An Aerodynamic Comparative Analysis of Airfoils based on different Speeds

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Abstract:- The research on the aerodynamic behavior of airfoils is based on the creation of aircraft modifications employing novel wing designs. The airplane will experience a lift force as a result of the action of aerodynamic forces. The current study compares the efficiency of airfoil NACA 0018 with NACA 64-208 as a baseline to determine the efficacy of airfoil shape based on different angles of attack. to denote the supersonic and subsonic instances, respectively. Simulating the specified airfoils based on angle of attack variations correlated with two Reynolds Numbers for each example was used to create the scenarios. The first consideration is low speed (Re 6,000,000), which serves as a baseline for all scenarios, and the second is supersonic speed (Re 60,000,000), which is defined by NACA 64-208. The air speed and pressure increase as the angle of attack increases until the angle of attack hits the stall angle, according to the CFD simulation results. It can be shown that wing shape design is an important component in determining aircraft speed based on lift force magnitude associated with aircraft mass, which constitute independent acceleration parameters

Keywords:- aerodynamic forces, airfoil, supersonic speed, lift force, drag force,

INTRODUCTION

Early design stages for aircraft and spacecraft provide a fundamental grasp of physical events, allowing designers to forecast and analyze crucial flight characteristics. Thousands of investigations have been conducted using the models in fields as diverse as aerodynamic and hydrodynamic drag reduction, high-lift systems, loads due to atmospheric gusts and landing impact, aircraft ditching, buffeting, propulsive efficiency, configuration integration, icing effects, and stability and control assessments. Models classed as "static" models calculate the system in equilibrium and are thus time-invariant, or "dynamic" models allow for time-dependent changes in the state of the system. [1] Takeoff and landing performance are critical in the early stages of an aircraft design process. For the takeoff phase effects, basic design factors were associated with different speeds. The flight tasks, which always include takeoff and landing, are used to determine basic design parameters such as aircraft mass, wing surface area, stabilizer position, control surface size, and so on. [2]. The goal of this research is to look into the effect of wing design on supersonic aircraft models. The longitudinal flight effect, which is conceded with the vertical plane and is connected with the aircraft movement in the vertical upward direction, will be considered in the flight behavior. [3]

BACK GROUND OF STUDY

Airplane structure design is useful in understanding the influence of the airfoil, which is used to determine if the lift force is sufficient to balance the plane's weight and how much drag force is supplied to the plane. It provides lift to the airplane during supersonic flight, but it also has a side effect termed drag, which opposes the airplane's motion. [4]. The lift force is produced by an airfoil. The streamline pattern and pressure distribution indicate zero lift when a symmetrical airfoil is placed at zero angle of attack to the airstream. When the airfoil is given a positive angle of attack, however, the streamline pattern alters. [5]. The positive angle of attack provides higher velocity on the top surface, which leads to an increase in upper surface suction, whereas the negative angle of attack causes lower surface suction to decrease. [6]. When the airfoil is given a positive angle of attack, however, changes in the streamline pattern and pressure distribution occur, much like when circulation is added to the cylinder. [7]. The positive angle of attack provides higher velocity on the top surface, which leads to an increase in upper surface suction, whereas the negative angle of attack causes lower surface suction to decrease. [8]. Additionally, ahead of the airfoil, up wash is formed, the forward stagnation point moves under the leading edge, and a downwash is visible aft of the airfoil. [9]. The net force created by the distribution of pressure over the top and lower surfaces of the airfoil will always be the generated lift. The goal of this work is to investigate the dynamics of wing design analysis at supersonic speeds in order to determine the best aircraft response to various angles of attack. The model will be built using multivariable parameters to simulate the influence of nonlinear equations, and it will be solved using simulation software using mode simplifications utilizing computational fluid dynamics (CFD) software.

THE AERODYNAMIC FORCES

Lift, drag, and pitching moment are the main aerodynamic forces that change with angle of attack. They are written as follows [10]
On an air foil, the lift force is given by

$$FL = \frac{CLrv2AP}{2} \qquad 1$$

CL: $the\ lift\ coefficient$
v : Velocity (m/s) of the undisturbed fluid and
AP : the projected are of the airfoil as seen from above plan area. This same area is used in defining the drag coefficient of the airfoil [11]. The lift coefficient can be approximated by the equation

$$CL = 2pk1sin(a + b) \qquad 2$$

which is valid for small values of a and b.
k : a constant of proportionality
a: angle of attack (angle between cord of airfoil and direction of flow)
b: negative of angle of attack for zero lift

The drag coefficient can be approximated by

$$CD = CDQ + \frac{CL2}{pAR} \qquad 3$$

CDQ: infinite span drag coefficient AR: b2/AP = AP/c2

1. The aerodynamic moment is given by
2.

$$M = \frac{CMrv2APc}{2} \qquad 4$$

where the moment is taken about the front quarter point of the air foil.
CM: moment coefficient
AP: plan area
C: cord length

The performance and properties of an airfoil can be affected by the following modifications, as shown in the diagram.

RESEARCH METHODOLOGY

The chosen software for wing design simulation must include the major characteristics that can deliver accurate results of effective parameters. As a result, ANSYS Fluent is a strong contender for the most powerful computational fluid dynamics (CFD) software. The researcher can get accurate data over the CFD program range because to the software functionality. The workflow for CFD is efficient and versatile, and it is completely integrated into the ANSYS Workbench environment. One of the most essential advantages of CED is its renowned accuracy in solving challenging fluid flow-related physics events. It can also solve complex multiphase flows, chemical reactions, and combustion models. Modeling sophisticated viscous and turbulent streams, internal and external flows, flow-induced noise predictions, and heat transport with and without radiation is another aspect of this tool. The focus of this research is on aerodynamic design methods. [12]. It examines the difficulties and complexities of designing aerodynamic wings. Due of the complicated structure of flow around the wing, ANSYS-based computational fluid dynamics (CFD) was chosen to simulate a variety of wing types in order to uncover the wing design effect that is connected with various parameters. In this study, the general modeling approach may be described as the CFD sequence procedure that allows the researcher to accurately generate the wing model. As indicated in Figure 1, CFD modeling can be divided into a few major processes.

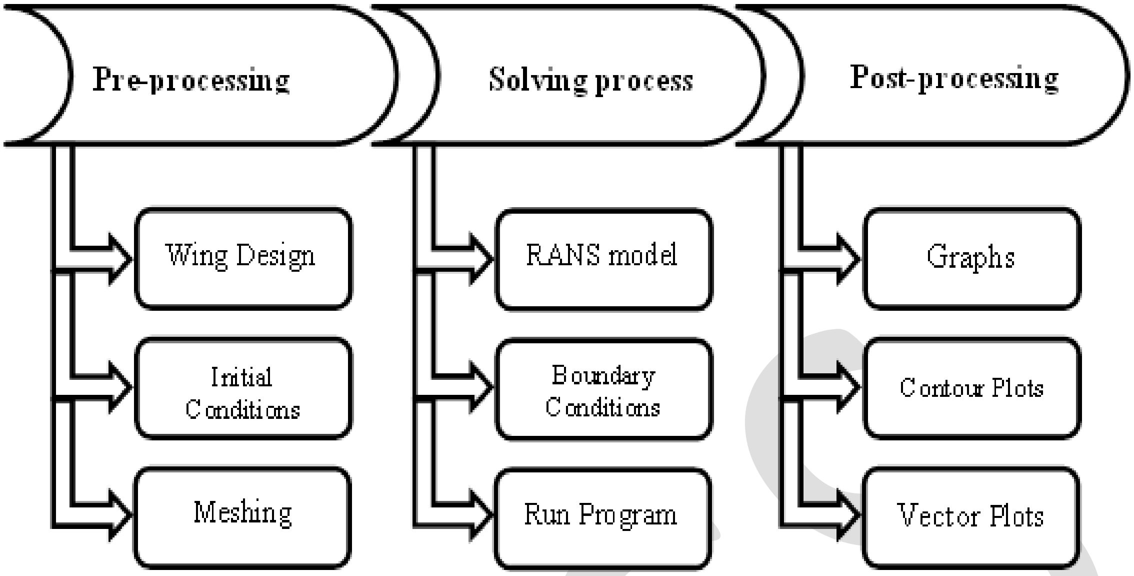

Figure 1: The CFD Wing Model

Pre-processing is the initial step in the CFD simulation process, and it aids in accurately characterizing the geometry. The fluid domain of interest must be identified. The mesh creation process further divides the zone of interest into smaller fragments. Once the physics of the problem have been determined, the fluid material parameters, flow physics model, and boundary conditions are defined in order to solve the problem with a computer. As a result, this stage is known as the solver. The next phase is Post- Processing, which allows you to acquire the results and analyse them using various methods. The first is visualization of plot vectors, plot contours, surface displays, cut planes, and x-y plots of results data obtained from ANSYS software, and the second is numerical reports used to estimate the average, minimum, and maximum of the velocity distribution. Iteratively solve the discretized conservation equations until convergence.

RESULTS AND DISCUSSION

One of the most essential wing parameters is the airfoil section. It's in charge of creating air pressure at the wing's surface boundary. Based on the aerodynamic effect, this pressure causes the lift force. As a result, the main phase in the design and development of aircrafts is to investigate the airfoil specification of parameters. In order to acquire a better grasp of airfoil concepts based on airfoil properties, this study compares three different airfoil types utilizing varying angle of attack. Due to two differing air speeds, the experiments were created. The chosen speeds are dependent on three factors. The first is the low speed (Re 6,000,000), which serves as a baseline value, and the second is the supersonic speed (Re 60,000,000), which is defined by NACA 64-208. The NACA0018 was subjected to all three speeds in order to establish a foundation for understanding the changes in airfoil behavior. The findings of the CFD simulations of the three airfoil types assessed the air flow characteristics and evaluated the lift force and drag, guiding the researcher to the best comparison results. The current findings meet the study's goal and provide a brief explanation based on four areas. The first section includes a plot of numerical results as well as an aerodynamic analysis of NACA0018 utilizing ANSYS data. On a 2D wing design, the CFD ANSYS results for testing NACA | 0018 were obtained. The turbulence shear stress transfer (SST) k-model was used in this study to determine changes in airfoil velocity and pressure. The air flow velocity is same in both the top and bottom of the wing, as seen by the contour. The tip of the wing has a higher pressure than the rest of the wing. This result reveals that there is resistance in front of the wing, which acts as a barrier to wing movement, as well as the logic indicator that there is no pressure differential between the upper and lower surfaces, implying that there is no lift force in this scenario. The researcher shifts the wing angle toward the air flow to analyze the flow dynamics in the wing. As demonstrated in Figures 2 and 3, the contour alterations exhibit significant variances as a result of varying wing angle slops.

The air speed increases in the upper area of the wing and decreases in the lower surface, as illustrated in the red region of the velocity contour. That suggests that the wing resistance to air flow should begin at the bottom of the wing, resulting in a slowing of the airfoil's lower surface airspeed, and the lift force and drag in this instance must be increased. The pressure contour profile confirms this phenomenon. The researcher will notice that the air speed and pressure have altered when the wing angle of attack increases because of the stated starting.

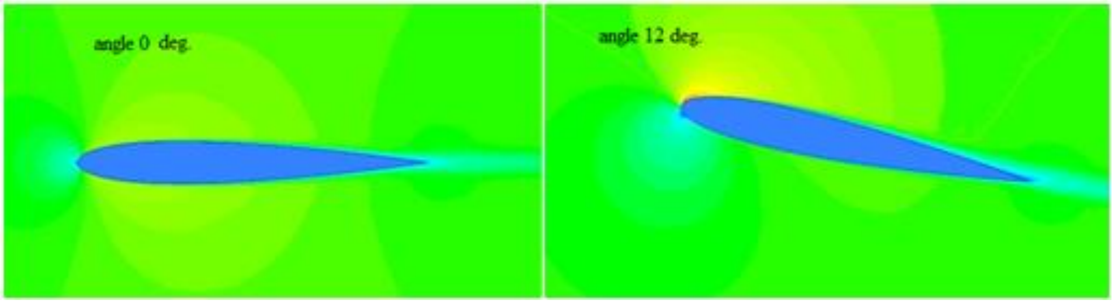

Figure 2: velocity profile of NACA 0018 with different angle of attack

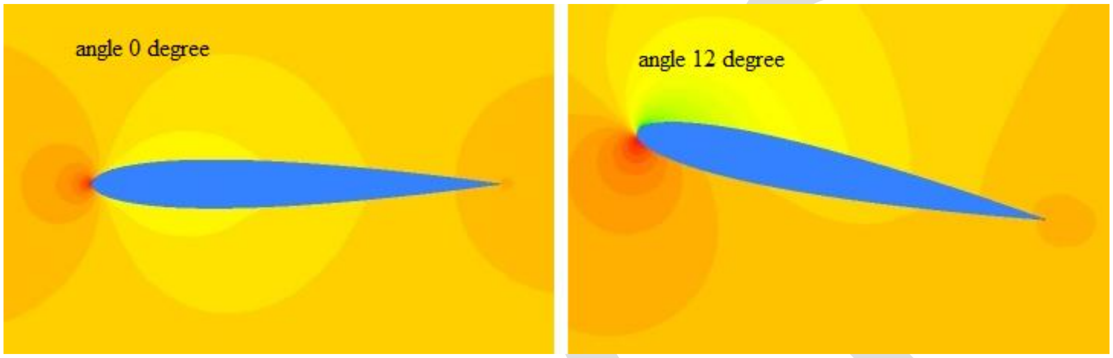

Figure 3: pressure profile of NACA 0018 with different angle of attack

This refers to the fact that the angle of attack is one of the most essential characteristics of an airfoil. The results show that in all situations, the rise of values is linearly tell angle 14.50. As a result, this angle is the stall angle. The values then decrease, indicating that the lift force is decreasing due to the stability of other factors. The graphic highlights an essential fact: the differences in lift coefficient values between cases. The stall angle, which is a critical factor in fixed wing design, will be described in the next section. The fundamental challenge in the airplane research is the fixed wing design. It raises and lowers the plane's body. For this reason, the researcher focuses on the effect of wing shape in this study.

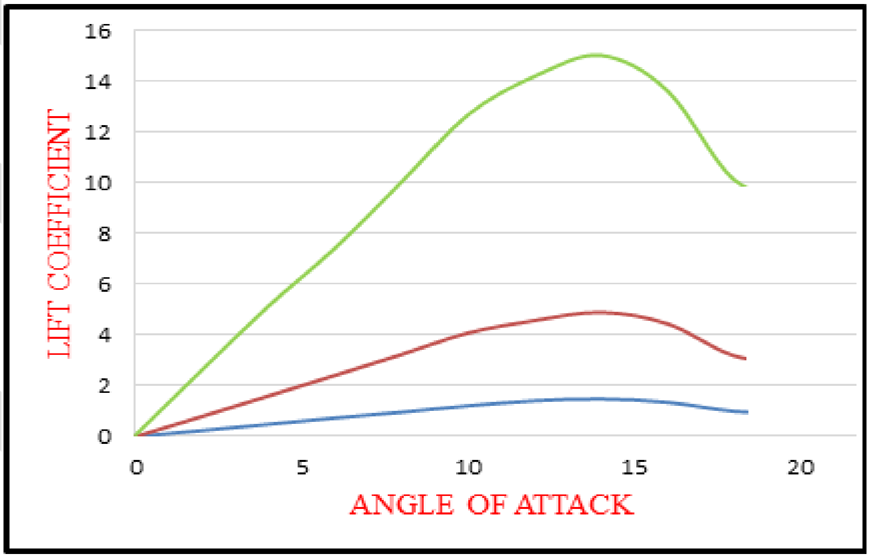

Figure 4: the correlation between the angle of attack and the lift coefficient

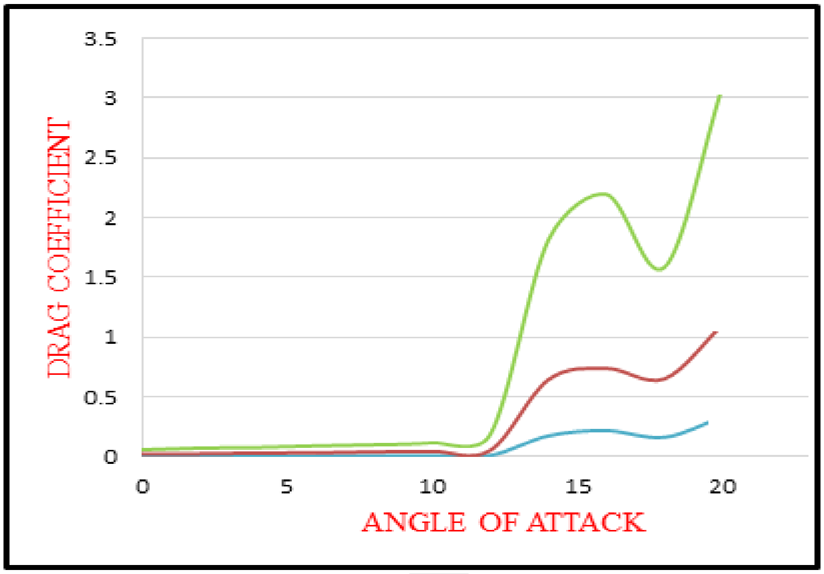

Figure 5: the correlation between the angle of attack and the drag

The drag is the airfoil's second effect. The interaction and contact of the wing frame with the air causes drag, which is a mechanical force. The differential in velocities between the wing item and the air causes this phenomenon. Normally, the difference was connected to the assault angle. The results show that the lift coefficient increases as the angle of attack increases for the second airfoil type (NACA 64-208). The association between the angle of attack and the aerodynamic requirements can be seen in Figures 6 and 7.

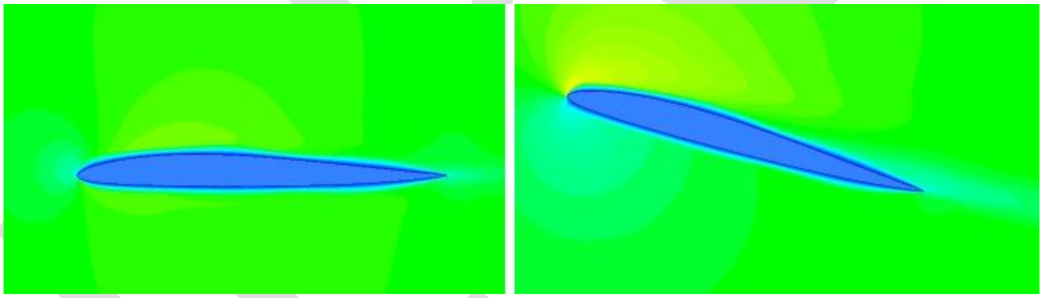

Figure 6:velocity profile of NACA 64-208 with different angle of attack

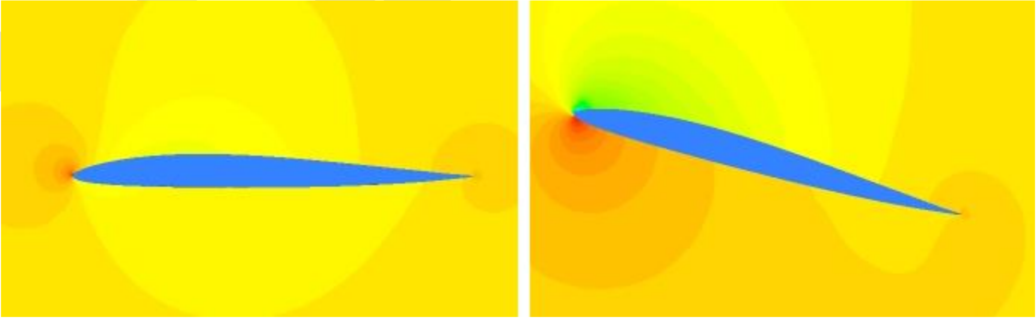

Figure 7: pressure profile of NACA 64-208 with different angle of attack

The lift coefficient values increase with stall angle 10.2° and thereafter decline, according to the data. Drag is caused by variations in velocities between the wing object and the air. The difference is due to the drag of the NACA 64-208 wing section, which causes the angle of attack to alter.

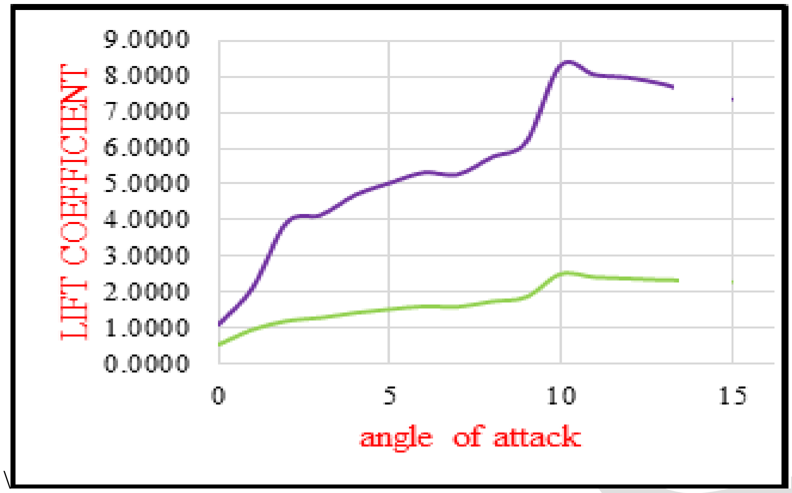

Figure 8: the correlation between the angle of attack and the lift coefficient of NACA 64-208 wing section

The data also show that when the angle of attack increases, the drag coefficient increases.

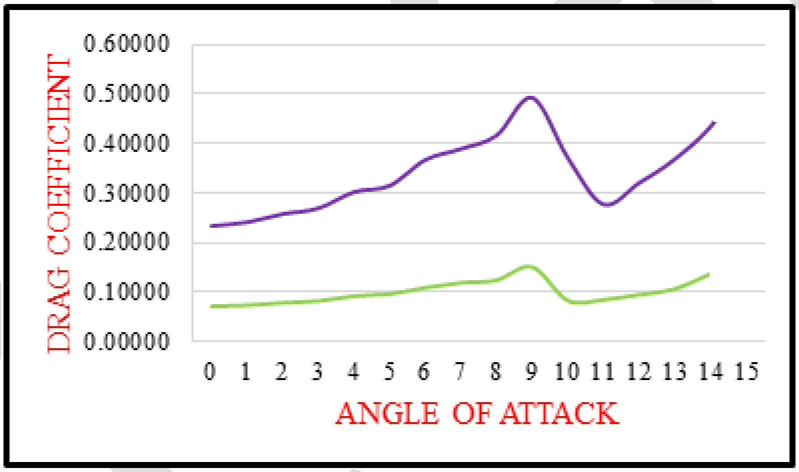

Figure 9: the correlation between the angle of attack and the drag of NACA 64-208 wing section

The results show that the drag coefficient increases in all angles based on the same sequence. These findings support the concept of calculating maximum lift force at a 10° angle. As indicated in Figure 7, the rise in drag coefficient values was due to an increase in air velocity. All of the findings from this study demonstrate that when the angle of attack increases, the lift force increases as well. However, this is not an infinite increase; it is limited to the optimum angle, which is referred to as stall in the next section.

CONCLUSIONS

The results of the CFD simulation show a different conclusion for each of the scenarios. The following is a summary of the findings:

1. The air speed and pressure have been adjusted as the wing angle of attack rises. In each case, the adjustment increases the maximum lift coefficient, which is expressed as a stall angle. NACA 0018 had a 14.50 stall angle, while NACA 64-208 had a 10.20 stall angle.

2. MIG-31 has a high lift coefficient. With a greater lift coefficient, you may get more lift force from a smaller wing surface area and lower airfoil velocity.

3. The study concludes that a higher lift coefficient is required in airplanes that require a higher rate of acceleration in flight. Because the lift force magnitude is associated with the aircraft mass, the independent parameters of acceleration are the lift force magnitude. The NACA 64-208 is a better rigger as a result of this viewpoint.

4. NACA 64-208 has a low drag coefficient. The value of form resistance to air movement is represented by this result.

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