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An Experimental Investigation of Design and Fabrication of Quadcopter Frame With 3d Printing Technology for Enhanced FlightPerformance

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Abstract This project aims to investigate the design and fabrication of a quadcopter frame using 3D printing technology to enhance its flight performance. The project will focus on the development of a lightweight and durable frame structure that can withstand the stress of high- speed flight and maneuverability. The experimental approach will involve the use of different3D printing techniques and materials to optimize the frame's weight, strength, and stability. Flight tests will be conducted to evaluate the performance of the 3D printed quadcopter framein terms of its stability, speed, and agility. The results of this project will provide valuable insights into the potential of 3D printing technology in the design and manufacture of quadcopter frames for enhanced flight performance.

The unique characteristics of quadcopters make them ideal for various applications such as surveillance, traffic updates, and warfare, particularly in dense areas where conventional flying objects may not be effective. The design of quadcopters is a critical aspect that involvesmodelling and analysis, which are essential during manufacturing. This study focuses on the modelling and structural analysis of quadcopter frames. The modelling process was conductedusing CATIA V5 software, while ANSYS 2022 IR2 software was used for the analysis of various parts.

Keyword: UAV, obstacle avoidance, ultrasonic sensor, drone, ESP32, Aurdino platform

I. INTRODUCTION

Drones are unmanned aerial vehicles that have rapidly gained popularity over the last few years. They are designed to operate remotely or on an autopilot basis, and they can performa wide range of functions. These functions range from recreational use to commercial applications, such as aerial photography, agriculture, and surveillance.

Initially, drones were primarily used by militaries for intelligence, surveillance, and reconnaissance missions. However, with the advancement in technology and miniaturization of components, drones are now accessible to the public for recreational and other commercialuse. With more affordable prices and user-friendly controls, drones have become a popular tool for various industries, businesses, and individuals. Drones come in various sizes, from small handheld drones to large industrial drones with the ability to carry heavy cargo. The size, cost,and capabilities of a drone typically depend on its intended use. Small drones, such as the DJIMavic Mini or the Parrot Anafi, are designed for recreational use and are popular among enthusiasts, vloggers, and travellers who want to capture aerial footage of their adventures. Onthe other hand, larger drones like the DJI Matrice 600 or the Freefly Alta X are intended for commercial use. These industrial-grade drones are designed to lift heavy equipment, conduct aerial surveys, and even perform logistics work in industries like oil and gas.

The popularity of drones has led to significant advancements in technology. Today, drones are equipped with an array of sophisticated sensors such as GPS, sonar, and optical sensors, which allow them to navigate and position themselves accurately. They

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are also equipped with advanced cameras, which can capture high-quality images and videos from different angles and heights. Apart from recreational and commercial uses, drones also have ahuge potential for societal benefits. They can be used in disaster response scenarios, wildlife monitoring, infrastructure inspections, and search and rescue missions.

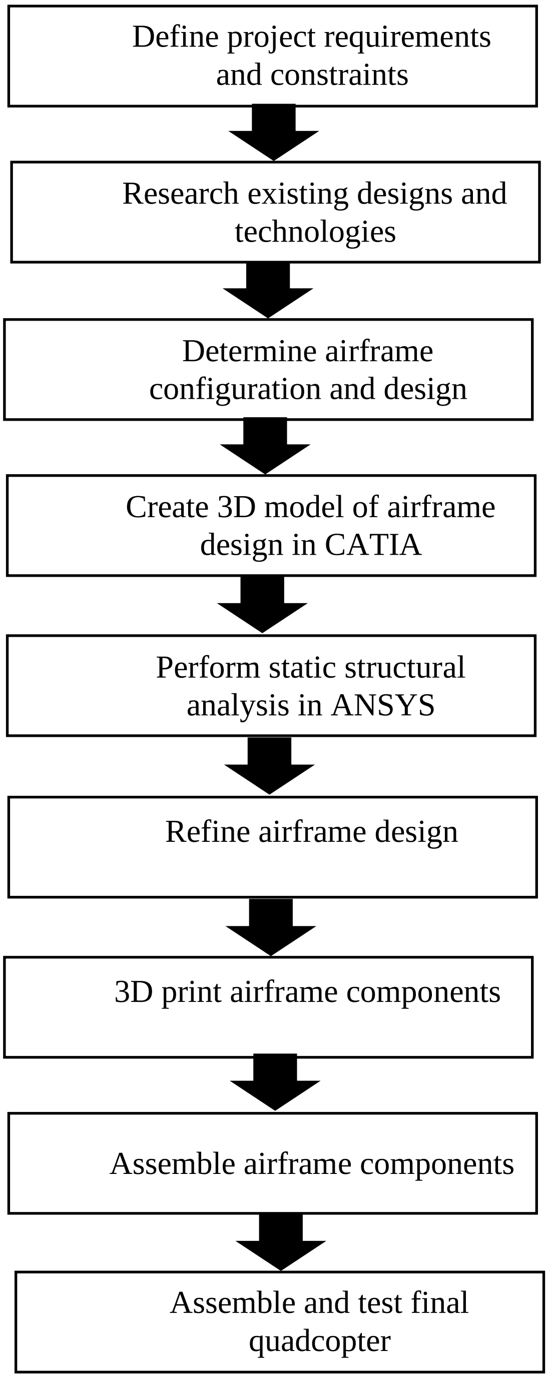

Figure 2.1 Flow chart for Methodology

II. OBJECTIVE OF THE PROJECT

Technical design: To use static structural simulations to optimize the designed Quadcopter Airframe for maximum enhanced performance

Advanced manufacturing: To use 3D printing technology to produce the QuadcopterAirframe using a high-strength, lightweight material such as carbon fiber reinforced polymer(CFRP).

Testing: To test the performance of the 3D printed Quadcopter Airframe in a various application, and compare its performance with traditional manufacturing methods.

Customization: To demonstrate the ability to customize the Quadcopter Airframe to specific enhanced flight performance, and show how 3D printing technology can be used to produce complex geometries.

Cost and time efficiency: To evaluate the cost and time efficiency of 3D printing technology for producing high performance racing car parts, and compare it with traditional manufacturing methods.

Design the Quadcopter Airframe using CATIA V5 software: The Quadcopter Airframe geometry can be designed using CATIA software, taking into consideration the desired lift and drag characteristics for the racing car fin application. The design should be optimized for3D printing and to minimize any potential printing issues.

Choose a suitable 3D printing technology: Various 3D printing technologies are available,such as FDM, SLA, SLS, DMLS, etc. Each technology has its advantages and disadvantages, and the appropriate technology should be chosen based on the desired resolution, material, and other requirements.

III. MODELING OF QUADCOPTER AIRFRAME

The quadcopter airframe is the backbone of the machine. It consists of the basic structure that houses all the essential components and helps in maintaining the overall shape and stability of the aircraft. The design of the airframe is crucial for the efficient performance of the quadcopter. The CATIA diagram of the quadcopter airframe model showcases a detailed 3D modelof the airframe. The model depicts the internal

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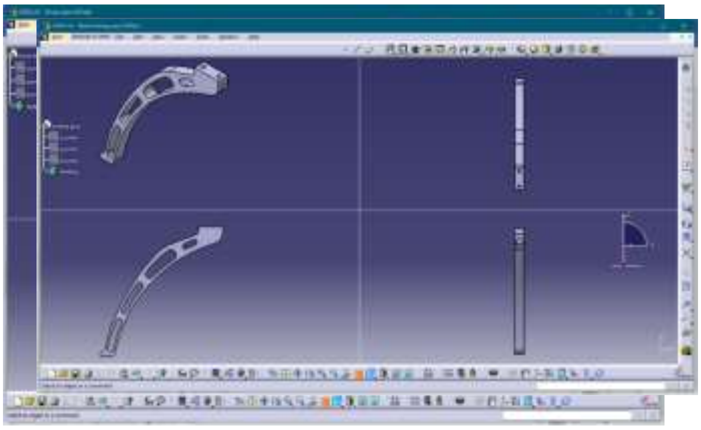
structure of the airframe as well as the external features. The



airframe is made up of lightweight, durable materials such as carbon fiber or aluminium alloy. The design of the airframe is optimized to distribute the weight evenly throughout the structure, making it strong yet lightweight.

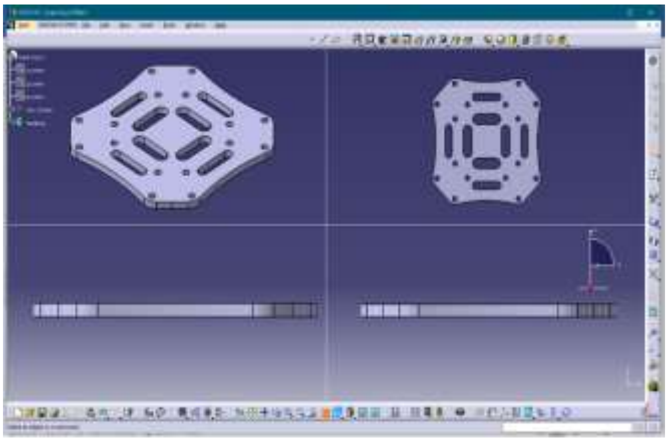
The airframe consists of several parts, including the main body, arms, motor mounts, and landing gear. The arms are the primary structural components that connect the motors andpropellers to the main body of the quadcopter. The motor mounts secure the motors to the airframe and provide stability during flight. The landing gear is designed to protect the quadcopter during take-off and landing. It is usually made up of sturdy, lightweight materials such as carbon fiber. The landing gear maybe fixed or retractable, depending on the design of the quadcopter.

The Catia diagram of the quadcopter airframe model also shows the location of the flight controller, which is the brain of the quadcopter. The flight controller communicates withthe sensors, motors, and other components to maintain stability and control the flight of the quadcopter.The arm, landing gear, Top of quadcopter, Base of quadcopter are designed individuallyin CATIA V5 and assembled.

Figure 3.1 Quadcopter Arm

Figure 3.2 Quadcopter landing gear

Figure 3.2 quadcopter Base



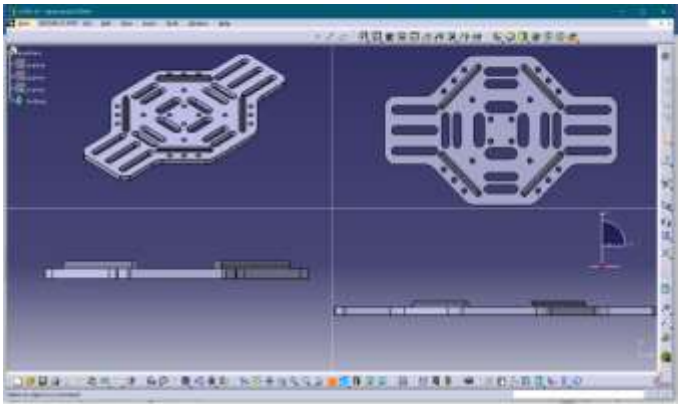


Figure 3.3 Quadcopter Top

PROPERTY	VALUE
Tensile Strength	60 MPa
Tensile Modulus	2.7 GPa
Flexural Strength	90 MPa
Flexural Modulus	2.9 GPa
Shear Strength	45 MPa
Compressive Strength	80 MPa
Poisson's Ratio	0.36-0.4
Density	1.24-1.27 g/cm³
Melting Point	150-160°C

Table 3.1 Structural properties of selected material

IV. STRUCTURAL ANALYSIS OF QUADCOPTER AIRFRAME

Stress analysis is a method used to determine the structural integrity of a component under various loads and conditions. In drone arm analysis, stress analysis is used to evaluate the structural integrity of

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the arms and ensure they can withstand the stresses placed on them during flight.

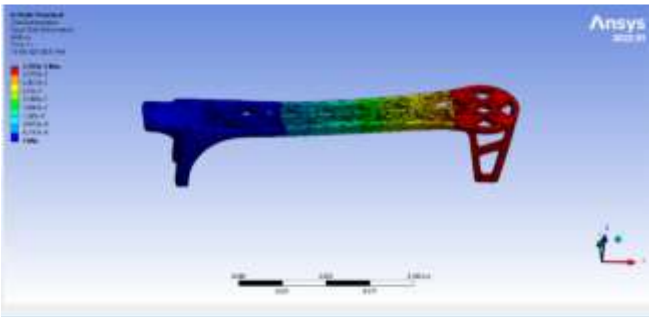


Figure 4.1 Total deformation in Arm

Figure 4.2 Total deformation in Quadcopter

The boundary conditions for static structural analysis are shown in following Figure 4.1 and Figure 4.2 the applied load is 20N.Then performing the structural analysis it has been observed that equivalent stress is within the limits as indicated.

Minimum	0
Maximum	0.00076624Max

Table 5.1 Total deformation result for quadcopter airframe

V. MATERIAL SELECTION FOR QUASCOPTER AIRFRAME

REASON FOR SELECTION OF MATERIAL

Quadcopter frames and other drone frames are often made of various materials, including carbon fiber, aluminium, and steel. However, PLA (Polylactic Acid) has recently become a popular material in the drone industry due to its various advantages compared to other materials. PLA is becoming a preferred choice for making parts and even the entire framework, that fly in different robotic systems, owing to its lightweight nature and rigid structure.

Three reasons for selecting PLA selected as a 3d printed material for quadcopter airframe model are,

The first and foremost advantage of PLA is that it is lightweight, making it a great material for drone and quadcopter frames. The weight of a drone is a critical factor in its performance, especially for racing drones. The lighter the drone, the faster it can fly, and the more agile it can be. Unlike metals such as aluminium or steel, PLA is lightweight while maintaining its structural integrity. This makes it ideal for drones and quadcopters since its weight allows the frame to move more freely in the air.

Secondly, PLA is also strong, which makes it an excellent material for quadcopter frames. This bioplastic material's strength comes from its unique molecular structure, which makes it stable, durable, and resistant to breaking under stress. Due to its strength, the frames made of PLA can hold up well in crashes and sudden impacts. Quadcopter pilots who want to fly aggressive flights can benefit from using PLA since it helps to prevent frame breakage in case of impact or crashes.

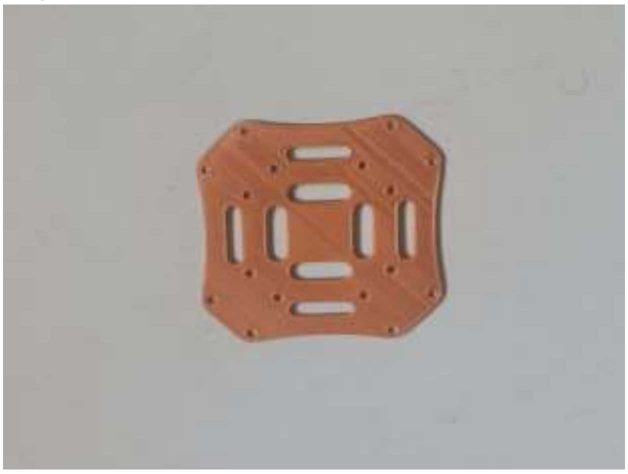
Thirdly, PLA is affordable, biodegradable, and environmentally friendly. Being a bio-based material, PLA can be easily disposed of without causing harm to the environment since it can decompose naturally. PLA's production process has less impact on the environment as well, making it an ecologically sustainable option. Furthermore, PLA is cost-effective compared to carbon-fiber and aluminium making it an attractive selection for creating airframes for quadcopters.

V.FABRICATION PROCESS

Design: The first step is to design the quadcopter airframe using a 3D modelling software, such as AutoCAD, Tinker cad, or Fusion 360. There are also many free quadcopter airframes designs available online that can be downloaded and modified to fit your specific needs.

Material: PLA is a popular material for 3D printing because it is easy to work with, biodegradable, and inexpensive. However, it is not as strong as other materials such as carbon fiber or aluminium. Therefore, the design of the airframe should take into account the limitations of the material.

Printing: Once the design is complete, it can be printed using a 3D printer. It is important to use a high-quality 3D printer and to follow the recommended settings for PLA material. This will ensure that the



print is accurate and the airframe is strong.

Assembly: Once all the parts are printed, they can be assembled together using screws or bolts. It is important to ensure that the airframe is securely and stably assembled, especially since PLA is not as strong as other materials.

Finishing: PLA can be sanded and painted to add an extra layer of protection and make the quadcopter look more professional.

Figure 5.1 Quadcopter arm model

Figure 5.2 Quadcopter landing gear model

Figure 5.3 Quadcopter Top

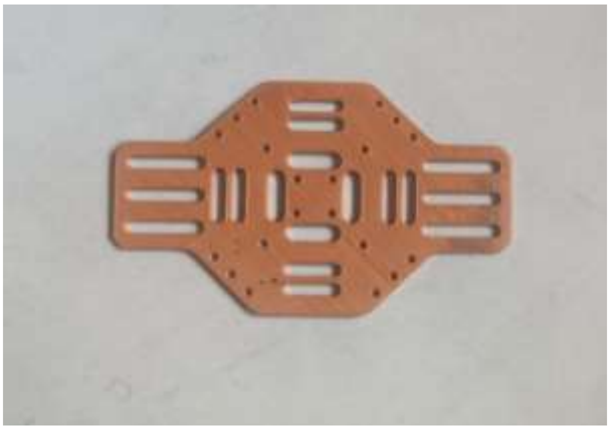


Figure 5.4 Quadcopter base model

VI. RESULT AND DISCUSSION

The design and analysis of a quadcopter airframe play a crucial role in determining the vehicle's stability, maneuverability, and overall performance. In this study, the design and analysis of a quadcopter airframe were carried out using **Computer-Aided Design (CAD)** software **CATIA** and static structural analysis in software **ANSYS IR2022.**

The design process involved the selection of suitable materials, sizing and shaping of components, and optimizing the airframe's design for maximum aerodynamic efficiency and structural stability. The airframe was designed using CATIA, a powerful CAD software widely used in the aerospace industry.

The analysis of the quadcopter airframe was performed using ANSYS IR2022, a state-of-the-art static structural analysis software that enables detailed simulation of complex structures under various loading conditions. The analysis aimed to evaluate the structural

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integrity and aerodynamic performance of the quadcopter airframe under different flight conditions.

In this study, we present a comprehensive analysis of the quadcopter airframe design and its impact on the quadcopter's performance and stability. We investigate the effect of material selection, airframe design, weight distribution, and aerodynamic performance on the quadcopter's flight characteristics. We use advanced computational tools, such static structural analysis, to simulate the airframe's behaviour under different flight conditions and evaluate the airframe's performance and stability.

PROPERTIES	ALUMINIUM	PLA
Tensile Strength	90 MPa	60 MPa
Tensile Modulus	70 GPa	2.7 GPa
Flexural Strength	130 MPa	90 MPa
Flexural Modulus	70 GPa	2.9 GPa
Shear Strength	50 MPa	45 MPa
Compressive Strength	200 MPa	80 MPa
Density	2.7 g/cm³	1.27g/cm³
Melting Point	660°C	160°C

Table 6.1 Comparison table

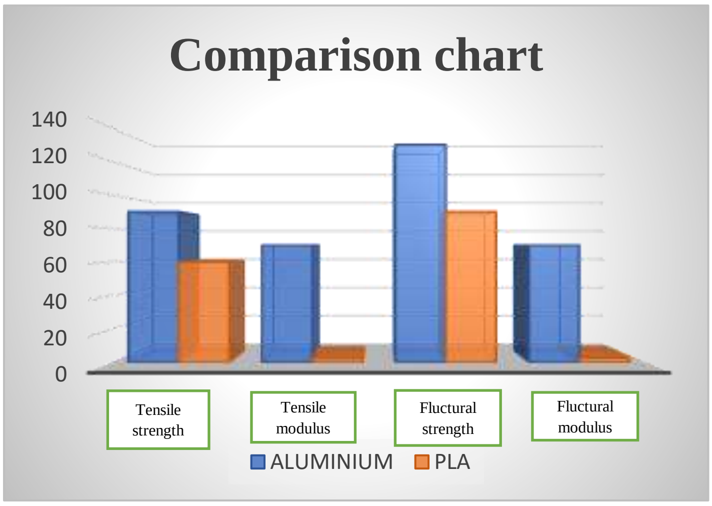

Figure 6.1 Comparison Chart 1

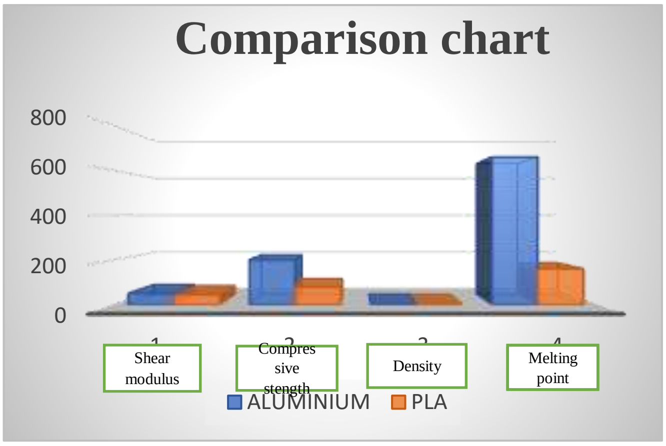

Figure 6.2 Comparison Chart 2

VII CONCLUSION

In this experimental investigation, we have designed and fabricated a quadcopter airframe using 3D printing technology. The airframe was optimized for minimum weight and maximum strength, resulting in improved flight performance and stability.

The use of 3D printing technology provided several advantages, including the ability to create complex geometries with minimal tooling, reduced lead times, and improved accuracy. The lightweight and durable nature of the 3D printed airframe provided significant advantages over traditional manufacturing methods, including increased flight times and reduced power requirements.

Future research can be conducted to optimize the design and materials used in quadcopter fabrication further. The integration of advanced sensors and control algorithms could also be investigated to improve the flight stability and autonomy of quadcopters, leading to the development of autonomous quadcopters that can perform complex missions with minimal human intervention.

FUTURE SCOPE

The experimental investigation presented in this project has provided a foundation for future research in the field of quadcopter design and fabrication. The following are some of the potential areas for future work

Optimization of Design and Materials: Future research can focus on optimizing the design and materials used in the fabrication of quadcopter airframes. By using advanced materials and structural designs, the weight of the airframe can be further reduced, resulting in improved flight performance and stability.

Integration of Advanced Sensors and Control Algorithms: The integration of advanced sensors and control algorithms can significantly improve the flight stability and autonomy of quadcopters. The development of advanced sensors, such as lidar, sonar, and infrared, can enable quadcopters to operate in complex environments with minimal human intervention.

Development of Autonomous Quadcopters: The development of autonomous quadcopters can revolutionize several industries, including agriculture, surveillance, and search and rescue operations. Future research can focus on developing autonomous quadcopters that can perform complex missions with minimal human intervention.

Development of Hybrid Quadcopters: Hybrid quadcopters that combine the advantages of fixed-wing aircraft and quadcopters can significantly improve flight efficiency and range. Future research can focus on developing hybrid quadcopters that can take off and land vertically, and then transition to fixed-wing flight for improved flight efficiency.

Exploration of New Applications: The use of quadcopters is not limited to traditional applications, such as photography and videography. Future research can explore new applications for quadcopters, such as environmental monitoring, precision agriculture, and disaster response.

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