Review of Aerofoil Geometry for Drag andLift Study

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Abstract

This paper aims to study the aerodynamic behaviour of different aerofoil shapes and to optimize their design for enhanced performance. The research will involve both computational fluid dynamics simulations and wind tunnel testing to gather data on the aerofoil lift and drag properties. By analysing the results of these experiments, the paper will seek to determine the most effective aerofoil geometry and materials to achieve optimal performance. The outcome of this research will provide important insights into aerofoil design and could lead to the development of more efficient aerodynamic systems.

Keywords — Flow separation, angle of attack, CFD, Coefficient of lift, Coefficient of drag, pressure coefficient, lift and drag properties, effective aerofoil geometry, aerofoil design, efficient aerodynamic system.

I. INTRODUCTION

An aerofoil, also known as an airfoil, is a streamlined shape that is designed to generate lift by manipulating the flow of air around its surface. It is a critical component in the design of wings, propellers, and other devices that move through the air, such as aircraft, wind turbines, and race cars. The shape of an aerofoil is conscientiously crafted to engender a difference in pressure between the upper and lower surfaces of the wing. When air flows over the curved upper surface of the aerofoil, it expedites, engendering a lower pressure zone. The air flowing underneath the wing is slower, resulting in higher pressure. The difference in pressure generates an upward force, or lift, that allows the aircraft to stay aloft. Aerofoils come in various shapes and sizes, depending on their application. They are commonly used in commercial airliners, military aircraft, wind turbines, and even in automobiles as spoilers. The study of aerofoil is a paramount area of research in aerodynamics, and advances in aerofoil design have led to paramount ameliorations in aircraft performance and efficiency.

The history of aerofoils can be traced back to the early experiments of aviation pioneers like Sir George Cayley and Otto Lilienthal in the 19th century. These early researchers recognized the importance of generating lift to enable sustained flight, and they developed a variety of aerofoil shapes and configurations to achieve this goal. One of the earliest and most famous aerofoil designs was created by the Wright brothers, who developed a cambered wing with a curved upper surface and a flat lower surface. This design allowed them to generate lift more efficiently than previous designs and was instrumental in enabling the first sustained, powered flight in 1903. The German physicist and mathematician, Ludwig Prandtl, studied the behaviour of airfoils. In the early 20th century, Prandtl conducted ground-breaking experiments that laid the substratum for modern aerodynamics. Prandtl's work was continued by a number of other researchers, including the British mathematician and engineer, Geoffrey Ingram Taylor, who made significant contributions to the study of turbulence and boundary layers.

In the 1920s and 1930s, aerofoil design underwent a period of rapid development, with the introduction of new materials, such as aluminium and steel, and advances in wind tunnel testing. and the advances in aerofoil technology continued to improve the performance and safety of aircraft. In the 1930s, NACA (the precursor to NASA) began a comprehensive study of aerofoil design, which resulted in the development of the NACA airfoils, a series of standardized aerofoil shapes that could be easily tested and optimized for different applications.

One of the important figures in the history of aerofoil design was the American engineer and inventor, Theodore von Kármán. Von Kármán's pioneering work in aerodynamics and fluid mechanics helped to establish the field as a rigorous scientific discipline. He made consequential contributions to the development of the swept wing, which became a defining feature of modern aircraft design. During the World War II, aerofoil design reached new heights of sophistication, as engineers worked to create faster, more agile, and more efficient aircraft. An aerofoil technology played a critical role in the development of high-speed fighter aircraft, such as P-51 Mustang and Spitfire. These planes used advanced aerofoil designs to achieve high speeds and manoeuvrability, which were essential for success in air combat. Advances in computational methods, such as the use of analog computers, helped to accelerate the design process and improve the accuracy of predictions.

In the post-war era, aerofoil design continued to evolve, driven by the demands of the emerging commercial aviation industry and with the development of new materials and manufacturing techniques allowing for more complex and optimized shapes. Today, aerofoils are designed using sophisticated computer modelling techniques, computer-aided design (CAD) and Computational Fluid Dynamics (CFD) in the 1980s and 1990s, revolutionized aerofoil design, allowing engineers to model, test aerofoil shapes and to achieve maximum efficiency and performance under a wide range of operating conditions in unprecedented detail and accuracy.

Today, aerofoil technology perpetuates to play a critical role in the Aviation Industry, with incipient designs and materials perpetually being developed to ameliorate aircraft performance, efficiency and safety.

II. TERMINOLOGIES

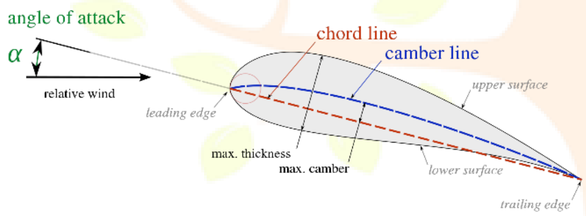
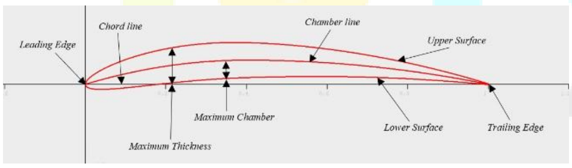


Fig No. 1: Terminologies of aerofoil

1) ***Leading Edge:*** - The edge of the airfoil faces the plane's direction of kineticism. It is typically circular and deflects air so that the air velocity on the top surface is more preponderant than the air velocity on the lower surface.

2) ***Trailing Edge:*** - In nature, it is the pointy edge of the airfoil. It is annexed to the airfoil's rear.

3) ***Camber:*** - It usually refers to the shape of the airfoil's cross-section, specifically the amount of curvature



or camber of the upper and lower surfaces of the airfoil. An airfoil with no camber is symmetrical, meaning that its upper and lower surfaces are identical in shape. The amount of camber affects the lift and drag characteristics of the airfoil ***Chord line:*** - It's a straight line that connects the leading and trailing edges. It divides the airfoil into two sections when it is symmetrical but may not do so when it is asymmetrical. It also establishes another critical parameter, the assault angle.

4) ***The angle of attack*** is the angle composed by the chord line and the plane's direction of motion. It is a critical parameter since it influences the lift and drag coefficients.

5) ***Chamber line:*** - This linear feature links the front and back edges of the wing profile, separating it into two symmetrical parts. The shape of the line can take either a straight or curved form.

6) ***Lift coefficient*** is a unitless measure that defines the connection between the force of lift, the velocity of a body, its surface area, and the density of the fluid that it is being lifted in. [4]

III. NOMENCLATURE

This NACA aerofoil series is controlled by 4 digits e.g. NACA 2412, which designate the camber, position of the maximum camber and thickness. If an aerofoil number is NACA MPXX

e.g. NACA 6412

M is the maximum camber as a percentage of chord line (divided by 100 of chord line). In the example M=6, the camber now becomes 0.06 or 6% of the chord line. P is the position of the maximum camber (from the leading edge) divided by 10. In the example P=4, so the maximum camber is at 0.4 or 40% of the chord. XX is the maximum thickness of aerofoil section as a percentage of chord line (divided by 100). In the example XX=12, so the thickness is

0.12 or 12% of the chord.

- Chord length/line = 1mm
- Maximum Camber = 0.06mm
- Position of maximum chamber = 0.4mm
- Maximum thickness of airfoil = 0.12mm

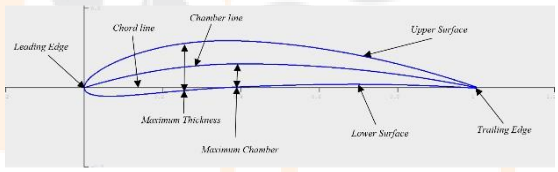


Fig No. 2: Terminologies of aerofoil 6412

NACA 6409

M is the maximum camber as a percentage of chord line (divided by 100 of chord line). In the example M=6 the camber now becomes 0.06 or 6% of the chord. P is the position of the maximum camber (from the leading edge) divided by 10. In the example P=4, so the maximum camber is at 0.4 or

40% of the chord. XX is the maximum thickness of aerofoil section as a percentage of chord line (divided by 100). In the example XX=09, so the thickness is 0.09 or 9% of the chord.

- Chord Length/line = 1mm
- Maximum Camber = 0.06mm
- Position of maximum camber = 0.4mm
- Maximum thickness of an airfoil = 0.09mm

Fig No. 3: Terminologies of aerofoil 6409

IV. CONCLUSION

To summarize, this research paper aims to investigate the aerodynamic behaviour of various aerofoil shapes and improve their design to enhance their performance. The paper has used computational fluid dynamics simulations and wind tunnel experiments to gather data on the lift and drag properties of the aerofoils. The analysis of these studies has been conducted to identify the most effective aerofoil shape and materials that can lead to the desired results. This research brings significant information on aerofoil design and highlights the significance of understanding and enhancing aerodynamic systems. The outcomes of this investigation can guide the development of

next-generation aerofoil designs and promote more efficient aerodynamic systems.

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