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EFFECT OF DIFFERENT SHAPED DIMPLES ON AIRFOILS

Rubiat Mustak[1,*], MD. Nizam Uddin[2] and Mohammad Mashud[3]

[1,2,3]Department of Mechanical Engineering, Khulna University of Engineering & Technology, Khulna-9203, Bangladesh
[1,*]rubiatpantho@gmail.com, [2]engrnizam02@gmail.com, [3]mdmashud@yahoo.com[3]

***Abstract**:- The present work describes change in aerodynamic characteristics of an airfoil by applying certain surface modifications in form of dimples. At first surface modifications that are considered here have outward and inward dimples on the wing model. A comparative study of modified airfoil models showing variance in lift and drag at different angle of attacks (AOA). The surface modifications are done here by considering the different types and shapes of dimples. Dimples help in reduction of pressure drag when airfoil attains some angle of attack because that time, wake formation starts due to boundary layer separation. Application of dimples on aircraft wing works in same manner as vortex generators. They create turbulence which delays the boundary layer separation and reduces the wake and thereby reducing the pressure drag. It's assist to enhance the lift and increase the Stall AOA. Dimples on the surface aircraft wing does not affect the pressure drag much since it is already aerodynamic in shape but it may affect its aerodynamics properties when the airfoil is at AOA that is one of the concern of this paper. A Subsonic wind tunnel (100×100×100 cm) is used to investigate the effect of using dimples over the airfoil surface (NACA-4415) having uniform cross-section along span. For design purpose solid works software is used. Three wooden Airfoil Models with outward and inward dimples and without dimples have been constructed here. From this experimental investigation it has been observed that the flow separation on the airfoil can be delayed by using the dimples on the upper surface and the lift force and stall AOA are also increased remarkably.*

Keywords: Airfoil, Angle of attack, Drag and Lift.

1. INTRODUCTION

From the beginning of human race, man has always dreamt of flying and on December 17, 1903 Wright brothers gave human race new wings and hoped for continuous endeavours in this field. Now we have progressed to great extent in air but still after so much has been done there are certain constraints binding us. Freedom in the air is still not complete. Continuous attempts are being made to increase freedom in air, be it speed, size or manoeuvrability. From commercial jetliners to supersonic fighters, there has been an exponential growth in the aviation industry. Still there is vast scope for further improvements. Here is a study that makes one such attempt.

At present, different kinds of surface modifications are being studied to improve the manoeuvrability of the aircraft. Vortex generators are the most frequently used modifications to an aircraft surface. Vortex generators create turbulence by creating vortices which delays the boundary layer separation resulting in decrease of pressure drag and also increase in the angle of stall. It helps to reduce the pressure drag at high angle of attack and also increases the overall lift of the aircraft.

The surface modifications which are being considered in the given study are dimples of types and shapes. Application dimples on aircraft wing model works in same manner as vortex generators. They create turbulence which delays the boundary layer separation and reduces the wake and thereby reducing the pressure drag. Flow separation begins to occur at small angles of attack while attached flow over the wing is still dominant. As angle of attack increases, the separated regions on the top of the wing increase in size and hinder the wing's ability to create lift. At the critical angle of attack, separated flow is so dominant that further increases in angle of attack produce less lift and vastly more drag. In order to verify the effect of dimples, the following experimental study has been made of inward and outward dimpled airfoil. Different kinds of dimples were considered. The long-term goal is to design and manufacture optimal vortex generators, outward dimples that can produce vortices of prescribed strength and duration for the real-time control of aerodynamic flows that are either undergoing transition or are fully turbulent, attached or separating. Through this study we aim at making aircrafts more manoeuvrable by dimpled airfoils. Also we are looking to improving performance by more L/D ratio i.e. increasing aerodynamic efficiency. Aerodynamic efficiency is one of the key parameters that determines the weight and cost of an aircraft. Roughly speaking, an aircraft's range is directly proportional to its aerodynamic efficiency without any increase in fuel usage. Improved aerodynamics is critical to both commercial and military aircraft. For commercial aircraft, improved aerodynamics reduces operating costs. It also significantly contributes to the national security by improving efficiency and performance of military aircraft. The results justify the increase in the overall lift and reduction in drag of the airfoil.

2. EXPERIMENTAL SET-UP AND PROCEDURE

Experiments were conducted in the Aerodynamics Laboratory of Department of Mechanical Engineering (Khulna University of Engineering & Technology) with subsonic wind tunnel of 1 m× 1 m rectangular test section. The wind tunnel could be operated at a maximum air speed of 43 m/s and the turntable had a capacity for setting an angle of attack of 45 degree. Figure -1 shows a schematic of the experimental set up. A small sized model is appropriate to examine the aerodynamic characteristics for the experiments. If we desire to examine the aerodynamic characteristics of a large model, a large scale wind tunnel facility is necessary for testing or the inflatable wing must be drastically scaled down to match the usual wind tunnel size violating the Reynolds number analogy requirements. Furthermore, it would be difficult to support the inflatable wing a desirable attitude in these wind tunnel experiments. Since the vertical part of the aerodynamic force produces the lifting force necessary to suspend the load. We are mainly interested in the aerodynamic characteristics of each model. The model was placed in the middle of the test section supported by flat iron bar. For the purpose of measuring the surface pressure a box consists of the sensors was placed outside of the wind tunnel test section. The surface of the model is drilled through 1.5 mm diameter holes and small sizes tubes are placed inside the drilled holes. Tubes having small diameter were used to connect between the tubes inside the model and the sensors of the aero lab measurement system. Surface pressure of the model at different points was measured. There is an angle measuring instrument to measure the angle of attack. For a constant motor speed of the wind tunnel, difference of the inside surface pressure of wind tunnel and the surface pressure of the model were measured. So finally the static surface pressure at different points on the surface of the model was obtained. For this experiment NACA 4415 airfoil profile has been selected for wing model construction. Three types of models were prepared shown in Figure-2. One is (a) Regular surface model, one is (b) Dimpled (Inward) surface model and last one is (c) Dimpled (Outward) surface model. All the models are prepared by wood. The chord of regular surface airfoils is 210 mm and the chord of dimpled surface airfoil is also 210mm.

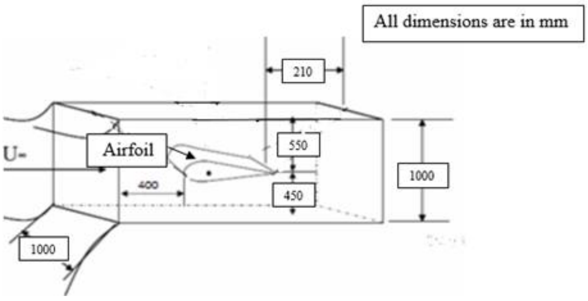

Fig .1: Schematic diagram of wind tunnel test section

Fig .2(a): Constructed model with regular surface

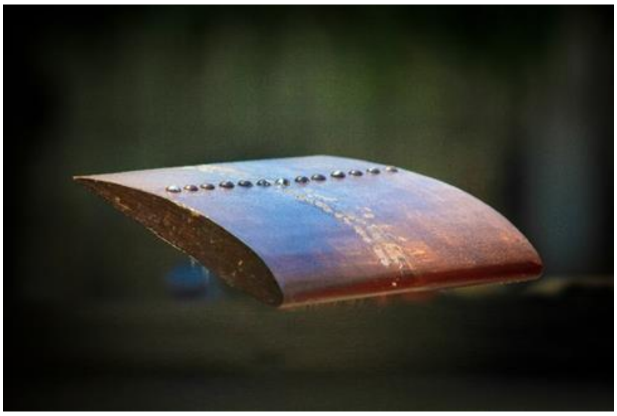

Fig .2(b): Constructed model with outward dimples

Fig.2(c): Constructed model with inward dimples

3. RESULTS & DISCUSSION

The experimental results of surface pressure distributions are shown in Figures 3 to 7 for regular and dimpled surface model. As shown in graph there is no flow separation occurs for both model (regular and dimpled) at zero attack angle. As the attack angle increased from 0° to 12°, flow separation occur at regular surface model. As the attack angle increased from 12° to 14° clear flow separation appeared on the upper surface. At angle of attack 12° flow remain attached with the upper surface in case of dimpled surface. At 16° angle of attack the flow is separated from the upper surface in case of dimpled surface. From the experimental investigations it has been observed that the flow separation on the airfoil can be delayed by using the dimples on the upper surface. Flow separation occurs at 12° angle of attack in the regular surface. But for surface having dimples it occurs at 16° angle of attack. That indicates the surface having dimples successfully controls the flow separation and increases the lift force of an airfoil. Dimples delay the boundary layer separation by creating more turbulence over the surface thus reducing the wake formation. Most importantly this can be quite effective at different the angle of attacks and also can change angle of stall to a great extent. A stall is a condition in aerodynamics and aviation where the angle of attack increases beyond a certain point such that the lift begins to decrease. It is seen from figure-8 dimples change the angle of stall. This in turn reduces drag drastically. The surface pressure distribution for both regular and dimpled (inward and outward) is shown below at various angle of attack.

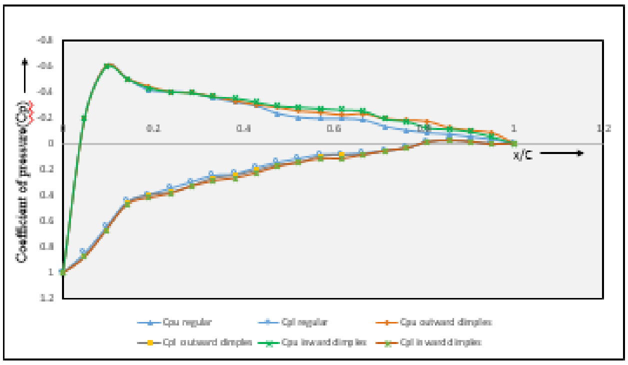

Fig.3: Coefficient of pressure vs distance at 0° angle of attack.

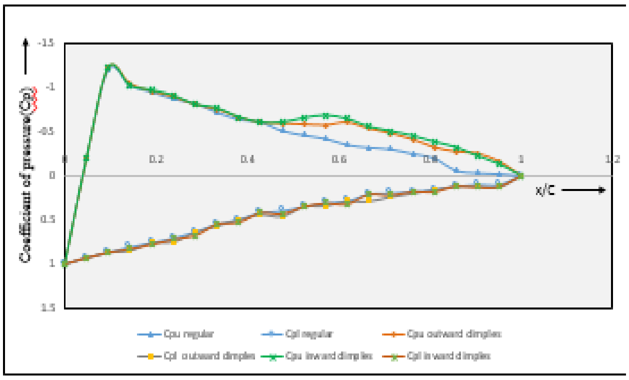

Fig.4: Coefficient of pressure vs distance at 12° angle of attack.

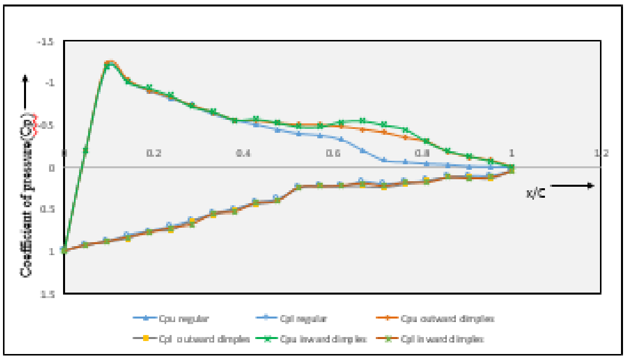

Fig.5: Coefficient of pressure vs distance at 14° angle of attack.

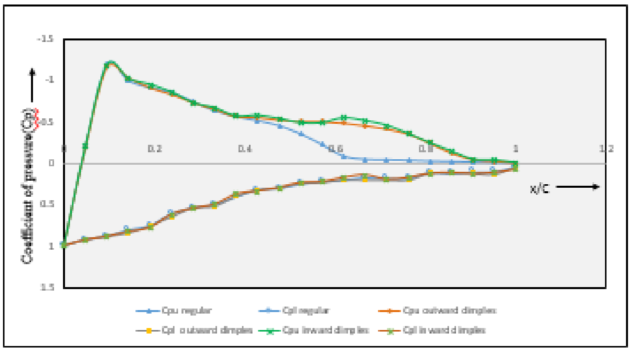

Fig.6: Coefficient of pressure vs distance at 16° angle of attack.

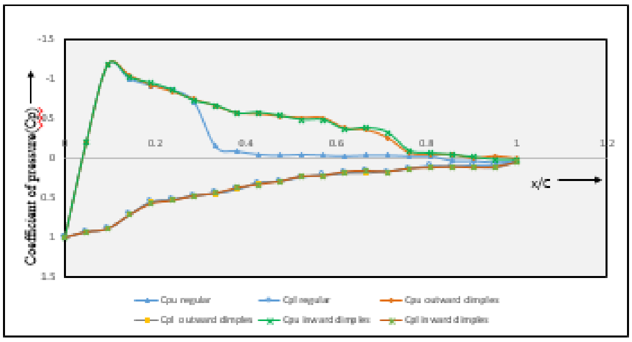

Fig.7: Coefficient of pressure vs distance at 18° angle of attack.

Figure -8 and 9 show changes in lift and drag as the angle of attack increases. Figure-8 shows effect of angle of attack on Coefficient of Lifts of all configurations. Both inward and outward dimpled airfoil show more lift than a Plain airfoil configuration at corresponding angles of attack. Also outward and inward dimpled models shows uniform increase in lift throughout all angles of attack considered for the study. Figure -9 also shows variation in coefficient of Drag with respect to angle of attack. Both dimpled model (outward and inward) show decrease in drag than plain airfoil model. Out of outward and inward dimpled airfoil, outward shows least drag. The angle of stall also increased in case of dimpled airfoil.

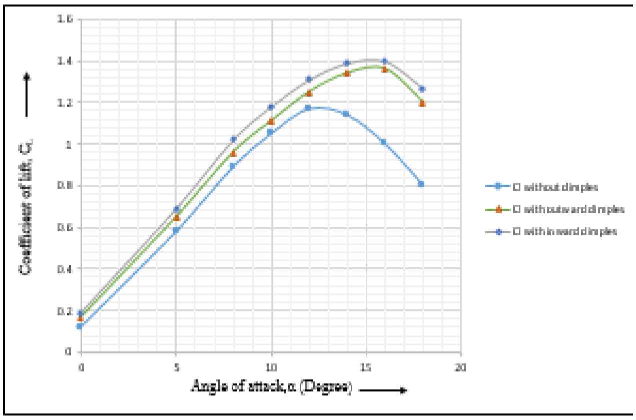

Fig.8: Coefficient of lift vs Angle of attack.

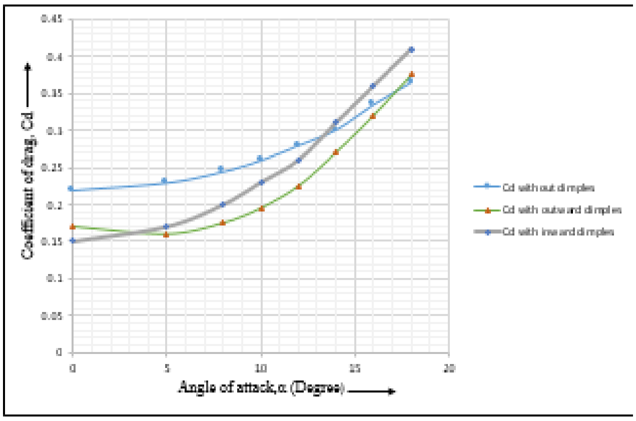

Fig.9: Coefficient of drag vs Angle of attack.

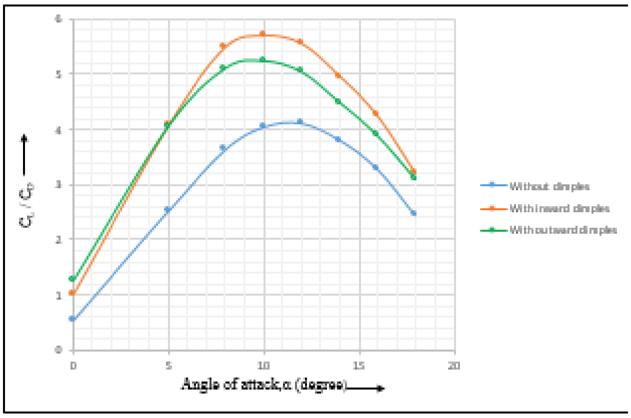

Fig.10: C_L /C_D vs Angle of attack

4. ACKOWLEDGEMENT

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6. NOMENCLATURE

Symbol	Meaning	Unit
L	Lift force	N
D	Drag force	N
C_l	Coefficient of lift	Dimensionless
C_d	Coefficient of drag	Dimensionless
C_p	Coseeicient of pressure	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