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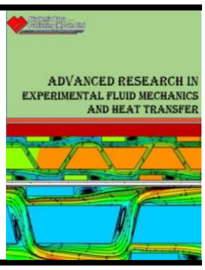

Evaluation of Streamline on Aerofoil With Suction Hole in Wind Tunnel

Basnayake Mudiyanselage Sachinthana Bandara Moonamale[1], Syahrullail Samion[1,*], Mohamad Nor Musa[1], Kamyar Shameli[2], M'hamed Beriache[3]

[1] Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[2] Institute of Virology, Department of Medicine, Technical University of Munich, Munich, 81675, Germany
[3] Rheology and Mechanics Laboratory, Faculty of Technology, Department of Mechanical Engineering, University Hassiba Benbouali, Algeria

ABSTRACT

This study looks into the impact of pressure suction holes in the NACA 0012 airfoil on aerodynamic performance. The goal is to use wind tunnel tests to compute the lift and drag forces for the NACA 0012 airfoil with suction holes at various air speeds and angles of attack. The relationship between air speed, angle of attack, drag coefficient, and lift coefficient will be determined by analysing the obtained data. The goal of the research is to better understand the flow patterns and variations in streamlines of the NACA 0012 airfoil at different velocity and attack angles. The test model will use the NACA 0012 airfoil, which is recognised for its symmetrical shape. Suction holes, varying from one to four, will be installed to provide insight into the influence of pressure suction on the boundary layer and streamline behaviour of the airfoil. The study will be carried out in a low-speed wind tunnel within the Fluid Mechanics laboratory, with the streamlines visualised using a smoke generator. This study is significant because it contributes to our understanding of flow characteristics, pressure distributions, and boundary layer control in aerodynamic design. It also provides excellent exposure to wind tunnel testing procedures, aviation industry practises, and continuing airfoil design research. This study adds to the body of knowledge on optimising airfoil performance by evaluating the effect of pressure suction holes on the NACA 0012 airfoil. The findings will be useful to researchers, aerodynamic enthusiasts, and aviation experts, allowing them to further investigate the potential benefits of pressure suction techniques in improving airfoil efficiency and performance.

Keywords:
pressure suction slot; NACA0012; wind tunnel; aerofoil analysis

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1. Introduction

Human ingenuity and design have evolved over thousands, if not millions, of years. Humans have continuously strived to construct and develop new artefacts from the early Stone Age to the current day, pushing the boundaries of their knowledge and skills. Aerodynamic designs have played a critical role in the advancement of technology, particularly in the pursuit of flight [1]. The study of aerodynamic properties and the desire to mimic avian flight may be traced back several centuries, with Leonardo da Vinci's designs of flying machines serving as one of the oldest known attempts [2,3].

[*] *Corresponding author*
Email address: syahruls@mail.fkm.utm.my

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Aerodynamics has advanced significantly since then, culminating in humans' successful flight to the moon.

The airfoil is a crucial component in aviation and other aerodynamic-related disciplines. An airfoil's sophisticated design allows it to generate lift force through precise angle of attack and velocity flow [4]. Airfoils are widely divided into two types: symmetrical and non-symmetrical, with the latter producing more lift [5]. Despite tremendous advances, airfoils have yet to attain their full potential due to the occurrence of boundary layer separation near the airfoil's center [6].

Researchers throughout the world have been conducting substantial research to prevent or postpone boundary layer separation and improve airfoil efficiency [7]. One such area of research is the use of suction or the blowing of turbulent air via suction holes in the airfoil [8]. This field of research has a long history, with ongoing investigations continuing to investigate its potential.

Airfoil development is critical to the evolution of the aviation industry. Continuous research is required because parameters are constantly being modified to improve airfoil performance [9,10]. In the subject of aviation, precise calculation of drag and lift forces, as well as comprehension of streamline behaviour, are required [10]. Given these factors, the major goal of this research is to drill pressure suction holes in the NACA 0012 airfoil and conduct wind tunnel tests to evaluate lift and drag forces [11,12]. Furthermore, the purpose of this research is to assess the efficiency of suction holes, identify their best positions, and investigate their effects on the airfoil's boundary layer and streamline behaviour.

The research objectives are as follows: calculate the lift and drag forces for the NACA 0012 airfoil with suction holes at various air speeds and angles of attack using wind tunnel tests, and analyse the data obtained to establish relationships between air speed, angle of attack, drag coefficient, and lift coefficient [13].

The scope of this project includes testing in a low-speed wind tunnel within a Fluid Mechanics laboratory. The usage of a smoke generator will aid in visualising the streamlines. The test model will be the NACA 0012 airfoil, which is noted for its symmetrical design, with suction holes added at varied locations ranging from 1 to 4 holes.

The importance of this research is in its contribution to a better knowledge of the flow patterns and variations in streamlines of the NACA 0012 airfoil at various velocities and attack angles [14]. The study intends to acquire insights into the relationship between streamlines and pressure distribution, as well as their impact on the boundary layer, by using pressure suction holes. Furthermore, this research exposes students to wind tunnel testing procedures and provides insights into the aviation industry and aircraft design. Suction hole research also provides an opportunity for aerodynamics aficionados to dive into ongoing airfoil research.

Overall, the goal of this technical article is to offer a thorough investigation of the impacts of pressure suction holes on the NACA 0012 airfoil, hence enhancing the knowledge base around airfoil optimization [15]. The study's findings will be useful to researchers, aerodynamics enthusiasts, and industry professionals, allowing for future investigation of the potential benefits of pressure suction techniques in improving airfoil efficiency.

2. Methodology

This study's technique sought to evaluate the effects of pressure suction holes on the lift and drag forces of a NACA 0012 airfoil. The research includes running wind tunnel tests and analysing the results. The experimental procedure included the following steps:

i. Setup of the apparatus:

The experiments were carried out in Fluid Lab 2, School of Mechanical Engineering, Faculty of Engineering, University of Technology Malaysia. The appropriate equipment was prepared, including a pressure manometer, a three-component balance, and a wind tunnel control unit. 3D printing was used to create the NACA 0012 airfoil model with suction holes

ii. Variables Identification:

The key variables addressed in this experiment were airflow velocity, angle of attack, and surface roughness. These variables were discovered as possible influences on the lift and drag force computations

iii. 2.4 Wind Tunnel Configuration:

Plastrochem.co, LTD AXD 360 model, WT300 wind tunnel was used. The wind tunnel had five sections: the entrance region, the test section, the control box and manometer, the outlet or discharge area, and the smoke producing set. The test part was 0.3m × 0.3m in size, and the airflow was controlled by a fan with an adjustable speed. In the control box and manometer component, a frequency inverter and digital screens were utilised to alter the parameters and monitor the measurements. During the trials, the smoke generator set was employed to visualise the flow patterns.

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v. Measurements of Load Cells:

The forces operating on the airfoil model were measured using load cells equipped with four digital screens. The load cells measured the angle of attack, as well as the lift and drag forces. The load cell numbers were utilised to determine the lift and drag forces using particular formulas.

vi. Procedure for Experiment:

The NACA 0012 airfoil model with suction holes was put in the wind tunnel's test section. Pressure, temperature, chord length, and width of the airfoil model were all measured and recorded. By pressing the green button on the control box, the wind tunnel was started, and the airflow velocity was adjusted to the required value. During the experiments, measurements from the load cells and manometer readings were acquired. Using the collected load cell values and certain algorithms, the recorded data was then used to determine the lift and drag forces

The effects of pressure suction holes on the lift and drag forces of the NACA 0012 airfoil were explored using this methodology. The wind tunnel test data were analysed to determine the correlations between airflow velocity, angle of attack, and lift and drag coefficients.

3. Results and Discussion

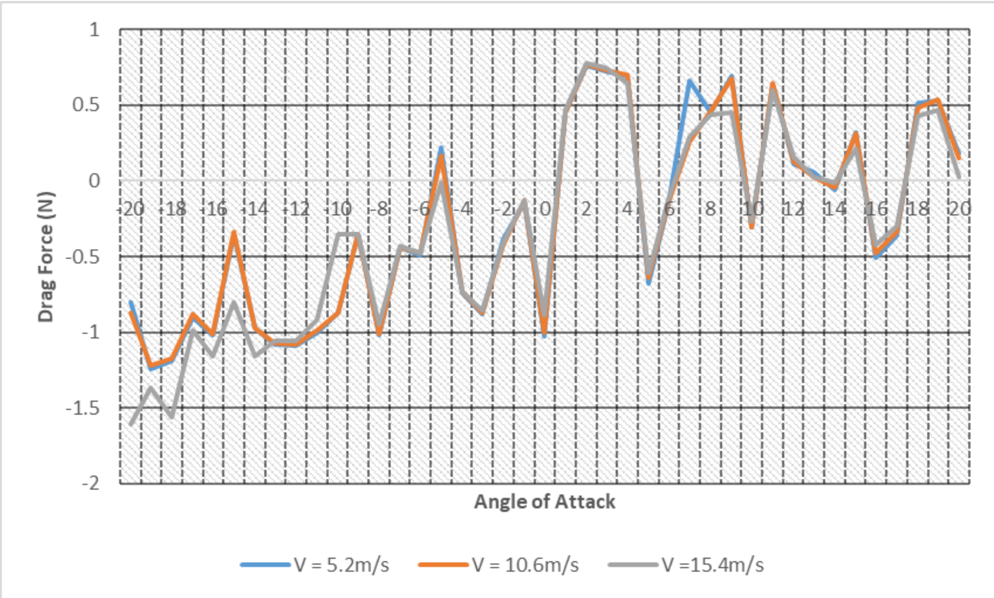

Fig. 1. Fd vs AOA for Model A

Figure 1 illustrates the necessity of a 2-degree angle of attack in determining system performance. For air velocities ranging from 5.2m/s to 15.4m/s, the largest drag force remains constant at around 0.76N to 0.78N, whereas the lowest drag force ranges between -1.24N and -1.6095N. These findings provide vital insights into the system's aerodynamic behavior and highlight the importance of certain angle of attack values for optimal performance.

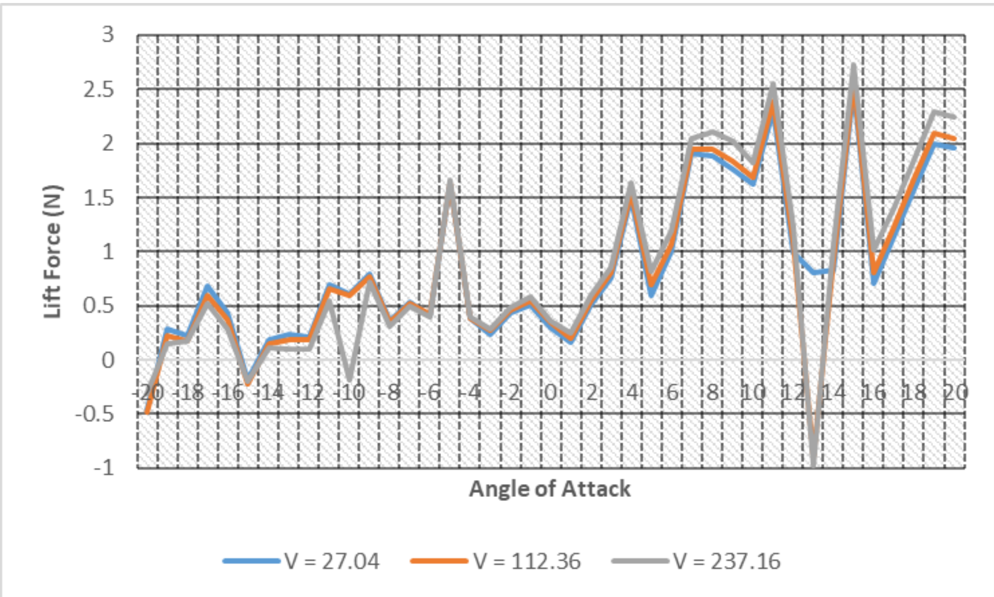

Fig.2. Fl vs AOA for Model A

The data are combined in Figure 2, emphasizing the importance of a 15-degree angle of attack in maximizing lift force. Notably, the lowest lift force for the first graph remains constant at -20 degrees, and 13 degrees for the second and third graphs. These findings imply that the optimal angle of attack for lift force generation may change with airspeed, emphasizing the significance of taking both aerodynamic efficiencies and lift-generating capacities into account when analyzing system performance.

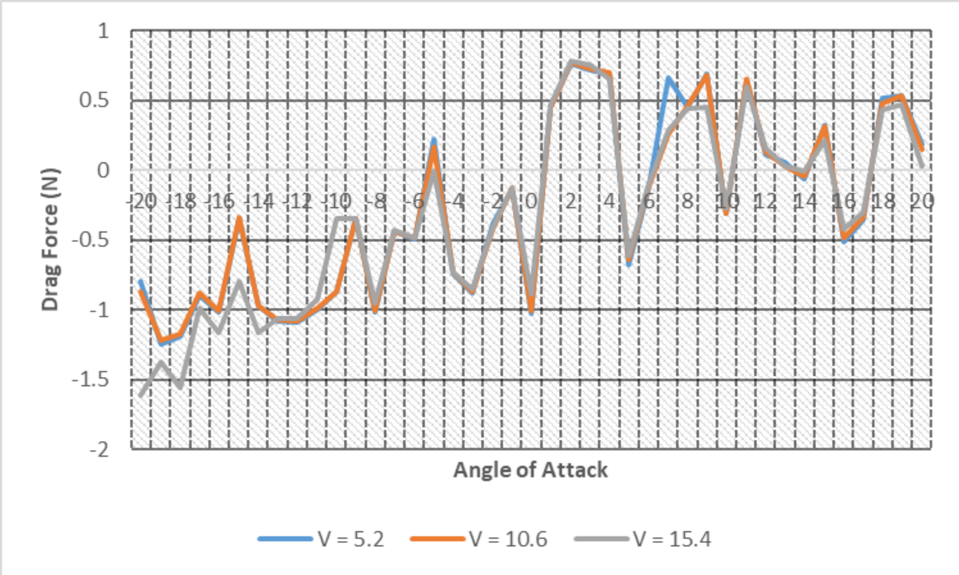

Fig. 1. Fd vs AOA for Model B

Figure 3 summarizes the data and emphasizes the importance of a 16-degree angle of attack in maximizing drag force. The lowest drag force for the first two plots remains constant at -14 degrees and -20 degrees for the third, suggesting potential aerodynamic efficiency at specified angles of attack. These data imply that the system's aerodynamic behavior is stable across airspeeds, with minor differences in the optimal angle of attack for minimizing drag force. Figure 4.3.1-4's full graph enables for direct comparison of drag force trends, emphasizing the significance of a 16-degree angle of attack in determining the system's drag properties.

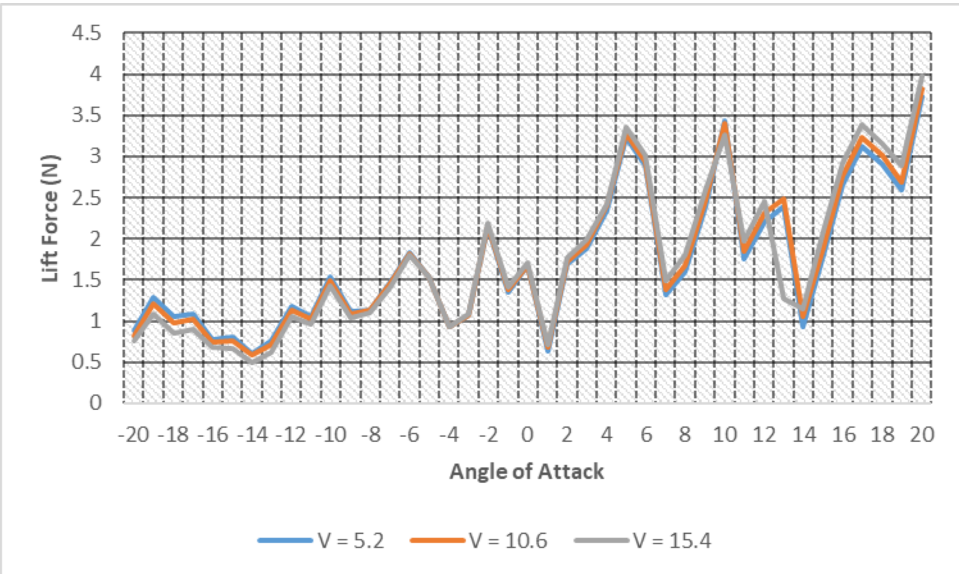

Fig. 2. Fl vs AOA for Model B

Figure 4 summarizes the findings, emphasizing the importance of a 20-degree angle of attack in maximizing lift force. According to these findings, positive angles of attack result in higher lift forces, while negative angles of attack result in lower lift forces. The analysis shows that the best angle of attack for maximizing lift force remains constant throughout airspeeds, highlighting the significance of a 20-degree angle of attack in evaluating the system's lift-generating capabilities. Furthermore, at all airspeeds studied, the lowest lift force point remains constant at -14 degrees.

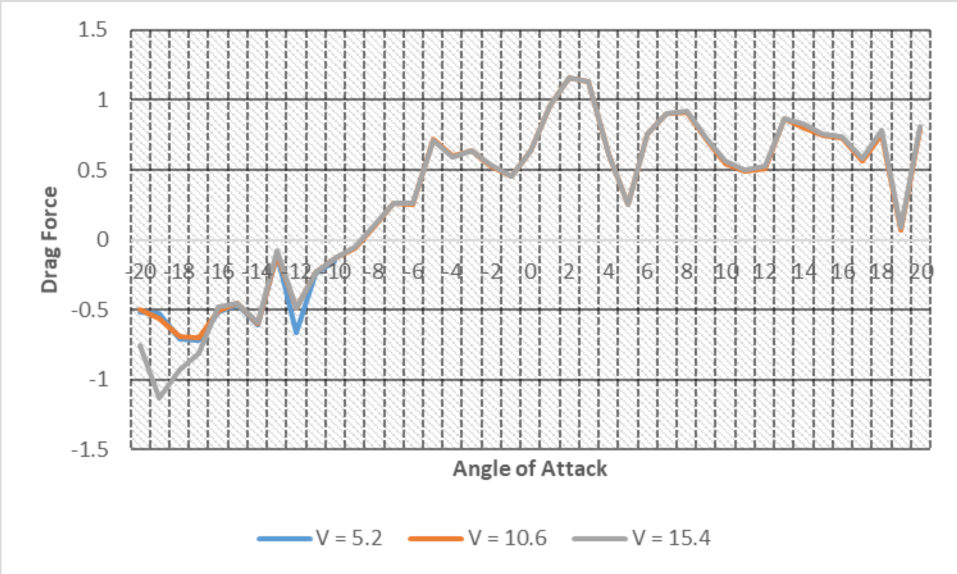

Fig. 5. Fd vs AOA for Model C

Figure 5 depicts a direct comparison of drag force trends at various angles of attack and air velocity. Notably, across the airspeed range, the ideal angle of attack for the greatest drag force remains constant. At greater air speeds, the lowest drag force point may change slightly. These findings highlight the significance of taking certain angle of attack values into account when evaluating the aerodynamic performance of a system.

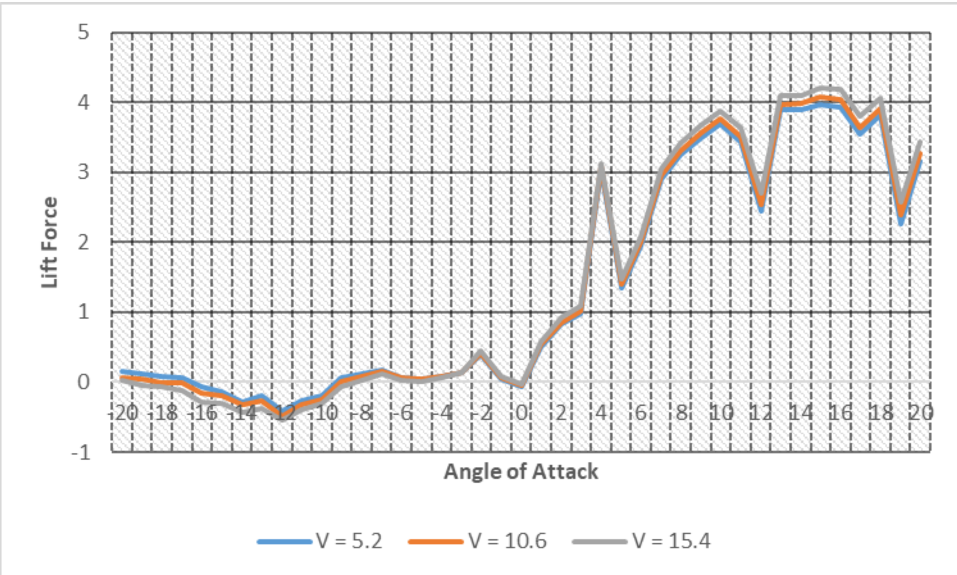

Fig.6. Fl vs AOA for Model C

These data show that a positive angle of attack of 15 degrees produces the most lift force, while a negative angle of attack of -12 degrees produces the least drag force. These findings hold true over a range of airspeeds. This consolidated graph enables a direct comparison of lift force trends at various angles of attack, emphasizing the importance of a 15-degree angle of attack in maximizing lift generation. Furthermore, the lowest drag force point is always at an angle of attack of -12 degrees.

4. Conclusion

This study was setup to determine the impact of pressure suction holes in the NACA 0012 airfoil on aerodynamic performance using wind tunnel. It was found that the optimal angle of attack for lift force generation may change with airspeed, emphasizing the significance of taking both aerodynamic efficiencies and lift-generating capacities into account when analyzing system performance.

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