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CFD Analysis of Flap of Airplane Wing Span at Subsonic Speed

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Abstract

Research on Flap and all the parts of the wing span is crucial as the need for fuel consumption is increasing in modern era. Reduction of gas emissions (CO2, NOx), noise and fuel consumption are becoming fundamental design criteria for future aircraft, especially with the high growth rate of air travel which is estimated to double coming 20 years. Many aeroplane accidents have occurred in past years due to improper opening of flaps during the take-off, landing & rolling. Analysis on the 2D wing span was carried out to determine the flow the airfoil when there is change in angle of attack of flap. NACA 0012 airfoil shape is considered for analysis purpose. Chord length was kept 150 mm during the analysis. Pressure contour, velocity contour, Vectors etc. were plotted for the design. Creo and ANSYS fluent software were used for the 2D modelling and analysis.

Keywords: Subsonic flow, pressure difference, wing span, flap

1. INTRODUCTION

Aerodynamics is the field that deals with interaction of air with the moving bodies, is considered as the backbone of design of aircrafts, space shuttles, high speed racing cars etc. In any aircraft the wing plays vital role in its functioning. The design and analysis of wings is regularly done to estimate values of lift characteristics and drag characteristics for different aeroplane operations.

Understanding the parts of the wing like aileron and flap has become challenge in modern aircraft design. These elements are used for rolling, landing and take-off operations of the aircraft. Consequently, reliable CFD prediction capabilities are needed for this class of complex configurations in industrial aerodynamic design [1]. NACA 0012 standard airfoil profile is selected for the wing span in this analysis. Flaps are a kind of high-lift device used to increase the lift of an aircraft wing at a given airspeed. They are used for extra lift on take - off. Flaps also cause an increase in drag in mid-flight, so they are retracted when not needed.

The main objective of the analysis was to determine the pressure variations on wing span due to opening of flaps. This will help us to understand the generation of vortex when there change in angle of attack on aileron & its effect on other parts & vice versa. To control the coefficient of lift and coefficient of drag on the wing will be the major goal of this analysis.

2. EXPERIMENTAL DATA

Many researchers study the phenomenon of lift and drag are studied, especially types of drag and their characteristics. Many airfoil profiles were search from [1] Airfoil tool database, I adopted NACA 0012 airfoil which was used in ancient days. Results of symmetric airfoil were taken from [1]. Also, it is symmetric in nature which ensures it is stable in almost all possible angle of attacks and Mach Numbers. The required airfoil plotting points were also obtain from same. They are used to plot the airfoil in ANSYS geometry module. Fluid domain is selected from NASA [2] Turbulence Modelling Resources available as an open source. Laminar Flow equations are used for analysis as the Reynolds number for velocity of 15 m/s is 1,44,048. With the help of above resources and ANSYS fluent inbuilt library information, all the required input information is gathered.

3. COMPUTATIONAL SETUP

3.1 Modelling of ANSYS Geometry-

Chord Length: 150 mm

Maximum Thickness: 18 mm from leading edge

Type: Symmetric

Stall angle: 15^0

3.2 Creating Domain and Meshing: -

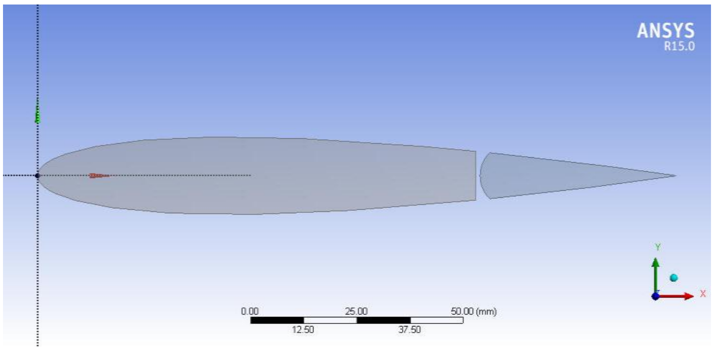


Fig 1. NACA 0012 airfoil at 0^o.

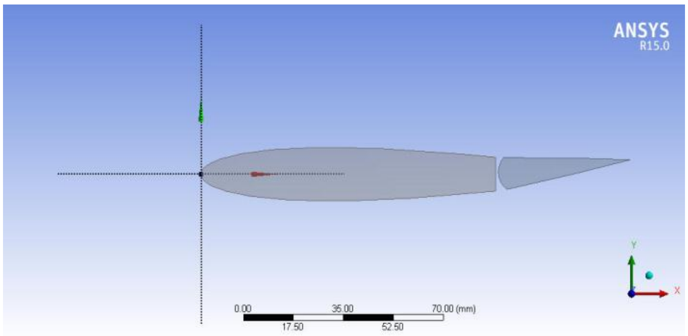


Fig 2. NACA 0012 airfoil at 6°.

Meshing is done using ANSYS mesh. Refinement, boundary layers are used at the surfaces of airfoil in order to obtain accurate results.

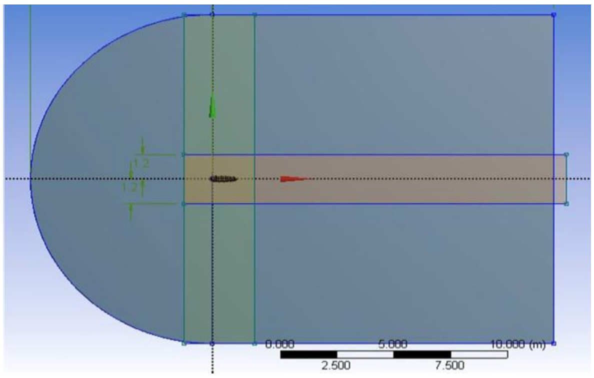


Fig 3. Fluid Domain over Airfoil [1].

For Fluid Domain around the airfoil

Front Side – 9c

Back Side – 20c

Fluid Domain was selected as per standard values.

3.3 Simulation: -

Fluent Solver is used to mesh the design in ANSYS workbench.

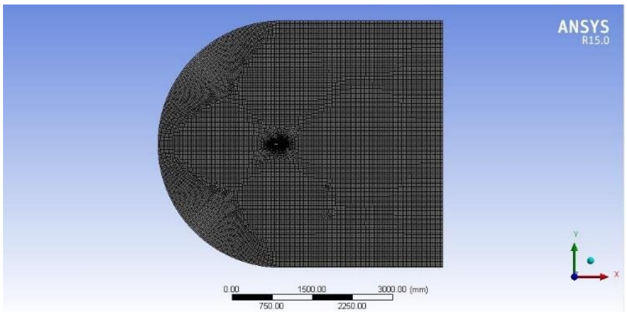


Fig 4. Mesh for all AoA

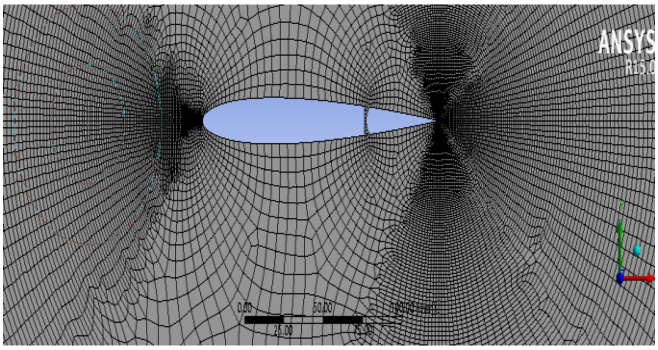


Fig 5. Closer View of Mesh for 0^o AoA

Various edge sizing on different edge of the domain were added to obtain desired mesh. Inlet velocity is entered of 15 m/s for the analysis. Angle of attack on flap is changed from +6^o to -6^o. Also the main body angle is changed from +6^o to -6^o

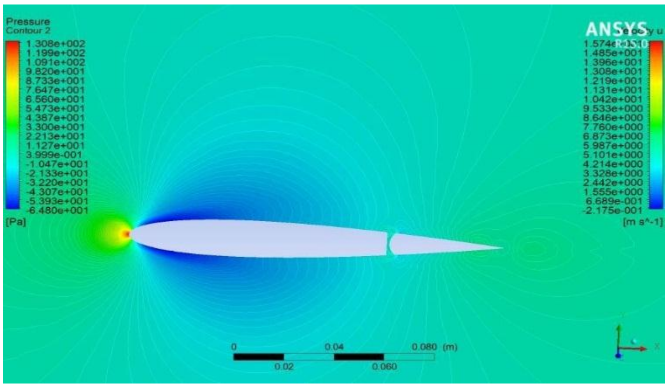


Fig 6. Pressure Contour for 0^o.

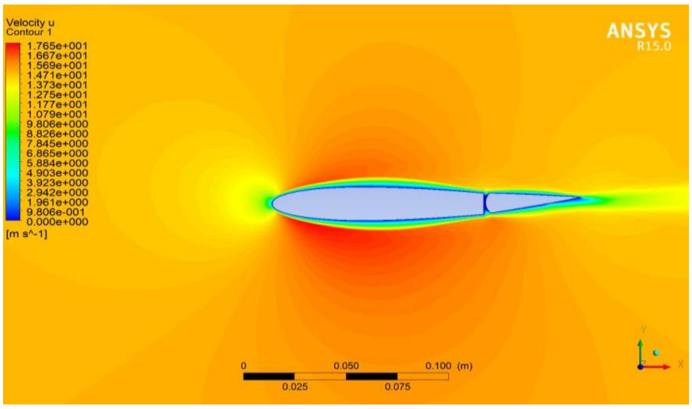


Fig 7. Velocity Contour for 0^o.

Fig 6. and Fig 7. represents the Pressure contour and velocity contour respectively for AoA on flap or aileron as 0^o. It is clearly visible the velocity is equally distributed over the lower and upper surface of airfoil geometry. So, the properties of the NACA 0012 are verified with the analysis.

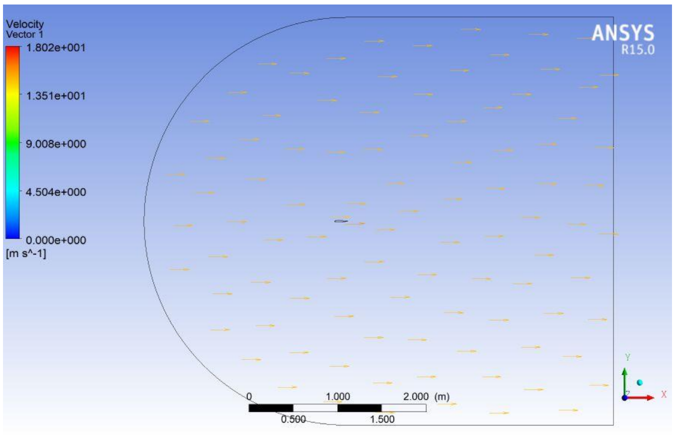


Fig 8. Vector for 0°.

Fig 8. represents the vector over the geometry. It is seen that the flow is moving from right to left.

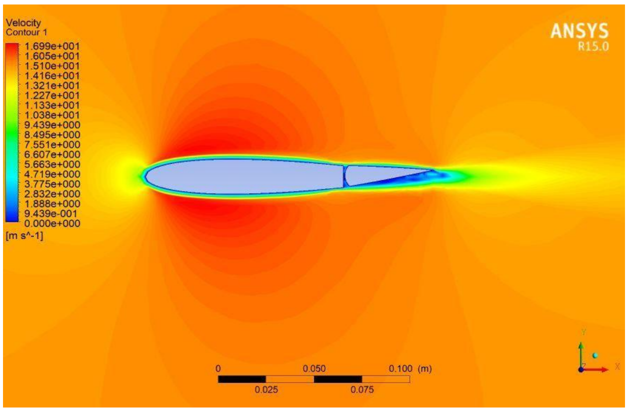


Fig 9. Velocity Contour for Flap 4° and Body 0°.

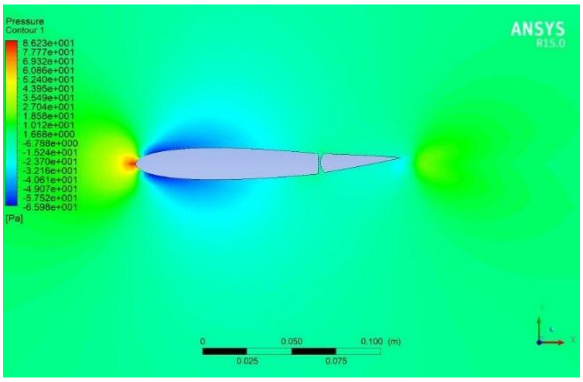


Fig 10. Pressure Contour for Flap 4° and Body 0°

Fig 9 and Fig 10. represents the pressure contour and velocity contour respectively for AoA on flap at 6° and body angle 0°. From velocity contour it is proved that lift force is generated as the high velocity is seen on the lower surface of the airfoil body. Vector plot 6^o and other angle of attack would also be similar as 0^o as inlet properties are not changed.

Various simulation with different angle of attack on body and flap was carried out in similar way. All the results can be viewed in Appendix A-I.

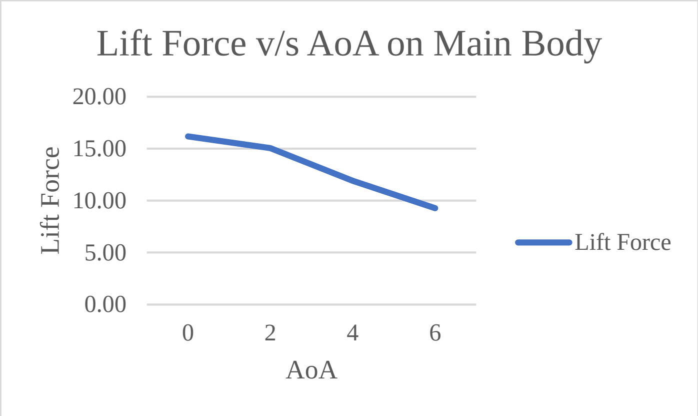


Fig. 11 Lift Force v/s AoA on Main Body

Results for lift force generated by changing angle of flap is shown in above fig. Positive and negative angle of attack showed similar results as it is symmetric airfoil section. All the values can be referred from A-II.

4. DISCUSSION

Many conclusions can be drawn from analysis results carried out on the flap or aileron of the wing span. When the airplane in its take - off mode maximum lift force is required and minimum drag force. Many angles of attack on flap are being simulated along with change in angle of attack on main body wing span. Flap angle is changed from +6^o to -6^o.

To get maximum force from the flap is expected to keep angle of attack as at 4^o. As it produces maximum lift force for almost all angle of attack on the body.

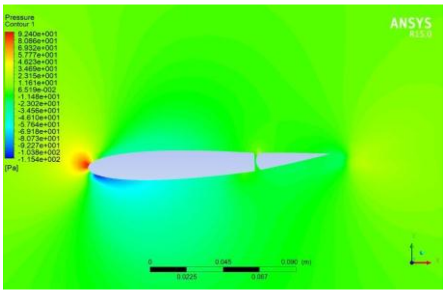
REFRENCES

[1] Talluri Srinivasa Rao, Trilochan Mahapatra, Sai Chaitanya Mangavelli, “Enhancement of Lift-Drag characteristics of NACA 0012”, Materials Today: Proceedings 5 (2018) 5328–5337.

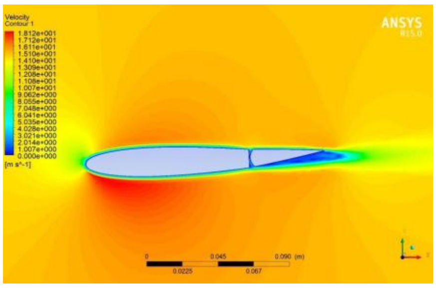
[2] Airfoil Tool Generator

[3] Turbulence Modeling Resources, Langley Research Center.

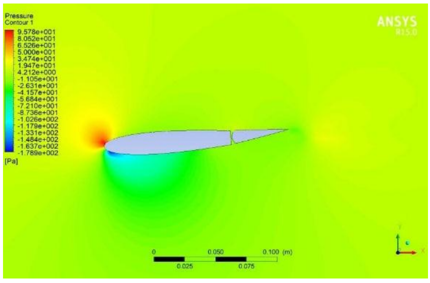
APPENDIX A-I



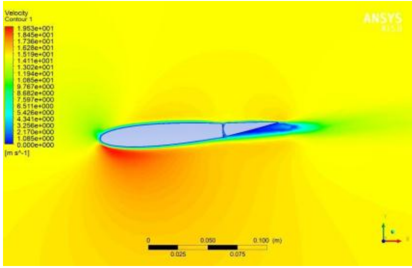
Pressure Contour for Flap 4º and Body2 º



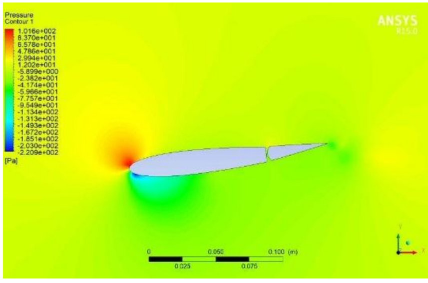
Velocity Contour for Flap 4º and Body2º



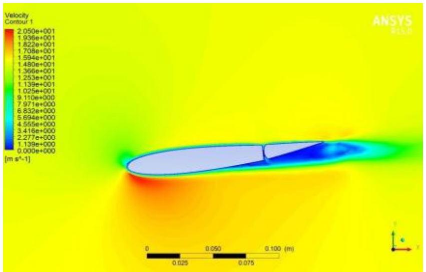
Pressure Contour for Flap 4º and Body4º



Velocity Contour for Flap 4º and Body4º



Pressure Contour for Flap 4º and Body6º



Velocity Contour for Flap 4º and Body6º

APPENDIX A-II

Body Angle	CFD
	L
0	16.19
2	15.06
4	11.91
6	9.28
-2	13.16
-4	10.62
-6	9.61