iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** IV **Month of publication:** April 2017

DOI: http://doi.org/10.22214/ijraset.2017.4229

Volume 5 Issue IV, April 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Performance Testing of NACA0012 Aerofoil by Providing Dimple Surface

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Abstract: The aim of research paper is to delay the flow separation of an aerofoil by providing dimples on the upper surface of aerofoil at trailing edge. In present work research is done on experimental and numerical analysis of lift and drag performance of NACA0012 aerofoil. The lift and drag forces are calculated at different angle of attack varying from 0^0 to 20^0 for low Reynolds number. The flow characteristics over NACA0012 aerofoil are studied experimentally in a low speed wind tunnel. All the models are prepared by wood and experiments are conducted in 300mm x 300mm x 1000mm subsonic wind tunnel. Lift and Drag coefficient were calculated and obtained results were plotted against angle of attack. From the experimental investigation has been observed that the flow separation of aerofoil can be delayed by using dimples on the upper surface. That indicates by providing dimple surface we can able to control flow separation successfully.
Keywords: NACA0012, flow separation control, dimpled surfaces, Angle of Attack, wind tunnel.

I. INTRODUCTION

As we know energy is most important in our day today life. There are two sources of energy, Renewable and Non-renewable energy resources. But Non-renewable energy resources are limited and they lead to pollution. For this reason, renewable energy as alternative resource is emerged necessarily. As the wind energy is the renewable energy and wind turbine uses wind to convert wind energy into electrical energy. For that wing is the most important parameter of the wind turbine.Aerofoil profile is the important parameter for wing design because wing efficiency depends upon aerofoil profile. We need to increase aerofoil performance. By effective flow control we can increase aerofoil efficiency. Various researches are done to obtain successful flow control over an aerofoil.

The main objective of flow control is to delay or eliminate flow separation, delay of boundary layer transition and reduce skin friction drag[3]. This research involves study of roughness over on aerofoil as a method to delay the flow separation. Surface modification helps in delaying boundary layer separation and this type of flow control is more efficient than the other boundary layer control methods[3].Hui Hu investigated laminar flow separation bubble over an aerofoil and it burst suddenly causing stall after AOA > 12.0 deg. [1].Mohammad Mashud investigated that addition of bumpy surface can be done in order to delay the flow separation on the aerofoil surface [2]. A. dhiliban studied aerodynamic performance of aerofoils by providing rear roughness. Significant reduction in drag is seen when the roughness provided on the upper surface of aerofoil when AOA is above 5 deg.[5] AgrimSareen tested four different sized riblet films at different Reynolds number. Results show that drag reduction is depends upon the size and location of riblet film, AOA and Reynolds number [7]. Syed HasibAkhterFaruqui has numerically investigated NACA 4315 profile result show that higher angel of attack can be attained by using the bumpy surface over the upper surface of the body at 80% camber [8].İzzetŞahin studied lift and drag performances of NACA 0015 aerofoil numerically and experimentally. They found optimum lift coefficient value at 16° AOA and the optimum aerofoil performance calculated at about 8° AOA [9].Bhushan Patil suggested that NACA0012 provides maximum lift and drag coefficient at higher Reynolds number [10].By referring all research papers, in present work we have provided dimple surface of size 3% of chord length from 70% of chord length on upper surface of NACA0012 aerofoil in order to delay the flow separation and improve the performance of aerofoil. In present work NACA0012 aerofoil is considered for analysis of wind turbine blade. The performance of an aerofoil is measured by Lift to Drag ratio, which can be increased by either increasing the lift force or decreasing the drag. The lift and drag forces were calculated at different angle of attack varying from 0^0 to 20^0 i.e. at 0, 10, 15, 17, 19, 21, 23 degree experimentally.

Volume 5 Issue IV, April 2017
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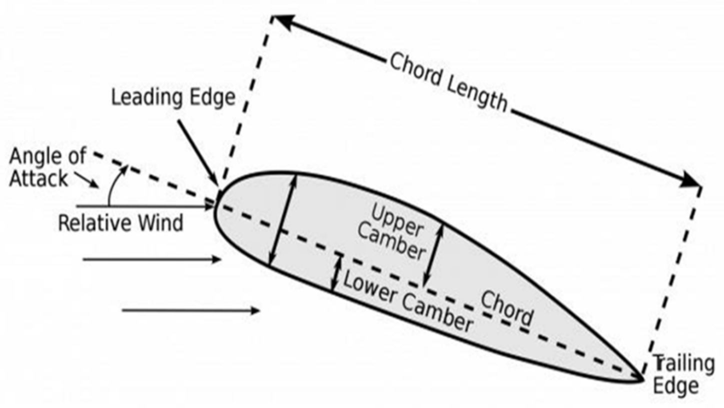

Fig.1: Nomenclature of aerofoil profile [6]

A. Definitions:

1) *Lift* : It is the component of aerodynamic force perpendicular to the oncoming flow direction.
2) *Drag* : It is the component of aerodynamic force parallel to the relative wind.
3) *Leading Edge:* The leading edge is the point at the front of the airfoil that has maximum curvature.
4) *Trailing Edge:* The trailing edge is defined similarly as the point of maximum curvature at the rear of the aerofoil.
5) *Angle of Attack*: It is the angle between an aerofoil chord line and oncoming air. It explores how the angle of attack changes the amount of lift the aerofoil experiences.
6) *Camber:* Camber is the asymmetry between the top and bottom surfaces of aerofoil.

Drag and Lift on aerofoil

The drag equation,

$$F_D = \frac{1}{2} C_D \rho A V^2$$

Where,

F_D is Drag force in N;
C_D is the Drag force on aerofoil;
ρ is density of working fluid in kg/m^3;
A is projected area of aerofoil body in m^2 and
V is velocity of air in m/s

In fluid dynamics the C_D is a dimensionless quantity that is used to quantify the drag or resistance of an object in a fluid environment such as air or water. It is used in the drag equation where a lower drag coefficient indicates the object will have less aerodynamic or drag. The drag coefficients always associated with a particular surface area. [5, 9]

The lift equation

$$F_L = \frac{1}{2} C_L \rho A V^2$$

Where,

F_L is the Lift Force on the aerofoil and
C_L is Coefficient of Lift

II. TEST MODELS

In the research all the simulations are carried out on NACA0012 symmetrical aerofoil. NACA0012 profile is made by using X and Y coordinates from NACA data. Steady state analysis is considered assuming laminar flow. Dimpled surface is provided on the upper surface at trailing edge of the aerofoil from 70% of the chord length. For the experimental model the two aerofoil profile of 300mm x 250mm are fabricated of wood and 15 pressure tapings, 7 on top and bottom and 1 on leading edge. From two models, one is having smooth surface i.e. no roughness is provided on it and another model has a dimple (having size 3% of chord length) on upper surface of aerofoil profile as shown in fig. The dimple is also made up of a wood. Developing of aerofoil profile with roughness with accurate dimensions was the most challenging part of fabrication process.

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Fig.2: Aerofoil with plane profile

Fig.3: Aerofoil with dimples (Radius = 3% of chord)

III. WIND TUNNEL SET UP

Wind tunnel used for analysing various effects as well as aspects of wind force on variety of objects like automobile vehicles to aircrafts is a very essential practice from industrial as well analytical point of view. Because whenever any such designed machine is expected to perform well for a long time, it will always work against wind force only. Wind tunnel set up like its entire ducting & related test section etc. is fitted on a main frame. Driving fan is provided with its controlled motorized drive with proper guarding. Various test models are provided along with lift & drag measurement set up which are to be used in connection with manometer panel associated with test section. Hot wire anemometer is provided to measure actual wind velocities during experimentation.

Well-designed & arranged electrical control panel is provided to exert the desired controls over entire testing cycle. It comprises of necessary safety devices like mcb, control device like speed variation drive & other necessary instrumentation which provides user with required indication for lift & drag forces etc.

Fig.4: Wind tunnel setup

The experiment was carried out at velocity of 6m/s and 10m/s. The aerofoil with chord length 300mm and span 250mm is placed in test section of size 300mm x 300mm x 1000mm to measure the lift and drag forces. The aerofoil was mounted with the help of a frame inside the test section. With the help of a round protractor, the desired angle of attack for the aerofoil was set. The aerofoil was held at this angle using a screw mechanism. The air flow in the tunnel was generated by a single stage axial flow fan and driven by a thyristor controlled 3.75kW DC motor having a maximum speed of 2800rpm.

The aerofoil model is fitted on lift and drag set up, with angle pointer at centre position- vertically as well as horizontally. The selected model on lift and drag set up with desired inclination angle is set using angle pointer and locking knob/nut. The values of forces directly displayed on indicator are noted down. Experiments were performed by varying the angle of attack, from 0^o to 23^0.

IV. RESULT AND DISCUSSION

The aerofoils were tested for lift and drag forces at 6m/s and 10 m/s wind velocity (V). Lift and drag coefficient of NACA0012 aerofoil at different angle of attack between 0° and 23° were calculated based on values of lift and drag forces. Model 1 represents aerofoil with regular shape and model 2 represents aerofoil with dimples of radius 3% chord length.

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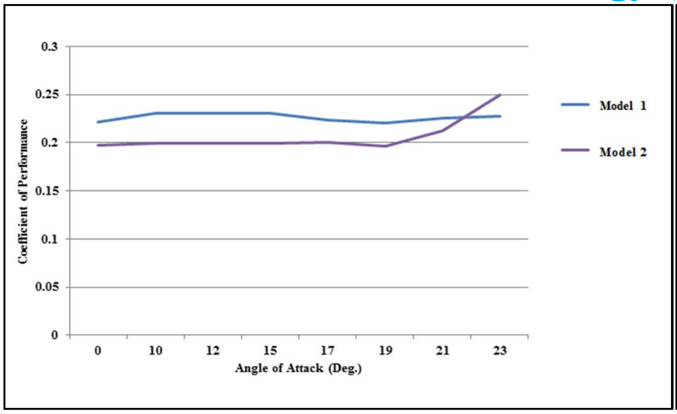

Fig.5: Coefficient of performance for 6 m/s velocity

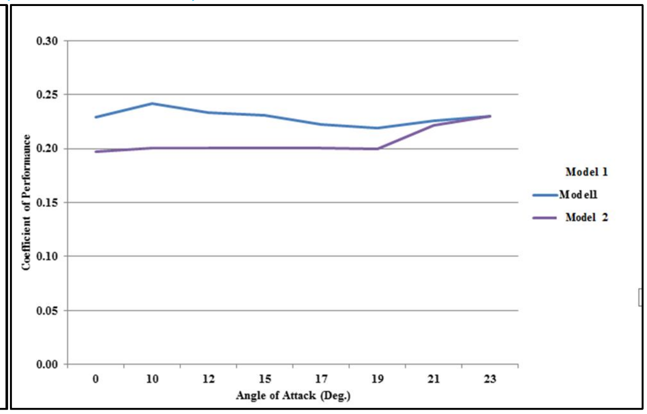

Fig.6: Coefficient of performance for 10 m/s velocity

V. CONCLUSION

In this study lift and drag performances of NACA 0012 aerofoil were performed. Experimental results were plotted. The results were given as follows:

A. Drag and lift coefficients increased with increasing angle of attack.

B. Addition of dimples on surface of aerofoil can results in increased performance of aerofoil.

VI. ACKNOWLEDGMENT

The authors gratefully acknowledge the Faculty of Rajarambapu Institute of Technology, Islampur for allowing us to use wind tunnel setup. Experimental investigation has been conducted in this wind tunnel. Also the authors gratefully acknowledge to Rajendra Mane College of Engineering and Technology, Ambav to allow us to work on this project and helping us for doing our project.

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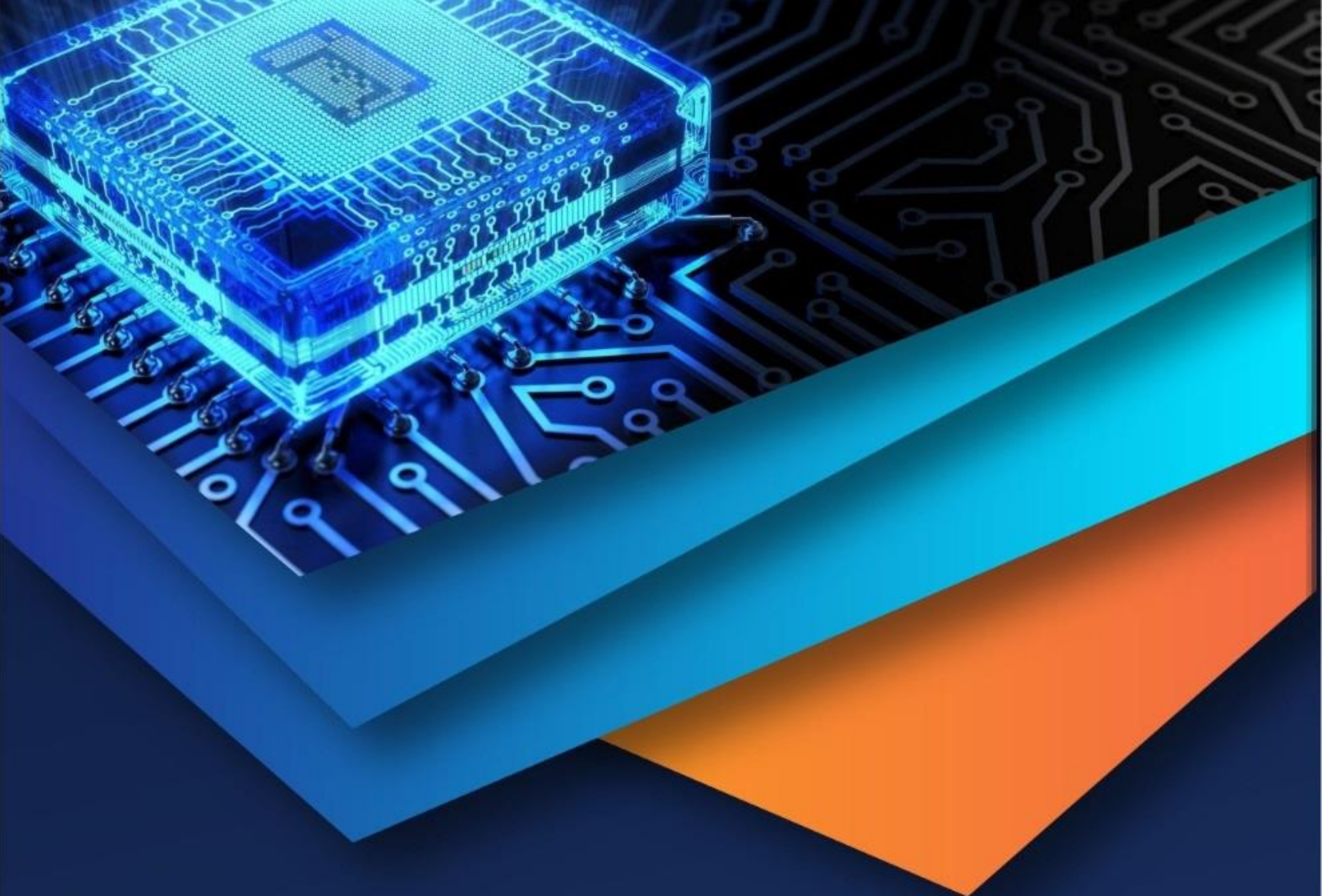

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