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PASSIVE FLOW SEPARATION CONTROL BY STATIC EXTENDED TRAILING EDGE

Mahfuja Akter[1,*], Md. Tanvir Ibne Gias[2], Rubiat Mustak[3] and Mohammad Mashud[4]

[1-4]Department of Mechanical Engineering, Khulna University of Engineering & Technology, Khulna-9203, BANGLADESH
[1,*]Mousumi069@gmail.com, [2]liton0705012me@yahoo.com, [3]rubiatpantho@gmail.com, [4]mdmashud@yahoo.com

Abstract*- The experiment was about to enhance the lift of NACA0012 airfoil with static extended trailing edge. A thin sheet was introduced to the wing trailing edge as a mechanical device without changing basic configuration of the wing. Calculations were done to compare the coefficient of lift using static extended trailing edge with those of using flap. The geometrical quantities, chord distribution and other properties are given in convenient analytical expressions.*

Keywords: Aerodynamics, trailing edge, airfoil, lift, drag.

1. INTRODUCTION

A force that must be generated to fly an airplane is called lift. It is the force that is stronger than the weight force and perpendicular to the direction of the airflow.
The primary concern of aerodynamics is to increase lift. Flaps and slats are the conventional lift enhancement device. But drag is also increase with increasing lift in conventional flaps. Introduction of small trailing edge devices have attracted considerable attention for lift enhancement. Small trailing edge devices like Gurney flaps, mini flaps or thin metallic sheet can be used for this purpose. The Gurney flap was introduced by Liebeck for aeronautical applications, and considerable measurements and calculations have been performed to determine the aerodynamic characteristics of wings with Gurney flaps [1]. Measurements of avian wing geometry for extracting typical avian airfoil sections indicate that the merganser and owl wings have a very thin trailing edge that is a single layer of feathers extended from a 'normal' airfoil section [2]. In this project static extended trailing edge is used to increase lift. By using static extended trailing edge (SETE) the main airfoil element remains unchanged, but it is extended at the trailing edge by attaching a thin splitting plate of suitable length. The extension can be an aluminum plate, composite sheet or any rigid material plate. As there is no change in trailing edge element and no vibration is induced, it is called static extended trailing edge (SETE). The effects of SETE on the wing aerodynamics are mainly due to modifications of the airfoil camber and the lift enhancement by SETE is expectedly due to the camber effect.

2. THEORITICAL ASPECTS

2.1 High Lift Device

In aircraft design, a high-lift device is a component or mechanism which increases lift beyond that obtainable from the main aircraft components. The device may be a fixed component or a movable mechanism which is deployed when required. Common high-lift devices include wing flaps and slats. Less commonly used systems are leading edge root extensions and boundary layer control systems. High-lift devices allow the use of a more efficient wing in flight, while adding lift for takeoff and landing. To achieve reasonable field performance while also obtaining efficient transonic cruise a fairly sophisticated high lift system is required [3].

2.2 Flaps

The most common high-lift device is the flap, a movable portion of the wing that can be lowered to produce extra lift. When a flap is lowered this re-shapes the wing section to give it more camber. Flaps are usually located on the trailing edge of a wing, while leading edge flaps are used occasionally. There are many kinds of trailing-edge flap. In the split flap, the lower surface hinges downwards while the upper surface remains either fixed to the wing or moves independently. Slotted flaps comprise several separate small airfoils which separate apart, hinge and even slide past each other when deployed. Such complex flap arrangements are found on many modern aircraft [4]. Large modern airliners make use of triple-slotted flaps to produce the massive lift required during takeoff. The Gurney Flap is a small tab projecting from the trailing edge of a wing [7]. Typically it is set at a right angle to the pressure side surface of the airfoil [4], and projects 1% to 2% of the wing chord [5].

2.3 Slats

Another common high-lift device is the slat, a small airfoil shaped device attached just in front of the wing leading edge. The slat re-directs the airflow at the front of the wing, allowing it to flow more smoothly over the upper surface when at a high angle of attack. This allows the wing to be operated effectively at the higher angles required to produce more lift. A slot is the gap between the slat and the wing [5]. The slat may be fixed in position, with a slot permanently in place behind it, or it may be retractable so that the slot is closed when not required. If it is fixed, then it may appear as a normal part of the leading edge of a wing, with the slot buried in the wing surface immediately behind it. Large modern airliners make use of triple-slotted flaps to produce the massive lift required during takeoff.

A slat or slot may be either full span, or may be placed on only part of the wing.

2.4 Extended Trailing Edge

Lift can be increased by extending the trailing edge. The extension can be an aluminum plate, polymer membrane, composite sheet or smart material plate [6].

2.5 Wind Tunnel

A wind tunnel is a tool used in aerodynamics research to study the effects of air moving past solid objects. A wind tunnel consists of a tubular passage with the objects under test mounted in the middle. Air is made to past the object by a powerful fan system or other means. The test objects, often called a wind tunnel model is instrumented with suitable sensors to measure aerodynamics forces, pressure distribution, or other aerodynamics- related characteristics. The earliest wind tunnels were invented towards the end of the 19th century, in the early days of aeronautic research, when many attempted to develop successful heavier-than-air flying machines. The wind tunnel was envisioned as a means of reversing the usual paradigm: instead of the air standing still and an object moving at speed through it, the same effect would be obtained if the object stood still and the air moved at the speed past it. In that way a stationary observer could study the flying objects in action and could measure the aerodynamics forces being imposed on it. The development of wind tunnels accompanied the development of the airplane. Large wind tunnels were built during the Second World War. Wind tunnel testing was considered of strategic importance during the Cold War development of supersonic aircraft and missiles. Later on, wind tunnel study came into its own: the effects of wind on man-made structures or objects needed to be studied when buildings became tall enough to present large surfaces to the wind, and the resulting forces had to be resisted by the building's internal structure. Determining such forces was required before building codes could specify the required strength of such buildings and such tests continue to be used for large or unusual buildings.

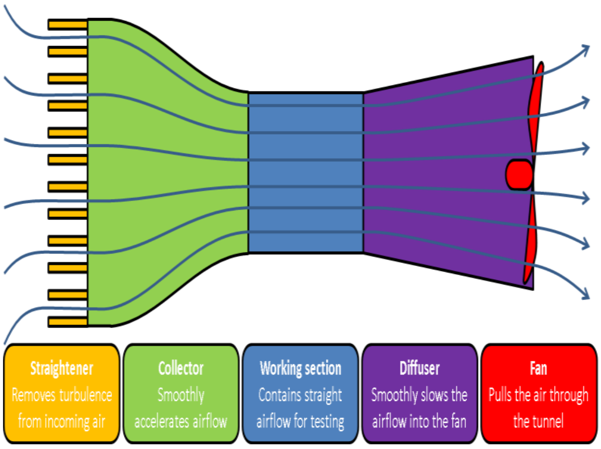

Fig.1: Various Parts of Typical Wind Tunnel.

Still later, wind-tunnel testing was applied to automobiles, not so much to determine aerodynamic forces per sec but more to determine ways to reduce the power required to move the vehicle on roadways at a given speed. In these studies, the interaction between the road and the vehicle plays a significant role, and this interaction must be taken into consideration when interpreting the test results. In an actual situation the roadway is moving relative to the vehicle but the air is stationary relative to the roadway, but in the wind tunnel the air is moving relative to the roadway, while the roadway is stationary relative to the test vehicle. Some automotive-test wind tunnels have incorporated moving belts under the test vehicle in an effort to approximate the actual condition, and very similar devices are used in wind tunnel testing of aircraft take-off and landing configurations. The advances in computational fluid dynamics (CFD) modelling on high speed digital computers has reduced the demand for wind tunnel testing. However, CFD results are still not completely reliable and wind tunnels are used to verify the CFD computer codes.

3. MODEL CONSTRUCTION

A wooden NACA0012 airfoil section model was used in the experiment. The chord and span of the model were 30 cm and 30 cm. along the wing span, a 6 cm long Galvanized Iron (GI) sheet was mounted to the baseline model with 2 screws for clamping SETE at the trailing edge, and they can be easily removed to place extended trailing edges of different material.

A flap of 6 cm chord and profile of NACA0012 was attached along the wingspan.

Figure-2 shows the NACA0012 airfoil model attached with a Galvanized Iron (GI) static extended trailing edge.

In order to support the model, the end parts were attached to the clamp, which were mounted on the wind tunnel.

Fig.2: NACA0012 airfoil model attached with a Galvanized Iron (GI) static extended trailing edge.

4. EXPERIMENTAL SETUP

Fig.3: Airfoil with extended trailing edge inside wind tunnel

5. EQUATIONS

Coefficient of pressure can be calculated as,

$$Cp = (p - p_\infty)/q_\infty \quad (1)$$

Where,

p = Pressure at any point

p_∞ = Pressure at standard condition

q_∞ = Dynamic pressure

$= (½)\ \rho_\infty V_\infty^2$

ρ_∞ = Density of air

V_∞ = Velocity of air

Coefficient of lift can be calculated as,

$$C_L = (1/c) \int (Cp_l - Cp_u)\, dx \quad (2)$$

Where,

Cp_l = Coefficient of pressure at lower surface

Cp_u = Coefficient of pressure at upper surface

c = Chord length

x = 0 to c

Thus lift can be calculated as,

$$L = q_\infty S\, C_L \quad (3)$$

Where,

q_∞ = Dynamic pressure

S = Wing area

C_L = Coefficient of lift

Induced drag coefficient can be calculated as,

$$C_D = C_L^2/ (\pi e AR) \quad (4)$$

Where,

e = Span efficiency

AR = Aspect ratio

$= b^2/S$

b = Wing span [8]

6. RESULTS

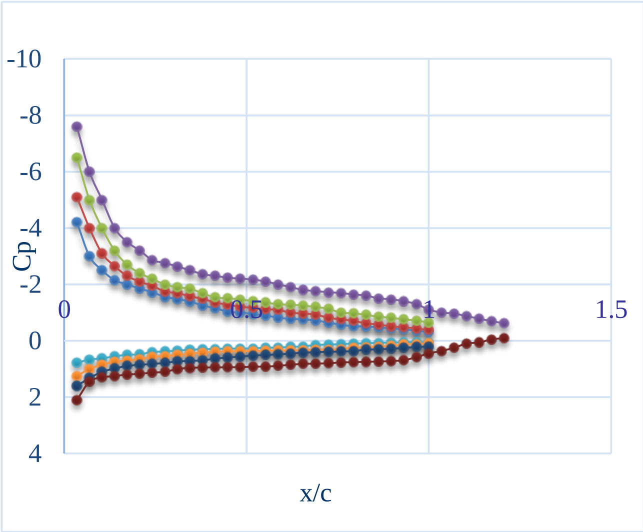

Fig.4 (a): Coefficient of pressure vs distance for 10 degree AOA

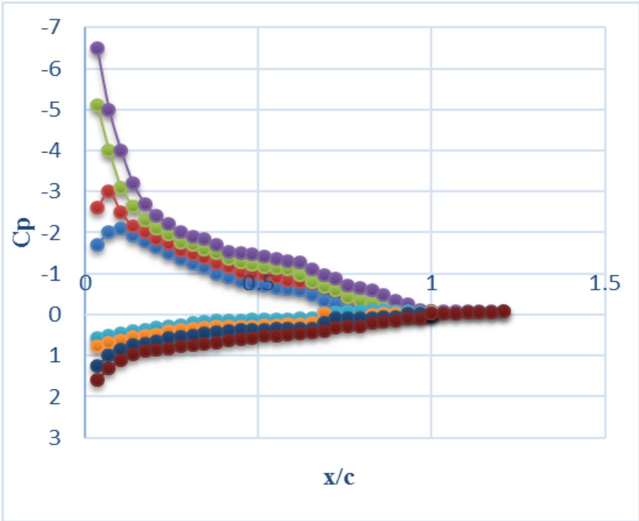

Fig.4(b): Coefficient of pressure vs distance for 12 degree AOA

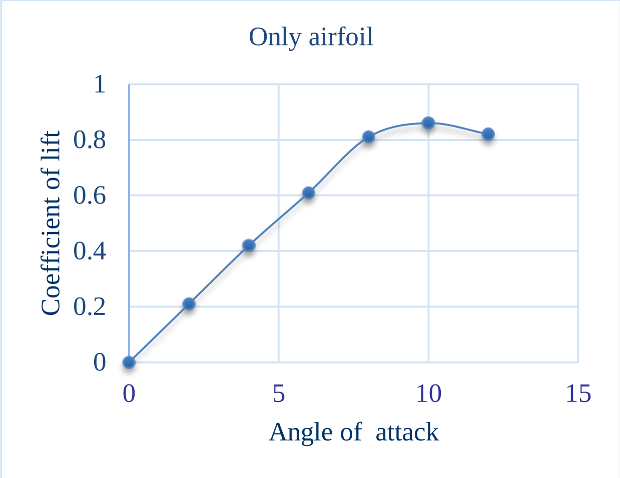

Fig.5(a): Coefficient of lift vs AOA for NACA0012 airfoil

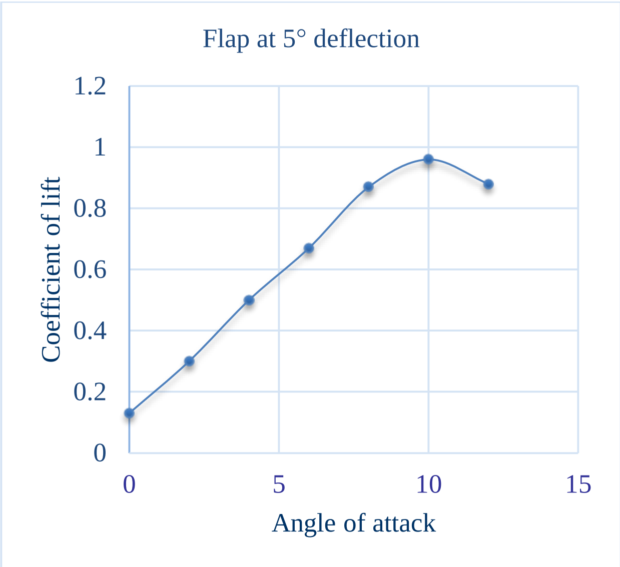

Fig.5(b): Coefficient of lift vs AOA for airfoil attached with flap at 5 degree deflection angle

Fig.5(c): Coefficient of lift vs AOA for airfoil attached with flap at 10 degree deflection angle

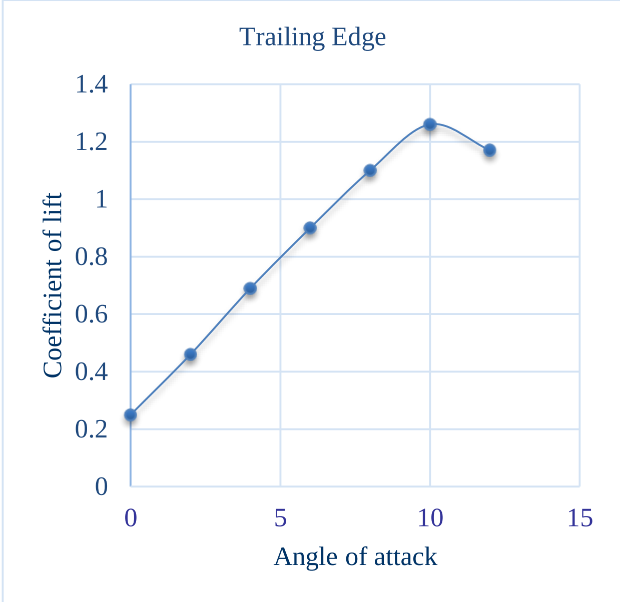

Fig.5(d): Coefficient of lift vs AOA for airfoil attached with SETE

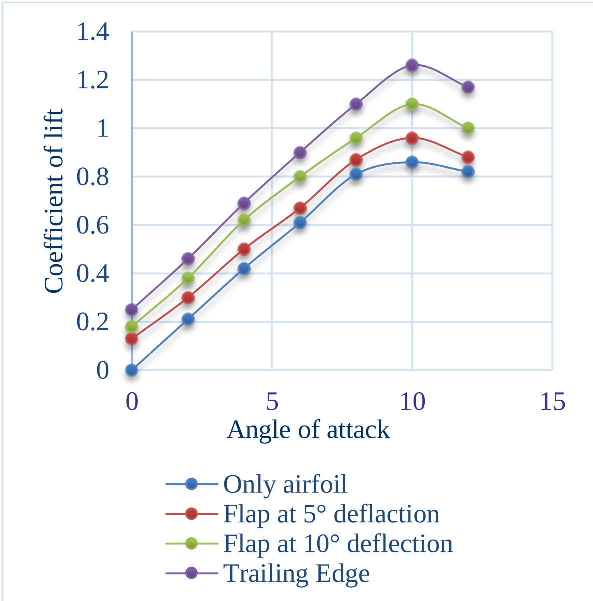

Fig.6: Comparison of coefficient of lift for only airfoil, airfoil attached with flap and airfoil attached with SETE

Figure 4(a) represents coefficient of pressure curve at an angle of attack where lift is maximum. Figure 4(b) represents coefficient of pressure curve at an angle of attack where stall occurs due to flow separation.
Figure 5(a), 5(b), 5(c) & 5(d) represents coefficient of lift curve for only airfoil, airfoil attached with flap at 5degree deflection angle, airfoil attached with flap at 10 degree deflection angle & airfoil attached with SETE respectively at different angle of attack.
Finally Figure-6 represents comparison of coefficient of lift. From the comparison it is seen that increase of lift is more in static extended trailing edge.

7. ACKOWLEDGEMENT

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8. REFERENCES

[1] Liebeck, R. H., "Design of Subsonic Airfoils for High Lift," Journal of Aircraft, Vol. 15, No. 9, 1978, pp. 547-561.

[2] Liu, T., Kuykendoll, K., Rhew, R. and Jones, S., "Avian Wing Geometry and Kinematics," AIAA Journal, Vol. 44, No. 5, 2006, pp. 954-963.

[3] Garner, P.L., Meredith, P.T., and Stoner, R.C., "Areas for Future CFD Development as Illustrated by Transport Aircraft Applications," AIAA Paper 91-1527, 1991.

[4] Van Dam, C.P.; Yen, D.T.; Vijgen, P. (1999). "Gurney flap experiments on airfoil and wings". Journal of Aircraft (0021-8669) 36 (2): 484–486. doi:10.2514/2.2461.

[5] Storms, B.L.; Jang, C.S. (1994). "Lift Enhancement of an Airfoil Using a Gurney Flap and Vortex Generators". Journal of Aircraft 31 (3): 542–547. doi:10.2514/3.46528.

[6] Tianshu Liu, J. Montefort, W. Liou, S. R. Pantula and Qamar A. Shams; "Static Extended Trailing Edge for Lift Enhancement: Experimental and Computational Studies," 3rd International Symposium on Integrating CFD and Experiments in Aerodynamics.

[7] Gai, S. L. and Palfrey, R., "Influence of Trailing-Edge Flow Control on Airfoil Performance," Journal of Aircraft, Vol. 40, No. 2, 2003, pp. 332-337.

[8] McCormick, B. W., "Aerodynamics, Aeronautics, and Flight Mechanics (Second Edition)," John Wiley & Sons, New York, 1995, p. 116.

9. NOMENCLATURE

Symbol	Meaning	Unit
L	Lift force	N
D	Drag force	N
C_l	Coefficient of lift	Dimensionless
C_d	Coefficient of drag	Dimensionless
v_∞	Free stream velocity	m/s
ρ_∞	Free stream density	kg/m^3
μ_∞	Free stream viscosity	m/s
α	Angle of attack	degree
T	Maximum thickness	m
C	Chord length	m
AOA	Angle of attack	degree