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Designing and Analysis of Morphing Wing

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Abstract

This study aims to investigate the aerodynamic performance of a morphing wing compared to a conventional NACA0015 wing profile across different angles of attack. Morphing wings, inspired by natural flight mechanisms, offer the potential for enhanced adaptability and efficiency in various flight conditions. Utilizing computational fluid dynamics (CFD) simulations, the aerodynamic characteristics of the morphing wing will be analysed and compared with those of the NACA0015 wing. The analysis will focus on parameters such as lift, drag, and stall behaviour. Additionally, a physical model of the morphing wing will be fabricated for better understanding purpose. The findings of this research will contribute to a deeper understanding of the advantages and limitations of morphing wing technology, providing insights into its potential applications in aerospace engineering for improved performance and manoeuvr ability.

Keywords

Morphingwing, NACA0015 airfoil, Solid Works Designing, Ansys

I. INTRODUCTION

The word morph derives from the Greek word ‘morphos’, which means shape. In today’s meaning, morph indicates the ability to transform shape or structure. The majority of the references reviewed in this article emulate biological structures and functions. During flight, aircraft fly at different flight conditions with corresponding targets and requirements. Consider, for example, the take-off and cruise phases of flight. The overarching idea of a morphing wing is to adapt its aerodynamic shape to each flight condition to obtain better performances, such as flight envelope, flight control, and flight range.

The cost and complexity of design, manufacture and maintenance can also be decreased by replacing specific mission tailored aircraft designs with a single type of morphing aircraft. The largest economic driver is having a fleet of a single morphing aircraft capable of being utilized on different mission objectives and flight conditions, as opposed to a fleet of several aircraft types, each designed for a specific mission objective and function. A large body of work on morphing structures exists, and is based either on material or shape morphing mechanisms.

Some of these references classified morphing wings based on the geometry change or the actuator concepts, while other references focused a tone specific element, such as special materials and relative techniques special actuators and applications. As documented in these references (and references therein), it is apparent that considerable progression morphing wings has been made. It is believed that this was made possible by the increased sophistication of methods and tools deployed in the design and analysis phases, as well as continued efforts in wind tunnel and flight experimentation.

The present review is intended to identify the modelling and analysis methods (structure, aerodynamics, aeroelasticity, control and optimization) with applications on morphing wings, and to provide an alternative reasoning to categorize morphing concepts.

II. LITERATURE STUDY

Morphing a wing in flight may improve the aircraft overall performance or specific target parameters. This is achieved by shaping appropriately the wing to different and critical phases of flight. The parameters of the spatial frequency and the phase shift at different angles of attack were varied to conduct the comparative study of the morphing wing through analytical approaches and numerical Computational Fluid Dynamic (CFD) simulations. The morphing wing had a better performance than the non-morphing wing for $CL > 0.8$, which is near the stall region. It is a very important application for achieving future developments and popularity both in the UAV sector, civil aviation sector and military aviation sector, by performing the desired characteristic changes in the desired phase of the flight, by switching to the desired characteristic features. The design details of a novel morphing wing a represented. Aero dynamic models based on lifting line theory for such wings operating by twisting are studied and compared with wind tunnel test results. Finally, some flow visualization is presented.

III. METHODOLOGY

The methodology is as shown in below figure 1

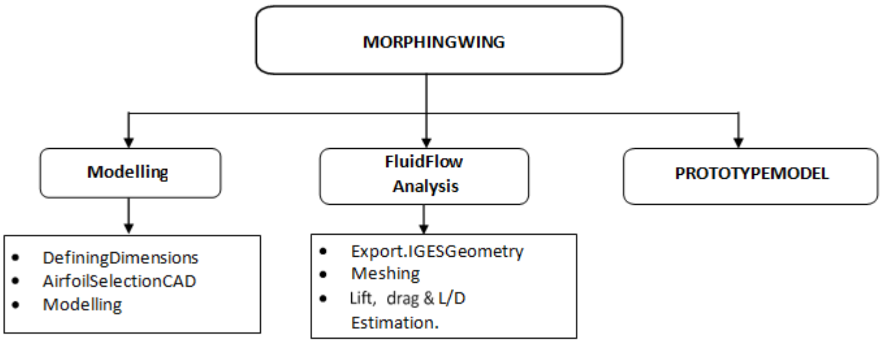

Figure 1 Methodology

The design of Morphing wing is done by the following methods. The model of morphing wing is shown below. It is designed by the following methods.

Dimensions of Morphing wing using NACA0015 Airfoil;

The dimensions of the Morphing wing for various parts of wing Model are shown in table below.

BWB Part	Parameter	Dimensions (mm)
Wing root	Chord Length	163.2

The morphing wing design involves implementing a mechanism to bend the wing at 40% from the trailing edge, maintaining structural integrity while accommodating a 15-degree angle of attack.

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Airfoil Selection

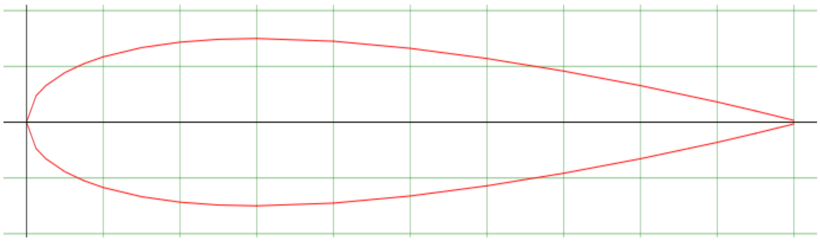

Figure 2 NACA0015 Airfoil

After airfoil selection model of morphing wing modelling was done using the above table of dimensions. The comparative analysis evaluates the aerodynamic performance of the designed morphing wing model against that of a standard NACA 0015 wing configuration.

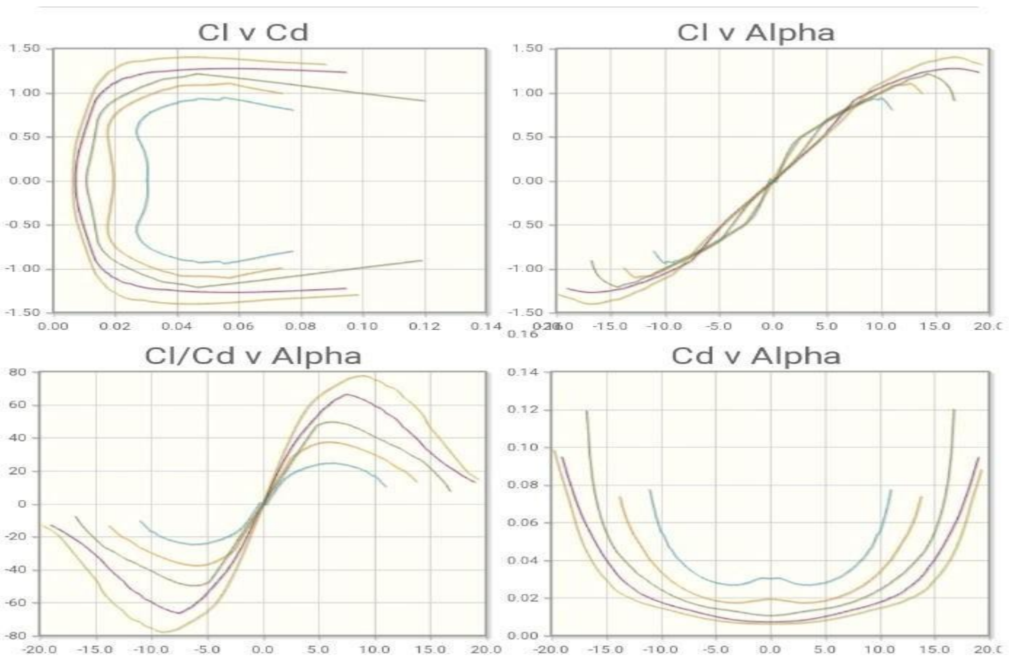

Figure 3 Aerodynamic characteristics for NACA0015 Airfoil

Final CAD Model of Wing Model – (NACA0015 Airfoil)

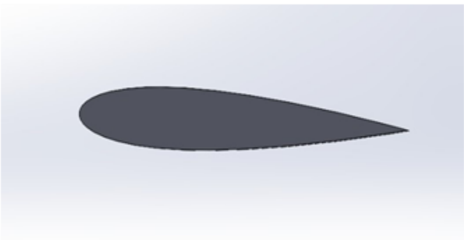

Figure 4 NACA00152 Design

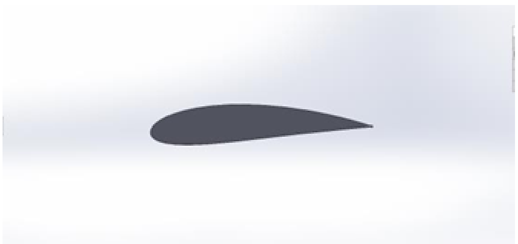

Figure 5 2D Morphing wing design

Boundary Condition

Solver	Pressure based
Model	Laminar
Velocity	10 m/s

AOA range	0-30 degree
Operating temperature	300K
Number of iterations	135

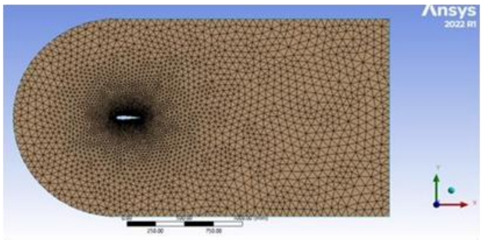

Figure 6 Boundary Condition

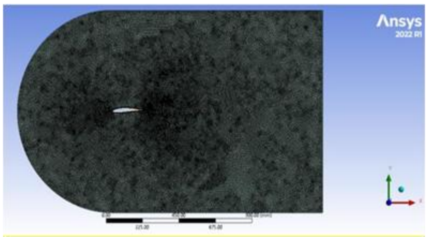

Figure 7 2D View of Meshing at Airfoil Region

IV. RESULT AND DISCUSSION

Contour Plots

Veloctiy Contour

A velocity contour is a plot of the velocity of the fluid at different points around the airfoil. The colours in the contour plot represent different velocity magnitudes.

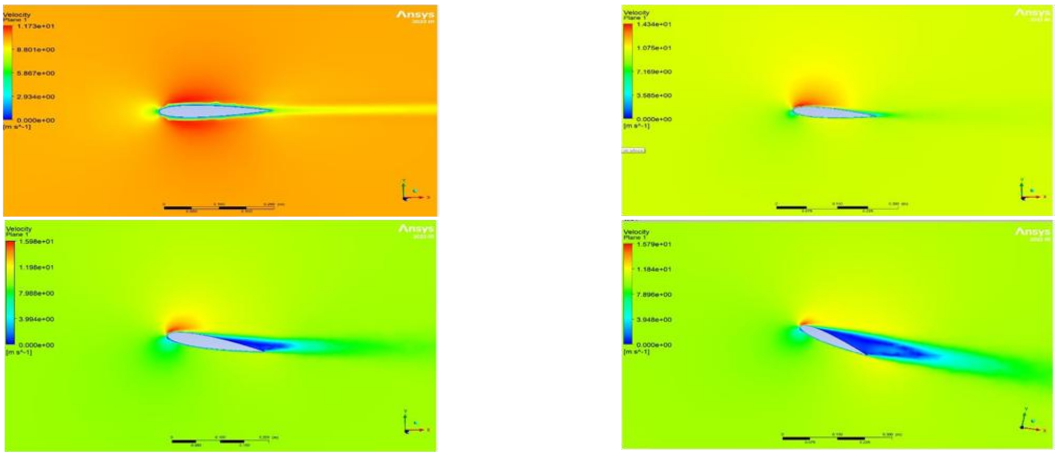

Figure 8 NACA0015 Aerofoil Velocity Contour

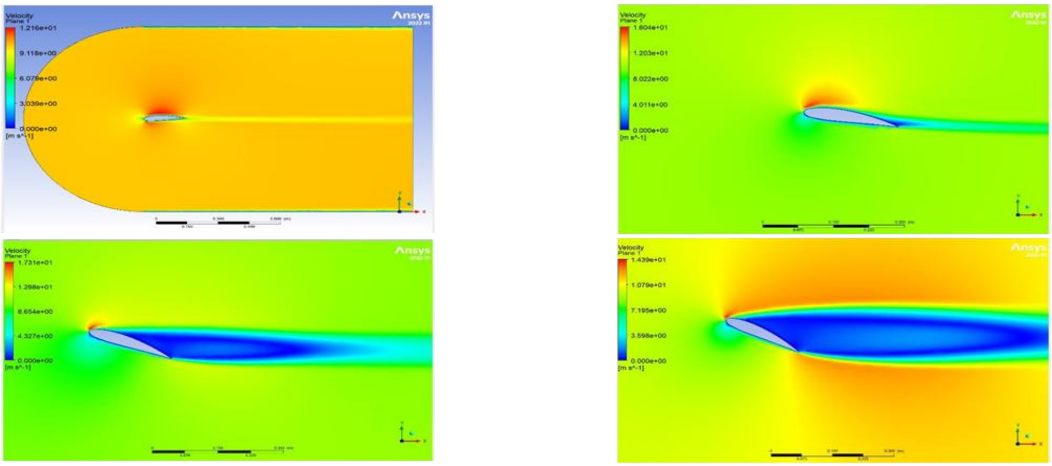

Figure 9 Velocity Contour for Morphing Wing AOA 0-30 deg

Pressure Contour

Pressure contours, also known as isobars, are a type of graphical tool used to visualize the distribution of pressure in a fluid or gas. They are similar to the velocity contours you described earlier, but instead of representing flow speed, they represent pressure levels.

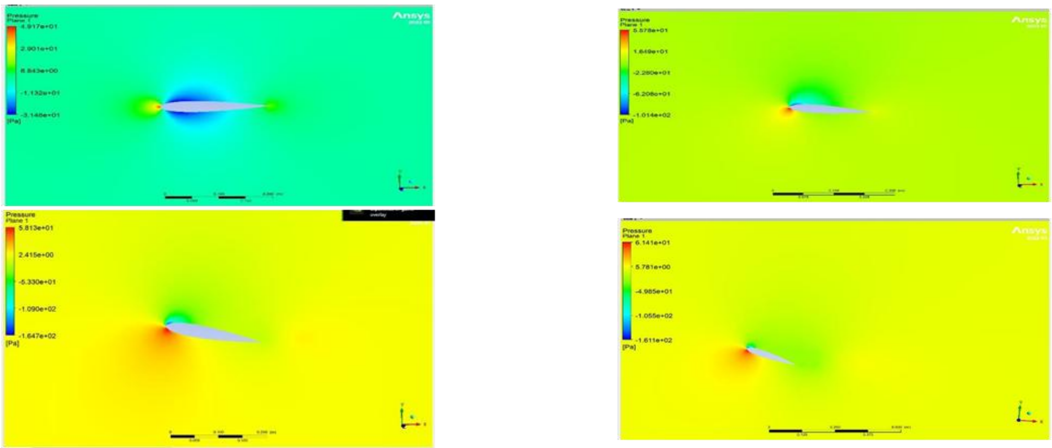

Figure 10 NACA0015 Aerofoil Pressure Contour

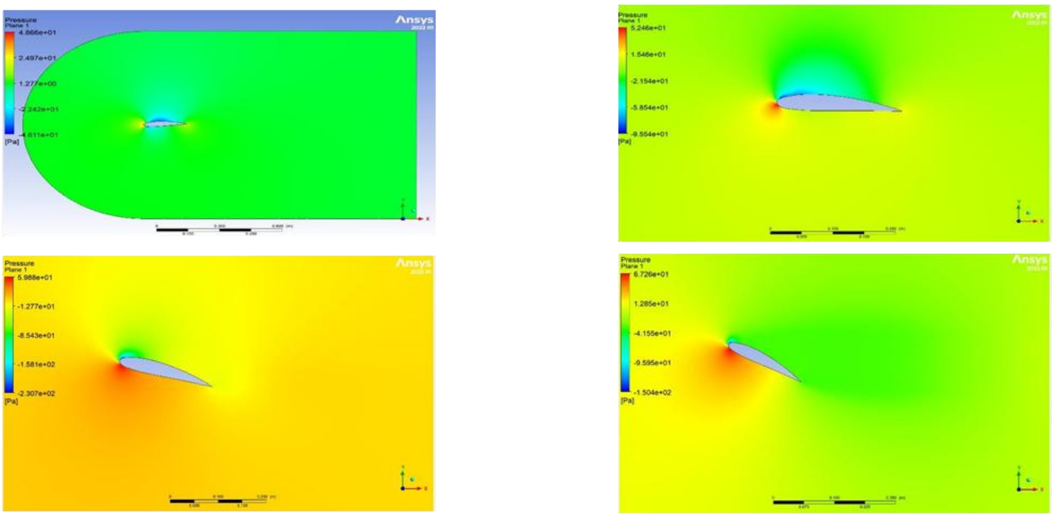

Figure 11 Pressure Contour for Morphing Wing AOA 0-30 deg

Plots

AOA	Lift [N]	Drag[N]	Cl	Cd	CL/CD
0	0.032016	0.204512	0.000523	0.004174	0.125299
6	6.48395	0.346859	0.10586	0.007079	14.95409
12	8.54193	0.905296	0.13946	0.018475	7.548579
18	7.85069	1.91672	0.128175	0.039117	3.276708

Figure 12 Normal NACA0015 Aerofoil

AOA	Lift	Drag	Cl	Cd	CL/CD
0	3.14746	0.253286	0.051387	0.005169	9.941381
6	10.5156	0.293146	0.171683	0.005983	28.69514
12	12.665	0.775416	0.206776	0.015825	13.06641

18	13.7914	1.38231	0.225166	0.02821	7.98177
24	12.0891	2.77419	0.197373	0.056616	3.48617
30	11.1585	5.07724	0.18218	0.103617	1.752057

Figure 13 Morphing Wing (NACA0015)

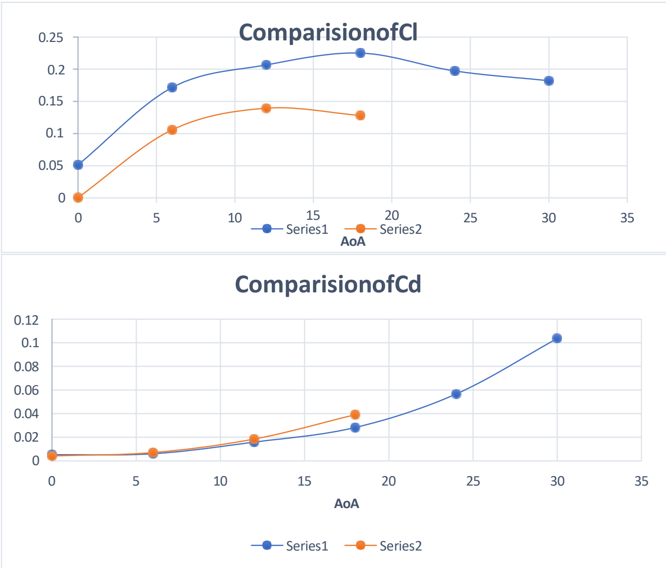

Figure 14 Comparison Plot of NACA0015 Aerofoil and Morphing Wing at Different Angle of attack

NACA0015 Aerofoil

- Cd will increase with angle of attack (AoA), indicating better drag at higher AoA.
- Cl will increase upto 12° but then slightly decreases at 18°.

Morphing Wing

- Cd is typically decrease than NACA0015 aerofoil at lower AoA but will increase rapidly at higher AoA.
- Cl will increase as much as 18° and starts off evolve to lower beyond that, indicating as tall round 24°.
- Maintains better Cl values than NACA0015 aerofoil a tall AoA.

Stall Analysis

- NACA0015 Aerofoil:- Stall in all likelihood happens between 12° and 18°, as Cl peaks at 12° and reduces at 18°.
- Morphing Wing:- Stall probably happens around 24°, as Cl peaks at 18° and starts to decrease at 24°.

Comparison

Lift Performance

The morphing wing out performs NACA0015 in lift generation, achieving higher Coefficient of lift across all AoA.

Drag Performance

- At lower AoA, the morphing wing has slightly higher Coefficient of drag than NACA0015, but the difference is minimal.
- At higher AoA (24° and 30°), the morphing wing experiences significantly higher drag, which is a trade-off for the increased lift.

Stall Behaviour

The morphing wing delays stall to a higher AoA (24°) compared to NACA0015 (around 18°), indicating better performance in delaying the onset of stall.

Future Program Development

Improving Morphing Wing Designs: Future studies may focus on optimizing the morphing wing design for different flight conditions to improve aerodynamic efficiency and its overall management has improved.

Advanced Control Algorithms: Using advanced control algorithms can further enhance the performance of morphing wings, allowing for real-time adjustments based on flight conditions.

Innovation: Research in to new materials for morphing wings that make them very flexible, stiff, and reduce weight can greatly improve their performance.

Integration with UAVs: Exploring the integration of morphing wings in Unmanned Aerial Vehicles (UAVs) can lead to improvements in surveillance systems, analysis, and delivery.

Full-Scale Testing and Certification: We are moving towards a comprehensive testing and certification program to validate the benefits and safety of morphing wings for commercial aircraft.

V. CONCLUSION

The comparison between a conventional NACA0015 aerofoil and a morphing wing demonstrates the potential advantages of morphing wing technology in aerodynamic performance. The morphing wing exhibited lower drag coefficients at high angles of attack and provided more consistent lift coefficients, indicating better performance in flight conditions. This work highlights the promising future of rotary wings in terms of fuel efficiency, manoeuvrability, and overall aviation performance, making it a valuable innovation in aerospace industry. Continued research and development in this are a could lead to significant advances in both commercial and military aviation.

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