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Simulation of Various Angles of Attack of NACA 23012 Airfoil Using CFD

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Abstract- This study focuses on the numerical investigation of the NACA 23012 aerofoil to improve its aerodynamic efficiency across different angles of attack. The primary goal is to enhance the lifting characteristics of the wing, which plays a crucial role during take-off and landing phases of flight. By implementing 20% split flaps, the aerofoil can generate higher lift without increasing the overall wing size, thereby effectively reducing drag and maintaining fuel efficiency. The aerofoil geometry and flap configuration were modelled using CATIA V5, and a Computational Fluid Dynamics (CFD) approach was employed for the analysis using ANSYS Fluent. Aerodynamic parameters, including lift coefficient, drag coefficient, and pressure distribution, were evaluated at various angles of attack to assess the performance improvements. The results of this study provide insights into the design optimization of aerofoils for high-lift applications in aircraft wings.

Keywords: NACA 23012, angle of attack, aerodynamic performance, lift & drag coefficient, aerofoil model using CATIA V5 & CFD, pressure distribution, design optimization, ANSYS fluent.

I. INTRODUCTION

Low speed handling of an aircraft is a feature of grid practical significance as it mostly concerns the low-speed flight of the aircraft characterized by the landing and take-off phases for reasons of safety is always desirable to have the achievement of as low speed as possible. Low speed characteristics of an aircraft are governed by the CL max that can be achieved by the lifting surface. Thus, the practical limit through what one can achieve to the CL max of an aerofoil typical values for the aerofoil's are on the order of 1.3 or 1.4. In order to achieve much larger values of CL max can be achieved by basic aerofoil.
The importance of flaps as high lift devices was already well understood in the early 19's barely after two decades of the development of Wright brothers. Over the years great advances have been made in the development s CL max of the order of 3.4 to 3.5 is achieved by some of the modern commercial airliners which also incorporate some kinds of leading-edge devices for lift enhancement.

Considering the trailing edge devices for the flaps can be several types beginning with the split flaps and going over to very complex multi slot flaps. Some of the most can be extremely complex in mechanical design and also may lead to significant added weight due to the flap actuation mechanisms. Some of these complications as well as the weight penalties cannot be afforded by smaller aircraft where mechanical complications and possible weight increases are to be avoided.

The simplest of these flap arrangements is so called split flap which is simply a flat plate hinge to the trailing edge of the basic aerofoil. With this flap claims of up to 65 percent of enhancement in CL max have been reported.

The complex nature of flow over a flap aerofoil does not permit any easy analysis of flow. The flow involves viscous, in viscid interactions, transition and turbulent phenomenon's making is more difficult for any analytical handling. The simulation of high lift flow over aerofoils.

Leading or trailing edge devices is also a challenging problem experimentally. This is due to the difficulty of simulation of minor geometric details of flow around small gaps between the aerofoil and flaps and because of the enhanced tunnel wall interface due to large wake characteristic of these flows. It so that turns out that in fact these many of the flapper invents on practical aircraft are far from optimum. This is due to the compromise necessary in containing the cost of development of aircraft.

At present times CFD offers a cost defective way of analysing and design of complex flow of multi component of aero structures. It also possible to obtain a clear physical understanding of complex viscous flow around high lift devices.

It's a purpose of this report to try and see how best one can analyse and bring out the nature of complex flow of field over one of the simplest high lift devices namely the split flap. We have studied here the case of NACA 23012 with 20 percent and 25 percent hinged flaps. Since standards experimental results are available for such situations. The commercial software fluent is used along with Gambit for grid generation.

II. LITERATURE REVIEW

Valarezo, W. O., Dominik, C. J., and McGhee, R. J., Reynolds and Mach Number Effects on Multi element Aerofoils, Proceedings of the Fifth Numerical and Physical Aspects of Aerodynamic Flows, California State University, Long Beach, CA, Jan. 1992. In this paper application of flaps during take-off phase has been highlighted. Slats are referred to as high lift devices which are attached to the leading edge of a wing. Their function is similar to that of the flaps. They help in increasing the coefficient of lift and stalling angle by reenergizing the airflow over the wings surface so that the airflow remains streamline up to high angles of attack. However, it may start becoming turbulent at much higher angles.

Arvind Prabhakar* and Ayush Ohri, CFD Analysis on MAV NACA 2412 Wing in High Lift Take-Off Configuration for Enhanced Lift Generation, Journal of Aeronautics & Aerospace Engineering, 2013 Perhaps the most widely used approach involves solving of incompressible Navier-Stokes equations on structured or Chimera grids.

III. METHODOLOGY

Fig 1 shows a sketch of a split flap on an aerofoil in its retracted position and Fig 2 shows the details of a 20 percent chord split flap in its flap extended position. It would be instructive to visualize the flow over this split flap. This would bring out clearly the flow mechanism involved in the generation of higher lift than that of the base line aerofoil.

Fig 1: Split Flap Retracted

Fig 2: Split Flap Deflected

The sketch of the possible stream line pattern that is plausible on the aerofoil with the extended split flap. The flow separates at the end of the split flap at the tip of its lower surface, where the pressure coefficient has a negative value after it undergoes expansion from the point on the aerofoil where the flap begins on the lower side of the aerofoil. This means that the flow has no chance to recover to a small positive pressure coefficient (point J on the Cp curve) at the trailing edge, which is typical for an aerofoil under attached flow conditions.

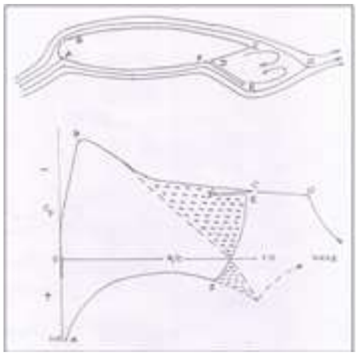

Fig 3: Pressure Distributions and Flow Pattern Over an Aerofoil

Fig 3 gives the possible pressure distribution corresponding to this flow picture. At the point A we have the leading-edge stagnation point. Over the top portion of the aerofoil the flow accelerates up to the point B, reaching a peak value of negative pressure coefficient that depends on the leading-edge curvature.

IV.DESIGN

Fig 4: NACA 23012

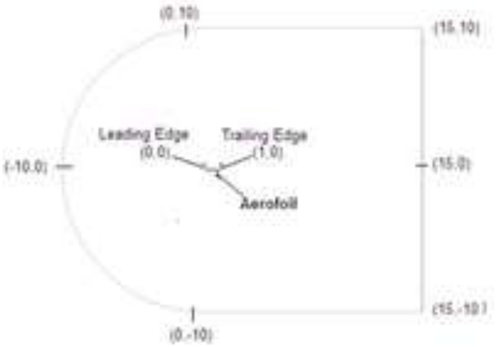

Fig 5: Computational Domain

Fig 4 shows NACA 23012 aerofoil and Table 1 (Appendix 1) contains standard coordinates. These coordinates are imported to GAMBIT and quadrilateral grids are created over sub-domains into which the main domain of fluid flow is divided. We have taken the various dimensions for the numerical flow domain as shown in Fig 5.The aerofoil is placed between (0, 0) and (1, 0). The chord of the aerofoil is thus unity.

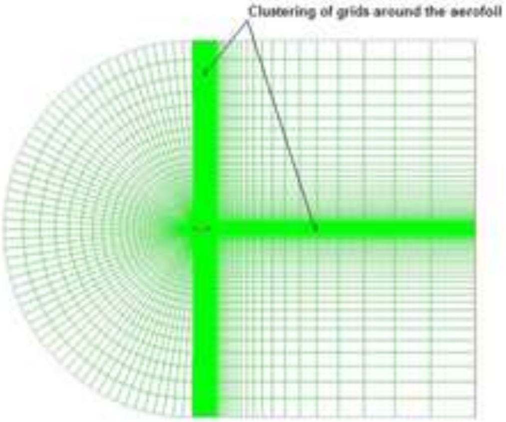

Fig 6: Quadrilateral Grids

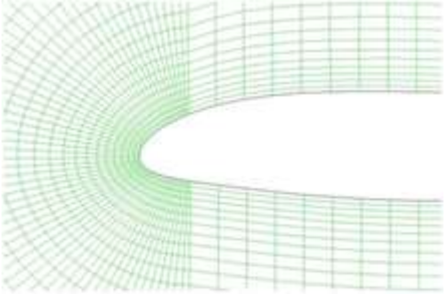

Fig 7: Close View of Grid at Leading Edge

Fig 7 shows closely spaced grid around leading edge close to the body in order to pick up rapid changes taking place in this region. In our study we have chosen spalart allmaras one equation code for model. We have retained default options for parameters in this model. We use simple algorithm as flow model and we have used second order upwind finite differencing.

There are several iterative methods available in fluent for solving simultaneous equations that results from discretisation of equation of conservation of motion from finite volume grid chosen. It's been our experience that converging results are obtained with relaxation factor continuity x and y and turbulence viscosity set as 0.3 and we also had chosen implicit choice as an available option in fluent.

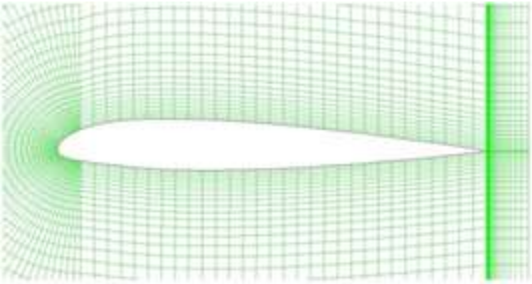

Fig 8: Close View of Grid Around Aerofoil

Results To Be Analysed
The investigation can be performed further in the following areas,

1. Simulating the flow around airfoil in ANSYS for 0 and 14 degrees at 36m/s
2. Comparing the obtained results with compiled data.

3. Suggesting the best feasible design based on simulated works.
4. To find the centre of pressure and coefficient of lift for this flap.

V. RESULTS AND DISCUSSIONS

Before results are presented for the case of deflected split flap, we recall here the results in Fig. 10 for the aerodynamic characteristics of the basic aerofoil NACA 23015 compared with standard wind tunnel test results. In this context recall the salient flow pictures and pressure distributions shown at the three different regions of the flow in: the linear region, the region beyond departure from the linearity of the lift curve and the separated flow regime around the aerofoil stall. We analyse next the flow over the NACA 23012 aerofoil with a 20% split flap since some experimental results are available for this case. For analysing the flow with splitter plate deflected by 30 degrees a grid is generated using the GAMBIT software. This grid is shown in Figs 11 and 12.

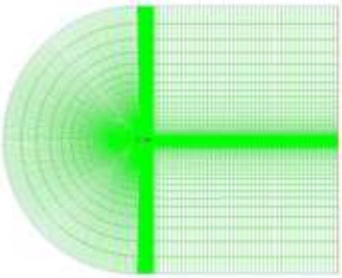

Fig 9: Grid Around Aerofoil With 20 % Deflection

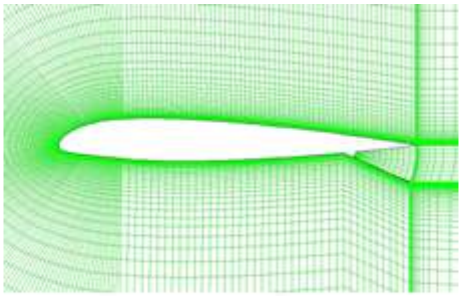

Fig 10: NACA 23012 Grids

The details of the grid around the deflected flap can be seen in Fig. 11. The free stream velocity is 36 m/s. in order to resolve the viscous effects we have chosen the first grid line next to the solid boundary to be at 0.0003m, the aerofoil chord being 1m. This value of the first grid distance corresponds to a y+ value of 30.

Fig 11 gives the flow details corresponding to the situation when the flow over the main aerofoil is attached and the split flap is effective in generating higher lift than the baseline aerofoil in the linear portion of the lift curve. Contours of pressure coefficient are given in Fig 11; the plot of pressure coefficient is given in Fig.11 while the details of the path lines are given in Fig. 11.

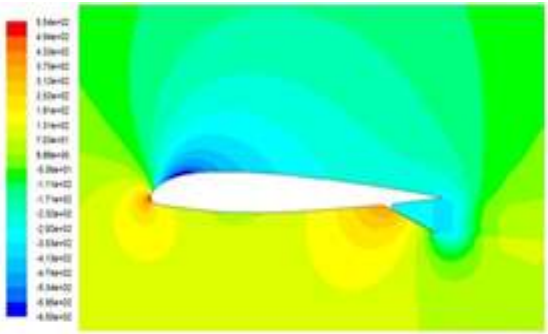

Fig 11: Pressure Contour at 0-Degree Angle

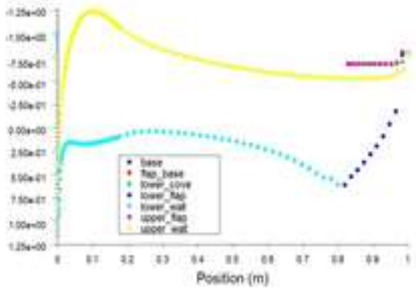

Fig 12: Pressure Distribution at 0-Degree Angle

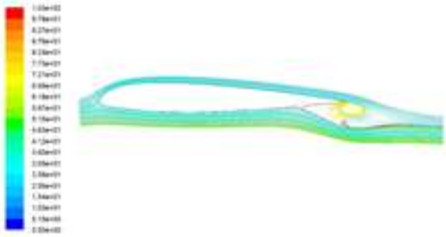

Fig 13: Path Lines at 0-Degree Angle

The situation corresponding to separated flow close to the leading edge of the main aerofoil, as in the region of flow beyond departure from linearity and around stall, is depicted in Fig5.6. This flow corresponds to an angle of attack of 14 degrees.

Fig 14: Pressure Contour at 14-Degree Angle

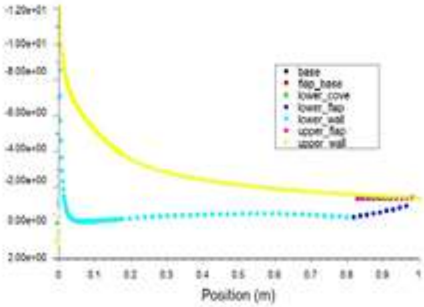

Fig 15: Pressure Distribution at 14-Degree Angle

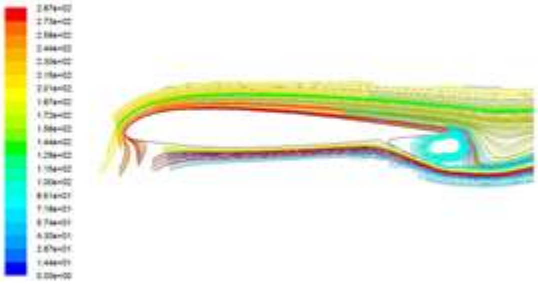

Fig 16: Pathlines at 14-Degree Angle

VI. CONCULSION

As it is summarized, the problems of high-lift aerodynamics have been studied since the early years of aviation. "The wings of commercial aircrafts must generate a tremendous amount of lift during take-off and landing in order to reduce ground speeds and runway lengths". It can be concluded that employing typical high-lift systems for different kinds of aircrafts can fulfil that requirements. But like it is stated that instead of complex multi-element high-lift devices for improvement of lift aerodynamics of ultra-light aircraft wing, a single slotted flap is desirable. When a portion of the rear of a wing can be rotated to leave a well-defined slot between it and the rest of the wing, then it is referred to slotted flap. The main function of flaps is to be used as tool for aerodynamics improvements. Consequence, the slotted flap was then adopted in order to provide more lift to reduce the stalling speed and decrease the drag to increase the gliding angle. In order to give perspective to the present review of slotted flap and the influence of the gap, some short overview is in order.

The slotted flap is a trailing-edge device which is separated from the main wing element by very small gaps. The point where the aerofoil is first cut away to form the slot on the lower surface is called the slot entry, i.e. gap is the distance between aerofoil and the flap. Since a slotted flap is an effective device for increasing the maximum lift coefficient CL and decreasing the drag coefficient provided by the flow through the slot, the important design parameter that should be better studied is optimal distance of the gap between the wing and slotted flap. Since, slotted flap is dominated by viscous effects as boundary layer transition, flow separation, etc. For optimizing the gap size, the only way is the numerical approach.

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