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Design Optimization of Drone Frame

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Abstract

One of the most crucial parts of any drone is the frame. In this research, we use ANSYS topology optimization to optimize the frame design in order to lighten its weight. Drone frame design is geared to bear big loads while having a light frame. Consequently, less material will be used, and the drone's performance will be enhanced. Due to its inherent advantage of deployment at the appropriate places, unmanned aerial systems, more often known as drones, have found important usage in the aerospace, strategic, and civil sectors. Drone utilisation is rising significantly over the world, especially for civil and defense operations, as a result of their many benefits. Drone development has become possible for a wide range of applications, thanks to technological breakthroughs in drone manufacturing, navigation, and control systems. UAVs are used for a variety of scientific and research purposes in a variety of settings, including the remote monitoring of wildlife and analysis of various environmental data. Extracting volume data from quarries, inspecting plants for precision agriculture, using communication antenna, and inspecting power lines are a few further applications.

Keywords: Drone frame, topology optimization, material reduction

INTRODUCTION

Unmanned aerial vehicles (UAV), also known as "drones", have the potential to be a defining piece of 21st-century technology, as recent years have demonstrated. Data processing, autonomy, and limitless mobility are the three pillars of technical modernity that drones combine. They provide access to (new) spaces and enable their analysis with the help of unprecedented methods of data collection. These capabilities, previously a privilege reserved to the military, are now increasingly incorporated into civil domains. Thus, drones generate potential use-cases ranging from surveillance/sensing missions to novel forms of logistics and passenger transportation. Regardless of their application, drones are driven by a general motivation to make processes faster and more flexible, while improving precision and cost-efficiency [1].

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In this study, drone frame is studied for design improvement. Comparing the polyethylene and carbon fibre results obtained from topology optimization, it is concluded that it is possible to reduce weight of frame by using polyethylene as well as carbon fibre without compromising load carrying capacity.

DETAILS OF MODEL

A drone frame model shown in Figure 1 is prepared using CATIA V5. Then it is imported to ANSYS 19 R3 for topology optimization. Frame has 11.237 kg mass with polyethylene material and 26 kg with carbon fibre before topology optimization [2].

Generative designing is an iterative design exploration technique that was invented by Autodesk. It leverages AI algorithms and the powerful cloud to produce a large number of design choices from a single CAD design by setting specific parameters. In essence, by defining our advanced goals and their restrictions, we will be able to automatically generate thousands of design outputs meeting the required specifications. Without experiencing a cognitive meltdown, the designer will be unable to assess all of the design outputs produced. The design space comprises of preserve and obstacle geometry, the design conditions consist of structural restrictions and structural loads, the design criteria consist of objective and manufacturing process, and the material used for the workpiece are a few examples of input factors. Traditional optimization techniques concentrate on a single variable, but generative design seeks to offer alternative design solutions and these design variants aid in satisfying the needs of numerous other practical applications that are logically difficult to define mathematically.

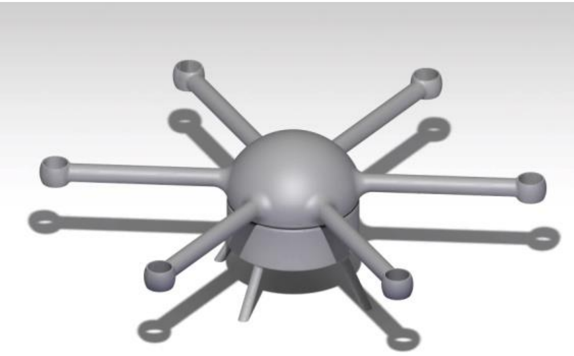

Figure 1. Model of drone frame.

BOUNDARY CONDITIONS

Drone stand (A) is considered as fixed support for this study. The motor thrust of 130 N is considered for this study. This load condition is applied at motor mount (C) in upward direction. The weight to be lifted as well as weight of the components like motors, battery, flight controller and electronic speed controller are all assumed to be 350 N. This load case is applied in the downward direction (B). Boundary conditions are shown in Figure 2 [3].

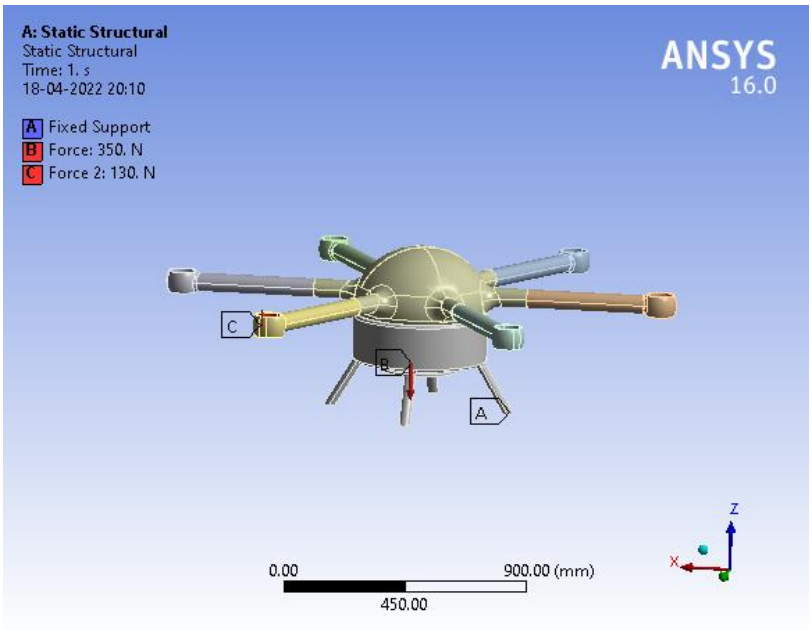

Figure 2. Boundary conditions.

Meshing Details

While doing an analysis, CFD Fluent Solver is used and Tetrahedron element with Patch confirming algorithm is used. Meshing details are shown in Figure 3.

Details of "Patch Conforming Method" - Method

Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Method	Tetrahedrons
Algorithm	Patch Conforming
Element Midside Nodes	Use Global Setting

Figure 3. Meshing details.

STRESS ANALYSIS

Figure 4 represents the stress distribution on the frame. The blue colour region represents the low stress area and the red region represents the max stress area. The maximum stress is 3.036 MPa, i.e., near the motor mount holes on the arms. It is possible to reduce material where there is low stress area. Therefore, mass of the frame can be reduced.

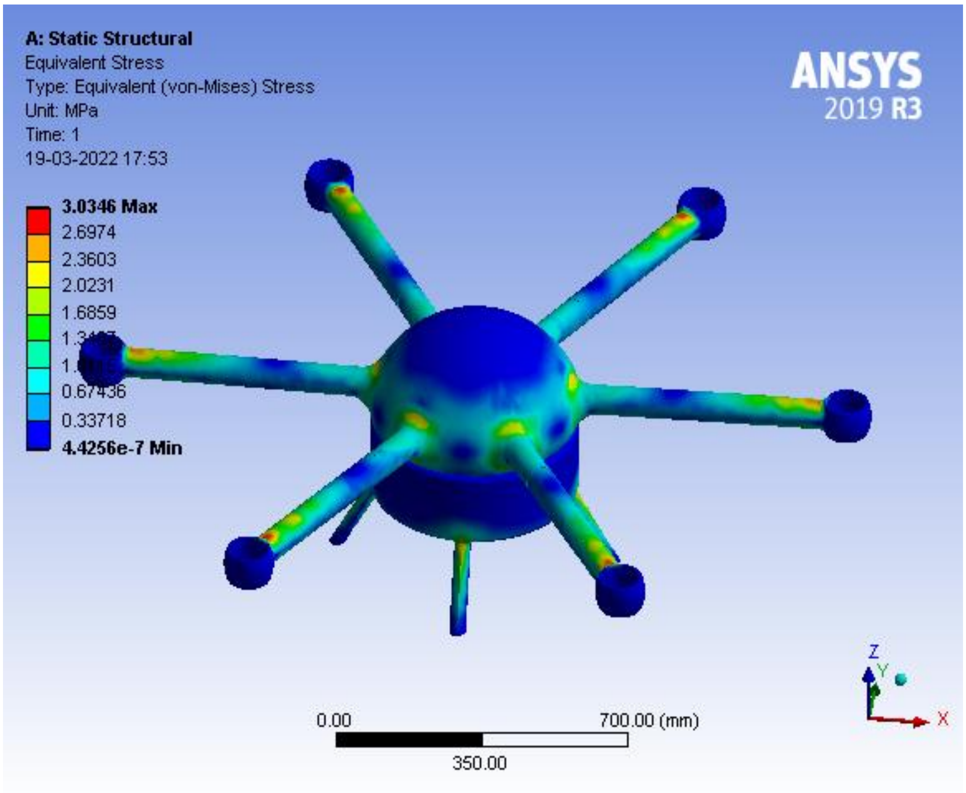

Figure 4. Stress analysis before optimization.

MASS ANALYSIS WITH POLYETHYLENE

Original mass of the drone frame shown in Figure 5 before topology optimization with polyethylene material is 11.237 kg. As there is possibility of material reduction, this mass can be reduced after topology optimization.

Details of "Geometry"

Definition	
Source	D:\Drone Topology Opti...
Type	Step
Length Unit	Millimeters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Properties	
Volume	1.1828e+007 mm³
Mass	11.237 kg
Scale Factor Value	1.
Statistics	
Bodies	8
Active Bodies	8
Nodes	93375
Elements	46032
Mesh Metric	None
Update Options	
Basic Geometry Options	

Figure 5. Original mass of model with Polyethylene.

TOPOLOGY OPTIMIZATION RESULTS

ANSYS removed material from low stress area in order to achieve 50% mass reduction without affecting limit stresses. Topology optimization result is shown in Figure 6.

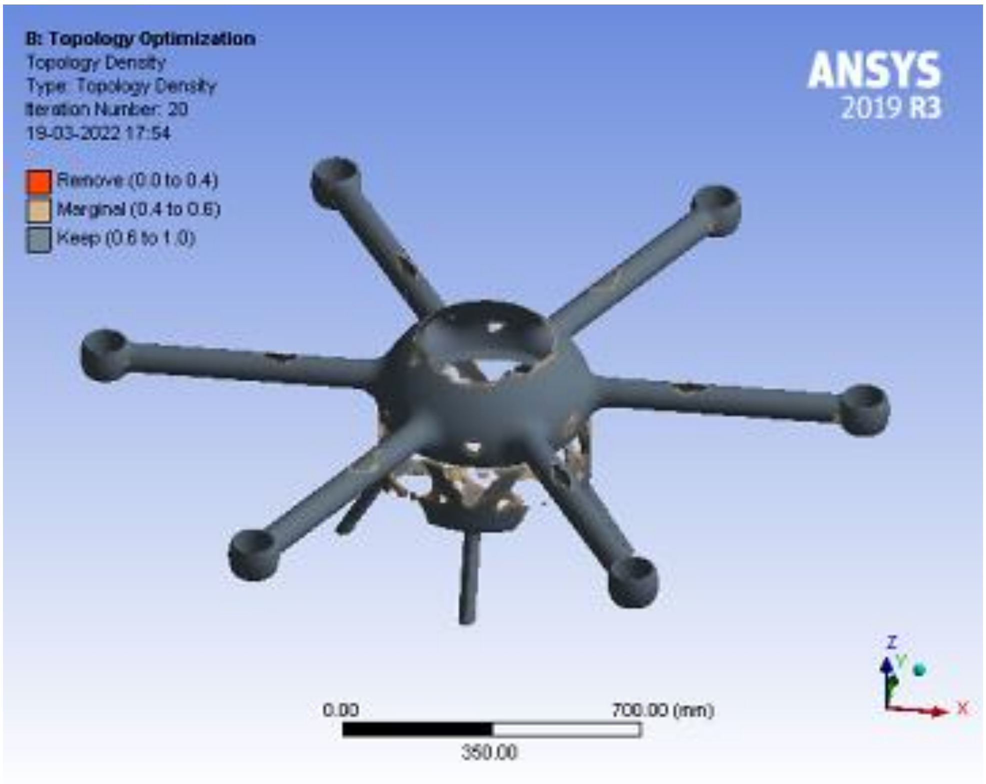

Figure 6. Topology optimization result.

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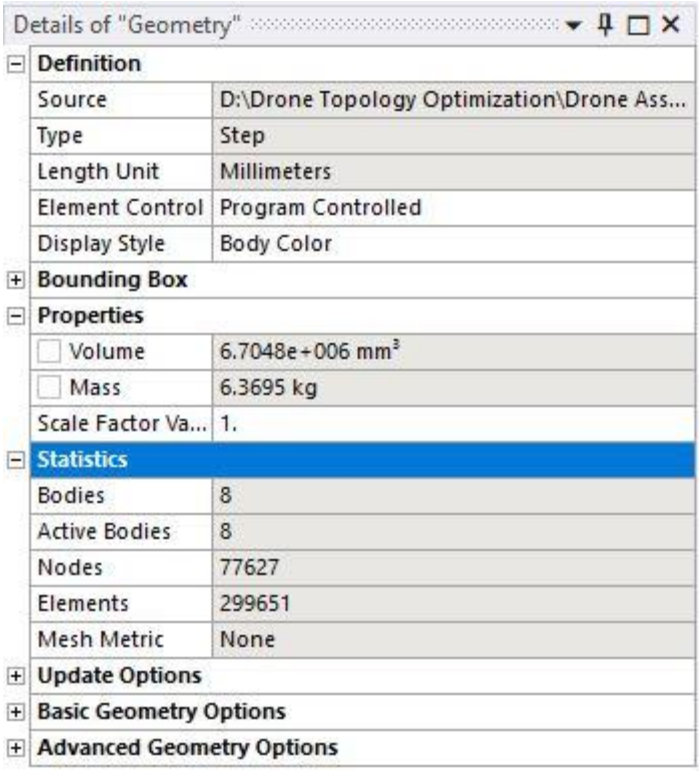
MASS REDUCTION AFTER TOPOLOGY

Mass of the polyethylene frame reduced to 6.3695 kg after topology optimization with 50% material reduction. Figure 7 shows mass reduction.



Details of "Geometry"

Definition	
Source	D:\Drone Topology Optimization\Drone Ass...
Type	Step
Length Unit	Millimeters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Properties	
Volume	6.7048e+006 mm³
Mass	6.3695 kg
Scale Factor Va...	1.
Statistics	
Bodies	8
Active Bodies	8
Nodes	77627
Elements	299651
Mesh Metric	None
Update Options	
Basic Geometry Options	
Advanced Geometry Options	

Figure 7. Mass reduction.

OPTIMIZED MODEL

After topology optimization, geometry of model changes drastically, so final model is prepared using CATIA V5. Figure 8 shows the optimized model.

Figure 8. Optimized model.

STRESS ANALYSIS OF FINAL RESULT

Figure 9 represents the stress distribution on the frame. The blue colour region represents the low stress area and the red region represents the max stress area. The maximum stress is 4.8221 MPa.

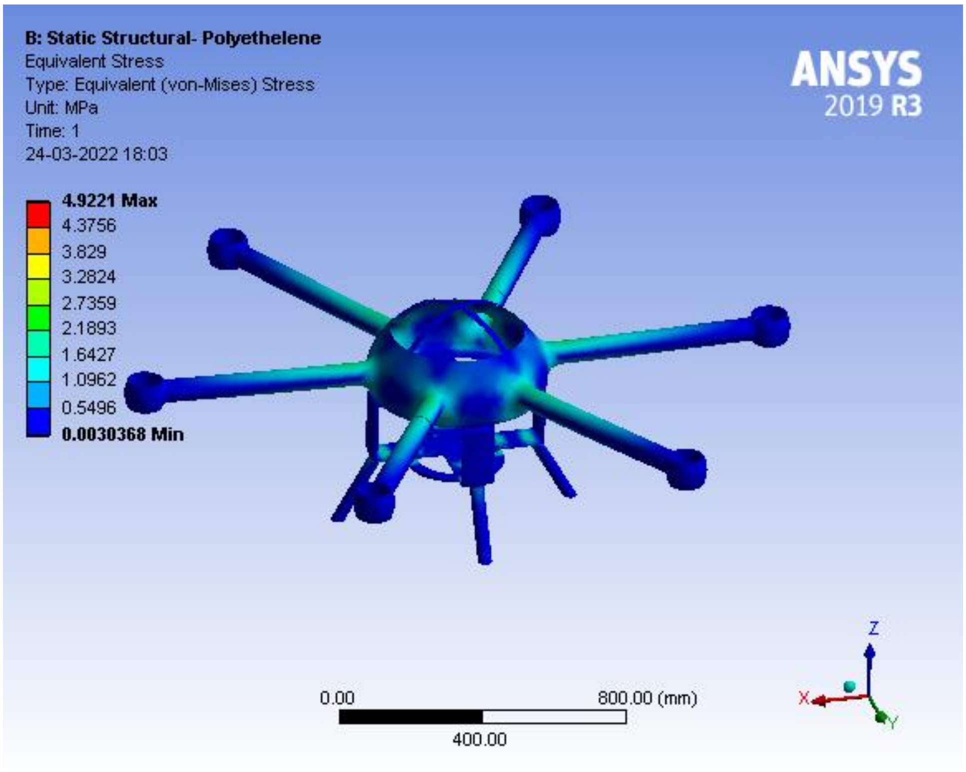


Figure 9. Stress analysis report.

Using generative design techniques, design issues are resolved in a variety of technological domains. Numerous studies have contributed to the use of generative design to find workable solutions. The MaRS Innovation District in Toronto, Canada, recently constructed new office space, and the floor plan was created utilizing generative design. Similar to this, Airbus utilizes generative design to redesign the A320 aircraft's centre panels. Similar to this, there have been numerous research and development initiatives in these fields, ranging from improvements in generative design to the modelling and analysis of the Quadcopter F450 Frame. Authors compared several frames created through generative design to those created through traditional design. To progress diverse stimulating designs, the variety of the designs must be properly regulated so that the design generated will be understandable, unpredictable, and most significantly, appealing [4–6].

The drone frame created through generative design is contrasted with the DJI Flame Wheel F450 frame that was created conventionally. Models are created utilizing base parameters and structural constraints given by the user before generation is started using Autodesk's generative design, hosted in Fusion 360 software. The outcomes of the simulation, which included static stress-strain analysis, displacement tests, and model frequency tests on frames created by generative design, were then compared with the outcomes of the DJI Flame Wheel F450 frame [7, 8].

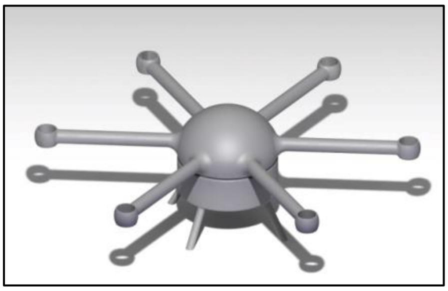
Generative Designing and Selection of Quadcopter Frames

Define, Generate, and Explore are the three dynamic phases that make up the human computer interface for the generative design process. Define is primarily the stage where we identify our issue and communicate it to the computer by adjusting the objectives and limitations. Generate is where the computer examines the design and limitations specified by the user and considers those alternatives from a variety of different perspectives. The computer will present the user with the possibilities it came up with using the parameters specified in the Explore phase. The user and machine engage in decision-making and interaction throughout the exploration phase. According to what was previously stated, generative design is carried out with the aid of AI techniques, such as convolutional neural networks, generative adversarial networks (GANs), conditional GANs (CGANs), conditional

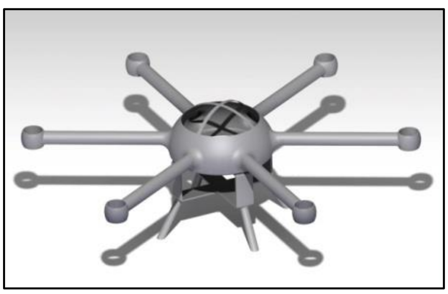
Wasserstein GANs (CWGANs), boundary equilibrium GANs (BEGANs), and others. Convolutional encoder-decoder architecture was explained by Ivan Sosnovik, who also discussed the difficulties associated with picture segmentation tasks. The development of Solid isotropic microstructure with penalization (SIMP) and Bi-directional evolutionary optimization (BESO) for structure-based topology optimization challenges was also addressed by Hongbo Sun, who explained and studied four different typical exploration approaches of Reinforcement Learning (RL). A paradigm including iterative design exploration and design evaluation sections was suggested by Sangeun. A generative designing technique called element self-governing nodal density was created by YI Ji-jun for topology optimization [9–15]. The conceptual building design possibilities of the interactive exploration can be enabled depending on the movable view preferences, according to a catalogue-based framework developed by Harish Doraiswamy.

CONCLUSION

Topology optimization significantly reduces the material required in the drone frame. Here 50% of weight reduction is achieved. This design improvement in component can be used in various ways. Firstly, the weight of the part is reduced and thus the cost of production. For a quadcopter structure, optimization and AM principles are integrated. To achieve the ideal product design layout, structural compliance and mass matrices are both taken into consideration. A quadcopter shape with the lowest possible weight that can withstand an all-up weight of 2 kg while meeting the displacement and loading boundary restrictions is the result of topology optimization. The created topologically optimised unified quadcopter structure provides greater structural integrity while cutting down on assembly time to zero. According to the results of the modal analysis, the design fails at the first natural frequency of 98.8 Hz, and the results of the fatigue analysis show that the built monocoque quadcopter structures have a fatigue life that can survive 1e7 cycles. Figure 10 shows the optimised model.



Original Mass 11.237 kg



Reduced Mass 6.36 Kg

Figure 10. Optimized model.

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