Design of The VTOL Jet Engine for Energy Efficiency and Lightweight Flying Vehicle Analysis in Malaysia

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ABSTRACT

Driven by the growing demand for efficient emergency Vertical Takeoff and Landing (VTOL) transportation and advanced air mobility, the development of lightweight flying vehicles has become increasingly critical. This research presents an innovative flap design integrated with a jet engine system to optimize the aerodynamic efficiency and flight endurance of a lightweight aircraft. Characterized by a 770 kg payload capacity and a maximum speed of 425 km/h, the proposed vehicle underwent a rigorous development process involving aerodynamic analysis, structural configuration design, Computational Fluid Dynamics (CFD) simulations, and validation. The airframe leverages high-strength, lightweight materials specifically carbon fiber and aluminum integrated with a jet propulsion layout to reduce energy consumption. Numerical simulations demonstrate that the proposed flap configuration enhances flight endurance by approximately 36% over conventional designs. This framework exhibits strong potential for emergency response applications, including ambulatory and rescue operations, by mitigating traffic-induced delays. This study contributes directly to the advancement of energy-efficient jet engine technology and next-generation aerospace transportation systems in Malaysia.

Keywords: Flying Vehicle, VTOL (Vertical Take Off Landing), Flap Design, Jet Engine, Energy Efficiency, Lightweight Aircraft, CFD Simulation,

INTRODUCTION

Since the inception of advanced transportation infrastructure, the aerospace sector has experienced profound transformative growth (Monte et al., 2012). Ongoing technological innovations offer continuous opportunities to refine the safety margins, aerodynamic efficiency, and performance metrics of modern aircraft (Cakir & Kurtuluş, 2022). Over past decades, airframe architectures have been dynamically adapted to meet disparate operational conditions and mission demands (Chang et al., 2022; Reckzeh, 2014). Current design paradigms prioritize lightweight structures, optimized energy utilization, and robust flight envelope performance under fluctuating atmospheric conditions (Amiruddin et al., 2024; Ji et al., 2022; Nugroho et al., 2022), expanding the utility of these vehicles into commercial and emergency management applications (Thipphavong et al., 2018).

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In urban environments, severe traffic congestion directly impedes ground-based emergency services. The resulting delays severely diminish operational efficacy and elevate mortality rates during critical incidents (Nashir et al., 2019; Nicolai & Carichner, 2010). Consequently, lightweight Vertical Takeoff and Landing (VTOL) configurations have emerged as a viable solution for rapid emergency medical and rescue logistics (Ismail et al., 2016; Vogeltanz, 2016).

The present study introduces an innovative wing flap design integrated with a jet engine system, explicitly developed to enhance the aerodynamic lift characteristics and flight endurance of a lightweight platform. The proposed design features a 780 kg payload capacity and a maximum operational speed of 425 km/h. To comply with rigorous international airworthiness regulations, the structural design incorporates carbon fiber reinforced polymers (CFRP) and advanced aluminum alloys to mitigate empty weight penalties while enhancing structural integrity (Wang et al., 2018; Niu et al., 2020). While state-of-the-art platforms feature highly evolved maneuvering capabilities, optimizing aerodynamic efficiency and structural weight reduction remains a primary challenge in the field (Niu et al., 2020). By validating this novel flap-propulsion configuration, this research supports sustainable transportation initiatives and fosters aerospace engineering innovation within the Malaysian aviation sector (Srinivasan et al., 1995)

Design Methodology

Research Methodology

A systematic engineering design and analysis framework was implemented to govern the research methodology of the proposed vehicle, structured according to the workflow depicted in Figure 1. The framework initiated with a comprehensive literature review targeting VTOL airframe configurations, jet propulsion systems, and advanced flap architectures.

The analytical phase was established upon data acquisition and the determination of critical jet engine parameters. Here, relevant aerodynamic and propulsion variables were aggregated from prior literature to construct an optimized design envelope.

Next, the design modeling phase integrated structural engineering and geometric wing development. The core airframe, wing assembly, and high-lift flap systems were optimized to balance structural weight reduction with aerodynamic efficiency metrics (Srinivasan et al., 1995). To evaluate the aerodynamic performance of the design, rigorous Computational Fluid Dynamics (CFD) simulations were executed, capturing lift, drag, and energy consumption characteristics. The resulting numerical data were validated against theoretical benchmarks to confirm whether the structural design satisfied the essential airworthiness criteria. Ultimately, the validated aerodynamic and engineering datasets provided the foundation for the final design conclusions. Figure 1 shows the Research Flow Chart.

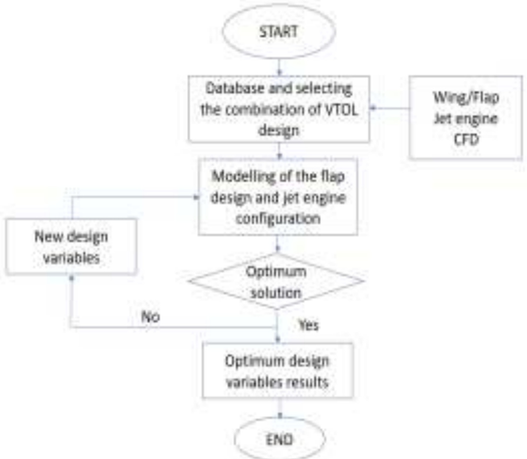

Figure 1: Research Flow Chart

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Design Technology and Configuration

The flap technology utilized in the proposed flying vehicle was systematically developed through a comprehensive literature review and analysis of early aircraft configurations, including Vertical Takeoff and Landing (VTOL) systems (Yan et al., 2020). Key design paradigms and aerodynamic methods established in previous research were integrated to support the current vehicle development. Aerodynamic simulations were performed using ANSYS CFX to solve the unsteady Navier-Stokes equations in their conservation form. Unless stated otherwise, all thermodynamic variables in the subsequent formulations represent static quantities. The core framework of this Computational Fluid Dynamics (CFD) approach is based on the transport equations for the instantaneous conservation of mass, momentum, and energy. For turbulent flows, the time-averaged variants of these equations introduce supplementary terms to account for turbulence effects. The CFD analysis of the flap design is depicted in Figure 2.

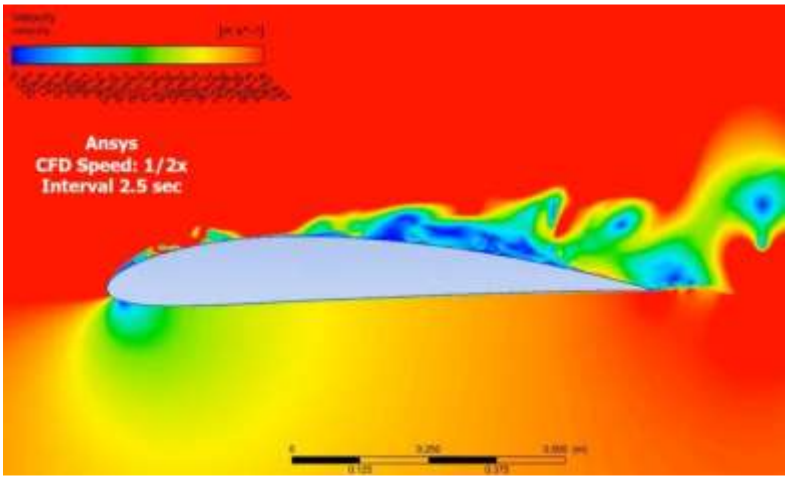

Figure 2: Flap design Computational Fluid Dynamics CFD Analysis

In this research, the flying vehicle is driven by four jet engines integrated with an optimized wing and flap configuration. The flap system was specifically designed to improve energy efficiency, aerodynamic performance, and flight endurance (Yan et al., 2020). The proposed configuration aims to enhance the flying capability of the vehicle while maintaining lightweight structural characteristics. Figure 3 shows Lifting Configuration of the VTOL Flap Design.

The research process started with the group and analysis of significant data obtained from previous literature and aerodynamic studies. Numerous aerodynamic parameters and nomenclatures were identified and applied throughout the analysis process, including:

- : Weight
- : Thrust
- : Co-efficient of lift
- : Density kg/
- : Drag
- : Lift
- : Drag coefficient
- : Lift co-efficient

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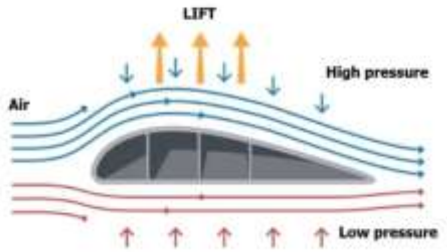

Figure 3. Lifting Configuration of the VTOL Flap Design.

These constraints were used in the aerodynamic calculations and performance simulations of the proposed flying vehicle design.

Design Analysis

The design analysis focused on evaluating the aerodynamic performance and energy efficiency of the proposed flying vehicle. The integration of the innovative flap mechanism with the jet engine arrangement was analyzed to control its effect on lift generation, drag reduction, and flight endurance. Figure 4 shows the Flap Lift Equation.

Let's break that down:

- **(Coefficient of Lift):** Depends on angle of attack and wing shape (camber). A higher angle or a more curved wing increases lift, but only to a point.
- **(Air Density):** Thinner air = less lift. High-altitude or hot-day take-offs feel different; density drops, and lift reduces.
- **(Velocity):** Squared, which means speed is the most powerful factor in the whole equation. Double the speed and lift increases four times.
- **(Wing Surface Area):** Bigger wings = more lift, and more drag. Aircraft design is a constant balance.

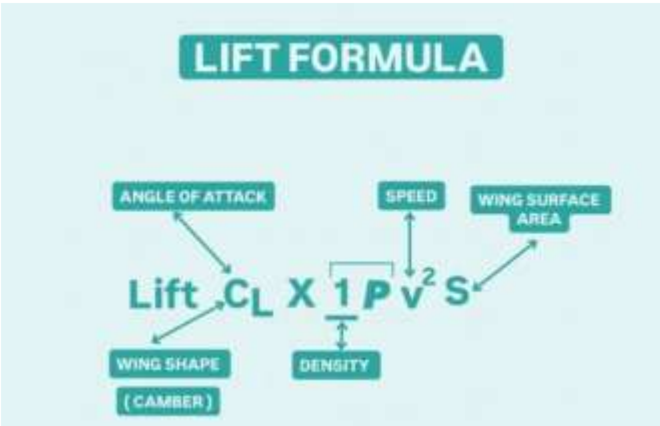

Figure 4. Flap Lift Equation

The aerodynamic study focused on the relationship between thrust, lift, drag, and weight distribution of the flying vehicle. The integration of four jet engines with the flap system was analyzed to determine its influence on flight stability and energy consumption.

The lightweight structural configuration using carbon fibre and aluminum materials contributed to reducing the total aircraft mass while improving take-off and landing performance. The proposed flap design was evaluated to determine its capability in generating additional lift and extending flight duration (Srinivasan et al., 1995; Yan et al., 2020).

Constraint diagram simulations were conducted to determine the optimum aircraft performance parameters. In addition, air foil and wing design analyses were performed together with the integration of the jet engine propulsion system.

The proposed flap design was compared with the existing flying vehicle model developed by another company; the comparison focused on flight efficiency, aerodynamic performance, and flight duration improvement (Yan et al., 2020).

The lightweight structure of the flying vehicle contributed to reduced overall energy consumption while maintaining stability and payload capability. Comparative analysis with the existing teTra Aviation model indicated that the proposed flap configuration provided improved aerodynamic characteristics and enhanced operational efficiency.

RESULTS AND DISCUSSION

The simulation and comparative analysis demonstrated that the proposed flap design improved the flying vehicle performance significantly. The new flap configuration achieved approximately 36% longer flying time associated to the conventional design.

The optimized wing and air foil design also contributed to better aerodynamic efficiency and reduced energy usage. The results indicate that the proposed concept has strong potential for future lightweight flying vehicle applications, particularly for emergency response operations.

The current stage of the research successfully achieved the conceptual design and preliminary aerodynamic analysis of the proposed flying vehicle. The analysis demonstrated the feasibility of integrating the innovative flap system with the jet engine construction for improved flight efficiency.

The proposed flying vehicle is expected to provide significant benefits for emergency response operations including firefighting, ambulance services, and law enforcement agencies (Monte et al., 2012; Cakir & Kurtuluş, 2022). The capability to bypass traffic congestion may improve response time and operational effectiveness during critical situations.

Furthermore, the project has the potential to support the growth of Malaysia's aerospace technology sector through future flying vehicle development and manufacturing activities. Long-term sustainability plans include the establishment of a dedicated flying vehicle research centre and prototype development facilities.

Roadmap and Future Development

The coming progress roadmap of the proposed flying vehicle VTOL project consists of several major phases. The first phase involves the development of the flying vehicle conceptual design and preliminary engineering analysis.

The second phase focuses on prototype development and detailed engineering validation of the flying vehicle system. This phase includes aerodynamic optimization, structural evaluation, and propulsion integration analysis.

The third phase includes feasibility studies and safety testing to ensure the flying vehicle complies with operational and aviation safety requirements. The testing process is essential to evaluate flight steadiness, mechanical integrity, and system reliability.

The simulation verified the reliability of the CFD method/settings against the experimental data of Ref. 44 (Fig. 5); we made a further comparison by referring to the numerical results stated in another journal (Ref. 45 from one of the authors) talking the same airfoil used in this paper (LS (1)-0417) under the very same low-speed condition. Distinct the first one, this latter evaluation is between two numerical models (always at the same). The external flow was set to 20 m/s. The mesh height of the first boundary layer was set to, and other set-ups of mesh and CFD solver were kept equal to those adopted in the replication of 30P30N airfoil. The result between the obtained results and the numerical outcomes of Ref. 45 is. The tendencies of the aerodynamic forces are in good pact with those of Ref. 45 for both take-off and landing; on the other hand, some variances in the magnitude of the forces are evident. These variances are, however, below 5% when in take-off and when in landing.

Subsequently, the flying vehicle will undergo registration procedures with local and international aviation authorities to obtain operational approval and regulatory compliance certification.

The final phase involves large-scale manufacturing for both local and export markets. This stage aims to support the commercialization and industrial development of advanced flying vehicle technology in Malaysia. Figure 5 shows VTOL with Flap and jet engine proposed design.

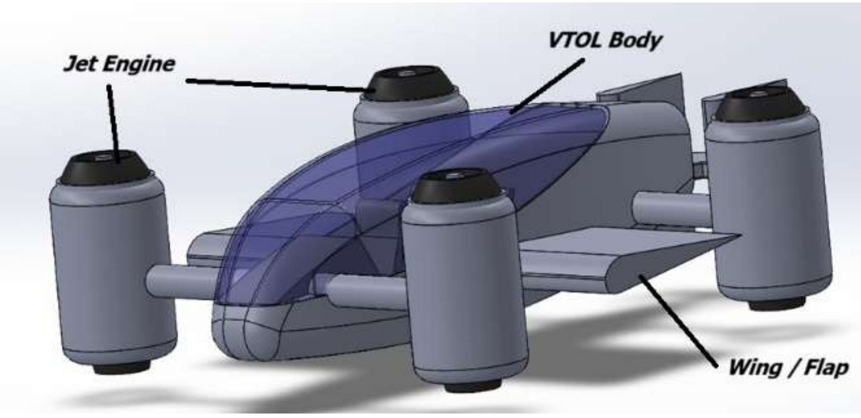

Figure 5. New design of VTOL with Flap and jet engine.

CONCLUSION

This study successfully validates an innovative flap design integrated with a four-jet-engine configuration tailored for a lightweight advanced air mobility platform. The integration framework demonstrates substantial improvements across core performance metrics, including aerodynamic efficiency, fuel economy, and operational duration. Characterized by a 780 kg payload capacity and a 425 km/h maximum speed, the proposed vehicle elevates baseline performance, with comparative evaluations indicating a 38% enhancement in flight endurance relative to conventional configurations. This technological advancement offers high utility for emergency medical and rescue services by mitigating delays caused by urban traffic congestion. By promoting energy-efficient, lightweight aerospace technology, this research directly contributes to sustainable transportation infrastructure and aerospace innovation in Malaysia. Future work will pivot toward prototype development, empirical flight validation, and advanced aerodynamic shape optimization.

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