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AERODYNAMIC ANALYSES OF NACA 63-215

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ABSTRACT

In this study, the aerodynamic performance of the NACA 63-215 airfoil was investigated. The aerodynamic performance of the airfoils is changed with respect to the angle of attack (AoA) values. The AoA increases, the separation of the boundary layers on the upper and lower surface of the wing increases. This situation is an effect on aerodynamic performance. So aerodynamic parameters (lift coeff. and drag coeff.) at different AoA values were investigated. Also, flow separation was investigated at different AoA values. After the analysis, there was no flow separation for three airfoil profiles at 0^0 AoA. Flow separation started in the middle of the airfoil for three airfoil profiles at 17^0 AoA. At 18^0 AoA, flow separation started in the middle of the airfoil. Maximum aerodynamic performance was obtained at 4^0 and 8^0.

1. INTRODUCTION

The aerodynamic performance of an aircraft wing is decreased by flow separation (Stall). Flow separation on an airfoil surface is related to the shape of the airfoil. Hence in the literature, many different studies exist about the investigation of the aerodynamic performance of airfoils (figure 1).

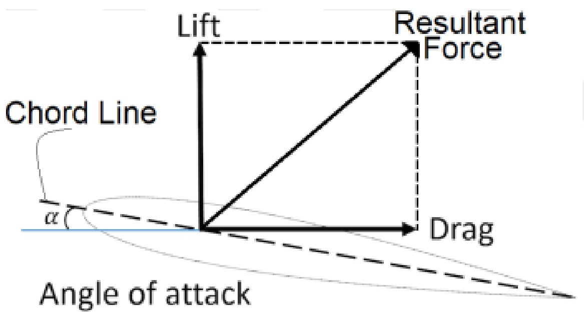

Figure 1. Lift force, drag force and AoA

Thanks to computational fluid dynamics (CFD), dependency on wind tunnel investigations is reduced so consequently design cost is also reduced. As a result of these developments, wing performances are increased using CFD tools [1].

Pressure distribution over the airfoils was analyzed at different AoA. The pressure distributions as well as coeff. of lift to coeff. of drag ratio of two airfoils were visualized and compared [2].

Static analysis is a type of analysis applied to determine the stresses resulting from the applied loads. Random vibration analysis and modal analysis were used to determine stresses due to frequencies. The buckling analysis was applied to determine the load factor and deformation. CFD analysis was performed to determine drag and lift forces. According to the analysis results, it was concluded that the drag force was modified better than the original model [3].

CFD analysis was performed for NACA 23024 airfoil using Ansys Fluent solver. In the analysis, the K-omega SST turbulence model, Spalart Allmaras turbulence model, and Standard K-Epsilon Turbulence model were used as the turbulence model. When the results obtained from the analysis were compared with the experimental wind tunnel results, it has been observed that the results were in good agreement with each other [4].

Lift and drag forces can be calculated by CFD analysis as well as by wind tunnel tests. A two-dimensional subsonic flow analysis study was carried out for the NACA 0012 airfoil in different AoAs and 3 × E + 06 Reynolds number. Analysis and simulation results match each other. Therefore, the analyzes proved their accuracy as an alternative to experimental methods [5].

Flow separation on the airfoils NACA 4412 and S809 were compared to each other. The aerodynamic performance of these two airfoil profiles was compared at different AoA (between 0^0 and 20^0) values. Drag coefficient (CD), lift coefficient (CL), moment coefficient (CM), and flow separation were used as a performance parameter [6].

The distribution of velocity over the shell is a critical specification for the bullet's range and penetration concept. Three different bullet tip shapes were examined. As a result of the study, velocity and pressure distribution on bullets with different tip geometries were obtained [7].

The shape of the wing profile (by aerodynamic design requirements) was changed during the flight to achieve maximum performance at different AoA values. In the study, 2-dimensional computational fluid dynamics analysis was used based on NACA 4412 airfoil. To achieve higher aerodynamic performance at different AoA values during flight, two different wing profiles (NACA 4412_1 and NACA 4412_2) were obtained by changing the NACA 4412 profile and the aerodynamic performances of these two profiles were compared with the original NACA 4412 profile. The lift coefficient, drag coefficient, and attachment loss performance parameters were examined in these analyses [8].

An alternative method was developed to reduce flow separation. Airfoil shape can be changed dynamically at different conditions (such as speed, angle of attack) also unusual airfoil design constraints can sometimes arise leading to some unconventional shapes and as a result of these desings different airfoil models can be used when the aircraft is climbing or descending [9].

The lift coeff. of a fixed-wing airplane can vary with changing AoA. Increasing AoA was associated with increasing lift coefficient up to the max. lift coeff., after which lift coeff. decreases. A numerical and experimental investigation was performed to obtain the lift and the drag forces.

ANALYSIS

The Angle of Attack (AoA) is the angle between the oncoming air or relative wind and a reference line (chord line) on the airplane or wing. This angle affects the aerodynamic forces to lift and drag. Area A in equation 1 increases with increasing AoA value. The drag force F_D is given equation (1).

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

where ρ is density, v is the velocity and A is the area. So, the coefficient of drag C_D is given by equation (2).

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

The lift force F_L is given equation (3).

$$F_L = \frac{1}{2}\rho v^2 C_L A \tag{3}$$

coefficient of drag C_L is given by equation (4).

$$C_L = \frac{F_L}{\frac{1}{2}\rho v^2 A} \tag{4}$$

In this study, CFD analysis was carried out from different angles and different profiles. Analysis parameters are listed in table 1.

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Table 1. Analysis Parameters

Node	30272
Elements	29920
Solver	Pressure based steady-state
Viscous model	Spalart Allmaras
Density (kg/m3)	1.225
Turbulent viscosity	1
Inlet velocity (m/s)	1
Chord-length (m)	1
Momentum	Second-order upwind

The aerodynamic efficiency of NACA 63-215 airfoil was investigated at various AoA values from 0^0 to 23^0. The coefficient of lift and drag values were calculated for 7,0388 $\times 10^4$ Reynolds number.

The computational fluid dynamic (CFD) analysis was used to determine the aerodynamic performance of two-dimensional (2D) flow over the NACA 63-215 airfoil (figure 2). The aerodynamic performance of this airfoil was investigated at different AoA (between 0^0 and 23^0) values. Drag coefficient, lift coefficient, and flow separation was used as a performance parameter.

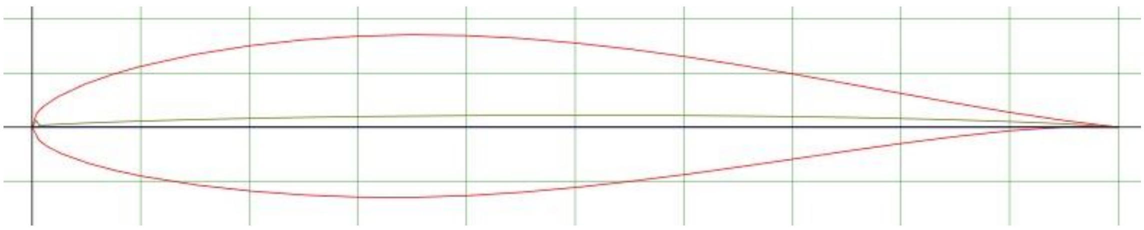

Figure 2. NACA 63-215 Airfoil

The analysis was performed using the CFD tool of ANSYS software, which is a commercial finite element analysis program. Complete mesh distribution can be seen in figure 3, an enlarged view of NACA 63-215 mesh is given in figure 4.

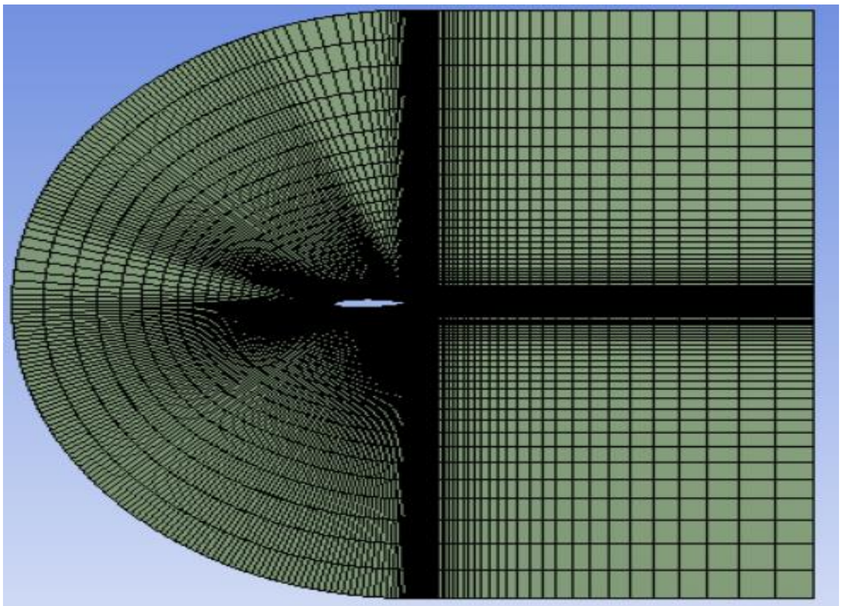

Figure 3. Complete mesh

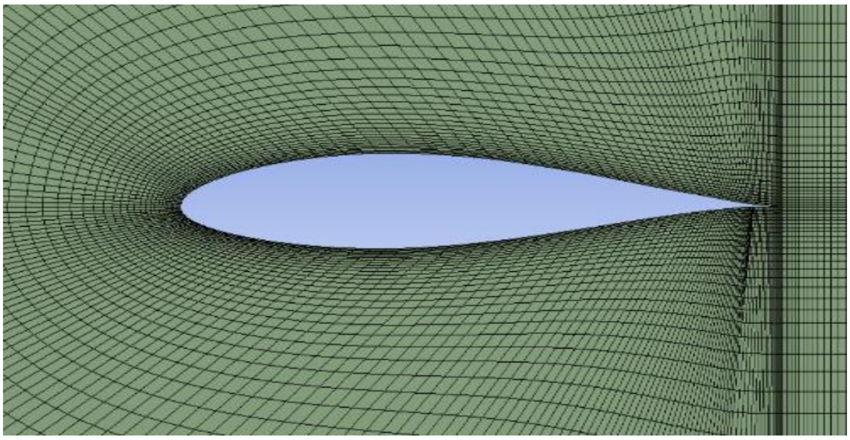

Figure 4. Enlarged view of NACA 63-215 mesh

RESULTS AND DISCUSSIONS

Lift coefficients of NACA 63-215 at different AoA were given in figure 5. Also, drag coefficients of NACA 63-215 at different AoA were given in figure 6.

When figure 5 was investigated, it was seen that the maximum lift coefficient was obtained at 17^0 AoA for NACA 63-215 and the minimum lift coefficient was obtained at 0^0 AoA for NACA 63-215.

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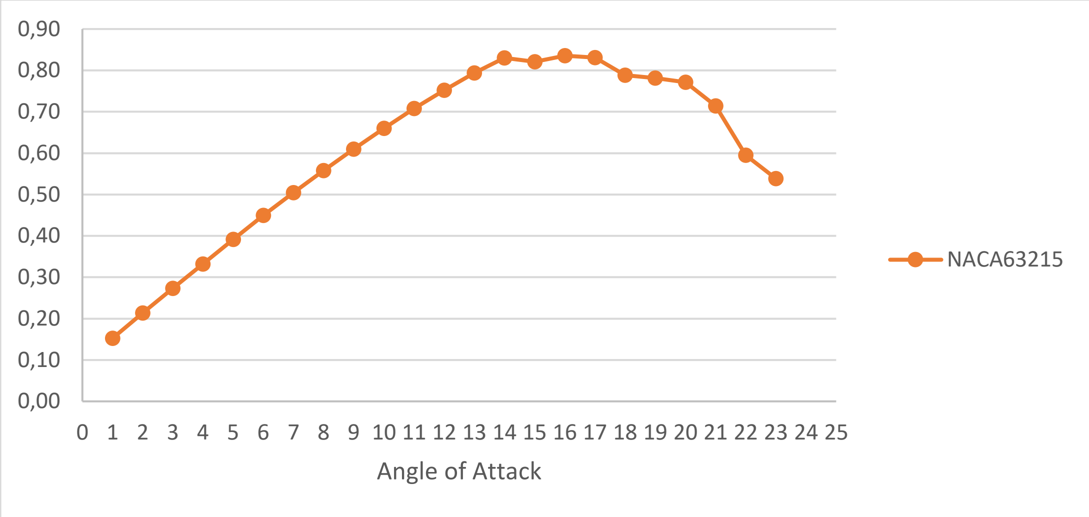

Figure 5. Lift coefficient at different AoA

The NACA 63-215 airfoil should be used between 16^0 and 21^0 AoA values, to obtain maximum lift.

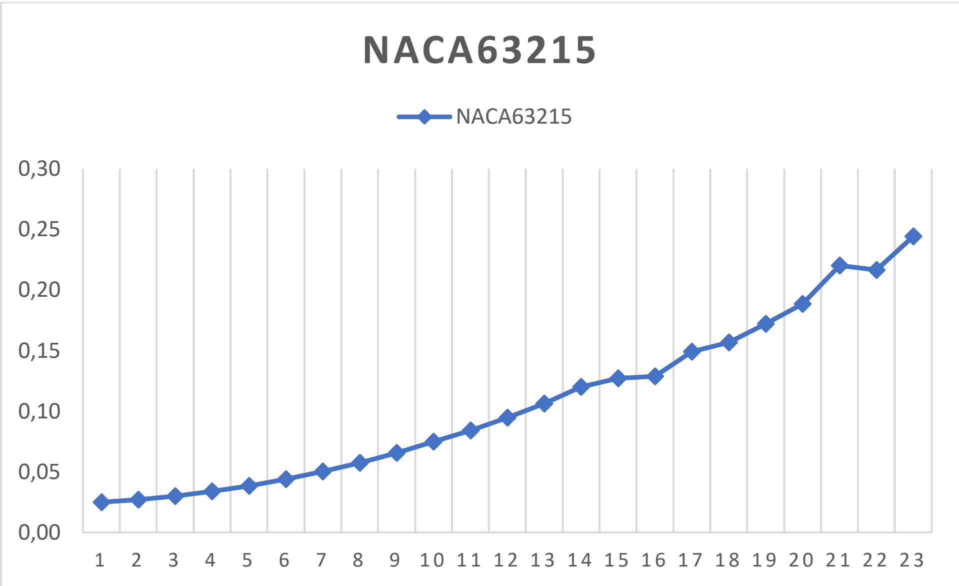

Figure 6. Drag coefficient at different AoA

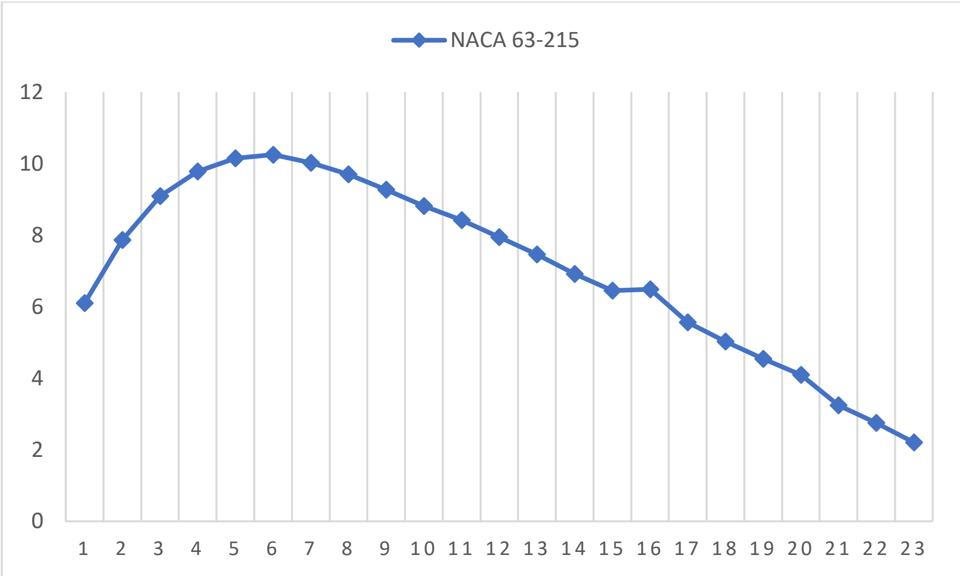

Figure 7. Cl/Cd at different AoA

The NACA 63-215 airfoil should be used between 4^0 and 8^0 AoA values to obtain maximum aerodynamic efficiency. Cl/Cd ratio was given according to AoA in figure 7.

The pressure distribution of NACA 63-215 at 0^0 AoA value was given in figure 8. The velocity distribution of NACA 63-215 at 0^0 AoA value was given in figure 9.

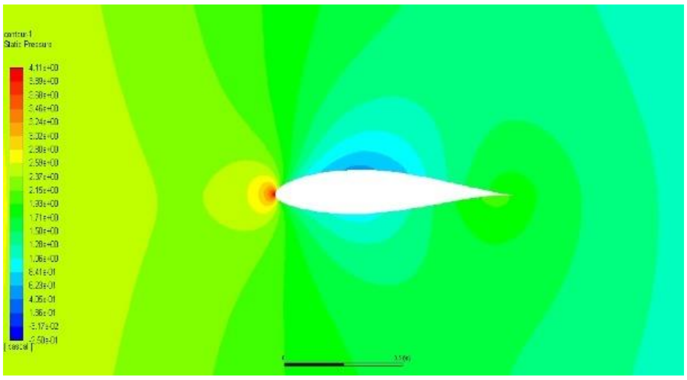

Figure 8. Pressure distribution of NACA 63-215 at 0^0 AoA

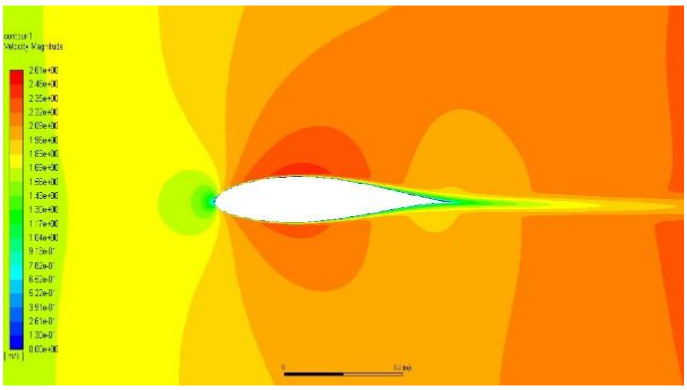

Figure 9. Velocity distribution of NACA 63-215 at 0^0 AoA

The pressure distribution of NACA 63-215 at 17^0 AoA value was given in figure 10. The velocity distribution of NACA 63-215 at 17^0 AoA value was given in figure 11.

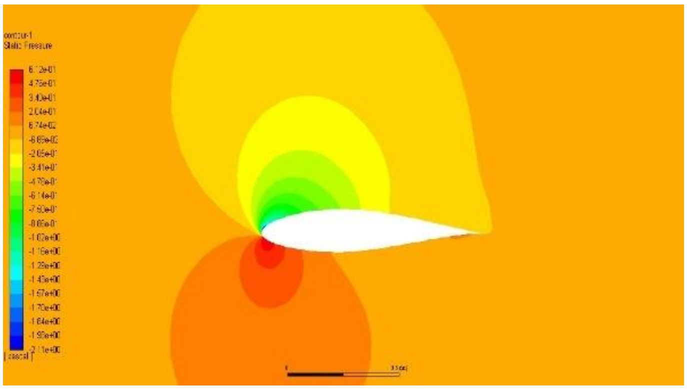

Figure 10. Pressure distribution of NACA 63-215 at 17^0 AoA

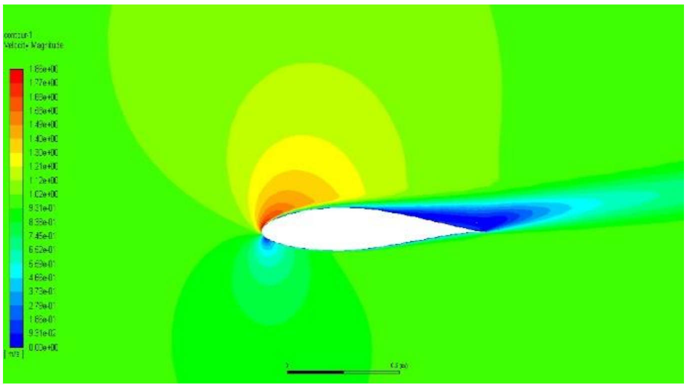

Figure 11. Velocity distribution of NACA 63-215 at 17^0 AoA

The pressure distribution of NACA 63-215 at 21^0 AoA value was given in figure 12. The velocity distribution of NACA 63-215 at 21^0 AoA value was given in figure 13.

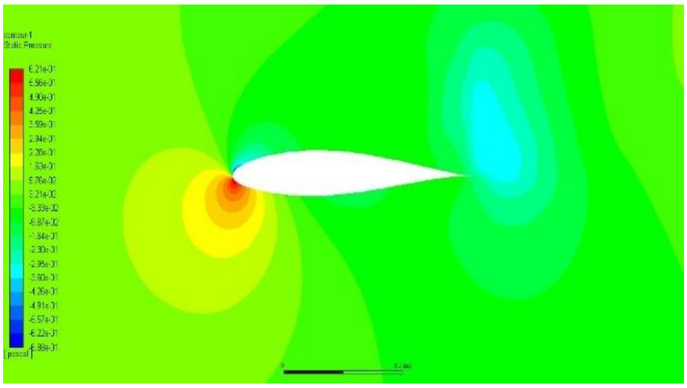

Figure 12. Pressure distribution of NACA 63-215 at 21^0 AoA

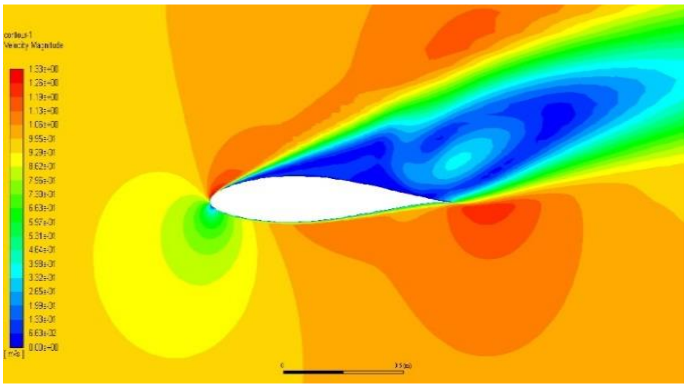

Figure 13. Velocity distribution of NACA 63-215 at 21^0 AoA

The velocity vector of NACA 63-215 0^0 AoA value was given in figure 14.

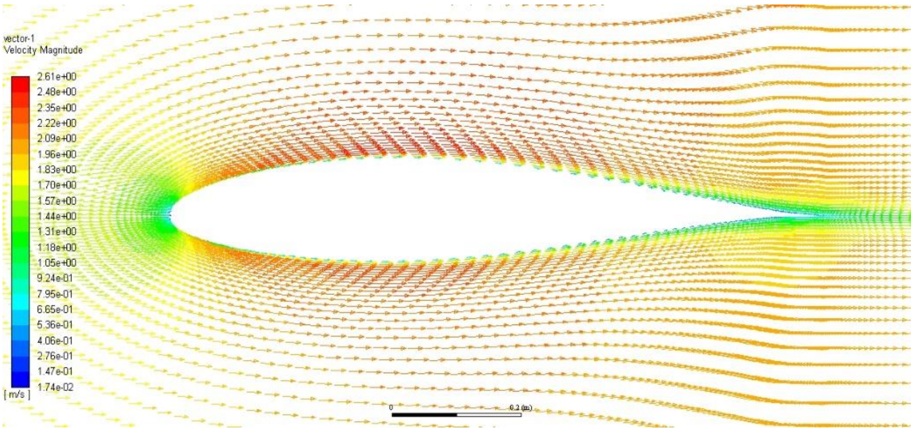

Figure 14. The velocity vector of NACA 63-215 at 0^0 AoA

When figure 14 was investigated it was seen that there was no flow separation at 0^0 AoA.
The velocity vector of the NACA 63-215 at 17^0 AoA value was given in figure 15.

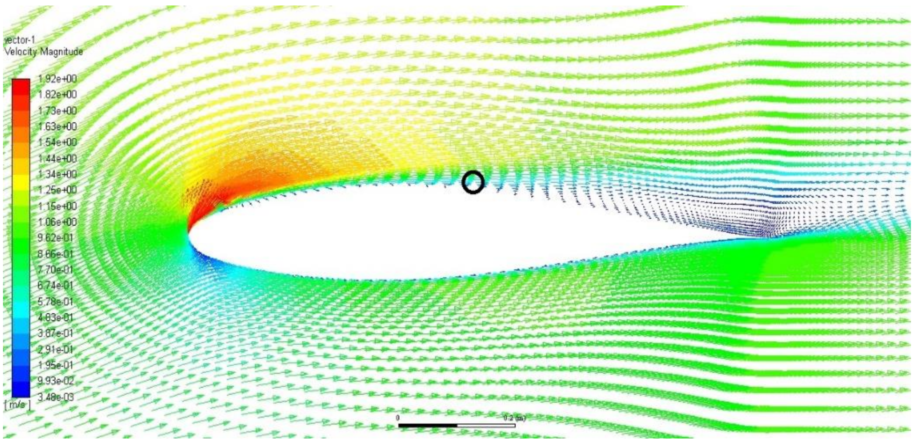

Figure 15. The velocity vector of NACA 63-215 at 17^0 AoA

When figure 15 was investigated it was seen that flow separation started at the nearly middle of the airfoil for NACA 63-215 at 17^0 AoA.

The velocity vector of the NACA 63-215 at 21^0 AoA value was given in figure 16.

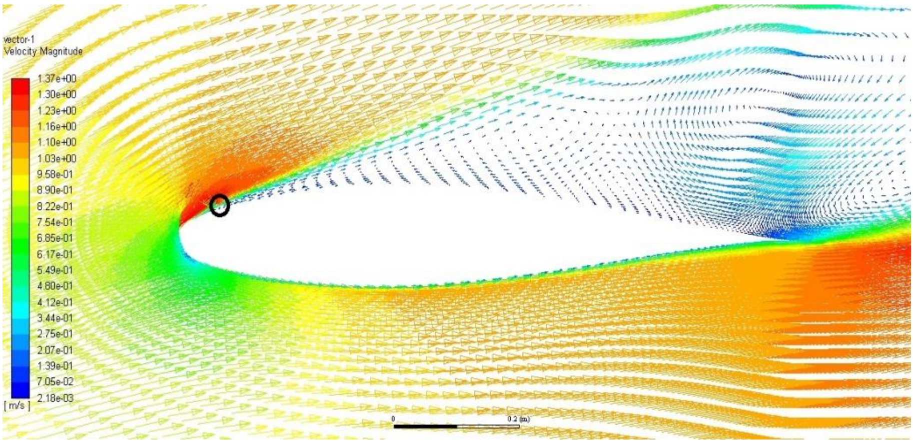

Figure 16. Velocity vector of NACA 63-215 at 21^0 AoA

When figure 16 was investigated it was seen that flow separation started at the front of the airfoil for NACA 63-215 at 21^0 AoA.

CONCLUSIONS

In this study, the aerodynamic performance of NACA 63-215 was investigated at different (between 0^0 and 23^0) AoA values. Drag coefficient, lift coefficient, and flow separation was used as a performance parameter.
After the analysis, the results were given below:

- The maximum lift coefficient was obtained:
    - at 17^0 AoA
- There was no flow separation for three airfoil profiles at 0^0 AoA.
- Flow separation started in the middle of the airfoil for three airfoil profiles at 17^0 AoA.
- At 18^0 AoA, flow separation started:
    - at the middle of the airfoil
- Maximum aerodynamic performance was obtained at 4^0 and 8^0.

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