Design, Aerodynamic analysis and Fabrication of Eppler-61 Airfoil (chord = 10.03% of chord)

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Abstract- **The equations for fluids are quite complex and can be difficult to solve, especially if the geometry of a problem is intricate. To overcome such difficulties, Computational Fluid Dynamics (CFD) has been constantly developed over the past few decades. A wooden modified Eppler-61 airfoil is fabricated with fifteen static pressure taps for measurement of surface pressure. The main objective of this investigation is to analyse the flow behaviour around the airfoil body and to calculate the performance coefficients at Reynolds Number 1.2×105 and angle of attack from -100 to 150. The section-lift and drag coefficient for an asymmetric airfoil are obtained by analysing the measured pressure distribution at pressure taps on the airfoil surface.**

A Multi-tube manometer is used to monitor the surface pressure and provide a visual display of the dynamic changes associated with varying angle of attack. The experimental data for modified Eppler-61 from wind tunnel is validated with simulations computed in the software FLUENT. The lab data and simulations are performed at various angles of attack and lift and drag coefficients are computed. The simulations in FLUENT yielded the best correlation to the experimental data with the inviscid mode and had the overall best performance in determining the lift and drag coefficients. Lift increases as the angle of attack increases between -10 and +15 degrees and at +10 degrees maximum lift is generated. If the angle of attack is increased, any further drag becomes the dominant factor and the wing enters the stall mode.

I. INTRODUCTION

Aerodynamics is the science of airflow over airplanes, cars, buildings, civil structures and other objects. When objects move through air, forces are generated by the relative motion between the air and the surfaces of the object. Aerodynamics is the study of these forces, generated by the motion of air. Aerodynamic principles are used to find the best ways in which airplanes produce lift, reduce drag, and remain stable. In the design of a commercially viable wing, it is critical that the design team have an accurate assessment of the aerodynamic characteristics of the airfoils that are being considered. Errors in the aerodynamic coefficients will result in errors in the aircraft's performance estimates and economic projections. Most of errors are resulted from such that the equations for fluids are quite complex and can be difficult to solve, especially if the geometry of a problem in intricate. The calculation of lift and drag coefficients for subsonic flow over an airfoil is very important for aerodynamic applications and has been a subject of continued research. The most desirable situation is to have accurate experimental data sets for the correct aerofoils throughout the design space. However, such data sets are not always available and the designer must rely on calculations. Recent applications of CFD to solve the Navier-Stokes equations for flow around the airfoils are reflected in the works.

In predicting the low-speed performance characteristics of aircraft with stalling speeds corresponding to Mach numbers of about 0.1, the maximum lift coefficient has been considered to be free of compressibility effects. High-speed performance requirements, however, have resulted in stalling speeds corresponding to Mach numbers of 0.2 or higher where the effects of compressibility may be significant. In as much as the stalling speed is indicative of the landing speed and of the speeds involved in low-speed manoeuvres, a knowledge of the effects of Mach number and Reynolds number on maximum lift is desirable. A series of investigations have been conducted by the National Advisory Committee for Aeronautics to study the effects of Mach number and Reynolds number on maximum lift coefficient. In most of these investigations, the results were obtained from tests of three-dimensional models and the Mach number varied simultaneously with the Reynolds number. Investigations of two-dimensional models in which the Mach number is varied while the Reynolds number is held constant are needed to obtain an indication of the magnitude of the effects on two-dimensional sections.

II. WIND TUNNEL

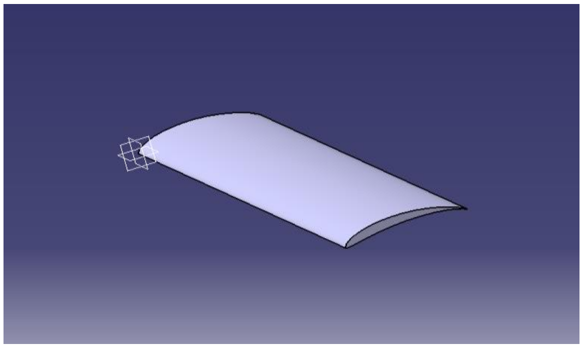
A wind tunnel is a tool used in aerodynamic research to study the effects of air moving past solid objects. A wind tunnel consists of a tubular passage with the object under test mounted in the middle. Air is made to move past the object by a powerful fan system or other means. The test object, often called a wind tunnel model is instrumented with suitable sensors to measure aerodynamic forces, pressure distribution, or other aerodynamic-related characteristics.

III. EXPERIMENTAL PROCEDURE

A wooden airfoil of chord 150 mm and length of 590 mm is placed in the test-section such that axis of the airfoil is perpendicular to the direction of the flow. For easy location of pressure points, tags are fixed to each pressure tapping with the respective pressure tapping number writing on it. Multi-tube manometer containing Alcohol as the manometric liquid is used to measure the pressure difference. The airfoil is fixed in such a manner that the pressure tapping at θ =0^0 is the forward stagnation point which also gives the total head of free stream.

IV. MODELLING

The CATIA V5 is used to design the 3D wing model for the wind tunnel testing wing model. The designed Eppler-61 airfoil profile is marked on the both side faces of rectangular wooden piece. And then wooden pieces are rubbed with Abrasive paper to remove an extra material in wooden piece and made exact shape of Eppler-61. Afterwards the wooden pieces are detached and pressure tapping marks are done on inner surface of the wing model. The holes are drilled on the marked pressure tapping holes and Copper tubes are inserted in the holes. Simultaneously the Stainless-steel tube is also inserted on one side of the wind tunnel wing model. The copper tubes are taken into the Stainless-steel tube for the Pressure Readings.



Isometric view of the model

V. RESULTS

A. Analytical results

The table shows the wind tunnel test (Experimental) Results, contains the Lift and Drag Coefficients for angle of attack from -10^0 to 15^0

Above Table shows the wind tunnel test results for designed airfoil at Reynolds number of 124518, corresponding to velocity 20 m/s, which is in the incompressible flow regime. Table shows the CFD analysis results computed using inviscid model, which employs standard wall function approach. This approach over predicts the lift in the stalling region, which is unphysical. This model has predicted a drag coefficient of 0.087 and a lift coefficient of 1.392 at angle of attack of 16 degrees, which is the onset of stalling. The tables show the Lift and Drag coefficients obtained from the RNG k-epsilon Model for angle of attack from -10^0 to 15^0.These results are compared with the experimental or wind tunnel test results mentioned in the table

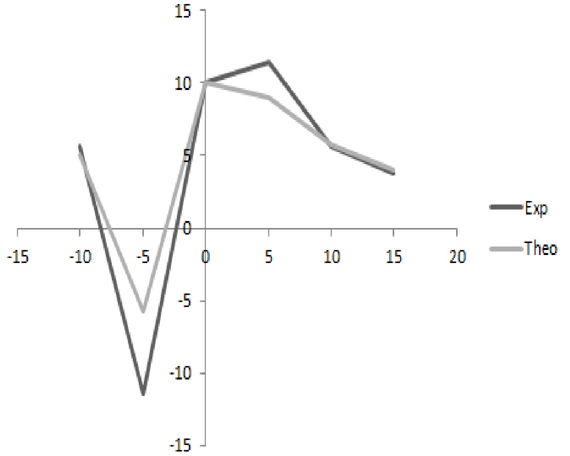
Angle of attack	Lift co-efficient	Drag co-efficient
-10	0.004552	0.000901
-5	0.0395	-0.00545
0	0.10876	0
5	0.137738	0.01525
10(stalling)	0.155544	0.026826
15	0.14121	0.035552

CFD Analysis results at Re = 0.12e6

Angle of attack	Lift co-efficient	Drag co-efficient
-10	0.004996	0.000881
-5	0.039404	-0.00345
0	0.118882	0
5	0.137856	0.012053
10(stalling)	**0.149224**	**0.026313**
15	0.139733	0.037446

Wind tunnel analysis at Re = 0.12e6

Graph shows the ratio of coefficient of lift and drag versus the Angle of attack, which comprises of the experimental and theoretical values of the lift and drag coefficients.



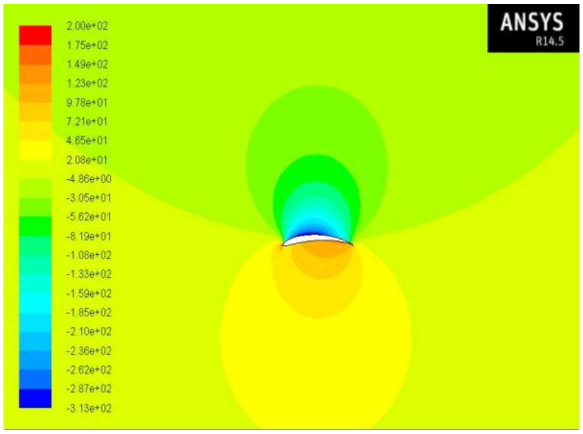
VI. ANSYS PLOTS

Using ANSYS Fluent14.5 software, the plots are drawn as shown for the respective angle of attacks

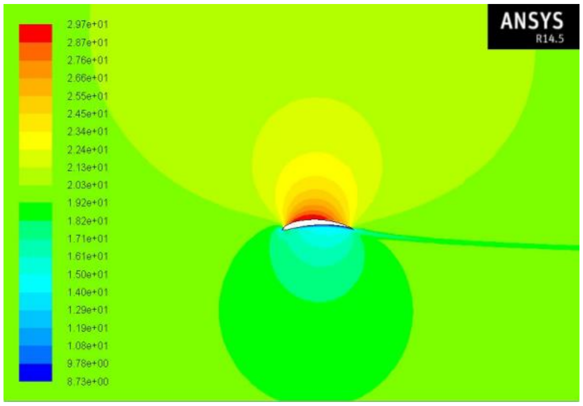
At angle of attack 0^0

The above figure shows about the contour plots of pressure and velocity at angle of attack 0^0. Here the pressure contour shows maximum pressure at the stagnation points compare to previous negative angle of attacks. At this angle of attack the co-efficient of lift would be 0.118882

The velocity plot describes the less velocity at the lower surfaces compare to upper surface of this airfoil. There is a maximum velocity on the upper surface of the airfoil compare to previous angle of attacks.



Pressure plot

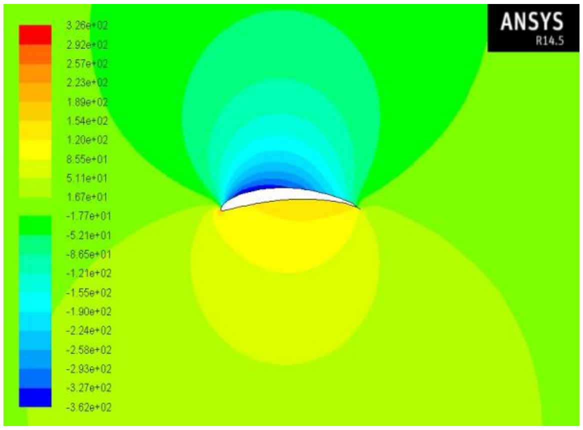


Velocity plot

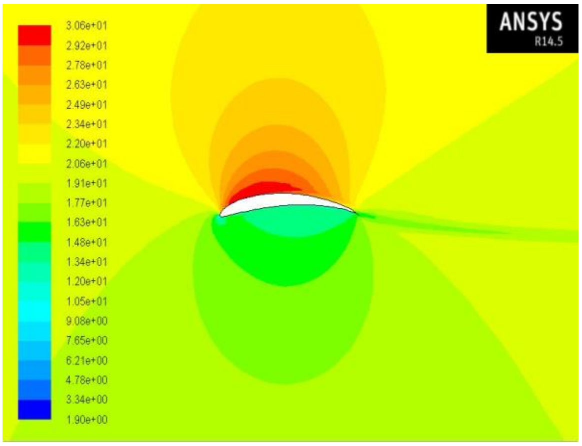
At angle of attack 10^0 (stalling angle)

The stalling angle contour plots are as shown in figure. At this angle of attack there will be maximum co-efficient of lift. After this angle of attack the co-efficient of lift goes on decreasing.

The velocity is maximum at this point, further increase in angle of attacks leads to stall of the aircraft.



Pressure plot



Velocity plot

VII. CONCLUSION

In an aircraft, lift is caused by an upward force that is resulted from the difference in pressure between the top and the bottom surface of the wings. This difference in pressure is due to the special shape of the airfoil, and the amount of this lift is dependent upon the angle at which the wing is inclined.

To find the maximum performance of the wing, it should be tested in a wind tunnel at different angles of attack. From the above discussion the lift and drag coefficients taken from the experimental wind tunnel test results are 0.149224 and 0.026313 respectively at an angle of attack 16^0 (stalling region). Similarly, 0.155544 and 0.026826 are lift and drag coefficients obtained by the inviscid flow model.

The study shows that changing camber and thickness of airfoil increases the lift and reduces the drag. For designed Eppler-61 model airfoil co-efficient of lift is slight lesser than the reference airfoil, but there is large difference in the value of the ratio of co-efficient of lift and drag.

ACKNOWLEDGEMENT

I feel delighted to have this page to express our sincere thanks and deep appreciation to Dr. Ramakrishna N. Hegde, Head of the Department, Aeronautical Engineering, for his valuable guidance, keen interest and constant encouragement.

We thank our project guide Mr. Purushotham P. Katti, Assistant professor of Aeronautical Engineering, who has been our source of inspiration. He has been especially enthusiastic in giving his opinions and critical reviews.

We thank our beloved Principal Dr. Shrinivasa Mayya D. for his constant help and support throughout.

We are indebted to Management of A. Shama Rao Foundation, Mangaluru for providing an environment which helped us in completing our project.

Finally, we thank all the teaching and non-teaching staff of Department of Aeronautical Engineering for the help rendered.

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