Comparison of 2D aerodynamic coefficients of morphing trailing edge flap with a hinged flap.

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Abstract-- **Morphed trailing edge flaps are a promising technology for improving the aerodynamic performance of aircraft and other vehicles. They can change their shape to increase lift and reduce drag, especially at large flap deflections. In this paper, we present a CFD analysis of 2D flow over an NACA 4412 airfoil with a 40% trailing edge flap at a constant Reynolds number of 2.3×10^6 and a constant angle of attack of 0^o for a range of flap deflections from 0 to 25 degrees. We compare the aerodynamic coefficients, such as lift and drag, of a normal hinged flap airfoil against a morphed trailing edge flap in various flap deflection settings. Our results show that the morphed trailing edge flap produces about 15% more lift and less drag than the hinged flap airfoil, especially at larger flap deflections. Our findings suggest that morphed trailing edge flaps could be a promising technology for improving the aerodynamic performance of aircraft and other vehicles. For example, morphed trailing edge flaps could be used to increase the lift of an aircraft during takeoff and landing, or to reduce the drag of an aircraft during cruise flight.**

Keywords: ***Morphing wing, CFD analysis, NACA 4412, aerodynamic performance.***

1. INTRODUCTION

Morphing technology on aircraft has piqued the interest of many people during the last decade. The term "morph" comes from the Greek word "morphos," which meaning "shape." Morphing wings are wings that change configuration to maximize performance under a variety of flight circumstances. The underlying concept of a morphing wing is to alter its aerodynamic shape to each flight condition in order to improve flight envelope, flight control, and flight range. By replacing mission-specific aircraft designs with a single type of morphing aircraft, the cost and complexity of design, manufacture, and maintenance can be reduced. Morphing airplane wings must have flexible skins that can withstand huge strains and have low in-plane stiffness.

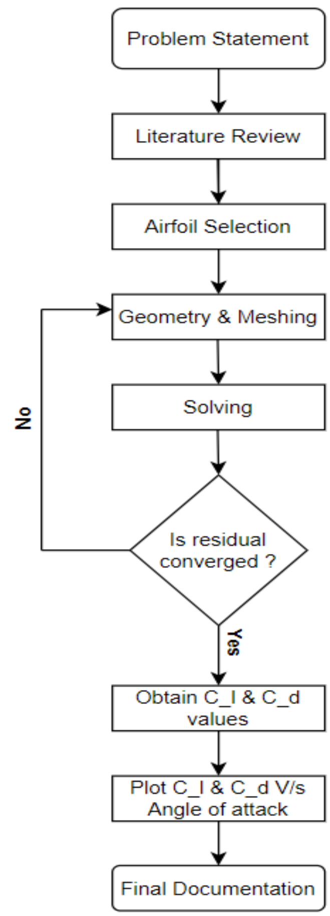
The paper focuses on quantifying the advantage of using morphing trailing edge compared to traditional flap. While there is a huge body of study on morphing trailing edges and their potential to improve aerodynamic performance, there is a significant research gap in terms of a full comparative analysis focusing specifically on the NACA 4412 airfoil.

- Industry Standard: The NACA 4412 airfoil is a well-known aerodynamic standard that is widely employed in a variety of aerospace applications.
- Applicability: Understanding how morphing mechanisms function on the NACA 4412 airfoil versus traditional flap will assist in determining the feasibility and benefits of incorporating morphing technology into existing aircraft or wind turbine designs that use this airfoil.

• Optimization: A comparison analysis identifying the benefits of morphing technology could enhance performance improvement procedures of airplanes or wind turbines using the NACA 4412 airfoil.

In the framework of the proposed paper, addressing this research gap by conducting a comparative analysis of morphing trailing edge applied to the NACA 4412 airfoil will considerably contribute to the implementation of morphing wings in commercial aircraft.

2. METHODOLOGY



3. COMPUTATIONAL SETUP

- **Modelling the geometry & Domain**

  NACA 4412 airfoil with 100mm chord length was chosen as shown in figure1. CATIA generative the shape design was used to import the coordinates and create the airfoil.

  C domain was used to get more accurate results with dimensions as shown in figure 2.

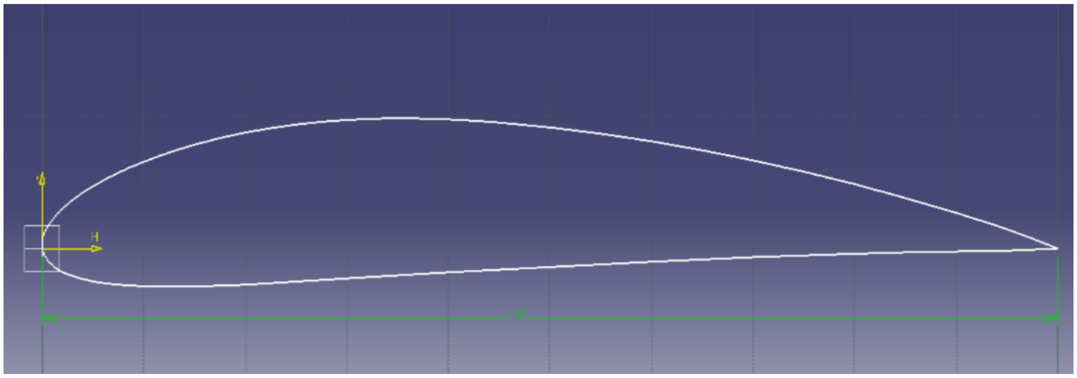


Figure 1. *Catia Airfoil 2D sketch*

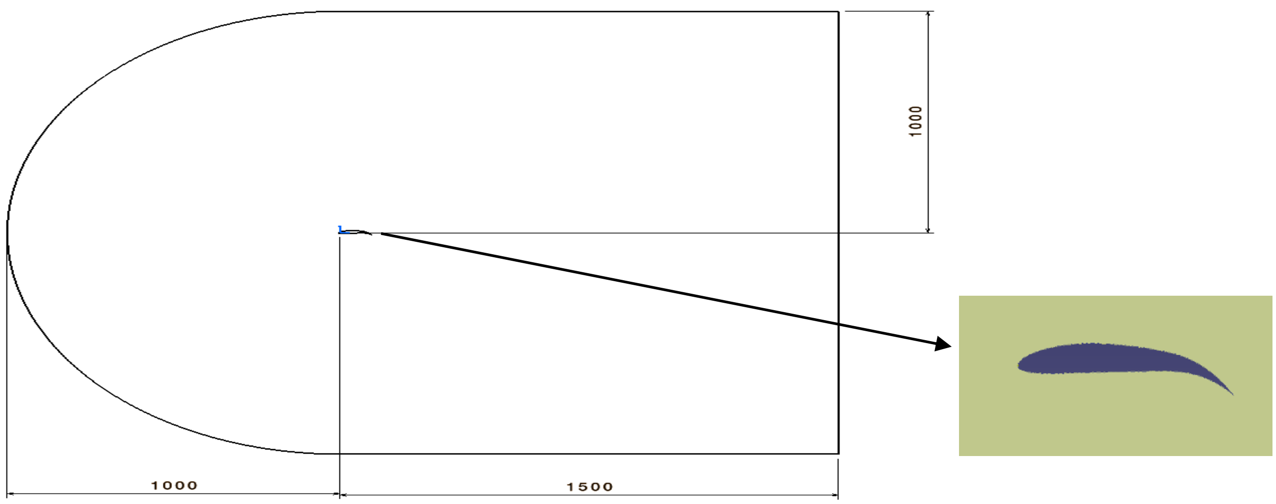


Figure 2. *C domain with airfoil*

- **Meshing**

For meshing unstructured grid was chosen as it made it easier to follow the morphed curvature of the airfoil. Firstly, after the geometry was loaded the mesh face sizing was done on the domain with 20mm element size. Then edge sizing was done on the airfoil with 450 number of division. Inflation was done up to 20 layers with first cell height of 8.8e-03.This was sufficient to capture the boundary layer phenomena. Similar parameters were applied for other flap deflection angle.

Mesh Details

Nodes	35361
Elements	34734

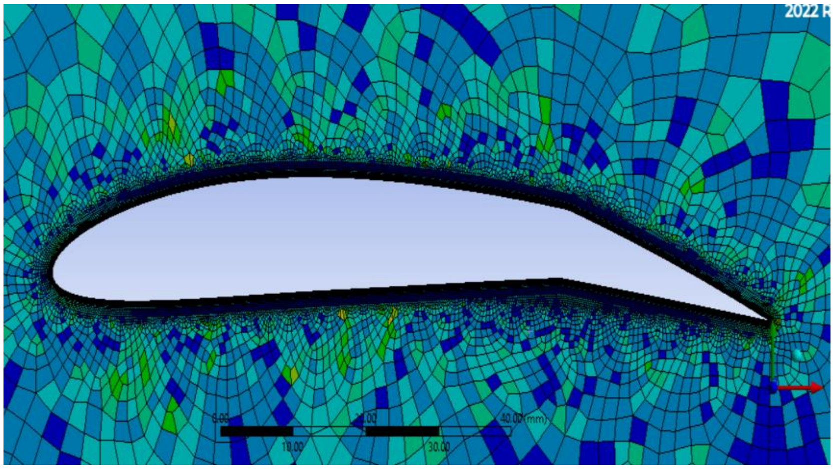


Figure 3. Element Quality of Generated Mesh

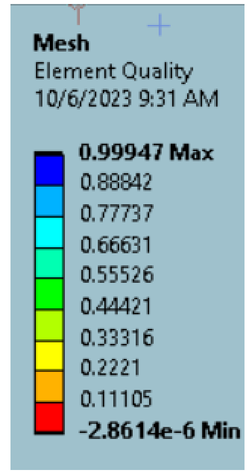


Figure 4. Index of Element

The quality of the element indicates the quality of the network in that region and should have a value close to one, although it can be made by reducing the size of the mesh and sharpening them, but this makes the base size much larger, heavy computing equipment is required and is not a viable option.

- **Setup**

  The inlet of 35m/s was specified to the flow from the inlet with initial gauge pressure of 0 Pa and turbulence viscosity ratio of 10.Outlet was specified as a pressure outlet. The upper and lower walls were kept stationary.

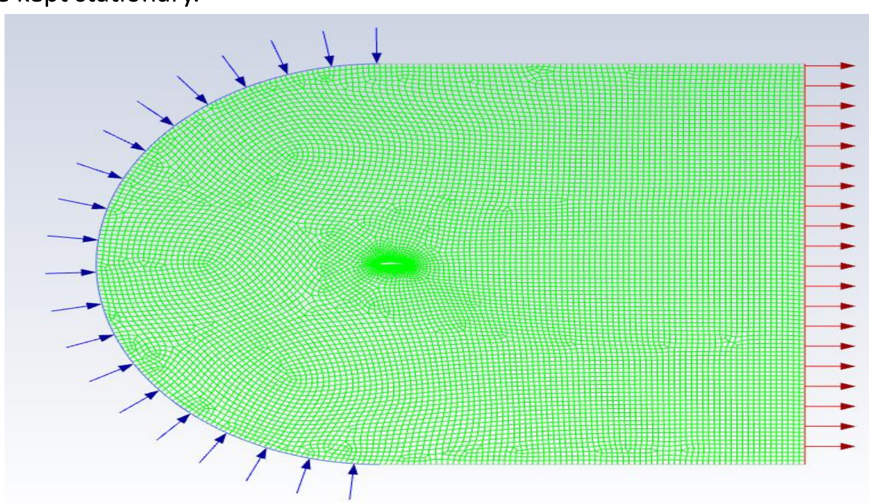


Figure 5. Inlet and Outlet of domain

- **Solver**

  The simulation was done in ANSYS Fluent 2022.

  - Spalart-Allmaras model was used with vorticity based production.
  - A pressure based type second order formulation and time steady method is employed for solver.

- The converging was set to achieve residual error of 1e-04, which was achieved in further iteration.

4. RESULTS AND DISCUSSIONS

The morphing and plain flap were analyzed. The lift & drag coefficient and flap angle deflection for 2D airfoil with flap was observed for five different deflection angle. For the first two cases of deflection angle of 0°, 5° the lift coefficient (C_l) for plain and morphed flap was observed to be similar with value of 0.72. However, the drag coefficient (C_d) for first three cases of 0°, 5°, 10° of morphed flap airfoil was greater than plain flap which is somewhat odd result. This can be due to issues with the quality meshing as it cannot capture the correct curvature for the morphed airfoil. After the first two cases, the lift coefficient (C_l) increases to value of 1.02, 1.26, 1.41, 1.54 for morphed flap and is greater than plain flap as seen from figure 6. The drag coefficient (C_d) of morphed flap is also less than the plain flap for other cases. We found that the lift coefficient (C_l) of morphing flap increased by around 15% than that of plain flap and the drag coefficient (C_d) decreased by around 12.5% only for larger deflections.

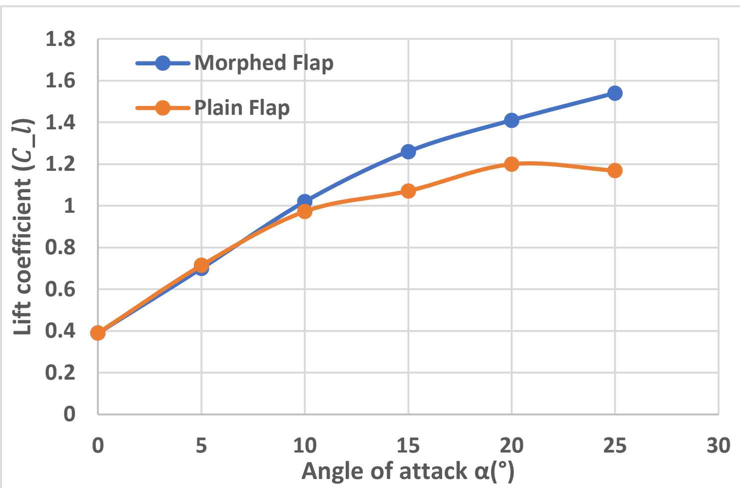


Figure 6. Lift Coefficient Vs Angle of Attack

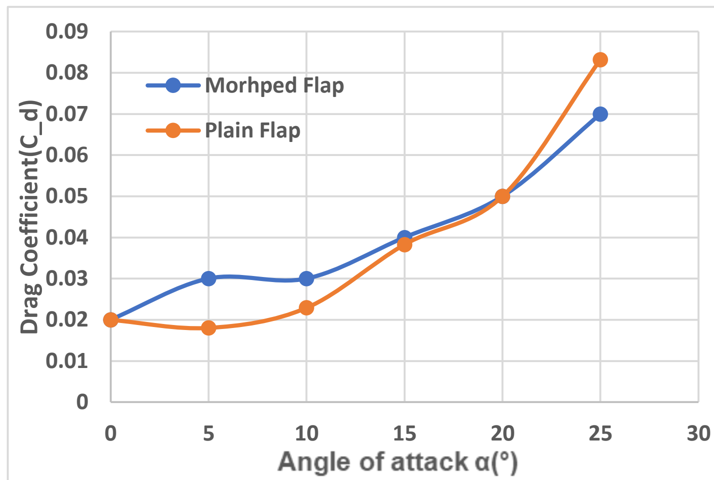


Figure 7.Drag Coefficient Vs Angle of Attack

5. CONCLUSION

The following major things were concluded from the work which are summarized in the following points:

- Five cases of flap deflection were investigated for 2D airfoil with morphed flap and plain flap.
- The results shows that lower deflection angle the plain flap give better lift and less drag than the morphed flap.
- At higher flap deflection angle the morphed flap provides better lift and less drag which is ideal for takeoff and landing scenarios.

6. ACKNOWLEDGEMENT

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