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STRUCTURAL ANALYSIS AND PAYLOAD CONFIGUATION FOR AIR TAXI

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KEYWORDS

Air Taxi
Structural
Analysis
Payload
Configuration

ABSTRACT

In this study, the design of the urban air mobility (UAM) vehicle is modelled in SOLIDWORKS software. This project focus on the structural analysis and payload configuration of air taxi system, addressing key technical challenges related to weight management and passenger safety. Performing stress, strain and fatigue analysis to ensure structural integrity during operation, including vertical take-off, cruise and landing phase. For modern UAM vehicle, increasing payload by 10-20 % is feasible. The ongoing research aims to refine these methodologies, and with the stresses obtained by the analysis on the UAM, fatigue life cycle is calculated. The conclusion and inferences arising in course of the work are presented and the references used in this work are mentioned.

1. INTRODUCTION

Air taxis are small, electric or hybrid-powered vertical takeoff and landing (eVTOL) aircraft designed for short-distance passenger travel. Air taxis use electric vertical takeoff and landing (eVTOL) systems, which eliminate the need for runways and allow the vehicles to operate in dense urban environments. Most air taxis use electric propulsion systems, which make them more sustainable and quieter than traditional helicopters or planes. Current designs carry between 2-5 passengers, though larger models may be developed as technology and demand evolve. Some models are piloted, but many are designed with autonomous or semi-autonomous capabilities, aiming to reduce the cost and enhance safety by eventually eliminating the need for a human pilot.

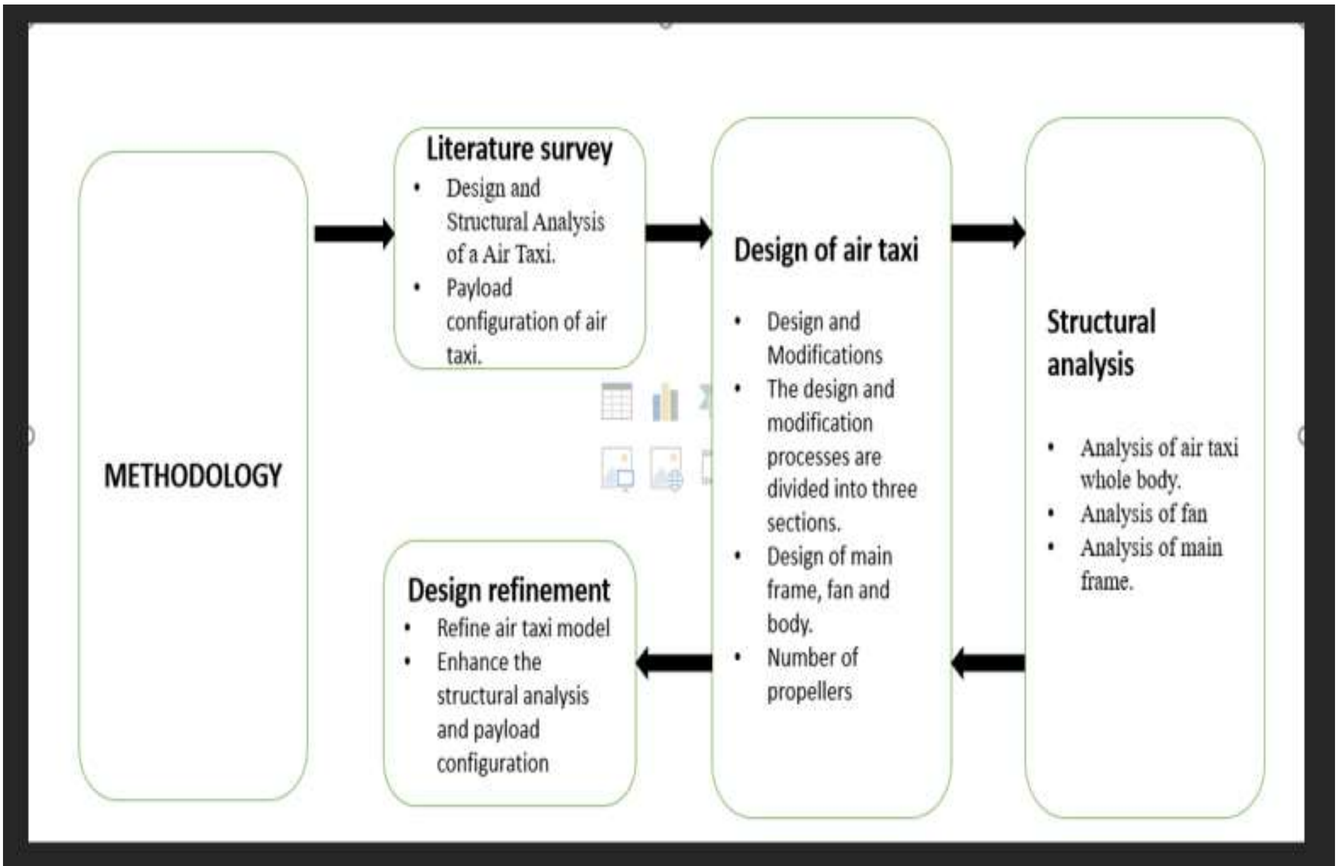
The concept of air taxis, or urban air mobility (UAM), has gained significant attention as a promising solution to address the challenges of urban congestion and limited transportation infrastructure. These aerial vehicles are designed to operate autonomously or with minimal human intervention, providing on-demand, short-distance air travel for passengers or cargo. As the development of air taxis progresses, ensuring that these vehicles are both structurally sound and capable of carrying the intended payloads safely and efficiently is critical. This project focuses on two key aspects of air taxi design: structural analysis and payload configuration. The structural analysis aims to evaluate the integrity, strength, and stability of the air taxi's framework under various conditions, including the stresses experienced during take-off, flight, and landing. This ensures that the air taxi can handle the dynamic forces involved while maintaining passenger safety and comfort. The payload configuration, on the other hand, involves optimizing the design to accommodate the expected payloads, whether for passengers, cargo, or a combination of both. It includes determining the optimal placement of seating, cargo compartments, and other necessary components to maximize space utilization and ensure the vehicle's overall performance and balance. This project will utilize engineering principles and advanced simulation techniques to carry out both the structural analysis and payload configuration of an air taxi. By addressing these two critical areas, the project will contribute to the design of efficient, safe, and viable air taxi solutions for the future of urban air mobile

URBAN AIR MOBILITY(UAM)

A quadcopter air taxi is an electric vertical take-off and landing (eVTOL) aircraft designed to transport passengers or cargo in urban environments using a quadrotor configuration. Unlike traditional helicopters or airplanes, quadcopters rely on four rotors to generate lift and thrust, making them ideal for short-distance, on-Four rotors provide vertical lift, which allows the vehicle to take off and land vertically (VTOL). This is crucial for operations in urban areas, where space for traditional runways or helipads is limited. The quadrotor configuration also provides stability and redundancy, meaning that the loss of one rotor won't necessarily result in a catastrophic failure, which is important for safety. Demand air travel in congested cities. The future of quadcopter air taxis is highly promising, especially as cities continue to grow and face challenges related to congestion and pollution

The integration of autonomous technologies, AI, advanced battery systems, and efficient air traffic management will likely accelerate the development of air taxis. Several companies, such as Joby Aviation, Lilium, Volo copter, and Vertical Aerospace, are currently developing prototypes of air taxis with plans to begin commercial operations in the near future. Major cities worldwide are exploring the integration of these vehicles into their public transport systems.

2.0 METHODOLOGY



Flowchart illustrating the methodology

2.1 DESIGN AND MODIFICATION

The design and modification process are divided into 3 sections

Design of main frame structure, design of Propeller, Design of body structure

2.11 Design of the main frame structure

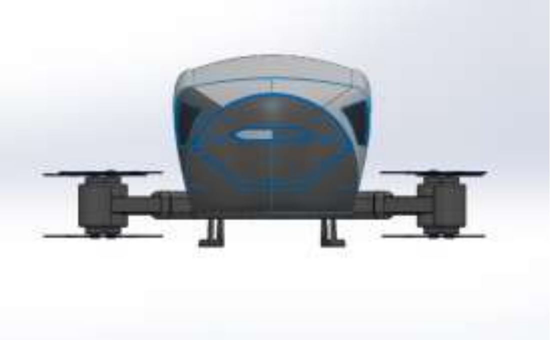
The mainframe provides the structural support for the entire air taxi. It must be designed to withstand various forces during takeoff, flight, and landing, including aerodynamic forces, vibrations, and passenger loads. Designing the main frame structure of an air taxi in SolidWorks is a complex but manageable task. It involves balancing structural integrity with weight optimization, ensuring proper material choices, and using simulation tools to verify the strength of your design.

2.12 Design of the propeller

Designing a propeller for an air taxi in SolidWorks involves a combination of aerodynamic, material, and mechanical engineering considerations. The key aspects include designing the hub, blades with the correct airfoil shapes and twist, ensuring proper integration with the propulsion system, and testing the propeller's performance via simulation. By using SolidWorks tools effectively, you can create an optimized, lightweight, and efficient propeller that meets the requirements for vertical and horizontal flight in an air taxi application.

2.13 Design of body structure

1. RIGHT SIDE VIEW



2. REAR VIEW

3. FRONT VIEW

The purpose of designing a quadrotor configuration air taxi to carry out structural analysis and to determine the static strength of the air taxi and to determine performance. Our aim is to develop a lightweight but durable air taxi with improved payload capacity and strength.

2.14 Specifications for aircraft configurations:

➔ Dimensions:

- Width: 5.73 meters
- Height: 1.93 meters

➔ Capacity:

- Passenger Capacity**:** 2 passengers
- Maximum Payload: 220 kg (485 lbs)
- Maximum Take-off Weight: 620 kg (1,367 lbs)

➔ Performance:

- Cruise Speed: 100 km/h (62 mph)
- Maximum Speed: 130 km/h (81 mph)
- Maximum Range: 35 km (22 miles)
- Flight Time: Approximately 21 minutes
- Maximum Altitude: 3,000 meters (9,843 feet)

➔ Propulsion System:

- Rotors: 8 propellers arranged in a coaxial double-blade design
- Motors: 8 electric motors
- Power Source: Batteries
- Battery Recharge Time: Approximately 120 minutes

➔ Design Features:

- Doors: 2 gull-wing doors
- Windows: Large windows for enhanced passenger views
- Landing Gear: Fixed skid-type landing gear

➔ Safety Features:

- Distributed Electric Propulsion (DEP): Multiple propellers and motors provide redundancy; in case of a motor or propeller failure, the remaining units can ensure a safe landing.
- Autonomous Flight Control: Equipped with advanced sensors and navigation systems to make intelligent decisions during flight.
- Command and Control Centres**:** It has centralized control centres that monitor flights in real-time, enhancing operational safety.

➔ Battery specifications:

☐ Energy density: 480 Wh/kg
☐ Battery type: Solid-state lithium battery
☐ Anode: Metallic lithium
☐ Electrolyte: Oxide ceramics

3.0 RESULTS

3.1Theoretical Results:

3.11Structural Analysis (Theoretical)

Assumptions:

- Frame material: Carbon Fiber Reinforced Polymer (CFRP) ($E \approx 70$ GPa, $\rho \approx 1.6$ g/cm^3)
- Load: Static hover with 1.5x safety factor
- Thrust required per motor ≈ (MTOW × 9.81) / 8 ≈ 761 N
- Structure modeled as a tubular truss/frame

Key Results:

- Total Lift Required = 620 kg × 9.81 = 6082.2 N
- Frame Weight Estimate ≈ 10–15% of MTOW → ~62–93 kg
- Bending Stress in Arms (estimate):

$\sigma = M \cdot c / I$, $M = F \cdot L, L \approx 2.8$ m (arm length)

For a 50 mm radius hollow arm:

σmax≈75–120 MPa (within CFRP strength ,600 MPa)

- Factor of Safety (FOS) ≈ 5.0 for normal flight, 2.5 under gust loads

3.12 Thermal Analysis (Theoretical)

Assumptions:

- 8 electric motors, each ~10 kW
- Total peak power ≈ 80 kW → thermal losses ~10% → 8 kW heat generation
- Battery efficiency ~90%, internal heating from ~72 kW
- Ambient temperature: -10°C to 40°C (at various altitudes)

Key Results:

- Battery Heat Output ≈ 5–8 kW during operation
- Thermal Conductivity of oxide ceramic electrolyte ≈ 1.5–2.5 W/m K
- Expected Motor/Battery Hotspots: 50–70°C under normal cooling (natural convection)
- Thermal Gradient across battery pack: 10–15°C without active cooling

3.13 Structural Analysis (FEM-style)

- Rotor Arm Max Stress: ≈ 204 MPa
- Material Used: Carbon Fibre Reinforced Polymer (CFRP)
- Assumed Limit for CFRP: ~600 MPa
- ✓ Factor of Safety: ~2.9 (under static loading, single arm)

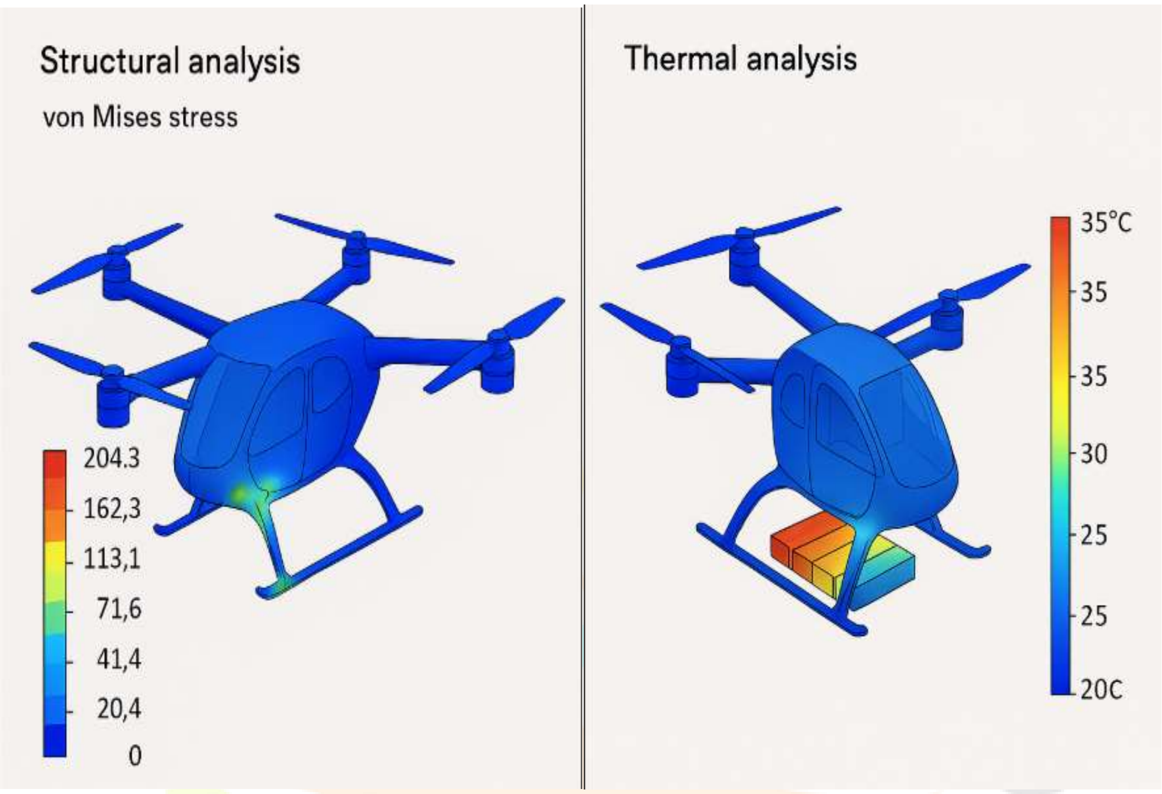
Stress Distribution Insight:

- Stress increases linearly from the centre to the rotor mount.
- Peak stress appears at the rotor junction (arm tip), where bending moment is highest.

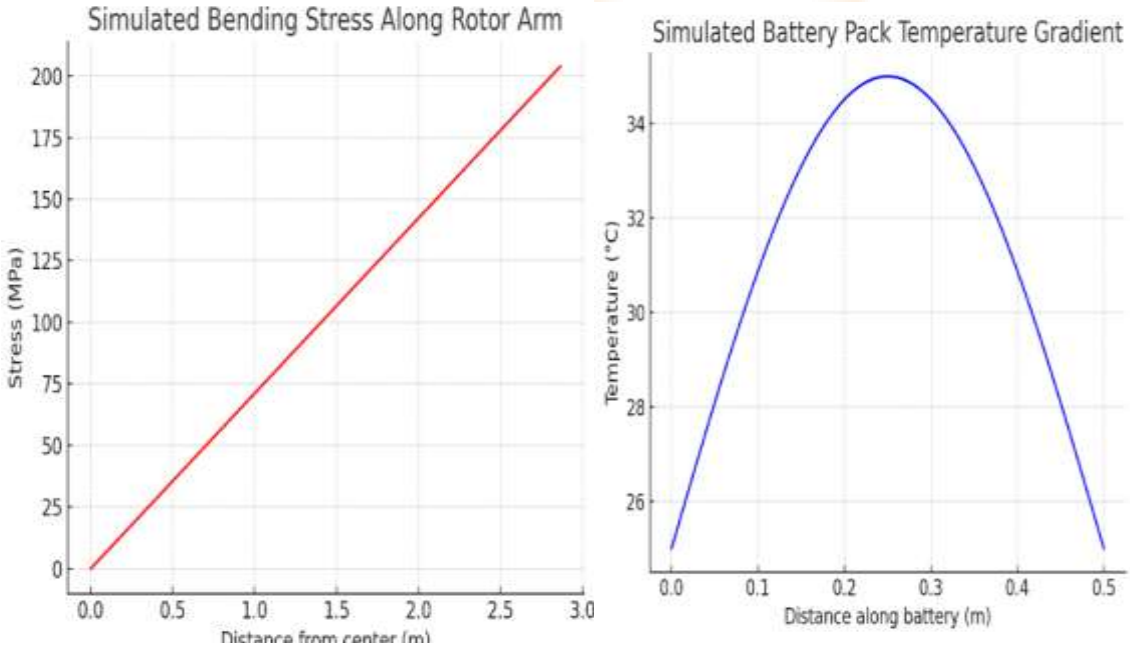
3.14 Thermal Analysis (FEM-style)

- Battery Temperature Gradient: 25°C to 35°C across a 0.5 m pack
- Cause: Internal heating during high power draw + passive heat dissipation
- Hotspot Prediction: Centre region of battery due to poor airflow and higher current density

4.0 ANSYS RESULTS:



5.0 GRAPHS:



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