APPLICATION OF GENERATIVE DESIGN APPROACH FOR OPTIMIZATION AND ADDITIVE MANUFACTURING OF UAV's FRAME STRUCTURE

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ABSTRACT

Additive manufacturing (AM) has the potential to change the way products are made, packaged, and marketed to consumers. Because of its ability to create complex geometries with customizable material properties, this technology has gotten a lot of attention from both academia and industry. AM has aided the development of the maker movement by democratizing design and manufacturing. In recent years, generative methods have risen in popularity across a wide range of technical fields. Using artificial intelligence software, they can elaborate and recommend a series of realistic solutions for a design problem to a human user. This paper describes the overall design of a UAV (Unmanned Air Vehicle) frame, followed by an analysis of the frame using the FUSION 360 programme. Choosing the right material and structure to meet the system's rigidity and strength requirements.

Keywords: Additive manufacturing, Generative design, Artificial intelligence, UAV, drones using generative design

1. INTRODUCTION:

According to the concept of additive manufacturing, is a process of combining materials to make a structure from a three-dimensional Computer Aided design model, usually layer by layer, as opposed to subtractive manufacturing methodologies, such as traditional machining" (AM). The media has focused on additive manufacturing, also known as 3D printing, which has piqued the interest of the general public as well as scientists and researchers in a number of fields. Thanks to recent interest, this technology is constantly being redefined, reinterpreted, and customized to a wide variety of applications, including automotive, aerospace, engineering, medicine, biological systems, and food supply chains.

With minimal post-processing, AM can manufacture parts with highly intricate and complex geometries, made from tailored materials with near-zero waste, and applicable to a broad range of materials, including plastics and metals. As a result, AM is a tool that allows designers and engineers more "design freedom" and allows them to create innovative products that can be mass-produced in small quantities at low cost. As an example of the design independence provided, traditional assemblies can be reconstructed into a single complex assembly that could not be assembled using current manufacturing techniques. Another fan of AM technology is the advantages it has for the climate and ecology.

Generative approaches have gained popularity in a number of technical fields in recent years. Using artificial intelligence software, they can elaborate and recommend a range of realistic design options to a human user. Generative Design is a collection of artificial intelligence and algorithm-based techniques for solving design problems. In practice, GD tools are used to find a solution to a mathematically expressed problem; this often leads to an iterative optimization approach aimed at minimizing an objective function. As a result, GD has proven to be effective in finding unique solutions that do not fit into the typical set of shapes or configurations. As a result, GD techniques were first employed to encourage divergent thinking and creativity. This is a defining characteristic of the technology, and it has contributed to its use in fields where aesthetics and creativity are critical in the product development process, such as product design and the automotive industry. Similar to Topology Optimization (TO), which shares many features with GD, parts can be engineered for compliance or minimal weight while maintaining a safety factor or deflection.

Unmanned Aerial Systems (also known as UAVs or UASs) are aircraft that can fly without a pilot or passengers. Using radio waves, drones can be controlled remotely or autonomously (with a predetermined route). Drones do not have a standard drive size or design. For surveillance and monitoring, they are often fitted with optoelectronic heads. Drones are unique in that they do not need any external infrastructure to register and track a particular area or organization. When it comes to commissioning and preparing the device for a flight, the incredibly fast response time is a huge benefit.

2. CASE STUDY

The measurements of the frame are 495 mm X 363 mm, as shown in fig 1.

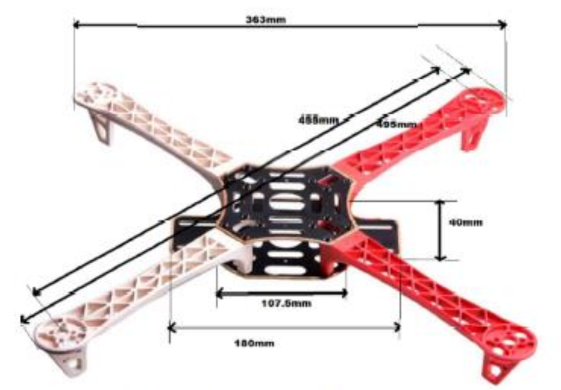


Figure 1: Quadcopter frame dimensions

The body frame is made up of two sections: a base frame and arms. The foundation frame is made up of two identical sections for the upper and lower base. In addition, the scale of all four weapons is the same. The quadcopter's frame was also designed to predict loose screws and bolts caused by vibrations when in flight. Materials such as plastic, carbon fibre, aluminum, and wood can be used to build the quadcopter frame. However, in this case, the arms are made of Polyamide nylon 6 and the quadcopter's base frame is made of E-glass fiber.

Structural Analysis:

The frame of the quadcopter is examined to determine its viability, rigidity, and usability. Static and explicit/dynamic analysis are included. The rigidity of the quadcopter body frame was assessed by comparing the vertical thrust provided by each motor to the weight of the quadcopter during flight. Every motor's thrust can be determined using the formula below:

$$\text{Thrust of each motor} = P \times D^3 \times RPM^2 \times 10^{-10} \text{ oz}$$

Where D is the propeller's diameter, P is its pitch, and RPM is the motor's rotational speed in revolutions per minute. The following data was collected for the purpose of analysis:

D = 8-inch, P = 4.5-inch, RPM = 11.1 x 1400 = 15540

The estimated thrust of each motor is equivalent to 55.639 oz after evaluating eq.1 (15.47 N). The pressure shift caused by the spinning propeller produces the upward thrust needed to raise the quadcopter to its four corners. The amount of thrust produced by quadcopter motors at various speeds is calculated. The amount of thrust produced can be used to measure the quadcopter frame's rigidity or structural analysis.

3. GENERATIVE DESIGN:

The three important phases of human-computer interaction for the generative design process are Define, Generate, and Explore. Define is simply to identify the loopholes or what needs to be sort out to solve the problem, for this one set a set of certain constraints and condition on machines so that the interaction between machine and human became successful. Generate is the next step of the generative design in which the machine examines the user's design and constraints and considers various solutions from various perspectives. In the Explore process, the machine can show the user the options it invented based on the conditions set forth in the Explore phase. The explore process is when the machine and the user make decisions and communicate. As previously mentioned, generative architecture is carried out using AI algorithms such as convolutional neural networks, Generative adversarial networks.

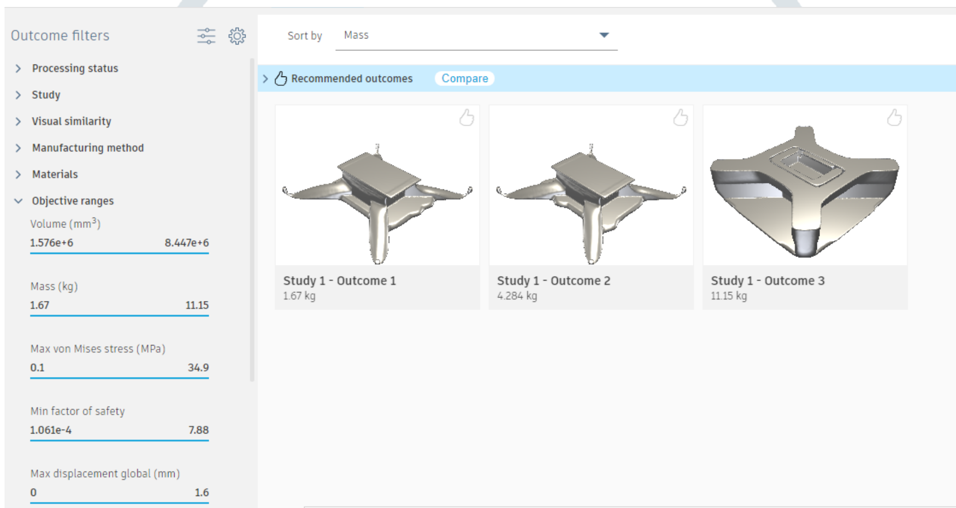


Figure 2: Various outcomes created when generative design was applied

The requirements in table 1 are used to build a quadcopters model, which is then subjected to generative design. After various iterations, many unconventional designs were produced in generative design, of which 4 design outcomes were found most perfect and relevant based on our requirements, and those outcomes of the designs are attached in the figure. To choose the best outcome, stress-strain analysis, total mass of the frame structure, factor of protection, and other factors are taken into account.

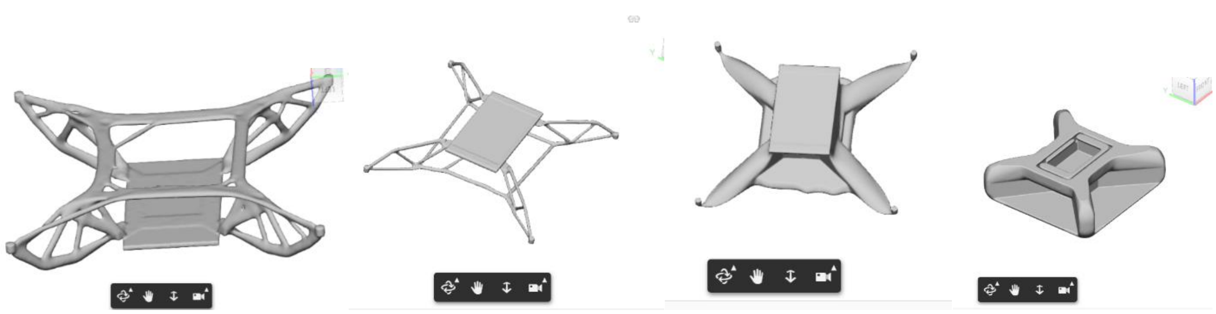
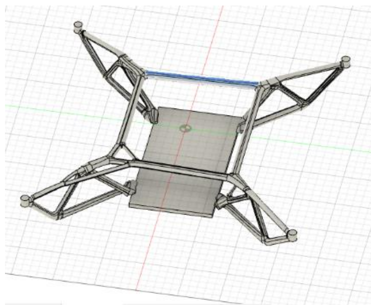


Figure 3: Few more outcomes created when generative design was applied

One notable benefit of these designs is that generative design gradually removes material from a large block, implying that regardless of how complicated the geometry of the CAD design is, the design's singularity is retained, or we can say, the new design is constructed as a single new component. The method actually works one by one, the prime purpose is to remove the material from the block and to design a new model. The hole kept preserved, it means no material will be inserted on the hole and neither in the region of the obstacle geometry. The computer algorithm plays this role by itself by its artificially intellect and the unwanted mass is being removed with optimistic approach. After generative designing, the design is checked to see whether the structure meets the goal requirements through parameter and structural constraints, failing which the design is discarded. Figure 1 shows the most effective design among a variety of other design outcomes; then compare this design with the default frame we have chosen of DJI F450 to get the different comparison of volume, mass, stress-strain analysis, factory of safety and displacement.



(a) Frame 1

(b) Frame 2

Figure 4: Optimal design outcome obtained from generative design

Factors	**Frame 1**	**Frame 2**	**DJI F450 frame**
Mass of the frame (g)	287	329	372
Minimum factor of safety	18.5	3.21	3.301
Manufacturing method	Additive manufacturing[b]	Additive manufacturing[b]	Advanced manufacturing[c]
Volume (mm^3)	271150	310444	-
Max von Mises stress (MPa)	1.1	6.2	21.33
Material used	ABS Plastic[a]	ABS Plastic[a]	Polyamide Nylon
Maximum displacement global (mm)	0.15	0.82	4.016

Table 1: Comparison of generative design frames with DJI F450 drone frame

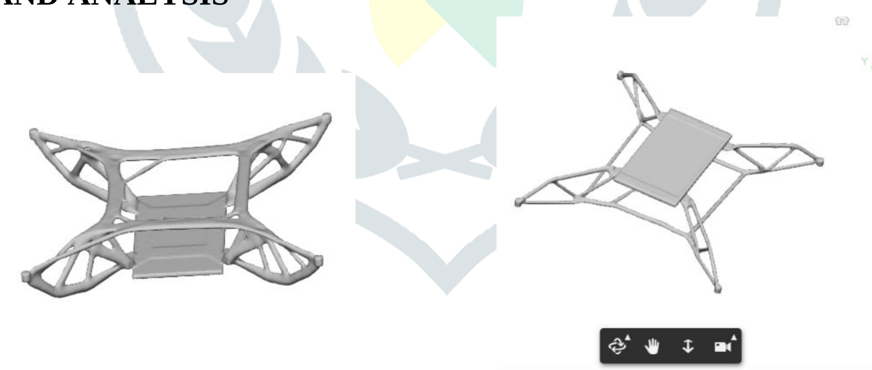
a The material chosen is the most important aspect of the design since it must withstand the weight of the components placed on the frame, as well as impact resistance. Because of its high rigidity, impact resistance, and tensile strength, ABS was selected.

b The filament used in 3D printing is obtained from the CURA programme, which includes the supports structures created in the length and weight of the filament.

c The data from the CAD file is extracted and converted into an STL file, which is then sliced in applications such as CURA, which generates G-Codes for 3d printing. Slicing would eventually provide the details for each and every layer that will be printed in the form of triangles.

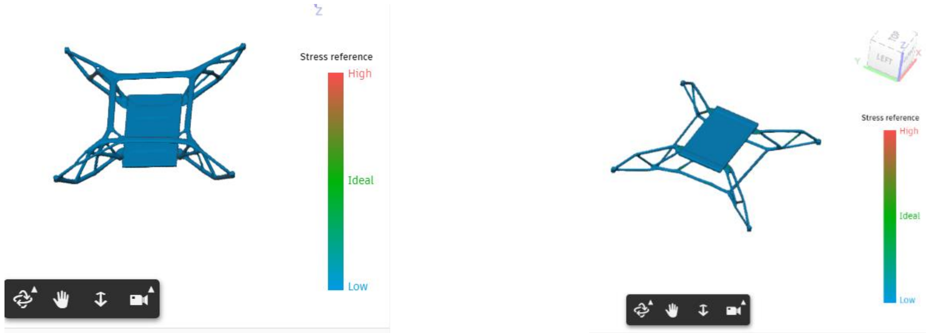
Figure 5: Properties of FRAME 1 and FRAME 2

4. RESULT AND ANALYSIS



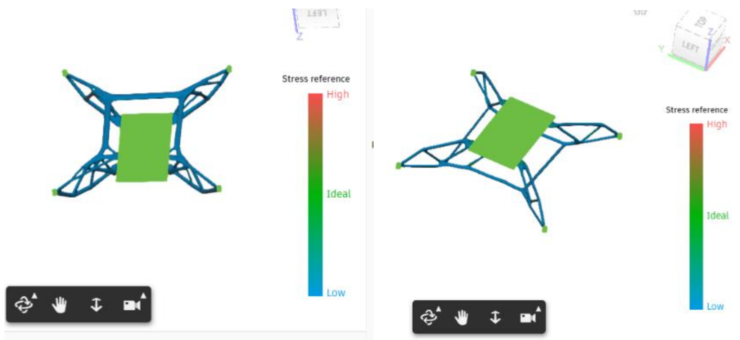
(a) Frame 1 *(b) Frame 2*

Figure 6: Optimal design outcome selected from various generative design



(a) Frame 1 (b) Frame 2

Figure 7: Comparison of stress-strain analysis of different frames of generative design



(a) Frame 1 (b) Frame 2

Figure 8: Comparison of stress analysis between different frames on preserve geometry (GREEN)

(a) Frame 1 (b) Frame 2

Figure 9: Comparison of stress analysis between different frames on applying obstacle geometry (RED)

The overall performance of the drone frame created using the generative design approach is three times better than that of the conventional F450 drone frame. The generative design drones are having a less chance and probability of getting failure in comparison to the old DJI Frame which is being used a case study in this research. based on the data and material parameters. Second, Von Mises stress determines whether a given material can yield or fracture over time. Figure 4's Von Mises stress value is 11.4 times that of frame 1, implying that frame 1's yield or fracture resistance is greater than a commonly built drone frame. As a result, a large amount of data is logged and analysed through various tests and analyses.

5. CONCLUSION

In a nutshell, generative design a very powerful tool and great supporter of humans and researchers it act as a bridge between man and machine and provide thousands of best of the solutions using clout computing technologies and artificial intelligence to solve every or most of the engineering problems, imitating the natural world's evolutionary progression. Innumerable remarkable diverse structures with a rather organic nature are produced as a result of these computational processes. A thorough comparison is made between conventional and generative design techniques, using two generatively constructed drone frames [Frame1 and Frame2] . Thus, it is hereby proved that theses frames which are produced as a output from generative designs are far more durable and better than the regular one’s and we can say that this generative design technology are much better in many ways that the regular conventional designing techniques or technologies, based on the study and simulation data logged.

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