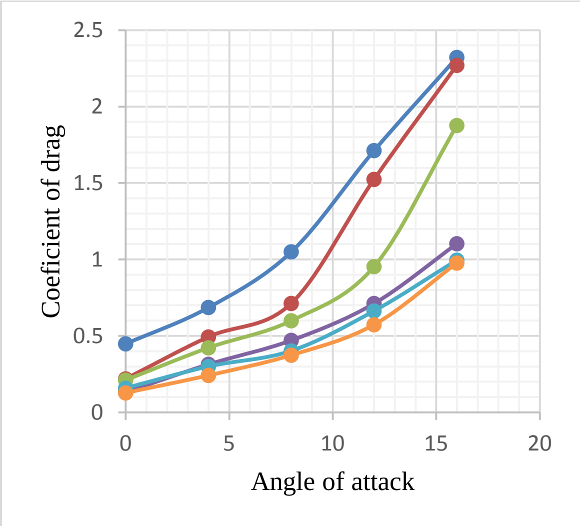

Fig 20:Comparison of Coefficient of drag vs angle of attack for differentReynolds number for with and without suction

Reynolds number has a negative effect on coefficient of drag. The magnitude of drag coefficient is largaer for without suction than for with normal suction.

4.5. Ratio of Coefficient of Lift to Drag with Reynolds Number at different Angle of attack with and without Normal suction

The ratio of lift to drag ratio will increase for the larger Reynolds number. The correponding graphs are shown below:

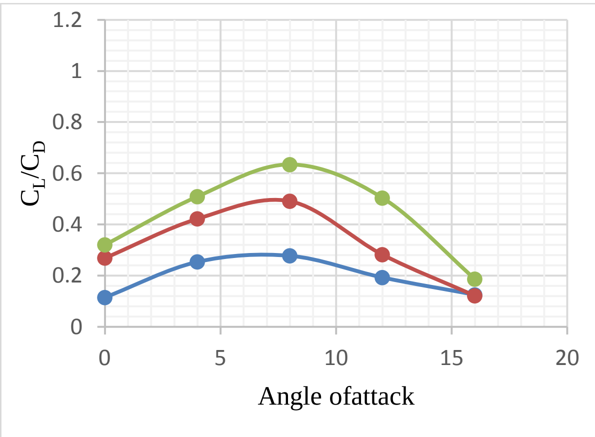

Fig 21: C_L/C_D vs angle of attack for without suction.

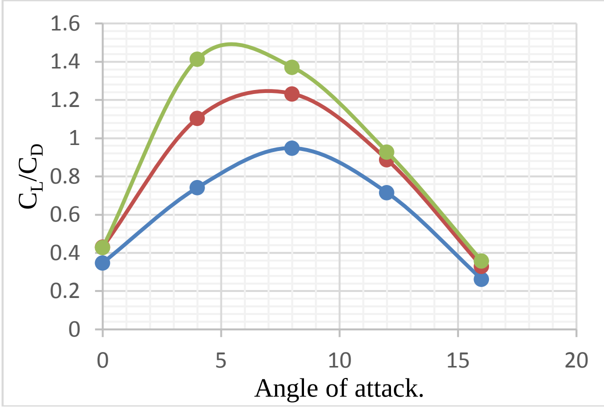

Fig 22: C_L/C_D vs angle of attack for with suction.

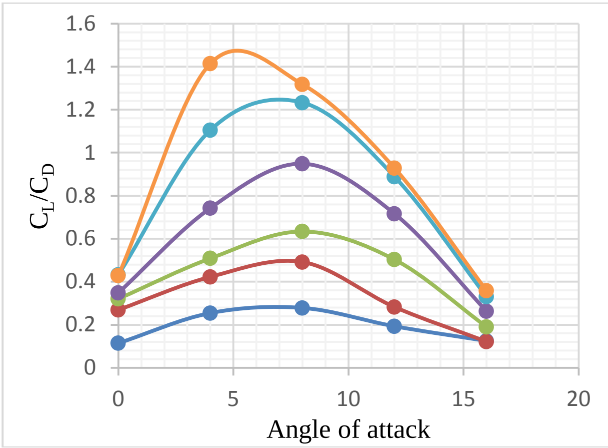

Fig 23: Comparison of C_L/C_D vs angle of attack for different Reynolds number for with and without suction.

5. CONCLUSION

After completing the experiment, it can be found that,

a. The continuous normal suction from the upper surface of the wing has positive effect on the lift coefficient.

b. The lift coefficient increased due to suction and as the magnitude of suction increases the lift coefficient is increasing more.

c. However, the suction has a negative effect on the drag coefficient, its values increase as the magnitudes of suction increase.

d. The effect of suction on the lift to drag coefficient ratio has a positive effect, as it can be seen that the ratios of lift coefficient to drag coefficient increase with suction.

e. As the Reynolds number increases, the ratio of lift to drag coefficients ratio are increased.

Finally, it can be conclude from this current study that in the case of present suction lead to significant increase in the ratio of lift coefficient to drag coefficient and this ratio play an important role in the aircraft flight characteristics (including take off and landing velocity, airport runway distance, aircraft maneuver and fuel consumption

6. ACKOWLEDGEMENT

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8. NOMENCLATURE

Symbol	Meaning
C_L	Coefficient of Lift
C_D	Coefficient of Drag
P	Pressure