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Advanced Wing Designs, Numerical Analysis of the Aerodynamic Performance on Wings with Morphed Trailing Edges for MAV Applications

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I. INTRODUCTION

The research paper titled "Numerical Analysis of the Aerodynamic Performance on Wings with Morphed Trailing Edges for MAV Applications" by Sandan and Pendyala (2023), published in the International Journal on Interactive Design and Manufacturing (IJIDeM) in the year 2024 is a detailed analysis on the application of morphing trailing edges to improve the aerodynamic performance of Micro Aerial Vehicles (MAVs). The purpose of this review is to critically discuss the presented methodologies, results, and contribution of this research, specifying how it fits into the larger context of important studies in the last few years. With the help of the presented analysis of the given study, it is comprehensible to outline the further developments in morphing wing systems and their effects on the performance of the aircraft.

II. RESEARCH PURPOSE AND OBJECTIVES

Thus, the primary goal of the work is to investigate how morphing trailing edges will lead to the enhancement of MAV's aerodynamics. The authors aim to address several key objectives:

1) Evaluate Aerodynamic Performance: To determine the changes of lift and use drag to measure the efficiency of the morphing coordinated trailing edges.
2) Validate Numerical Simulations: To analyze similarities of obtained data of numerical simulation with experimental data received through wind tunnel tests.
3) Explore Practical Applications: To introduce the real implications of using morphing trailing edges in MAV-related applications from the feasibility perspective and the possible benefits.

These objectives are essential for the comprehension of the utilitarian consequences of changing wing morphing technology and its probability of being a turning point in MAV design and production.

III. METHODOLOGY

The two authors adopted numerical simulations and experimental works to analyze the aerodynamic behaviour of the wings with morphed trailing edges. The numerical part of the project was carried out through the application of CFD tools for testing different morphing configurations and their impact on the lift and drag forces and pressure coefficients. The above-mentioned simulations were carried out under varying flight conditions to realize the different AC characteristics.

As for the experimental part, wind tunnel studies were performed to compare the results obtained numerically. The authors also built a concept wing, which can be morphed, and experimented with it in a wind tunnel to determine the effects on aerodynamics. These results were then compared to the wind tunnel data for validation of the models used in CFD.

In this study, the selected methodology involves modeling and computation of numerical results, besides physical experiments, to enhance the credibility of the results. Employing the CFD tools predicts the aerodynamic behavior of morphed configurations and flight conditions, which is critical in studying airflow over morphed wing surfaces. However, several concerning factors require attention. That is why the accuracy of the CFD simulation directly depends on the quality of the mesh adopted and the turbulence model used. Whether it is a sports match or a business venture, inaccuracies here can introduce errors into simulated performances vis-a-vis actual performances.

The study should describe the independence of a mesh and the choice of turbulence models to improve the reliability of numerical solutions. Despite most wind tunnel tests being quite common, they do not mimic actual flight conditions such as turbulence. Literature also calls for the use of in-flight data besides wind tunnel data to give a complete validation of morphing wing technology (Gabor, Koreanschi & Botez, 2016). The increase in MAVs attracts questions on the scale in which we operate. While beneficial for applications of a small scale it remains to be seen how morphing trailing edges would fare in the context of large airplanes. Studies show that increasing size brings new issues thus increasing the need for more studies on the applicability of this technology in large-size aircraft (Lim & Kim, 2019).

IV. FINDINGS AND ANALYSIS

A. Aerodynamic Performance Improvements

The research done in this paper established the fact that when these trailing edges are varied, the MAV aerodynamics is boosted. From the numerical simulations, significant changes were observed in lift-to-drag ratio which expresses the increase in efficiency (Tandis & Assareh, 2017). Experimental data was in parallel with these conclusions proving the efficiency of the morphed trailing edges in terms of drag and lift enhancement under various flight conditions.

The results given here correlate with other current research made in the scope of the branch. For example, another research by Ai et al. (2019) also showed an increase in aerodynamic efficiency through the morphing trailing edges; thus, the effectivity of this technology in enhancing aircraft performance (Yang et al., 2018). Moreover, Jeong and Kim (2021) also agree with the study done, the results are also found showing the effectiveness of morphing airfoils to produce enhanced aerodynamics through adaptable wings.

B. Numerical vs. Experimental Results

By comparing numerical data to the experimental data, the reflection showed a high correlation between these values, so the CFD models used in the analysis are effective. With these minor variations, the results were attributed to experimental errors and unrealistic simulations used in the models. This validation of the numerical simulation is important because it gives credibility to the results obtained through the CFD tools, permitting further study and enhancement of morphing wing technology.

Regarding this aspect of the work, the findings of this research align with Mukesh et al. (2020), who agreed that it is crucial to compare the results obtained using numerical simulation with experimental results to confirm the accuracy of the simulation and the generality of the results.

C. Practical Applications and Feasibility

In the study, the authors outlined real-life uses of morphing trailing edges to MAVs; the authors explained how such technology could help expand the mission capabilities of MAVs by increasing the efficiency of the system and decreasing the energy utilized. According to the authors, the modularity idea of morphing technology would result in MAVs that are customizable in aspects such as flight flimsiness and robustness in a way that will meet different conditions and execute more complex tasks.

As evidenced from the identified literature, similar advantages can be derived with the application of the variable-camber technology in supercritical airfoils as highlighted by Niu et al. (2020) on the aerodynamics issues and fuel efficiency. The far-reaching significance of transforming intelligence in the scope and configuration of airplanes as well as flight characteristics is obvious, as it provides the potential for boosting the multifarious functions of man as well as unmanned aerial systems (Fincham & Friswell, 2015).

V. CRITICAL ANALYSIS

A. Strengths

The first major asset of the study is that numerical simulations have been complemented with experimental outcomes. This makes the research to be reliable and gives a Stronger paradigm for future research to emulate. The works done by authors with the help of state-of-the-art CFD tools and wind tunnel tests offer appreciable knowledge for new investigations of morphing trailing edges (Della et al., 2019).

In addition to the concerns elaborated above, the study relates well to a significant feature of MAV design, the aspect related to enhancing the aerodynamic efficiency via wing design. This focus is rather timely given the increasing efforts towards enhancing the capabilities of MAVs for a myriad of uses such as surveillance and reconnaissance, environmental assessment, and monitoring (Niu et al., 2020).

VI. LIMITATIONS

Nevertheless, this study also has some limitations, which should be further discussed to avoid falling into generalization. Another limitation that can be mentioned is the testing of the experiments only to a certain extent. It is quite apparent that the wind tunnel tests were of immense aid but they were conducted in an environment without a real-world flight-like environment. Larger subsequent research endeavors should incorporate flight tests through which the onset of morphing trailing edge performance under actual operation conditions may be determined.

Also, the study mainly targets MAVs, and hence, the conclusions drawn in this study may not hold for larger flying vehicles. Morphing wing technology, therefore, has some challenges that have not been addressed regarding the scalability of the wings; thus, more research needs to be conducted to work out the viability and efficiency of the morphing wing technology in the practical applications of the large airframes.

Therefore, in the process of writing a recommendation, it is appropriate to compare the results of this work with other current theoretical and practical potential research related to advanced wing designs using morphing technology. Ai et al. (2019) have also published on the study of the aerodynamics of aircraft with morphing trailing edges: enhancement of the lift-to-drag ratio and overall efficiency was noted too (SpringerLink). Such consistency of results reaffirms the feasibility of morphing trailing edges as a likely solution for increasing high-lift aerodynamic effectiveness. In addition, Jeong and Kim (2021) discussed the concerns of morphing airfoils with the aid of the genetic algorithm to prominent mean aerodynamic benefits. Their work supports the study findings of the current study since it underlines the factor of optimization in warranting the best performance. Similarly, Niu et al. (2020) studied the effect of variable-camber technology in supercritical airfoils and identified a similar enhancement in the aero-forcing efficiency as well as the fuel consumption. This paper further supports the flexible wing concept as a way of positively affecting the performance of airplanes. Mukesh et al. (2020) stressed the significance of comparing numerical simulations with experimental data, which is a vital component that is effectively performed in this study. This validation is important in as much as it can ensure compatibility of the results to events in real life.

A. Implications for Future Research

Thus, the results of this research hold considerable promise for further research in the sphere of the morphing wing concept and aircraft design. As the following analysis indicates, the research in morphing trailing edges has indicated the potential to make evaluation and enhancement of aerodynamics, which means further investigation and advancement of the technology might result in considerable enhancement in the airplane's usefulness and efficiency.

Future research should focus on several key areas:

1) Scalability: Study the practicality and efficiency of the concept of variable geometry wings in bigger airplanes, and study the issues that may arise in the scaling up of employment of the morphing wings.
2) Optimization: Work on other techniques for improving the performance of morphing airfoils and trailing edges such that they meet the needs of aircraft.
3) Real-World Testing: Engage in flight testing to measure the impact of morphing wing designs under operative conditions to address concerns about the viability of the designs.
4) Material and Structural Innovations: Designer new materials and structures that would enable the use of morphing while at the same time focusing on the strength and stability of the structures required.

VII. CONCLUSION

The above-titled research paper is a comprehensive and highly validated study of the improvement of the aerodynamic performance of MAVs using morphed trailing edges of wings. Using numerical simulations in parallel with experimental tests ensures the solidity of the discussed advantages and the practicability of the presented approach.

The results of the study align with prior and current research in that the morphing wing technology has the capability of transforming the aircraft’s layout and efficiency. Thus, more research is required to investigate its limitations and other possibilities of this technology in larger airplanes and other realistic conditions. In conclusion, the contribution of this study is to provide significant findings and new advancements in improving the design of advanced wings, and modern tendencies of improving the aircraft's performances with the help of morphing wing technology.

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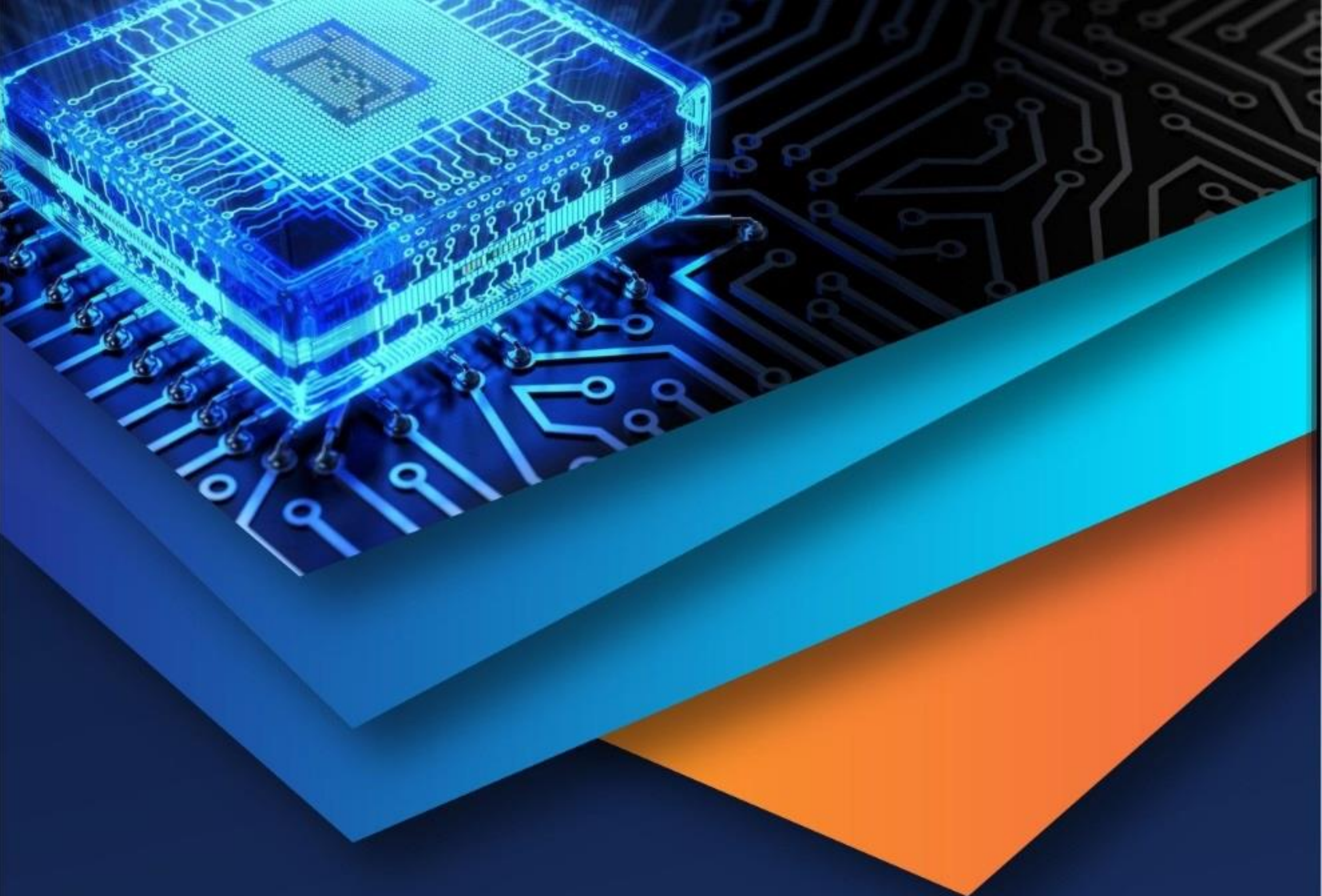

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