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Fabrication and Development of a Prototype Autonomous Drone for Delivery using a Pixhawk Flight Controller

DR. A. Raj kumar, DR. M. Anjaiah, D. Madhu, , E. Naveen Reddy, G. Joshua, G.Ganesh,

UG Scholars

Head of the Department, Department of Mechanical Engineering, GNITC, Hyderabad, Telangana, India

Professor, Department of Mechanical Engineering, GNITC, Hyderabad, Telangana, India

Department of Mechanical Engineering, GNITC, Hyderabad, Telangana, India

ABSTRACT: Unmanned Aerial Vehicles (UAVs), such as quadcopters, are designed for various tasks, including payload conveyance. A quadcopter, utilizing four rotors for lift, stability, and precise maneuverability, is selected for this project. It offers a reliable solution for autonomous delivery, with enhanced battery capacity for increased payload support. Our project focuses on the design, fabrication, and testing of an autonomous drone prototype, equipped with a Pixhawk flight controller to optimize delivery operations.

Using Fusion 360, the drone is meticulously modeled for accuracy, and ANSYS is used to analyze its structural integrity under various load conditions. Lightweight materials like ABS ensure the frame is both durable and optimized for safe operations. The drone integrates components such as brushless DC motors, LiPo batteries, GPS modules, and the Pixhawk flight controller, allowing for remote operation from a ground control station.

KEYWORDS: UAV, Quadcopter, Autonomous Drone, Delivery, Pixhawk Flight Controller, Payload, LiPo Batteries, GPS, Fusion360, ANSYS, Medical Supplies, Fabrication, Remote Control.

I. INTRODUCTION

Unmanned Aerial Vehicles (UAVs), commonly known as drones, have emerged as one of the most transformative technologies of the 21st century. Their evolution, driven by advancements in materials, electronics, and software, has propelled them from specialized military tools to versatile platforms applicable across a wide range of industries. Initially utilized for tasks such as reconnaissance and target practice, drones are now integral to diverse applications including environmental monitoring, precision agriculture, infrastructure inspection, logistics, and search and rescue operations. The inherent ability of drones to access challenging terrains quietly and perform complex tracking and positioning tasks makes them powerful tools for data collection and analysis. The increasing demand for automation and standardization in data acquisition across various sectors underscores the necessity for robust and reliable autonomous drone systems.

The development of autonomous drone systems, while offering significant advantages in efficiency and data consistency, presents considerable engineering challenges. Integrating disparate hardware components with sophisticated software to achieve stable, precise, and autonomous flight requires meticulous design, careful implementation, and thorough calibration. The Pixhawk 2.4.8 flight controller, a widely adopted open-source platform, combined with Mission Planner as its ground control station, forms a powerful yet complex ecosystem. Comprehensive documentation is essential to guide the assembly, configuration, and operation of such a system, ensuring its reliability and facilitating further development. Without clear and detailed guidelines, the intricacies of hardware integration, software setup, and calibration routines can pose significant barriers to successful deployment and optimization, particularly for users seeking to leverage its full autonomous capabilities.

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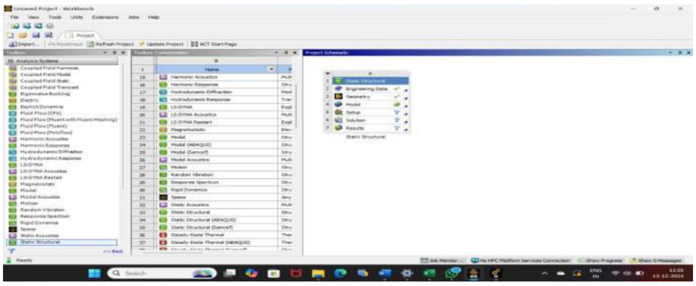
II. ANALYSIS ON MODELING OF DRONE

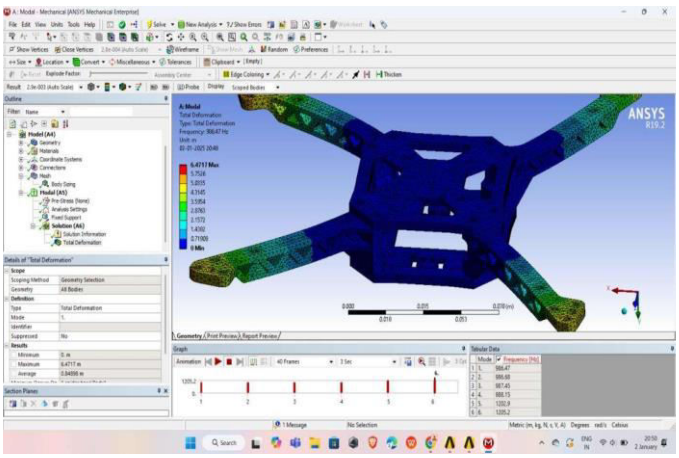
The purpose of this project is to perform a comprehensive structural analysis of a drone frame using ANSYS Workbench. This analysis helps in understanding the behavior of the drone frame under various loads and determining critical parameters such as stress distribution, deformation, and safety factors. The primary objective is to ensure that the drone frame design can withstand operational stresses while maintaining lightweight properties for optimal flight efficiency.

ANSYS Workbench is an industry-standard finite element analysis (FEA) software used extensively for structural simulations. Its robust capabilities allow engineers to perform accurate simulations, ensuring that the design meets safety and performance requirements before actual fabrication. In this project, the Static Structural module in ANSYS is employed to analyze the frame's response to static loading conditions, evaluate potential weak points, and optimize the design for better performance.

Workflow Phases:

1 **Engineering Data:** Material properties used for the analysis.
2 **Geometry:** 3D model of the drone frame.
3 **Model:** Meshing setup for finite element analysis.
4 **Setup:** Boundary conditions, loads, and constraints applied.
5 **Solution:** Solving the simulation to obtain results.
6 **Results:** Post-processing results such as stress, deformation, and safety factors.





Modeling Analysis

Static Structural Analysis examines the strength and stability of structures under steady, non- varying loads. It determines stresses, displacements, and reactions to ensure the structure's safety and reliability. This analysis is essential in designing buildings, bridges, and mechanical components to meet safety standards.

☐ **Problem Definition**: Identify the structure, materials, geometry, and the type of loading (e.g., point loads, distributed loads) to be analyzed.

☐ **Model Creation**: Develop a mathematical or computational model, including defining the geometry, boundary conditions, and constraints.

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☐ **Material Properties Assignment**: Assign material properties like Young's modulus, Poisson's ratio, and density.

☐ **Load Application**: Apply the static loads, such as forces, pressures, or moments, and specify their directions and magnitudes.

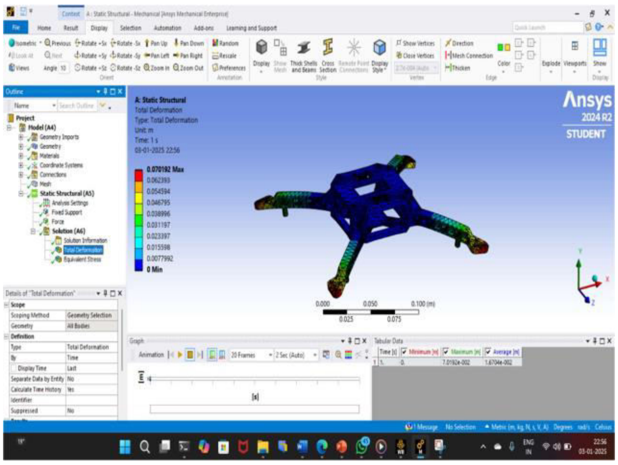
☐ **Mesh Generation**: Discretize the structure into smaller elements (finite elements) for numerical analysis.

☐ **Solution**: Use appropriate numerical methods or software to solve for unknowns, such as displacements, stresses, and reactions.

☐ **Results Analysis**: Interpret the results to evaluate stresses, deformations, and factor of safety.

☐ **Validation**: Verify the results against theoretical calculations or experimental data to ensure accuracy.

☐ **Optimization**: If needed, refine the design by modifying geometry, materials, or loads to improve performance or reduce costs.



Static Structrual Analysis

Model [A4] > Statistic Structural [A5] > Loads

Object Name	Fixed Support	Force
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	1 Face	4 Faces
Definition		
Type	Fixed Support	Force
Suppressed	No	
Define By		Vector
Applied By		Surface Effect
Magnitude		2000. N (ramped)
Direction		Defined

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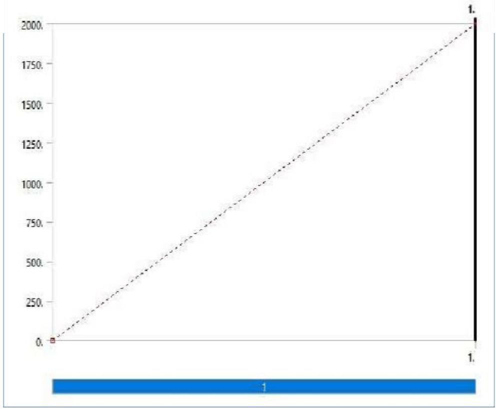

Model (A4) > Static Structural (A5) > Force

Solution:
static structural analysis conducted using ANSYS 2024 R2. It details the geometry of a quadcopter assembly imported as a STEP file, with material properties defined as Plastic, ABS (high-impact). The analysis includes mesh generation, applying a fixed support and a ramped 2000 N force. The simulation results highlight a maximum total deformation of 0.070192 m and a peak equivalent stress of 5.1011e+008 Pa. Key material properties, such as Young's modulus (2.09e+009 Pa) and Poisson's ratio (0.4089), ensure accurate modeling of the structure's behavior under applied loads.

RESULT
The performance of an autonomous drone system is a multifaceted outcome of its integrated hardware and software components, coupled with environmental factors. This chapter discusses the expected flight characteristics, navigation accuracy, communication reliability, power consumption, and fault handling capabilities of the Pixhawk 2.4.8 based system.

Detailed Drone Configuration
Flight Performance: The F450 quadcopter, with a wheelbase of 450mm, is designed to balance portability and payload capacity, making it a versatile platform for various applications. Its maximum take-off weight is approximately 1.8 kg, with typical flight times ranging from 10-20 minutes, or up to 25 minutes depending on the payload and flying style. Achieving stable flight fundamentally relies on the flight controller precisely varying the speed of each of the four propellers to generate lift and maneuverability. The thrust-to-weight ratio is a critical metric; typically, a ratio of 2:1 is desired for stable hover, while 3:1 allows for more agile performance.

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GPS Accuracy and Telemetry

GPS Accuracy: The NEO-M8N GPS module, a standard component, typically provides a position accuracy of 2.0-2.5 meters CEP (Circular Error Probable). However, observations indicate that GPS modules can exhibit "wandering" behavior when stationary, even with good satellite lock. This phenomenon occurs because the Extended Kalman Filter (EKF), which performs the actual navigation, requires motion data to accurately determine the drone's precise location. When the aircraft is stationary, the EKF lacks sufficient data to resolve the constant gaining and losing of satellites and the subtle changes in triangulation. This highlights a critical distinction: the raw GPS module's specified accuracy is a theoretical maximum, but the effective positional accuracy in a dynamic system relies heavily on sensor fusion (IMU, barometer) and motion data.

Telemetry Reliability: The 433 MHz telemetry link, utilizing protocols like MAVLink, provides a robust communication channel for real-time data exchange between the drone and the ground control station. Its inherent advantages include strong penetration through obstacles and the potential for extended ranges (over 300m out-of-the-box, extendable to several kilometers with a patch antenna). Features like Frequency Hopping Spread Spectrum (FHSS) and error correcting code further enhance reliability by increasing resistance to interference and ensuring data integrity.

However, the reliability of the telemetry link is significantly influenced by environmental factors. Electromagnetic interference (EMI) can weaken the signal, reducing operational range and potentially causing delayed responses or loss of control. Similarly, adverse weather conditions such as heavy rain or fog can lead to signal loss or data corruption due to increased scattering and attenuation. Higher altitudes can also result in lower communication throughput. This implies that even with robust protocols, real-world operational reliability is inherently limited by the physical environment, necessitating careful consideration during mission planning and execution.

Power Consumption Analysis

Understanding and optimizing power consumption is vital for maximizing the drone's flight endurance and mission effectiveness. For electric vehicles, motors typically consume the majority of power. However, a detailed analysis of the Pixhawk system reveals that ancillary components and diagnostic features also contribute significantly to the overall power budget.

A standard Pixhawk setup, including the flight controller, GPS/Compass modules, safety switch, buzzer, and a 433 MHz telemetry radio, can draw approximately 280mA of current when powered via USB. Notably, the GPS module alone accounts for almost one-fifth of this total current, and the Pixhawk's main diagnostic LED can consume a significant amount of power (around 0.5W). The Pixhawk generally draws more power when connected via a battery compared to USB, likely due to components operating at a slightly higher voltage. For a comprehensive assessment, comparing total power consumption in Watts is more appropriate across different power supply methods.

System Reliability and Fault Handling

The reliability of an autonomous drone system is paramount, and robust fault handling mechanisms are essential to ensure operational safety and mission continuity. Despite careful design and implementation, various challenges can arise during operation.

Common Operational Challenges and Troubleshooting:

- **Vibrations and Yaw Instability:** High vibrations and yaw instability are common issues, particularly in larger drones or those with specific motor/propeller configurations. These can lead to inaccurate sensor readings and degraded flight performance. Troubleshooting often involves adjusting IMU noise parameters and implementing notch filters in the flight controller software.
- **Sensor Calibration Issues:** Improper sensor calibration (e.g., accelerometer, compass) can cause the drone to drift, lose orientation, or exhibit erratic behavior. Regular calibration in an interference-free environment is crucial, and reviewing flight logs can help identify anomalies in sensor readings.
- **Firmware and Configuration Problems:** Issues during or after firmware updates, or unintended parameter resets, can lead to unexpected flight characteristics. It is important to check firmware compatibility, back up configurations before updates, and re-check parameters post-update.
- **Power-Related Issues:** Low battery levels or power anomalies can trigger critical failsafes. Real-time power consumption monitoring helps prevent unexpected failures.

Fault Handling Mechanisms (Failsafes): Pixhawk-based systems, running ArduPilot or PX4 firmware, incorporate comprehensive failsafe mechanisms to respond to critical events and ensure a safe outcome. These failsafes allow operators to define conditions under which specific actions will be performed:

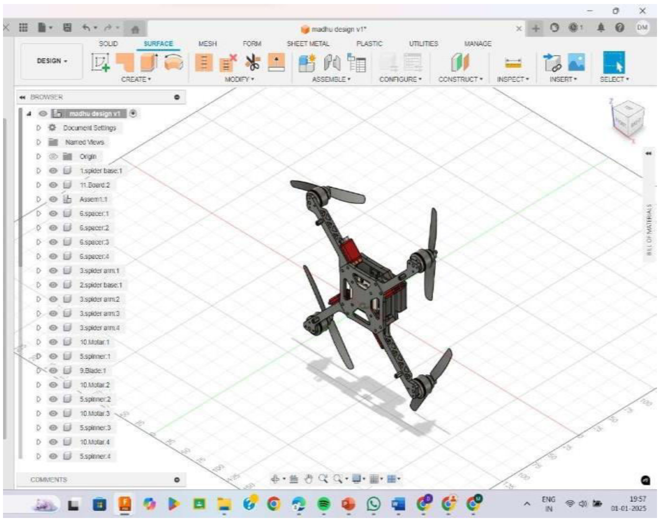
- **Low Battery Failsafe:** Triggered when battery capacity drops below predefined warning, failsafe, or emergency levels. Actions can include warning, returning to home (RTL), or initiating a safe landing.
- **RC Loss Failsafe:** Activated if the remote control transmitter link is lost. Configurable actions include returning to home, landing, or holding position.
- **GPS Loss Failsafe:** Triggered if the quality of the position estimate falls below acceptable levels (e.g., due to GPS signal loss). The system can switch to a less GPS-dependent mode (e.g., Altitude mode or Stabilize mode) or initiate a landing/flight termination.
- **Geofence Failsafe:** A "virtual" cylindrical boundary around the home position. If the drone moves outside the defined radius or above the altitude, a specified failsafe action (e.g., return, land, or terminate flight) is triggered.
- **Offboard Loss Failsafe:** Activated if the communication link with a companion computer (under offboard control) is lost. Actions can vary based on RC availability.
- **System-Level Redundancy:** The Pixhawk itself features redundant power supply inputs with automatic failover, ensuring continuous power to the flight controller even if one source fails. This multi-layered power redundancy is crucial for preventing in-flight power loss.

Key outcomes include:

- **Modeling:** A new, optimized, and lightweight airframe was designed to meet the requirements for delivery service applications. The frame design focused on minimizing weight while maintaining structural integrity and durability.

III. MODELING

Total Deformation: The maximum deformation observed was 7.0192e-002m, while the average deformation was 1.6704e-002 m



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