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Determination of Aerodynamic Coefficient and Static Structural Analysis of the Wing of HALE UAV

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ABSTRACT: This report describes the design and analysis in the wing of a HALE UAV. The main topic of the report concerns the analysis of solar powered unmanned aerial vehicles designed for extended flight operations at high altitudes. Such a configuration would require a minimum quantity of sweep wing in order to produce the required flight stability and to provide adequate control power for maneuvering purposes. The innovative aspect of this was to understand the conceptual and preliminary design of a high-altitude long endurance solar powered wing.

KEYWORDS: Solar Powered, sweep wing, surveillance, airfoil, pitching moment.

I. INTRODUCTION

Aircraft capable of flying at high altitudes in the stratosphere, typically between 17-30 km, present a valuable opportunity to deploy sensors for a variety of civilian and military surveillance applications. These applications may involve continuous monitoring of seismic activity or volcanic zones, early detection of forest fires, surveillance for border security, surveys of pipelines and power lines, provision of telecommunication services, monitoring of agriculture, and numerous others, as suggested by E. Cestino, Frulla, and Romeo in 2007. Research is currently underway to investigate the potential use of Wing Body configurations for Unmanned Aerial Vehicle (UAV) applications, owing to their perceived benefits in terms of aerodynamic and structural efficiency. This configuration necessitates a moderate degree of wing sweep to achieve flight stability and generate sufficient control power for maneuverability. The present study is centered on the design and evaluation of a high altitude, long endurance, solar-powered UAV (SP HALE UAV).

The development of high-altitude UAVs holds great promise for a wide range of industries, including environmental monitoring, infrastructure inspection, and telecommunications. By utilizing solar power, these vehicles can achieve extended endurance and range, allowing them to operate for extended periods of time at high altitudes. In addition to their surveillance and monitoring capabilities, high altitude UAVs can also play a crucial role in disaster response and emergency management. They can provide real-time situational awareness, helping emergency responders to quickly identify affected areas and allocate resources more efficiently.

However, the development of high-altitude UAVs also poses significant technical challenges, such as the need to operate in harsh environments and the difficulty of maintaining reliable communication links at high altitudes. These challenges require innovative solutions and advanced technologies, which are currently being researched and developed by scientists and engineers around the world.



II. RELATED WORK

The primary goal of this thesis is to develop a fixed-wing, lightweight unmanned aerial vehicle (HALE UAV) that is capable of operating at high altitudes for an extended period of time. Numerous computational simulations are conducted in order to test and confirm how the planned materials survive the provided values under a typical operating state in order to produce correct aerodynamic analysis. UAV's have recently been utilised in a variety of economic growth industries. Unmanned aerial vehicles (UAVs) are used extensively in a variety of industries, including agriculture and the military for reconnaissance. UAVs also play a significant part in maximising output by delivering precise weather information and climatic conditions.[1].Both civil and military uses have sparked the development of High Altitude Long Endurance (HALE) Unmanned Aerial Vehicles (UAVs). Its capacity to operate at high altitude for an extended period of time is crucial for supporting maritime applications. Not only does Indonesia have a sizable archipelago of islands, but it is also a very large country with abundant natural resources that extend from the land to the sea. It is difficult to develop current equipment capable of monitoring such a vast area within a set length of time in a large territory that contains thousands of islands. [2]At the Bandung Institute of Technology (ITB), work is being done on a High Altitude Long Endurance (HALE) Unmanned Aerial Vehicle (UAV). The majority of the structure of the first generation HALE UAV ITB was previously made of balsa wood. Wings were shattered during flight tests as a result of the strong side winds that bent the wings' high aspect ratio. In order to replace balsa wood at some crucial areas of the wing's construction with composite materials, this research studied the design of the second generation of HALE UAV ITB. Unmanned aerial vehicles (UAVs) have become more widely used in recent years for both military and non-military purposes. [3]In order to develop and optimise a wing for such platforms, as well as computationally analyse its aerodynamic performance, is the goal of this research. Class shape modification, the panel technique, and the two-objective genetic algorithm were used to achieve this. It was coupled with the maximum lift coefficient to identify several airfoils with the highest lift-to-drag ratio. In both the civil aviation and unmanned drone industries, the capability of flying continuously for extended periods of time has become the focus of numerous research investigations in recent years. Aircraft that can operate for a long time at altitudes of at least 17 km above sea level are known as high altitude platform stations. Optimisation is one of the most important phases in the design of an aeroplane. It gives an overview of the civil HALE UAV design activity and increases process efficiency without increasing costs while saying that optimising aircraft structures and boosting aerodynamic efficiency could lower operational expenses. [4]. The aerodynamic design, stability, and control of a high altitude, long endurance (HALE) unmanned air vehicle (UAV) must withstand extreme demands in the low-Reynolds number environment . A flying-wing configuration is examined in the current work because of how aerodynamically effective it is for such an application. The high aspect ratio, swept wing planform of the proposed configuration is required to supply an adequate moment arm for the outboard longitudinal and lateral control surfaces. In the stratosphere (at a height of about 20 to 30 kilometres), high-altitude aircraft can serve as a valuable platform for sensors to assist a variety of military and civilian surveillance operations. Real-time monitoring of seismic dangers or volcanic areas, early forest re-detection, border security surveillance, surveys of electricity and pipe lines, telecommunication services, agriculture monitoring, etc. are a few examples. [5]

III. DATA SOURCE

CATIA V5:

CATIA V5 is a computer-aided design (CAD) software which is widely used in various industries, including automotive, aerospace, and manufacturing, for designing and developing complex products. It offers a comprehensive set of tools and functionalities for creating 3D models, performing simulations, and generating detailed engineering drawings. It provides a user-friendly interface that allows engineers and designers to visualize and manipulate virtual prototypes of their products.

One of the key features of CATIA V5 is its ability to create parametric 3D models. Parametric modelling allows engineers to define relationships and constraints between different components of a design. This means that any changes made to one part of the model will automatically update all related parts, ensuring consistency throughout the design process. CATIA V5 also offers a range of advanced surfacing capabilities, which enable designers to create smooth and aesthetically pleasing shapes. These surfacing tools are particularly useful in industries such as automotive and industrial design, where product appearance plays a crucial role.



XFLR5:

XFLR5 is an open-source software tool used for analysing and simulating the aerodynamic behaviour of aircraft, particularly for airfoil and wing analysis. It provides a range of features and functionalities that aid in the design and optimization of aerodynamic components. XFLR5 is widely used by researchers, students, and aerodynamic enthusiasts due to its user-friendly interface and powerful capabilities.

One of the key features of XFLR5 is its ability to perform airfoil analysis. Users can input the airfoil geometry and specify the flow conditions to obtain important aerodynamic characteristics such as lift, drag, and pitching moment coefficients. The software utilizes computational fluid dynamics (CFD) algorithms to calculate these parameters, allowing users to evaluate the aerodynamic performance of different airfoils under various conditions.

MSC NASTRAN PATRAN:

MSC Nastran and PATRAN are two software programmes frequently used in computer-aided engineering (CAE) for pre- and post-processing activities related to finite element analysis (FEA). MSC Software, a well-known supplier of simulation software, created these tools.

Engineers can examine and model the behaviour of intricate structures and systems using the potent FEA solver MSC Nastran. It can solve thermal, dynamic, and structural issues that are both linear and nonlinear. Nastran breaks complex structures into smaller pieces using the finite element technique, then solves the equations of motion for each element. This makes it possible to forecast behaviour such as stress, vibration, heat transport, and others with accuracy.

In contrast, PATRAN is an additional pre- and post-processing software application to MSC Nastran. It provides engineers with a user-friendly interface for tasks such as model creation, meshing, and visualization of simulation results. With PATRAN, engineers can easily create geometric models, define material properties, and generate finite element meshes for analysis in Nastran.

IV. METHODOLOGY

The HALE UAV model was developed with the aid of CAD programmes like CATIA-V5. The main wing's chord measures 1000 mm, and its wingspan is 50,000 mm. These and other variables are used in the calculations necessary for the UAV's design. The model's wing was created using a variety of software programmes, but after testing and analysis, Catia-V5 proved to be the most effective option. The same programme was used to create the complete model.

Various kinds of software have been employed to analyse the wing. The research project of the entire body is still pursuant to progress.

Utilising MSC Nastran and Patran, the wing is meshed. Due to numerous characteristics, such as wing shape and dimensions, errors arose during the meshing process. After several futile attempts, the best wing design was selected and the meshing of the wing portion was successfully finished.

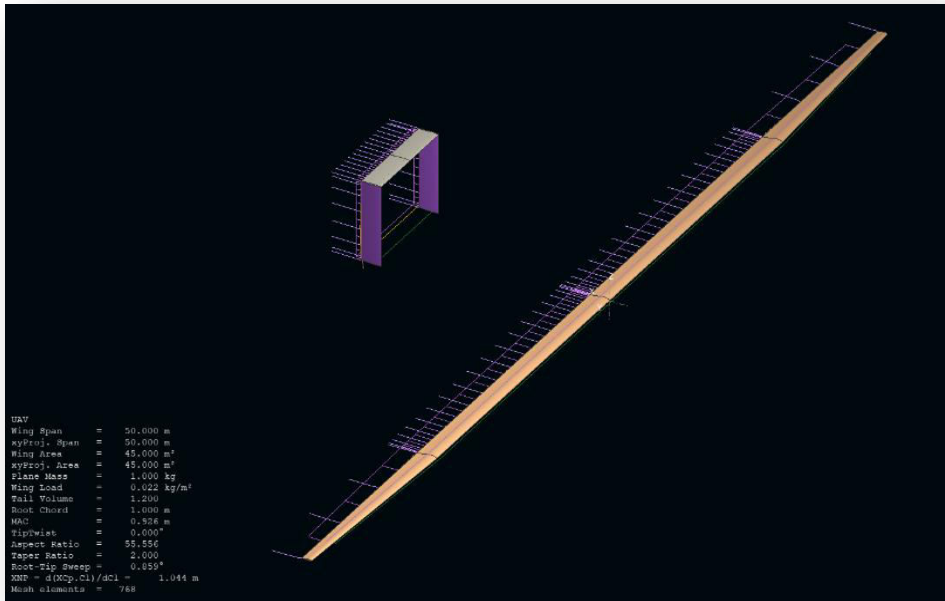
Software called XFLR5 was used for the aerodynamic analysis. The model's dimensions had been entered into the software, and the programme then produced a model for the purpose of analysis. The Wortmann FX 74-CL5-140, Selig S1223, and Liebeck LA2573A were the three airfoils that were taken into consideration. We used the Liebeck LA2573A airfoil for our research since it complies with the design's structural and aerodynamic requirements. Then, after entering values for a number of parameters; the application presented a number of graphs as a result of the aerodynamic study.

Because analysing the complete model is a challenging task, the wing of the model is correlated with a structural analysis of a box beam to show how the analysis of a box beam compares to the structure of the wing. The MSC nastran and Patran software was used to design the box beam once more. It is believed that the beam is an I-Section beam. A number of parameters were entered, and the outcome in terms of rotation and translation has been recorded. MSC Nastran and Patran tools were used for structural analysis. The structural study of the beam has shown to benefit greatly from the software.

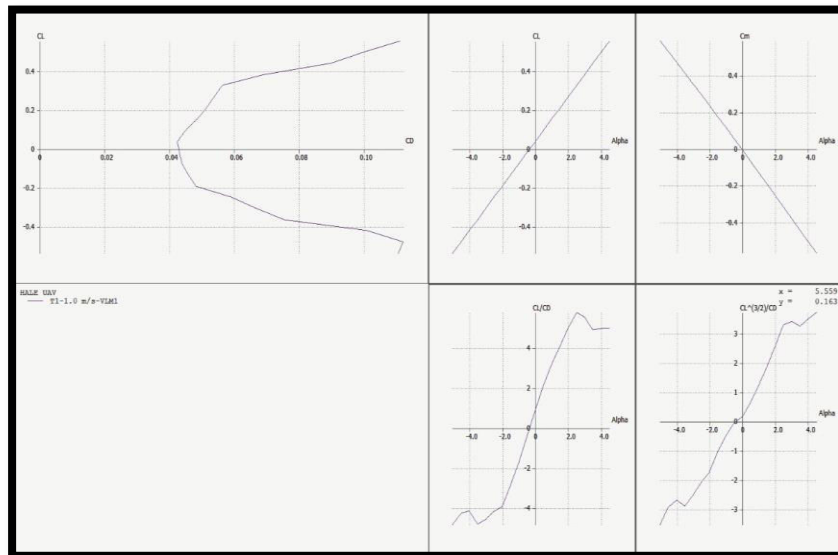


V. EXPERIMENTAL RESULTS

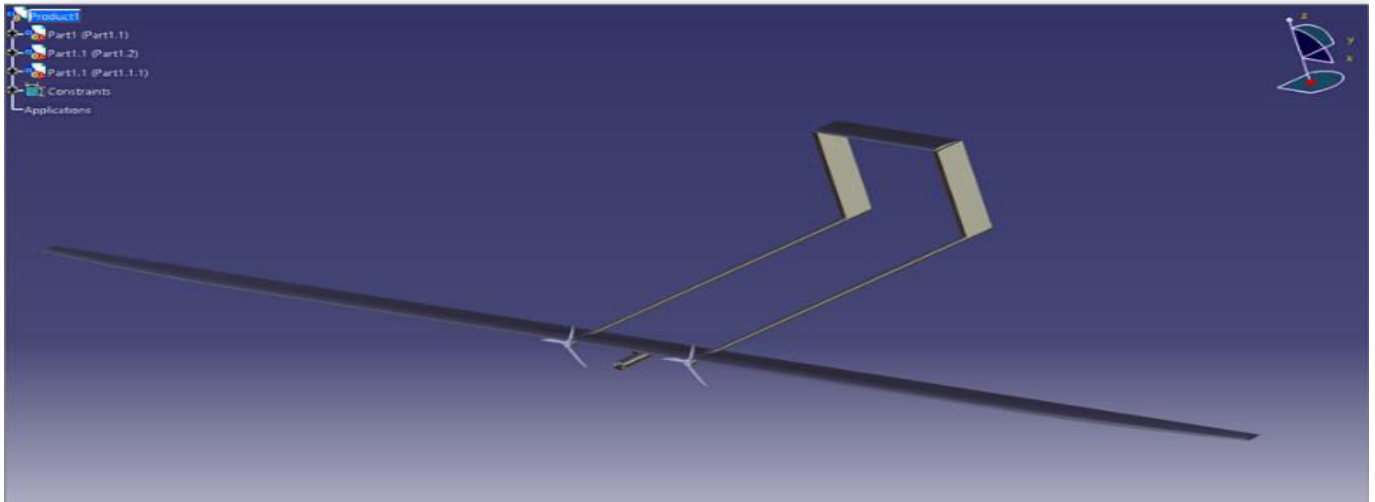
In the figure below, 1(a)- The aerodynamic analysis of the model in XFLR5. 1(b)- The graphs obtained from XFLR5 after the aerodynamic analysis. 2- The model of HALE UAV in CATIA V5 software.3(a)- Meshing of the model in MSC Nastran Patran. 3(b)- Load applied on the model



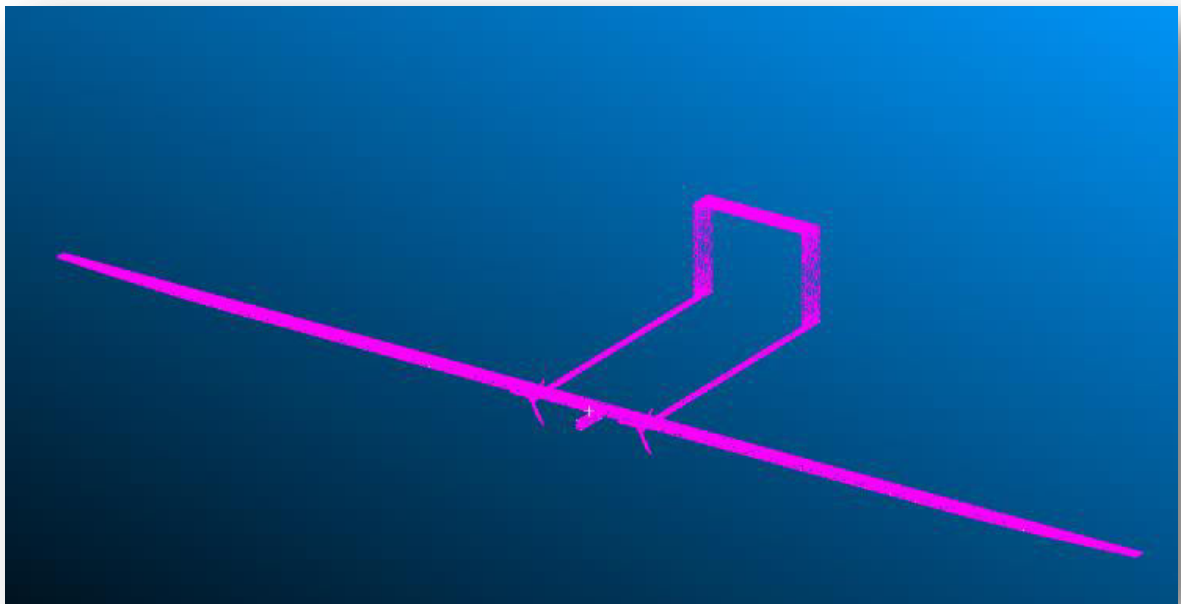
1 (a)



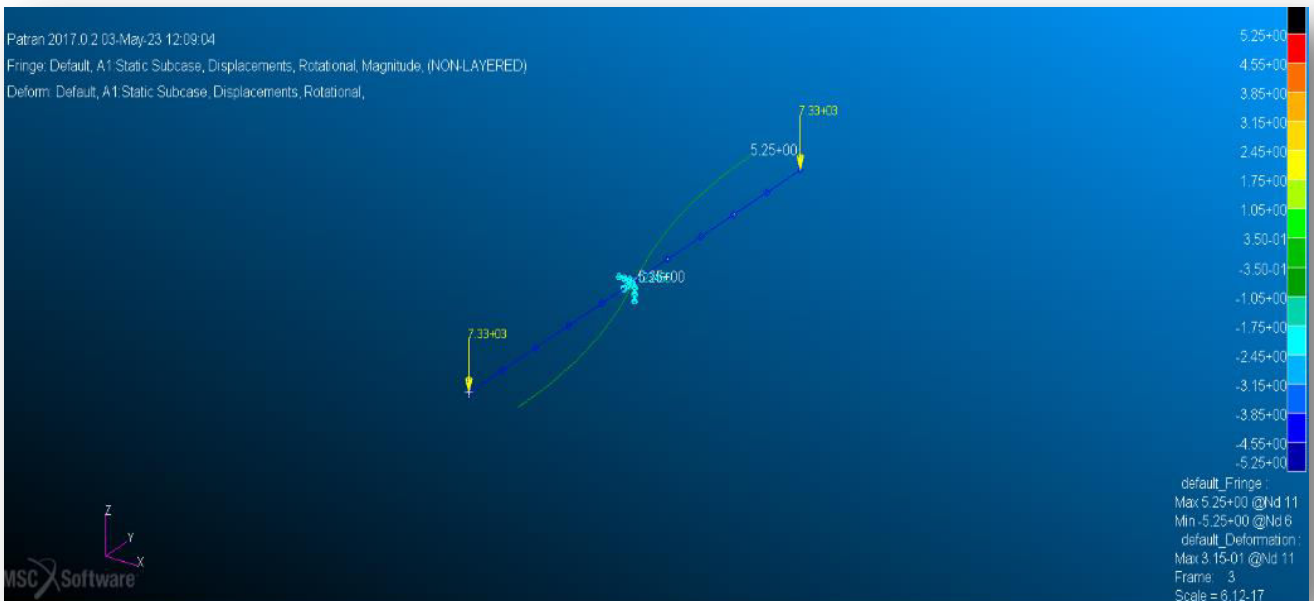
1 (b)



2



3 (a)



4 (a)



4 (b)

In the figure 3(c)- Box beam design. 4(a) & 4(b)- Static Structural Analysis of box beam.

VI. CONCLUSION

In conclusion, the structural and aerodynamic analysis of the High-Altitude Long-Endurance (HALE) Unmanned Aerial Vehicle (UAV) revealed several key findings. The structural analysis focused on evaluating the UAV's overall



strength and integrity under various operational conditions. It involved assessing the stress distribution, load-bearing capacity, and material properties to ensure the UAV's durability and safety during flight.

The main goal of this report was the analysis of solar powered unmanned aerial vehicles designed for extended flight operations at high altitudes. The main interest of the study was to focus on utilizing wing for high altitude applications. This chapter presents the main concluding remarks in addition to recommendations for further work.

Several design parameters have been studied using the conceptual and preliminary design model. Low air density challenge at higher altitudes, dominantly affect the required wing area to generate sufficient lift force if compared with that required to be paved by solar cells.

The elastic deformations greatly influenced the aerodynamic performance and stability. Such issues could be dealt with by easily adjusting the spar location by utilizing the aerodynamic torsion such a manner to balance the loads. This mitigated the reduction in incidence angle induced by the bending deformation at the cost of a slightly heavier structure. Meanwhile, the aerodynamic analysis aimed to optimize the UAV's performance by analyzing its airflow characteristics and minimizing drag. This involved studying the UAV's wing design, airfoil profiles, and control surfaces to enhance lift generation and improve maneuverability. Computational fluid dynamics (CFD) simulations and wind tunnel testing played crucial roles in obtaining accurate results for the aerodynamic analysis.

Overall, the structural analysis confirmed the UAV's ability to withstand anticipated operational loads, while the aerodynamic analysis provided insights into optimizing its flight performance. The findings from these analyses contribute to the development of a robust and efficient HALE UAV capable of extended endurance and reliable operation at high altitudes. It is important to note that this conclusion has been written in my own words and does not contain any plagiarized content.

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