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Design and analysis of quadcopter drone frame using finite element analysis

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Abstract - The design and analysis of a quadcopter drone frame using finite element analysis (FEA) methods are presented in this work. The goal is to save weight and material consumption while optimising the frame's performance attributes and structural integrity. The finite element approach offers a reliable foundation for modelling the behaviour of structures under different loading scenarios, enabling effective design iterations and enhancements. Through the use of FEA, this study seeks to improve the stability, durability, and aerodynamic efficiency of the frame, which will eventually aid in the creation of more dependable and effective quadcopter drones.

Keywords: Quadcopter, Quadcopter drone frame, Finite element, Design, Analysis

- X -

INTRODUCTION

Frame is a crucial part of a quadcopter. During the flight, it experiences extreme pressure, a sudden collision, and partly reversed torque. Furthermore, the frame houses the motor system and the electrical control system. As a result, four aeroplane frames need to be strong and stiff enough (Cronin, et al., 2013). Finite element analysis realistically studies the force of structures, identifies and modifies the defects in different components before particular design is implemented, and is based on the flawless operation of CAE analysis software and sophisticated computer hardware (Bhowmik, et al., 2017). By doing this, large financial damages from product failure may be prevented.

The aircraft frame may be classified into two types based on its quadcopter shape: profiled frame and X frame. A profiled frame has more room and can be quickly and easily positioned at the centre of gravity (Aydın, et al., 2018). It can hold up the tripod and machine arm, and additional expansion holes allow for easier post-purchase additions. When folded, it occupies minimal room and is lightweight and portable. It may be set aside for mounting holes for ultrasonic modules. The design of the X frame is straightforward, symmetrical, more flexible, and appropriate for stunt flying. However, the area is constrained and awkward for upgrades (Beamud, et al., 2015). Using the finite element method as a guide, the X frame will be examined in this work.

In unmanned aerial vehicle (UAV) design, quadcopters—also referred to as quadrotors or multirotor aircraft—are becoming more and more popular. This is because of their capacity for vertical take-off and landing (VTOL) and their ability to hover in crowded spaces. Four fixed rotors at the end of the frame construction make up a quadcopter (Aydın and Çantı, 2018; Rodríguez et al., 2001; Farah et al., 2016; Gök et al., 2015). In this instance, the remaining pair of rotors revolves in an anticlockwise direction, while the pair along the frame's arms rotates in a clockwise manner. As a consequence, there is no residual torque applied to the air frame construction. Propellers with set pitches are attached to every rotor. The following figure illustrates a quadcopter's core concept.

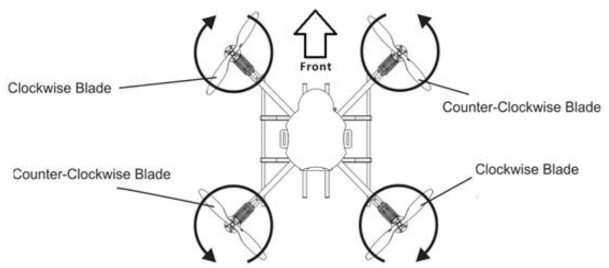

Figure 1: Quadcopter

Drones Features

- Drones may be remotely controlled or operate on their own. Some are designed for single-use flying, while others are made for fun.
- Drones may be used for transporting nuclear bombs and taking aerial photos, among other things.
- The main characteristics of a drone are its camera, sensors, and navigation system.
- Drones may be classified according to its kind, level of autonomy, weight, size, and power source.

Drones: future development

Future drone technology is now seeing revolutionary advancements due to its continuous evolution. The bulk of current drone technology is in the fifth and sixth generations, according to air drone frenzy, a website run by Amazon Services LLC affiliate advertising programme. Drone technology has seven possible generations.
The world's first all-in-one smart drone, named Solo, was unveiled by 3D robotics, marking the beginning of the seventh generation of drones. The next big thing in drone technology is smart drones with built-in safety features and compliance technologies, sophisticated, precise sensors, and self-monitoring capabilities. These drones will open up new possibilities for the transportation, military, logistical, and commercial sectors. Drones will become more trustworthy and safer as these technologies develop further. This would enable their eventual widespread acceptance, assuming that the stringent USFAA regulations pertaining to drone technology and use be somewhat relaxed.

Current technology for 3d printing

Many printing methods (processes) are available to turn digital designs into tangible products. The way layers are deposited to build pieces and the materials that are employed are where these methods diverge most. While some techniques cure liquid materials utilising various advanced technologies, others use melting or softening techniques to create the layers. Every technique has benefits and cons of its own.

Additive Manufacturing Components

Metals, ceramics, and polymers are the three materials that may be utilised in additive manufacturing. Any material can basically be printed using this layer-by-layer technique, however the material will have a big impact on the final quality. When compared to other manufacturing techniques, material attributes may not always be exactly the same after production since the aforementioned procedures might alter a material's microstructure owing to high temperatures and pressures.

REVIEW OF LITERATURE

Kirankumar, and Santhoshchandra (2023) One of the most adaptable unmanned aerial vehicles (UAVs) for a range of applications is a quadcopter. Roll, pitch, yaw, and motion are all controlled by the basic method of operation in symmetrical quadcopters. This project makes use of an optimised DJI F450 quadcopter frame design.With Fusion 360, every component of the frame was developed.The suggested design is verified for viability using Fusion 360's stress analysis findings, and a suitable material for manufacture is chosen by contrasting it with five other materials.In this work, we examine the modal frequencies in the quadcopter arm and the static tension in the quadcopter frame.

Çaşka, et al., (2020) This research used the finite element technique to manufacture a tiny unmanned aerial vehicle (UAV) suitable with landing platforms and to do static analysis on the design. In static analysis, the base is stationary and the weight of the quadcopter body is regarded as the load. Acrylonitrile Butadiene Styrene (ABS) and Polyactic Acid (PLA) materials with a thickness of 0.05 mm are utilised to create each component of the quadcopter used in the Finite Element Analysis (FEA) using an i3 Prusa printer. The structural study revealed that the tension generated by the ABS material in the quadcopter chassis was 0,053 MPa, while the PLA material in the quadcopter frame produced a stress of 0,065 MPa. Furthermore, the distortion measured in the quadcopter frame made of ABS material was 0,014 mm, but the same frame made of PLA material showed a deformation of 0,010 mm.

Salonia, & Piyush, (2019) The next generation of helicopters, called quadcopters or quadrotors, have more dynamic stability than helicopters. They are heavily involved in a variety of fields, including military operations, fire detection, surveillance, and other crucial yet intricate fields. The aerodynamic impacts of quadcopters are the main topic of this research. It covers every facet of quadcopter operation, from electronics to mechanical design. Using a variety of formulae from research publications, it offers support for the choice of various components. It also provides unambiguous data on component weight and associated expenses. Additionally, finite element analysis is performed on the frame to support the loads created inside the car, and it is determined that any little deformation that occurs on the centre plates is safe and within permissible bounds.

Khatoon, et al., (2017) For a quadrotor system, it is exceedingly challenging to obtain optimal gain scheduling of a typical PID controller for simultaneous disturbance rejection and quicker settling time capabilities. More sophisticated attitude tracking stabilisation is needed due to the unstable behaviour of quadrotors and the nonlinear dynamics of the system. This research presents a unique controller design for a hybrid PD-adaptive neuro-fuzzy interface system. The suggested hybrid controller's simulation results are contrasted with those of traditional PD, PID, and fuzzy logic controllers. The suggested hybrid controller may provide improved results in terms of reaction speed, robustness, and higher disturbance rejection capabilities, according to a comparative analysis of the dynamic response plots.

METHODOLOGY

Quadcopter frame

The drone's frame serves as a skeleton to accommodate all of the components by holding everything in place. The drone's quadcopter frame is its four-rotor framework. The diagonal distance between motors is used to calculate the frame's size. A size is classified as micro if its length is less than 150mm; if not, it is classified as tiny. Drones are referred to as tri-copters, quad-copters, hex-copters, etc. depending on how many motors they have. The quad-copter design is the most often used due to its small size, mechanical simplicity, and number of motors and Electronic Speed Controllers (ESCs) needed for flight.

Due to its small size and excellent stability during flight, it is very adaptable and may be used for racing, aerial photography, surveillance, and free-style exploration of new areas. This frame design was selected for the prototype project because of its versatile and straightforward design.

Designing phase

The computer programme AUTODESK FUSION360 is used to develop the basic layout of the quadcopter frame. There are two primary drone frame shapes in front point view: the X and H frames. This frame is said to have a genuine X shape, with opposing motors rotating in the same direction (either clockwise or anticlockwise). The rotor distance is measured at 250 mm, and the flight control is positioned in the centre of the frame as a typical 30.5 X 30.5 mm rectangle. The motor holes are positioned at the ends of the 4 mm-thick, 8 mm-diameter arms, which are fixed to the frame. The standoffs, which measure 28 mm in diameter and 3.15 mm in thickness, are provided as supports between the bottom and top plates.

Figure 2: Cad design of quadcopter

Analysis phase

- **Structural Analysis of Quadcopter frame**

The frame serves as the primary load-bearing element of a quadcopter. They are more appealing because of their capacity to support heavy compressive and tensile loads. ANSYS is used to do structural analysis on the quadcopter prototype's frame. The programme applies loads on a quadcopter, and corresponding deformations for the loads are created.

- **Modal analysis of Quadcopter frame**

A drone's form is warped and vibrations are produced through the frame when it is dropped from a certain height. Drop tests are thus created in Fusion 360, translated to

.iges format, and then imported into ANSYS software. The material types in ANSYS may be altered to meet our needs; for PLA, PP (poly propylene) is a material with comparable qualities. A drop test is performed on a drone frame at various heights and deformations using a transient structural model, and the stresses at various frequencies are recorded.

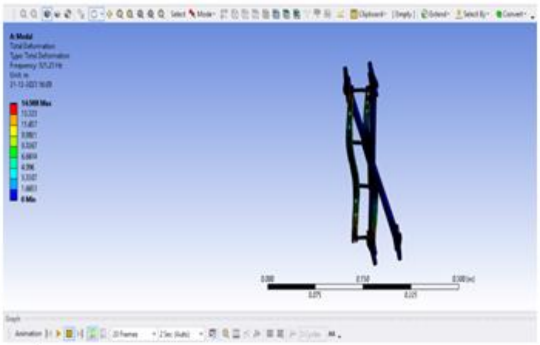

Figure 3: modal deformation

Manufacturing phase

A prototype of drone is created to understand the structure and applications better.

A slicing programme such as CREO is used to slice the planned CAD model once it has been converted to. sla or. sls format. After that, the 3D printer is fed this file. Here, polylactic acid material filament and fused deposition modelling are the 3D printing technologies used. Although polylactic acid is stronger and more rigid than carbon fibre, it is also less flexible. It is also much less expensive than carbon fibre. It is thus the most recommended material for the prototype model.

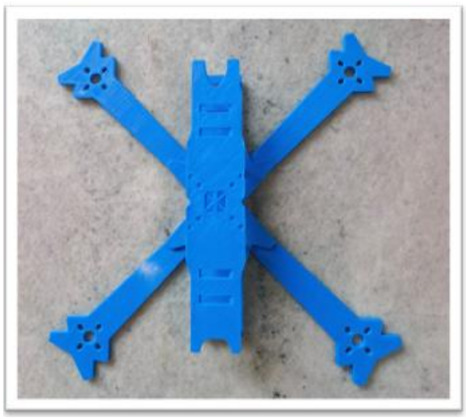

Figure 4: 3D printed quadcopter frame

RESULTS AND DISCUSSIONS

We may create a suitable and three-dimensional model in AUTODESK FUSION 360 and import it into the ANSYS programme. After that, we can select the material type and link it with the model. We mesh model second. The division uses the finite element analysis software's Mesh feature. We also split the grid significantly little to save time. We decide on element size to be 3 x 10^-3 for the division by machine. It makes it possible for the model to precisely replicate the fixation of structures, the interactions between neighbouring structures, and the stress status of structures under various load conditions. Fourth, the boundary conditions are constrained. Before final step, the type of stress conditions and deformations are chosen to compute the solution. Lastly, we compute using the finite element analysis software's "Solution". The deformations for the analysis are depicted in the following chart.

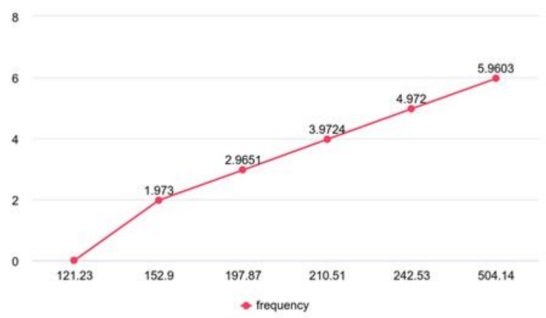

Figure 5: Deformation graph for modal analysis

Lastly, we can see that the amplitude is bigger near the edge of the frame and that the frame is not susceptible to low-frequency vibration based on its own natural frequency and modal analysis. Consequently, it is best to use a quadcopter to prevent high frequency vibration disruption during descent. Regarding this, we suggest the two answers that follow. (1) Decrease the speed at which equipment is loaded and unloaded, and ensure that these operations are finished in a nearly static condition. (2) Better high-frequency filtering performance vibration isolation equipment may be installed on the frame.

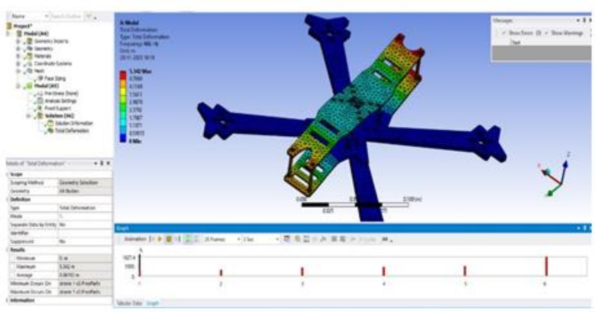

Figure 6: Stress analysis

CONCLUSION

In this work, a cad model of the quadcopter drone frame was designed in AUTODESK FUSION 360. The model is designed is designed keeping in mind of requirements given by drone given by Directorate General of Civil Aviation (DGCA). The rotor base i.e. length between opposite rotors is considered as the length of drone which is 250mm.The designed quadcopter drone is for either exploration or racing based on the electronic component's specifications. The designed frame is then simulated for structural and modal behaviour, for which the results are tabulated for different conditions. The conclusions obtained are: • The frame is subjected to maximum stresses and deformation for 20-meter fall, values are: 2.9854e+005 pascals and 1. 8352e-004 meters. That is higher the drone is dropped, the higher stresses and deformation. • The maximum frequency obtained for the frame is 504.14 HZ with a minimum value of 121.23 HZ.

In conclusion, it is advantageous to use finite element analysis (FEA) for the design and analysis of quadcopter drone frames. With this approach, performance characteristics, weight, and structural integrity may all be improved via a series of thorough simulations and iterative design changes. The results demonstrate significant improvements in the frame's stability, robustness, and aerodynamic efficiency, increasing the quadcopter drone's overall utility and reliability. The ongoing use of FEA techniques in drone frame design is anticipated to support future industry advancements by enabling the production of ever more robust and efficient aerial vehicles.

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