CFD Analysis of controlling the airflow over airfoils using dimples

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Abstract

Aircraft aerodynamic's primary goal is to boost the aircraft's aerodynamic qualities and manoeuvrability. Reducing the drag-and-stall phenomenon would naturally improve aerodynamic capabilities. This research is an attempt to improve airfoil's aerodynamic properties by adding several dimple-shaped surface modifications. The dimple form we chose is triangular in nature. We put 12 dimple numbers in both surfaces with 12 in the upper and 12 in the lower surface. The dimples were placed in a convenient location such that the creation of the boundary layer could be postponed. Typically speaking the dimple generates instability by generating vortices which in effect slows the forming of the boundary layer. Dimple pressure drag is decreased with the application and the sound effects are also minimized. This research involves the dimple effect on aircraft wing numerical analysis using NACA 0018 airfoil with uniform cross section along the airfoil range.

Key Words: Surface modification, Pressure drag, golf ball, dimples, aerodynamic performance

Introduction

The air-to-air contact is commonly referred to as aerodynamics concerned with the moments, movements, and pressures over the plane. Aerodynamic efficiency is one of the main parameters which determines an aircraft's effectiveness. Improving aerodynamic performance is very important for both military and commercial interests. For industrial purposes, if we improve aerodynamics we will reduce costs and in the military the maneuverability is improved by increasing aerodynamic efficiency. It could be done by cutting back on the drag. Various surface changes have been made to reduce the drag at present. The most widely used method for surface alteration is the vortex generator. Efforts have been made in this project to show that dimples could also be used as surface modifications to reduce the pressure drag. The dimples are relatively ineffective at zero angle of attack. Yet as the angle of attack increases, dimples slows the development of separation from the boundary layer thus reducing the production of pressure drag at high angles. Deepanshu Srivastav was attempting to enhance an aircraft's maneuverability and performance by controlling flow over the NACA0018 airfoil. Beginning from 2D analysis of inward and outward dimpled airfoil, quantitative research was performed to validate the effect of dimples. The dimples boost the aerodynamic efficiency while helping to improve the overall aerodynamic performance. "M. E. Livya, Anitha G., P. Valli "explained the change made to enhance the aircraft's aerodynamic qualities and maneuverability. Such initiative entails reducing the phenomena of drag and delay. The different dimple shapes were studied by positioning airfoil over NACA 0018 at the successful position to postpone the separation point of the flow. Mohanasaravanan P S "did a job modeling a wing with dimples on the wing's top surface and evaluating the findings using CFX tools in ANSYS. The result indicates an improvement in the point of separation for the stall angle, wind. Where the pressure drag occurs a decrease but the skin friction point drag may increase due to attached flow across the wing surface. A comparative analysis is also performed which shows the variation in lifting and dragging of modified airfoil models at various angles of attack with and without dimple over the wing surface. Bhadri Rajasai, Ravi Tej, and Sindhu Srinath's study of the turbulent flow over dimpled aerofoil profiles was completed. For their analysis the effects of the skin-friction drag and lift were using dimples of differing aspect ratio. External flow tests were conducted using the program ANSYS FLUENT. The subsequent reduction in pressure and decreased drag have been observed. Chang-Hsien Tai, Chih-Yeh Chao, Jik-Chang Leong and Qing-Shan Hong studied the flight distance of a golf ball According to their analysis the flight distance is determined not just by its substance but also by the aerodynamics of the inner dimples on its back. The flow field and aerodynamics properties of golf balls were analyzed and measured using the Computational Fluid Dynamics system. They used FLUENT tools and numerical calculations to approximate the aerodynamic parameters and noise levels for various types of golf balls with various dimple configurations were performed. Our experimental findings found that if tiny dimples were added between the initial dimples the golf ball's lift coefficient improved.

Modeling and Simulation

We selected NACA 0018 airfoil, which is a symmetrical airfoil with 1 m chord, to conduct the study. The wing has a span of 2.5 m. We put 12 dimples in the first row at a distance of 18 cm from the leading edge, as the average thickness is 18 cm of the total length of the chord. The dimples were put on both sides of the wing in similar proportion. The research was performed at two speeds and four different attack angles. The models were drawn using CATIA V 5 software.

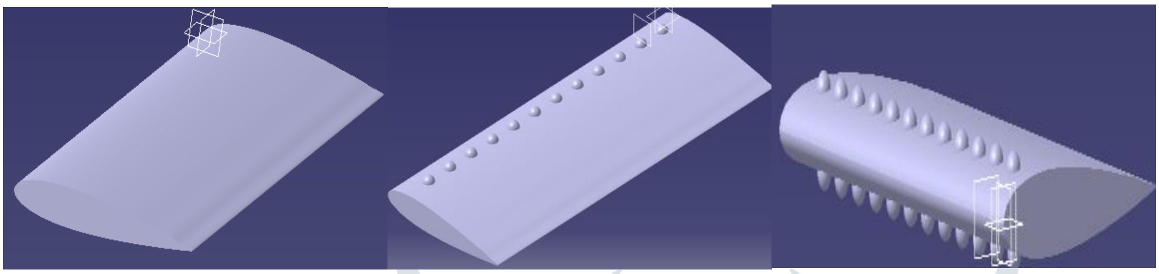


Figure1. Cad model of wing with various dimple configurations

ICEMCFD software did the part of grid creation. The 3-dimensional unstructured tetrahedral mesh was used, and we chose a hemispheric region for our study. The benefits of unstructured mesh are shorter grid time usage for complicated geometries and the ability to adapt the grid to improve numerical precision.

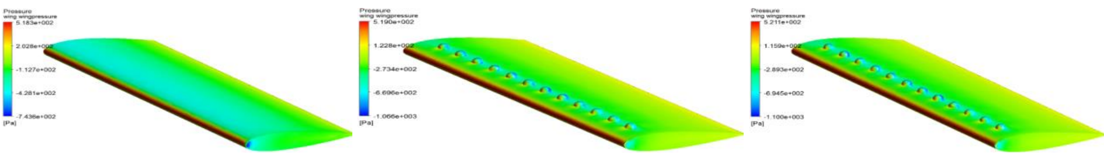
Results and Discussions

The review continued with wing without dimples, and ends with dimples with wing. For various angles of attack the flow patterns were observed over various wing models. The lifting coefficient, drag coefficient, and aerodynamic performance is measured and plotted against various attack angles.

Wing pressure

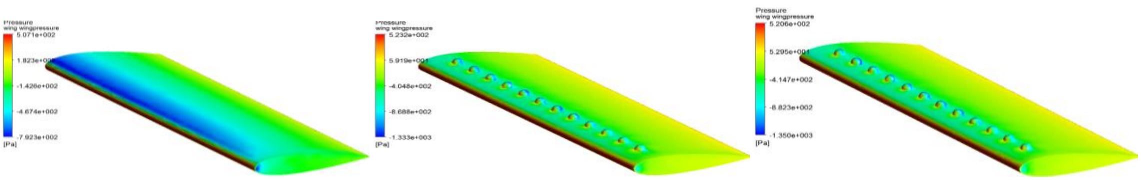
a) Wing Pressure contour at α = 0° and Velocity = 30 m/s

Without dimples upper surface dimples upper and lower surface dimple



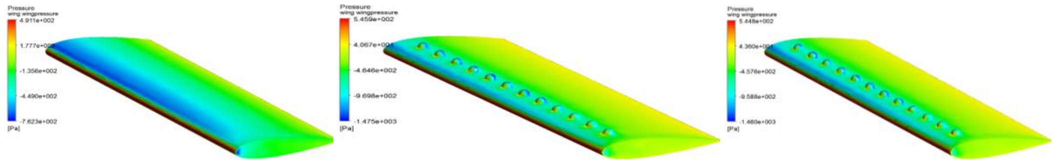
b) Wing Pressure contour at α = 5° and Velocity = 30 m/s

Without dimples upper surface dimples upper and lower surface dimple



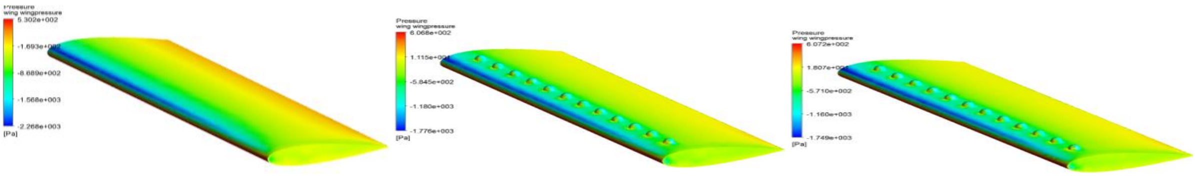
c) Wing Pressure contour at α = 10° and Velocity = 30 m/s

Without dimples upper surface dimples upper and lower surface dimple



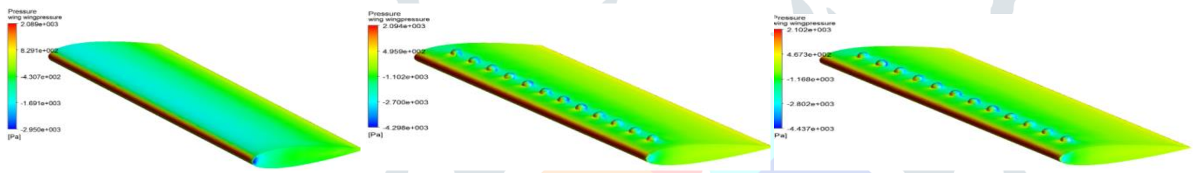
d) Wing Pressure contour at α = 15° and Velocity = 30 m/s

Without dimples upper surface dimples upper and lower surface dimple



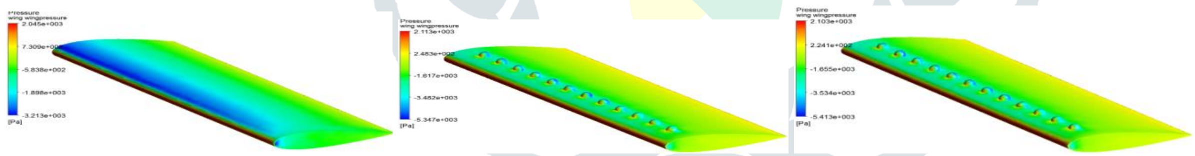
e) Wing Pressure contour at α = 0° and Velocity = 60 m/s

Without dimples upper surface dimples upper and lower surface dimple



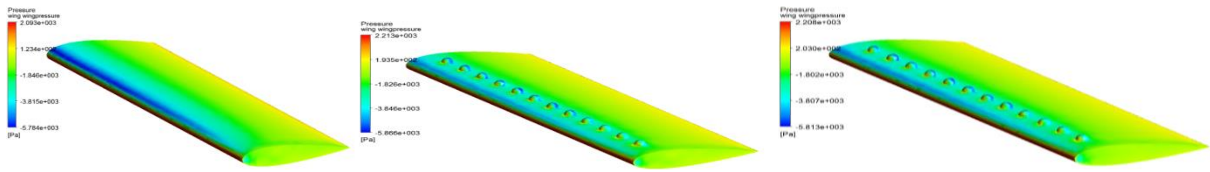
f) Wing Pressure contour at α = 5° and Velocity = 60 m/s

Without dimples upper surface dimples upper and lower surface dimple



g) Wing Pressure contour at α = 10° and Velocity = 60 m/s

Without dimples upper surface dimples upper and lower surface dimple



h) Wing Pressure contour at α = 15° and Velocity = 60 m/s

Without dimples upper surface dimples upper and lower surface dimple

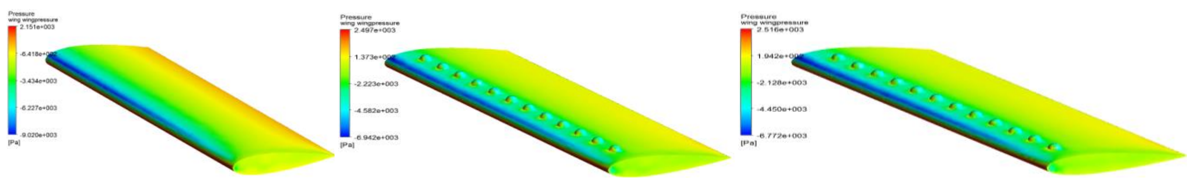


Figure 2: Wing pressure contour for various wing configurations

Pressure distribution over wing surface for various wing configuration at different angle of attack and velocity is shown in figure 2. Figure 2 a to d presents the pressure distribution over wing surface at 30 m/s with an angle of attack varied from 0degree to 15degree with 5degree increment. For the wing configuration without dimples when the angle of attack is increased the low pressure region is shown in the upper surface of the airfoil. This low pressure region is reduced when the dimples are introduced in the upper surface or in the upper surface and lower surface. Since the maximum angle considered for this study is 15degree there is no flow separation is seen in flowfield. The introduction of dimples originates small vortices in the surface of the wing. This vortices energize the flow and makes the flow to get attached to the surface of the wing. Figure 2 e to h presents the flow pressure distribution over the wing surface at 60m/s in this flow field also the dimples reduces the low pressure region in the upper surface of the airfoil. This reduction in low pressure region near to the leading edge reduces the adverse pressure gradient and result in presentation of the flow separation of the airfoil.

Lift Coefficient Curve

At Velocity V= 30 m/s At Velocity V=60 m/s

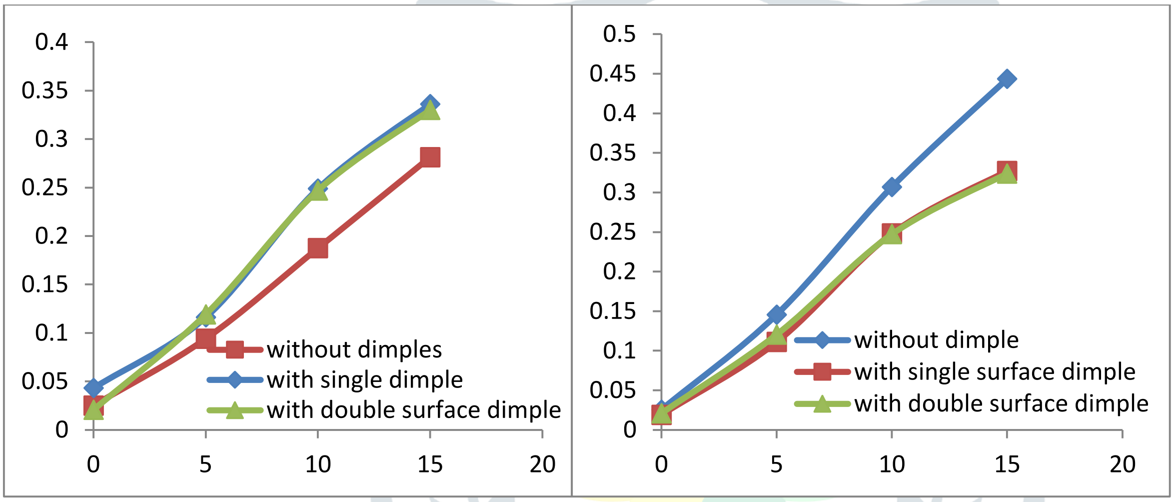


Figure 3: Lift coefficient Vs AOA

Drag Coefficient Curve

At Velocity V= 30 m/s At Velocity V=60 m/s

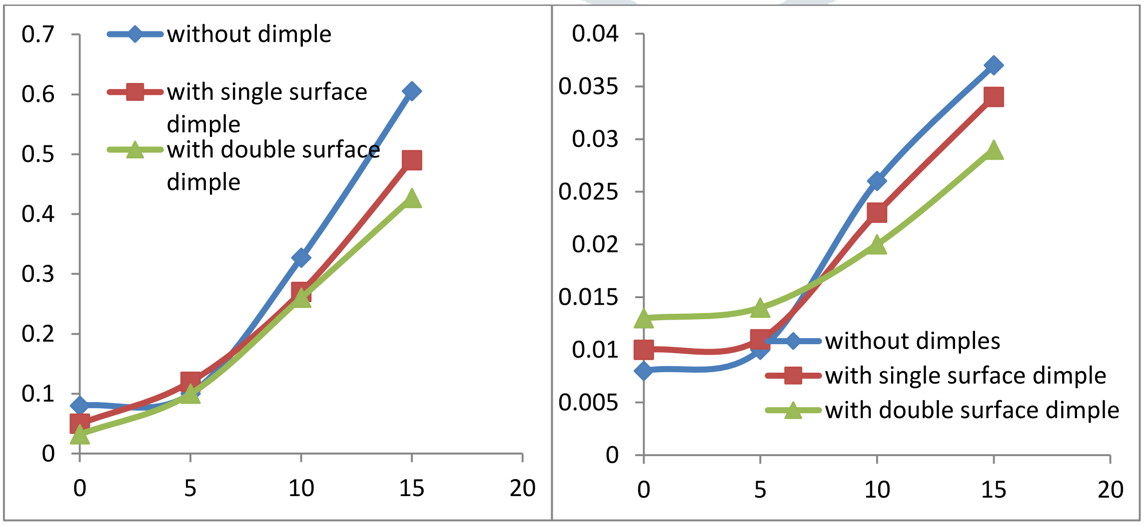


Figure 4: Drag coefficient Vs AOA

Figure 3 shows the variation of lift coefficient with the angle of attack for different configuration of wing at 30 m/s and 60m/s. At 30m/s flow velocity the lift curve for without dimple and with double surface dimples are similar and the curves almost coincide with each other. But in the case of 60 m/s flow velocity the dimpled configuration is inferior to the non-dimpled configuration. This may be due to the strength of the vortices increases with the flow velocity. Figure 4 represents the variation of the drag co-efficient with respect to angle of attack for flow velocity 30m/s and 60 m/s configuration. As expected the wing with dimples exhibits more drag than the wing without dimple configuration.

Aerodynamic Performance Curve

At Velocity V= 30 m/s At Velocity V=60 m/s

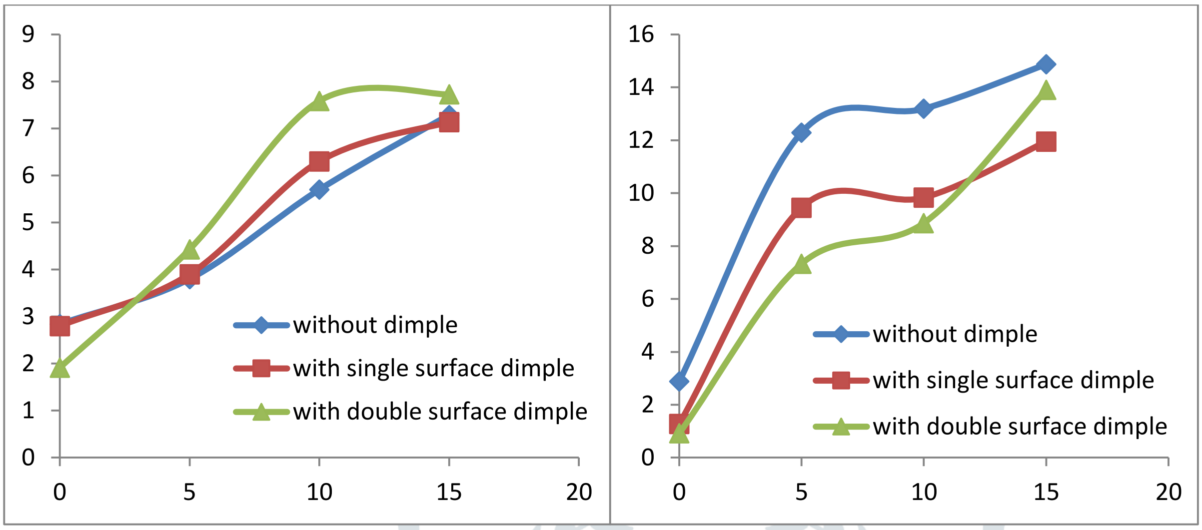


Figure 5: Lift to Drag ratio Vs AOA

L/D variation with angle of attack at different velocity is shown in figure 5. At 30m/s flow condition the L/D is minimum for the double surface dimple at AOA 10. Since the drag is more for the wing with dimple configuration at 60m/s L/D is also lower. So the current design with dimpled configuration can be applicable to lower velocity flows only.

Conclusions

Adding dimples over the surface of the wing has proved successful in altering the direction of the flow over the wing during high angle of attack. Thanks to this change in the flow system, the lift and drag forces also change. The idea of dimple is very recent and making an aircraft more maneuverable by altering the design of flow may be an incredibly advantageous activity. This also improves the aerodynamic efficiency which in effect also boosts optimal performance. This dimple idea can help to take offs at low speed in shorter periods.

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