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Journal of Aeronautics and Aerospace Engineering

Research Article

Analysis of Wing (NACA 0012 Aero foil) with and without Winglets to Enhance Aerodynamic Efficiency

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ABSTRACT

Aerodynamic drag can be reduced by modifying a wing's geometry and the wingtip design. Winglets play a vital role in the wing design. The winglets present at the tip of wings helps in reducing the drag and that results in increase of lift to drag ratio.

This work deals with the analysis of winglet at the tip of wing to reduce the induced drag in order to enhance the aerodynamic efficiency. Considering the NACA 0012 airfoil for the rectangular wing and two types of winglets *i.e.*, wing grid, blended wing so as to analyze performance of each. The focus is to study the lift and drag forces generated by merging winglet design with the constrained aircraft wing. The wing and wing with winglets are constructed in the solid works software and the same has been analysed in the ANSYS fluent workbench. The effects on lift and drag of the wing can be obtained using computational fluid dynamics considering the contribution of aerodynamic forces and winglets.

At last, the efficiency of wing was further determined by evaluating lift to drag ratio with obtained lift and drag forces and the comparison was made between the winglets used based on its performance and contribution to the enhancement of the aerodynamic efficiency.

Keywords: Winglets; NACA 0012 aero foil; Lift; Drag; Aerodynamic efficiency; Solid works; Ansys fluent

INTRODUCTION

In this work comparative and quantitative analysis of various types of winglets are done in order to achieve better aerodynamic performance for lighter aircrafts and through this analysis, identified key parameters which influences winglets efficiency [1-3].

Fuel efficiency is directly linked with aerodynamic efficiency hence fuel efficiency will be good which results in low emission and less operating cost.

Here the major concern is lift to drag ratio because as lift increases along with it drag increases. Hence higher lift does not always signify better performance as it produces high drag. Therefore, lift to drag ratio is the optimum measurement of performance and it is called as aerodynamic efficiency in this work.

In this paper analysis are made to compare and study the aerodynamic characteristics of rectangular wing and wing with winglets. A parametric study is made modifying the winglets in order to optimize aerodynamic and fuel efficiency, as well as investigate the effects of surface roughness on the turbulent boundary layer.

In this work NACA0012 aero foil's lift and drag characteristics curves are developed. In many constructions this aero foil is used hence this aero foil is considered for the study (Figures 1).

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Received: 10-May-2022, Manuscript No. JAAE-22-17421; **Editor assigned:** 12-May-2022, PreQC No. JAAE-22-17421 (PQ); **Reviewed:** 26-May-2022, QC No. JAAE-22-17421; **Revised:** 09-Jul-2022, Manuscript No. JAAE-22-17421 (R); **Published:** 16-Jul-2022, DOI: 10.35248/2168-9792.22.11.286

Citation: Banakar P (2022) Analysis of Wing (NACA 0012 Aero foil) with and without Winglets to Enhance Aerodynamic Efficiency. J Aeronaut Aerospace Eng. 11:286.

MATERIALS AND METHODS

Methodology

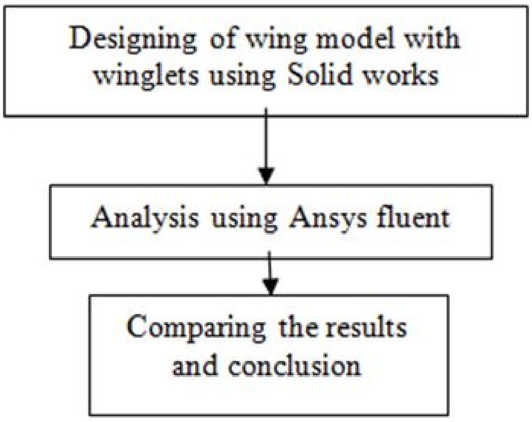

Figure 1: Methodology.

Research starts with designing wing models with winglets of different structures using solid works software and analysis of that wing with winglets are meshed and analyzed through Ansys fluent for various angle of attacks and finally the results are compared and concluded (Figures 2-34, Tables 1 and 2) [4-8].

MODELLING AND DESIGN PARAMETERS AND INPUTS

Rectangular wing

Span: 300 mm

Chord: 150 mm

Aspect ratio: 2

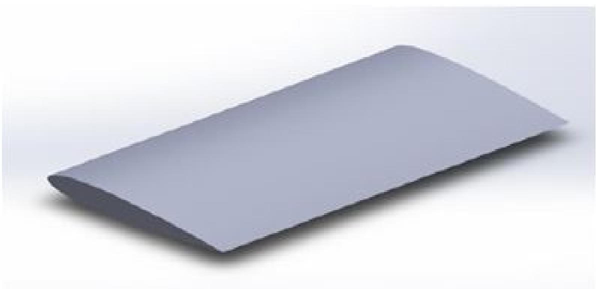

Figure 2: Rectangular wing.

Blended Winglet (Assembled to Main Rectangular Wing)

Span: 75 mm

Chord: 45 mm

Aspect ratio: 2.5

Cant angle: 45°

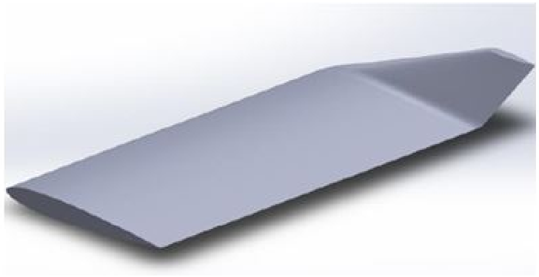

Figure 3: Wing with blended winglet.

Grid wing (assembled to main rectangular wing)

Span: 75 mm

Chord: 30 mm

Aspect ratio: 2.5

At can't angle 45°

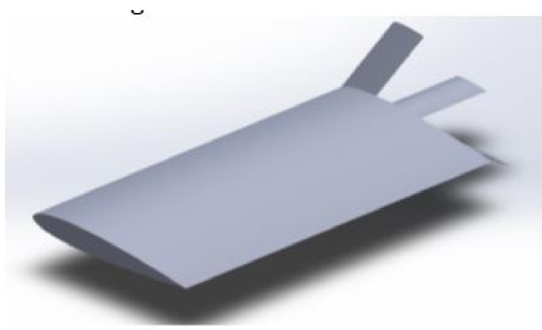

Figure 4: Wing with grid wing winglet at 45° cant angle.

Solver type-pressure based

Viscous model-Spalart-Allmaras

Boundary conditions:

Inlet-Velocity based (30 m/s)

Outlet-Pressure based

Meshing

Inflation (Total thickness):

No. of layers-10

Maximum thickness-4 mm

Edge sizing:

No. of divisions-420

Rectangular wing

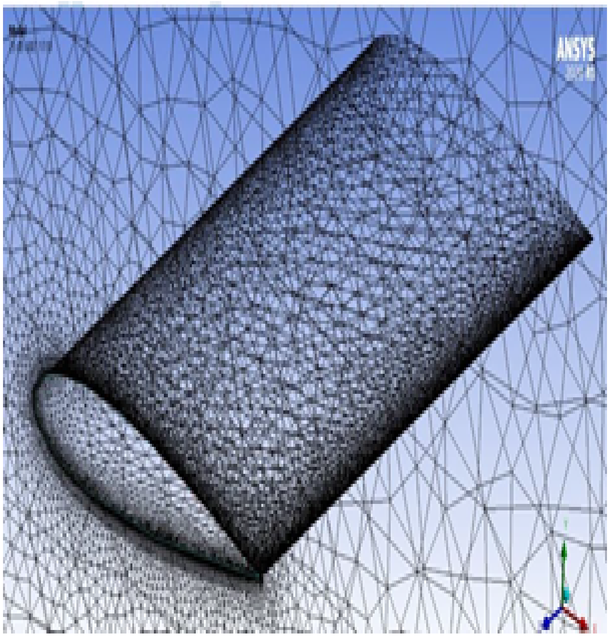

Figure 5: Meshed model of rectangular wing.

Blended winglet (assembled to main rectangular wing)

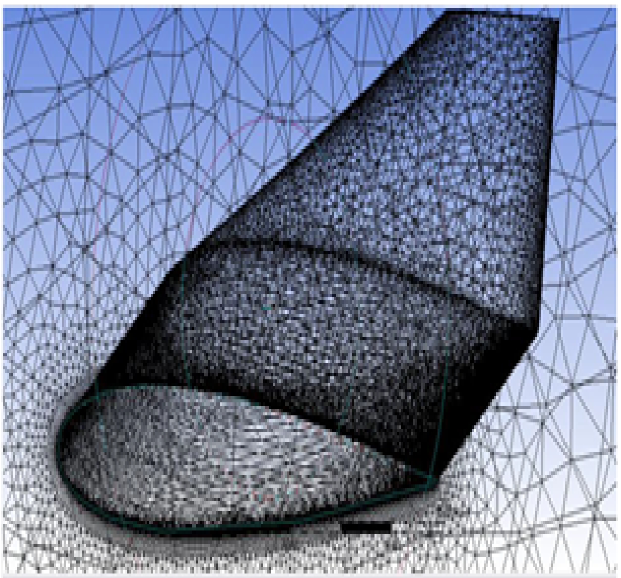

Figure 6: Meshed model for blended winglet-wing.

Grid wing (assembled to main rectangular wing)

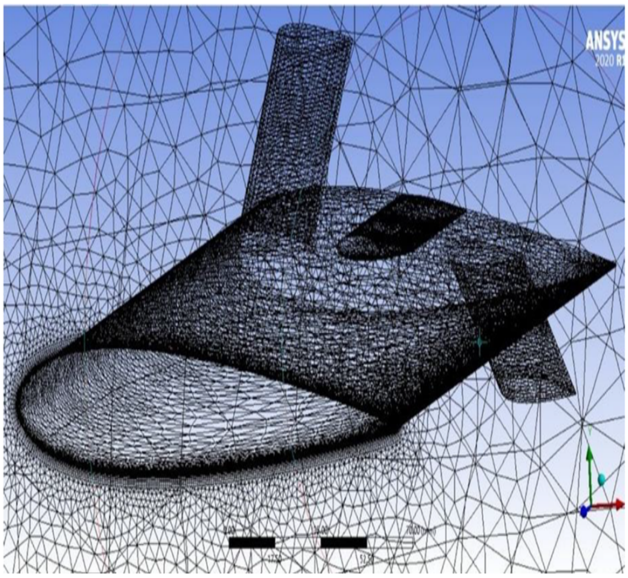

Figure 7: Meshed model for grid winglet-wing.

RESULTS AND DISCUSSION

CFD counter plots

Wing without winglets:

a) At 0°-Velocity contour

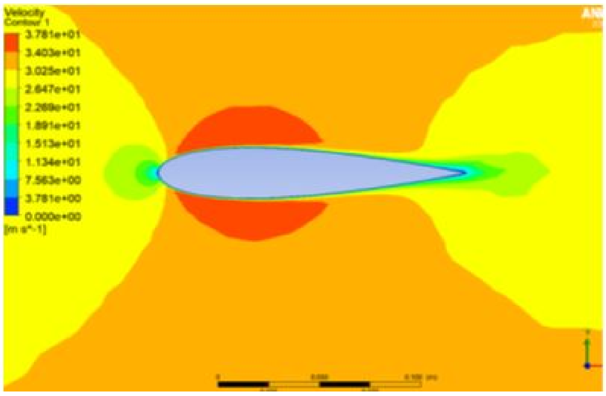

Figure 8: Velocity contour of wing at 0°.

b) Pressure contour

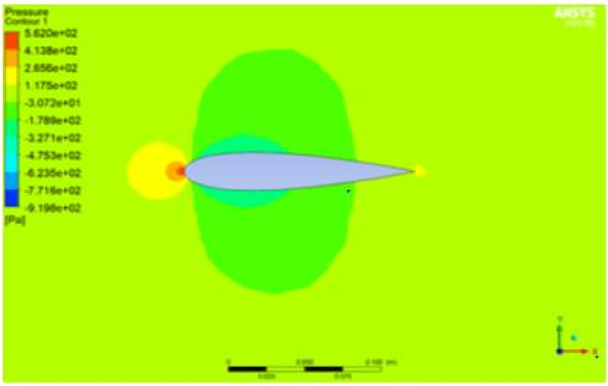

Figure 9: Pressure contour of wing at 0°.

a) At 4°-Velocity contour

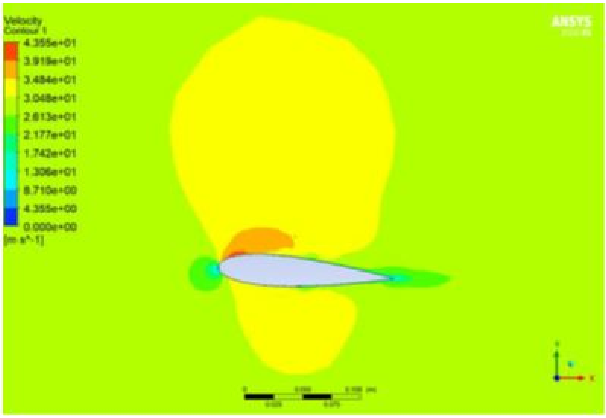

Figure 10: Velocity contour of wing at 4°.

b) Pressure contour

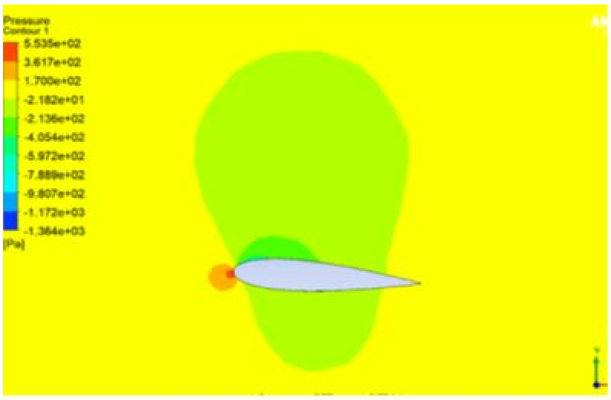

Figure 11: Pressure contour of wing at 4°.

a) At 8°-Velocity contour

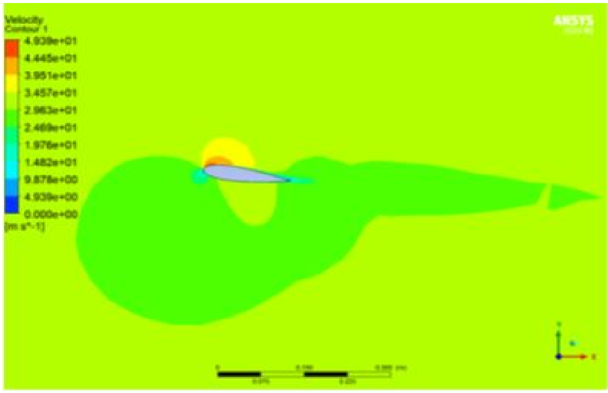

Figure 12: Velocity contour of wing at 8°.

b) Pressure contour

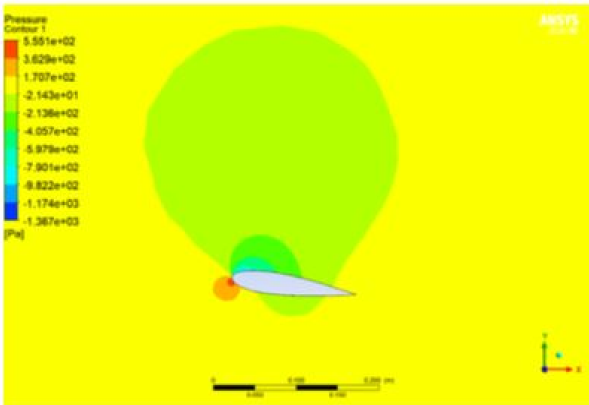

Figure 13: Pressure contour of wing at 8°.

Wing and Winglet

a) At 0°-Velocity contours

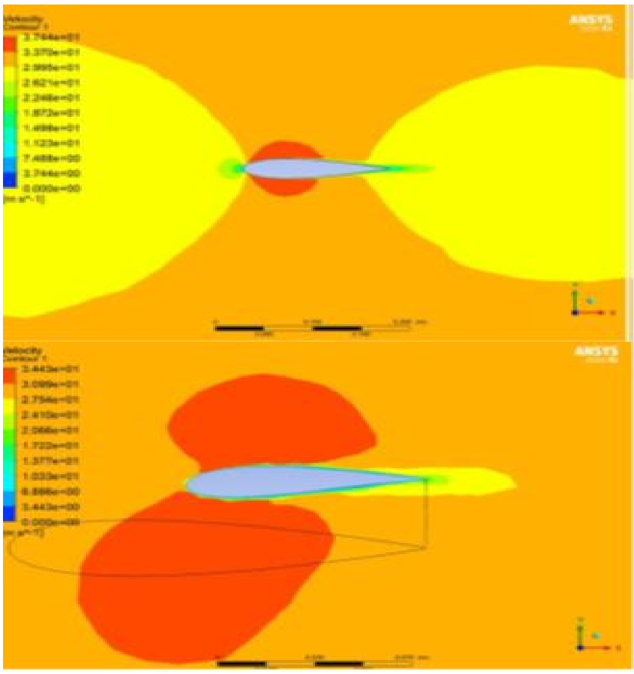

Figure 14: Velocity contours of blended wing and winglet at 0°.

b) Pressure contours

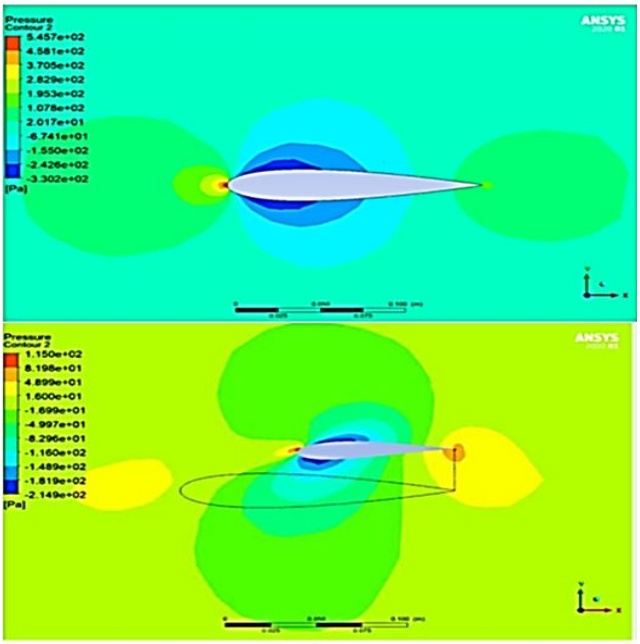

Figure 15: Pressure contours of blended wing and winglet at 0°.

a) At 4°-Velocity contours

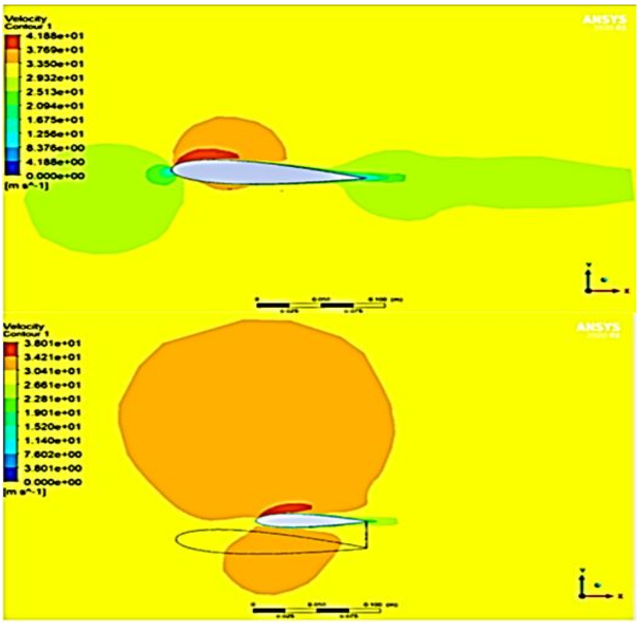

Figure 16: Velocity contours of blended wing and winglet 4°.

b) Pressure contours

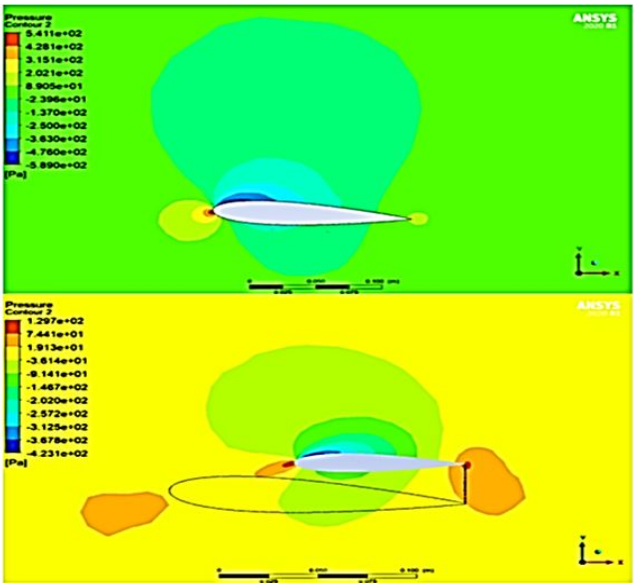

Figure 17: Pressure contours of blended wing and winglet at 4°.

a) At 8°-Velocity contours

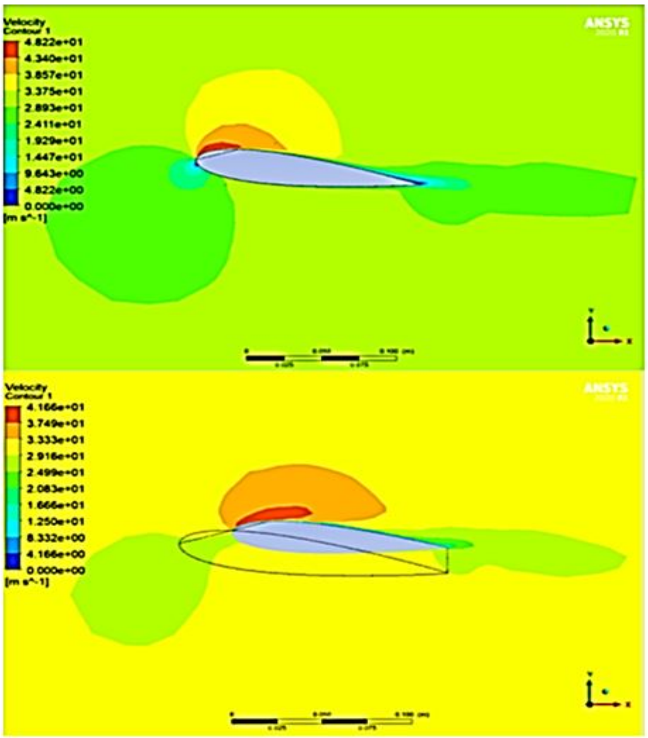

Figure 18: Velocity contours of blended wing and winglet at 8°.

b) Pressure contour

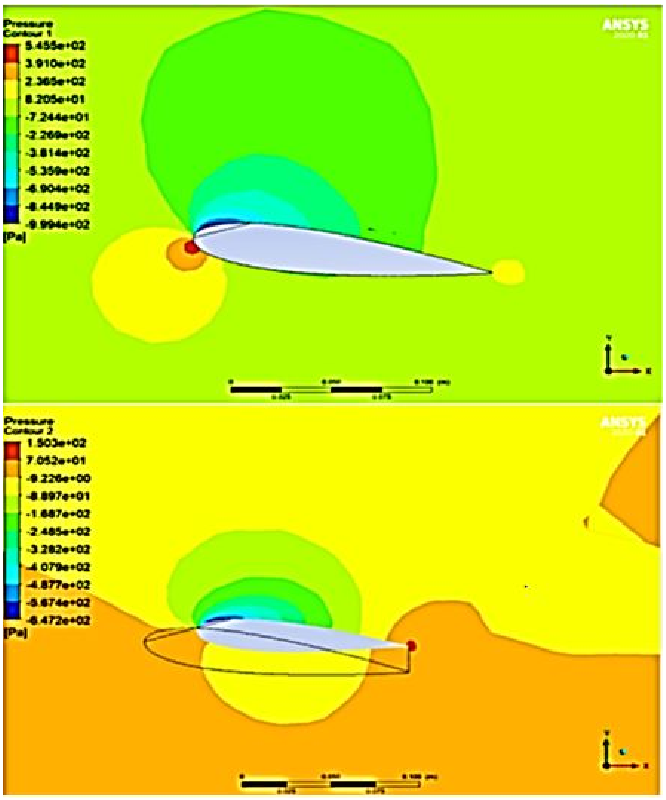

Figure 19: Pressure contours of blended wing and winglet at 8°. Wing with grid winglet (Can't angle 45°)

a) At 0°-Velocity contour

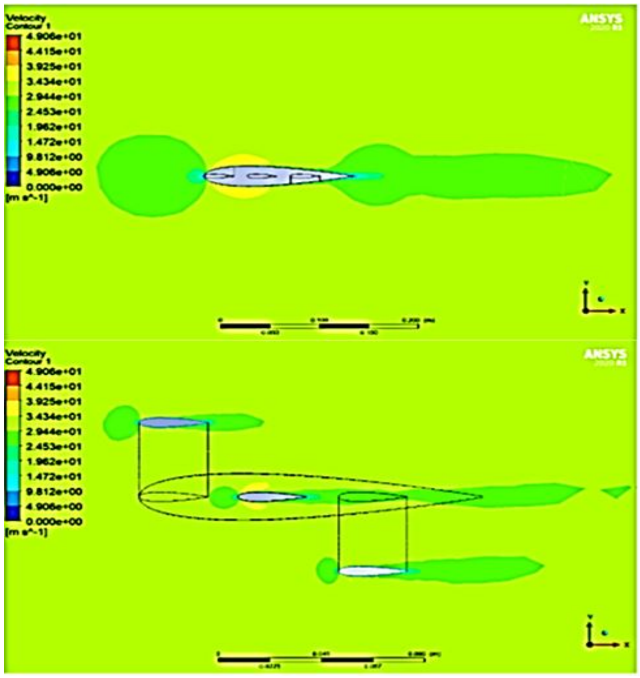

Figure 20: Velocity contours of wing with grid winglet 45° cant angle at 0° AOA.

b) Pressure contours

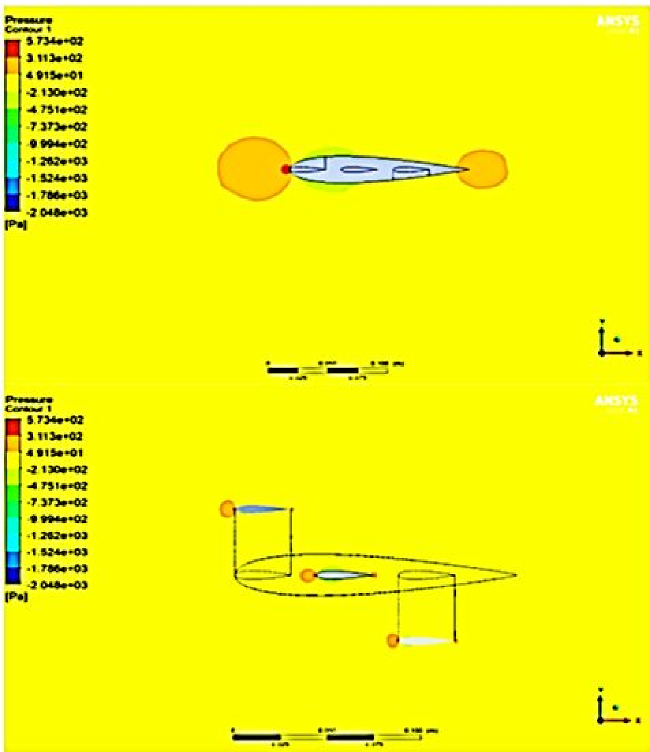

Figure 21: Pressure contours of wing with grid winglet of 45° cant angle at 0° AOA.

a) At 4° AOA -Velocity contours

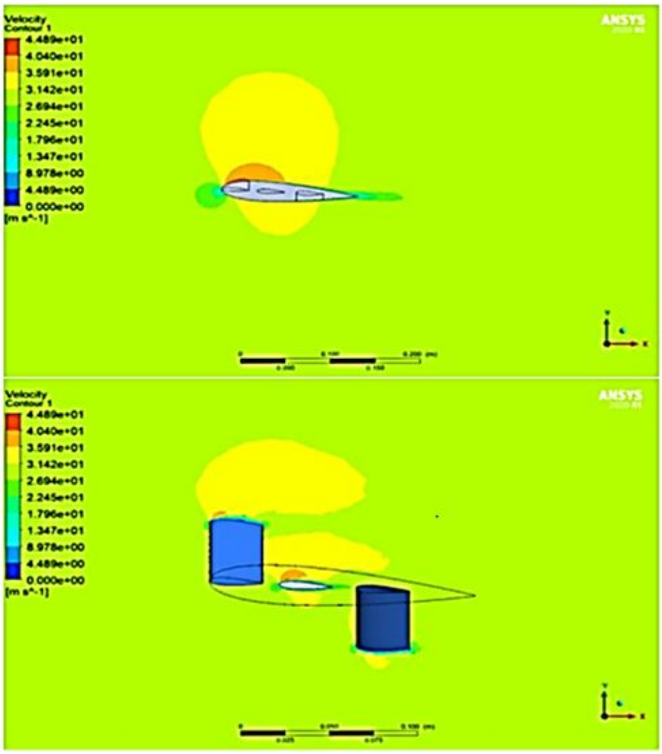

Figure 22: Velocity contours of Wing with grid winglet of 45° can't angle at 4° AOA.

b) Pressure contours

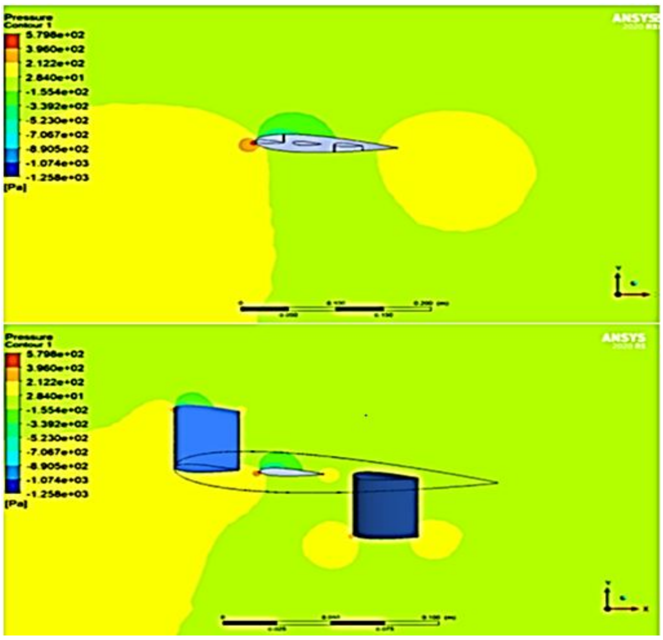

Figure 23: Pressure contours of wing with grid winglet of 45° can't angle at 4° AOA.

a) At 8° AOA-Velocity contours

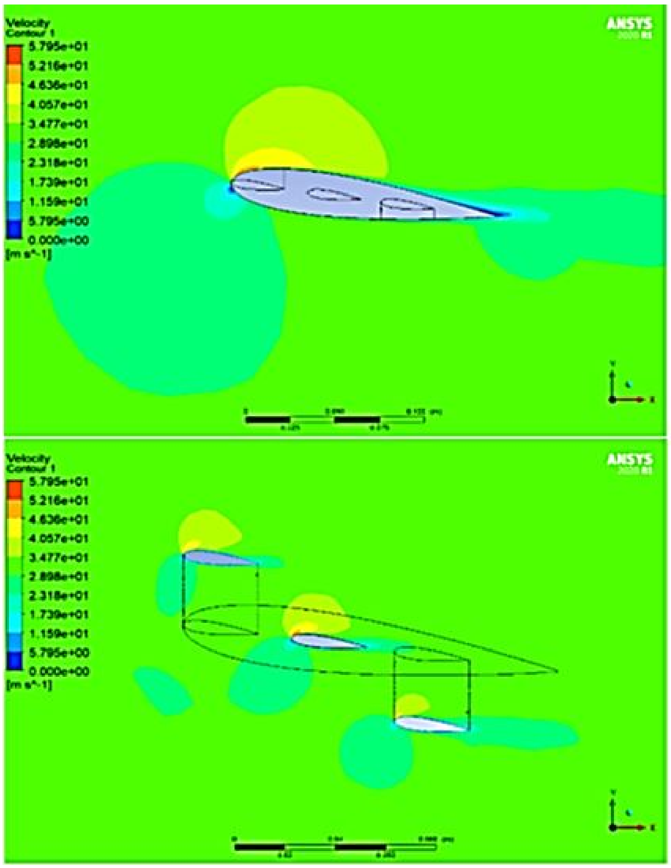

Figure 24: Velocity contours of wing with grid winglet of 45° can't angle at 8° AOA.

b) Pressure contours

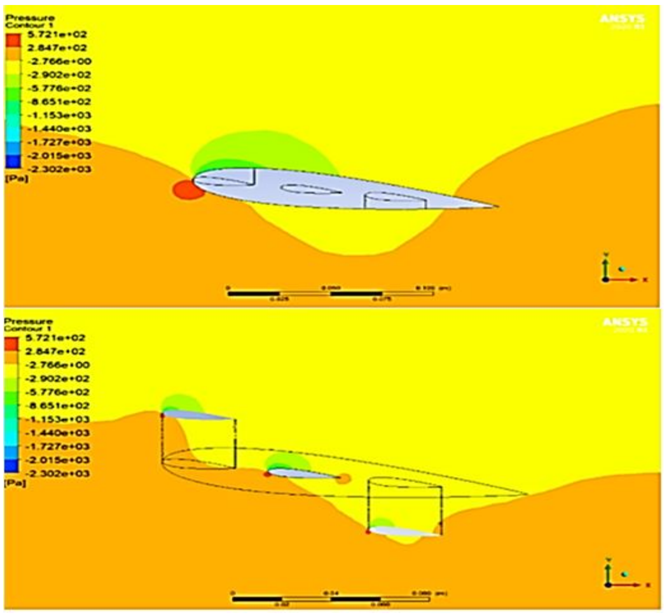

Figure 25: Pressure contours of Wing with grid winglet of 45° can't angle at 8° AOA.

CL and CD plots

Wing without winglets

I) At 0° AOA

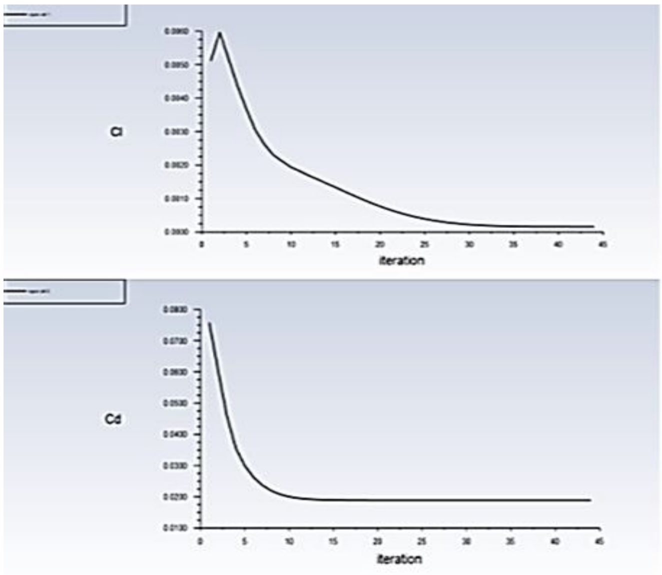

Figure 26: CL and CD plots of wing without winglet at 0° AOA.

II) At 4° AOA

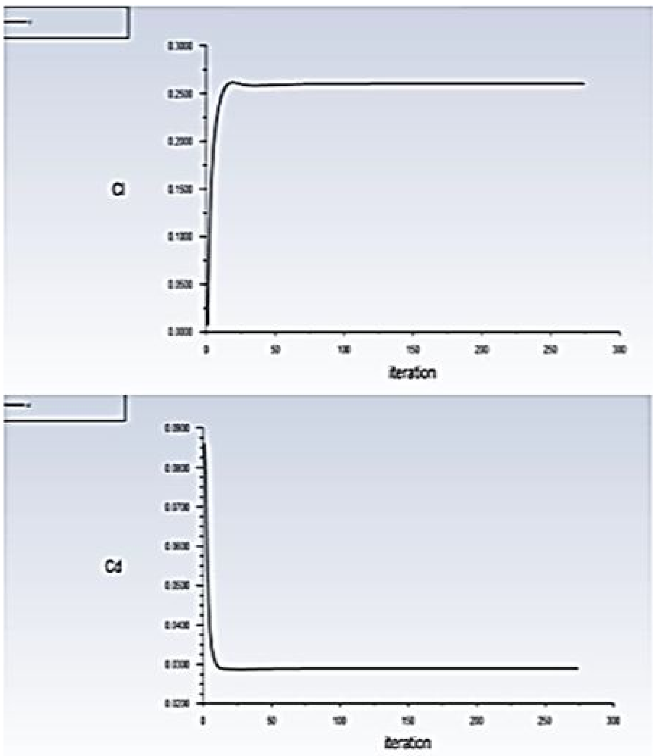

Figure 27: CL and CD plot of wing without winglet at 4° AOA.

III) At 8° AOA

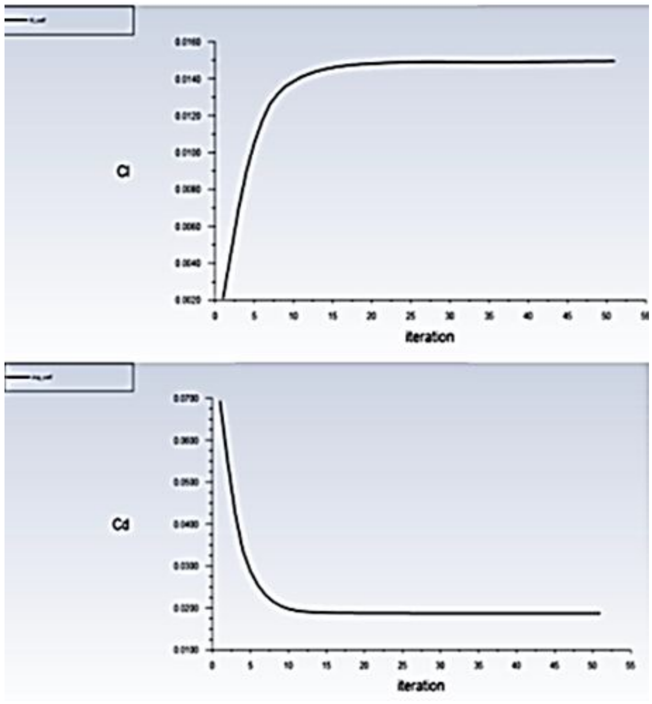

Figure 28: CL and CD plots of wing without winglet at 8° AOA.

Blended winglets

I) At 0° AOA

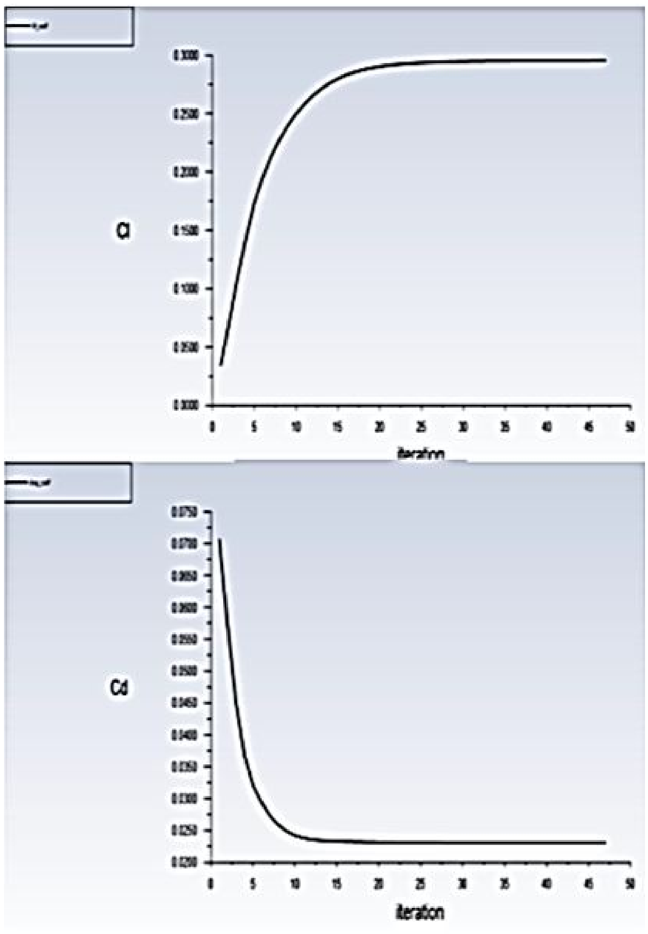

Figure 29: CL and CD plots of blended winglet at 0° AOA.

II) At 4° AOA

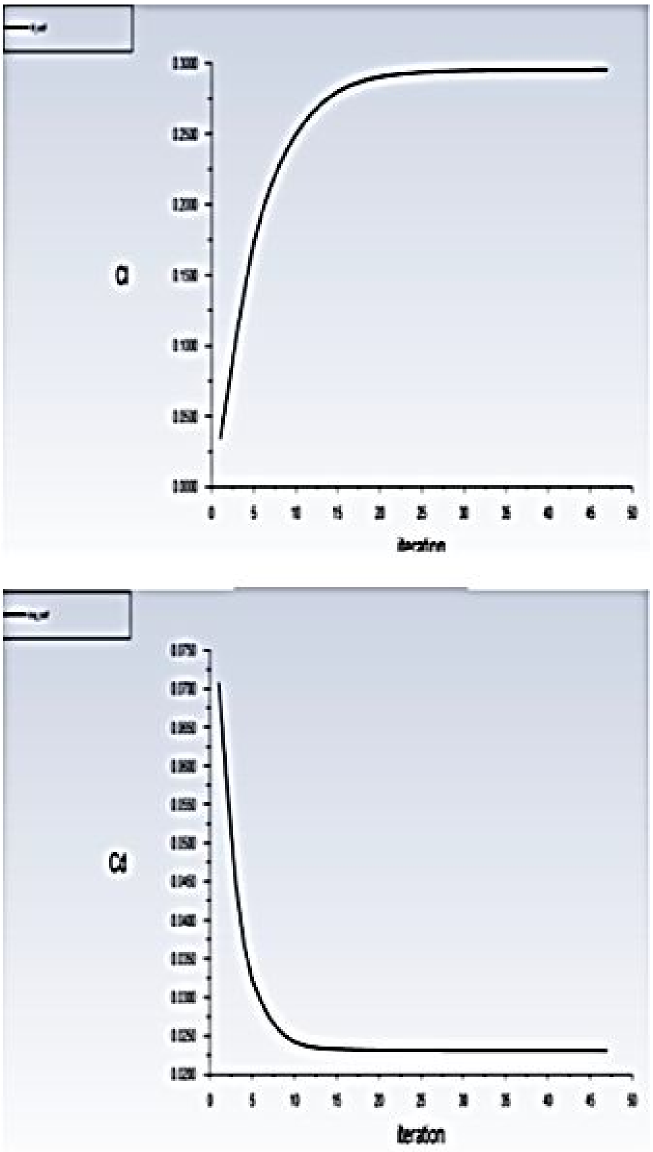

Figure 30: CL and CD plots of blended winglet at 4° AOA.

III) At 8° AOA

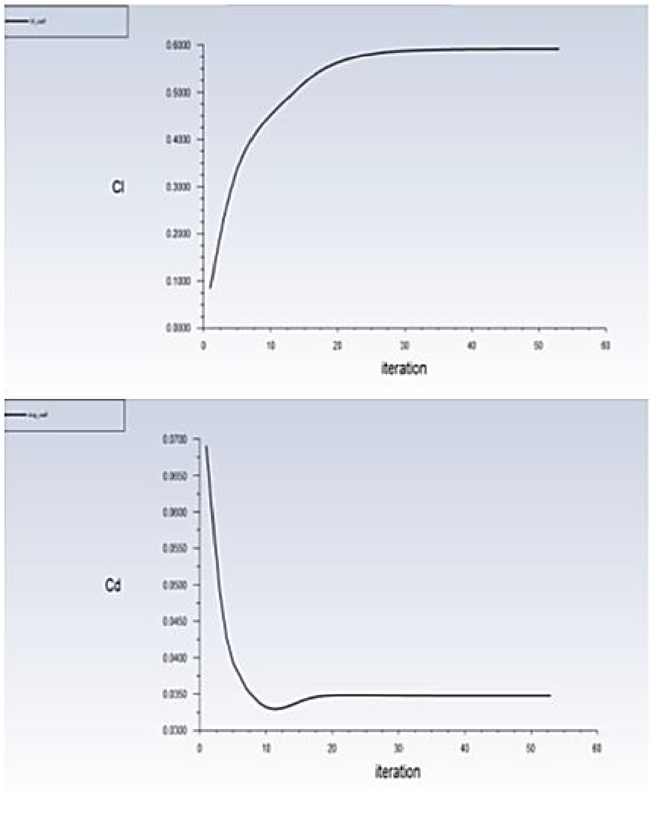

Figure 31: CL and CD plots of blended winglet at 8° AOA.

Grid winglet (45° Cant angle)

I) At 0° AOA

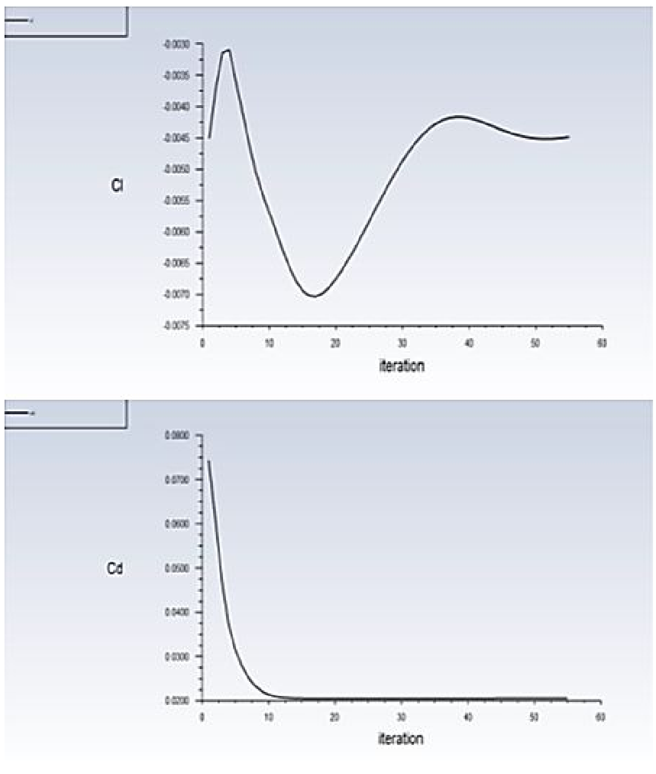

Figure 32: CL and CD plots of Grid winglet at 0° AOA.

II) At 4° AOA

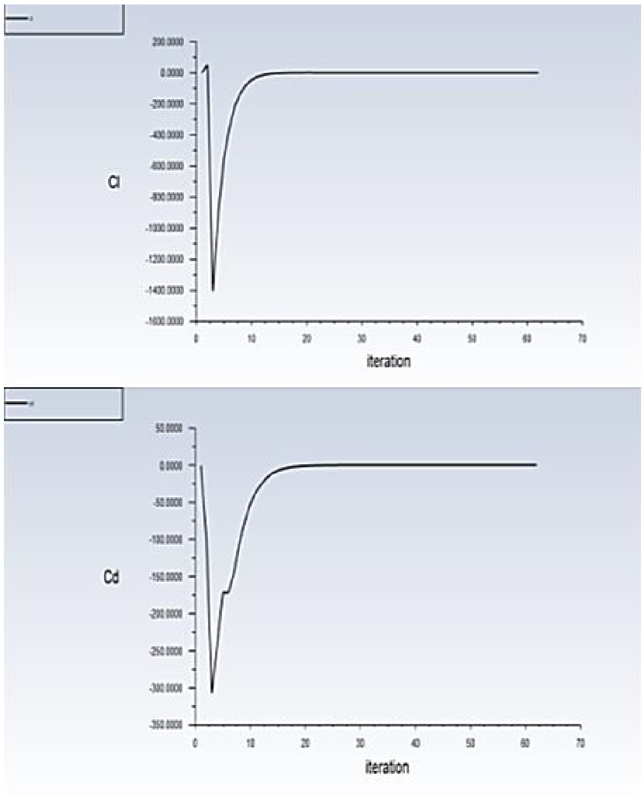

Figure 33: CL and CD plots of Grid winglet at 4° AOA.

III) At 8° AOA

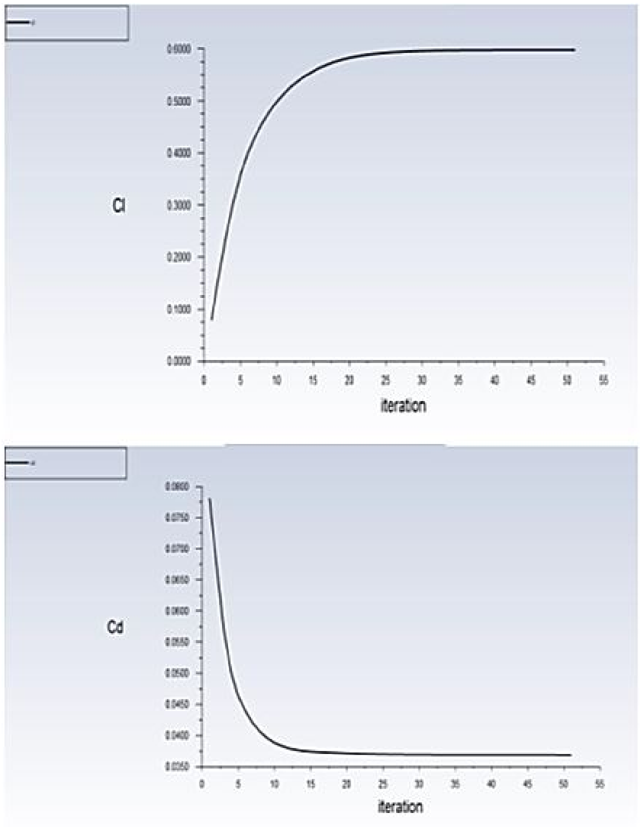

Figure 34: CL and CD plots of Grid winglet at 8° AOA.

Table 1: Result table.

Type of wing	Coefficient of lift (CL)	Coefficient of drag (CD)	Aerodynamic efficiency (CL/CD)
Without winglets (0° AOA)	0.00016	0.01886	0.00848
Without winglets (4° AOA)	0.25871	0.02396	10.79757
Without winglets (8° AOA)	0.51382	0.03948	13.01469
Blended winglet (0° AOA)	0.01494	0.01877	0.79595
Blended winglet (4° AOA)	0.29519	0.02308	12.78986
Blended winglet (8° AOA)	0.57515	0.03593	16.00759
Grid winglet (45° cant angle) (0° AOA)	0.00448	0.020563	0.21789

Grid winglet (45° cant angle) (4° AOA)	0.30253	0.02706	11.17997
Grid winglet (45° cant angle) (8° AOA)	0.59715	0.03692	16.17416

Table 2: Validation.

	CL from Ansys	CL from Matchup
Without winglets (0° AOA)	0.00016	0.00015
Without winglets (4° AOA)	0.25871	0.3243
Without winglets (8° AOA)	0.51382	0.5382
Blended winglet (0° AOA)	0.01494	0.01268
Blended winglet (4° AOA)	0.29519	0.3721
Blended winglet (8° AOA)	0.57515	0.6414

From the above table, it is seen those results from Ansys and results from Matchup are in good agreement with minimum variation which is less than the variation accepted *i.e.* ± 10%.

CONCLUSION

Analysis of rectangular wing of NACA 0012 airfoil without winglets, with blended and grid winglet has been carried out at three different angles of attacks where CL and CD values of each were drawn, subsequently finding the aerodynamic efficiency in all the cases. Hence the two conclusions are drawn from the work.

Firstly, it was seen that the wing with winglets showed more aerodynamic efficiency than wing without winglets concluding that usage of winglets enhances the aerodynamic efficiency of the wing.

Secondly, on comparing the results of blended winglet and grid winglet, it was found that grid winglet at 80 AOA possessed greater aerodynamic efficiency. Hence it can be concluded that Grid winglet is more efficient than Blended winglet.

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