Optimization of quadcopter frame using generative design and comparison with DJI F450 drone frame

1 Department of Mechanical Engineering, Vellore Institute of Technology, Chennai, India

VIT®
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)
CHENNAI
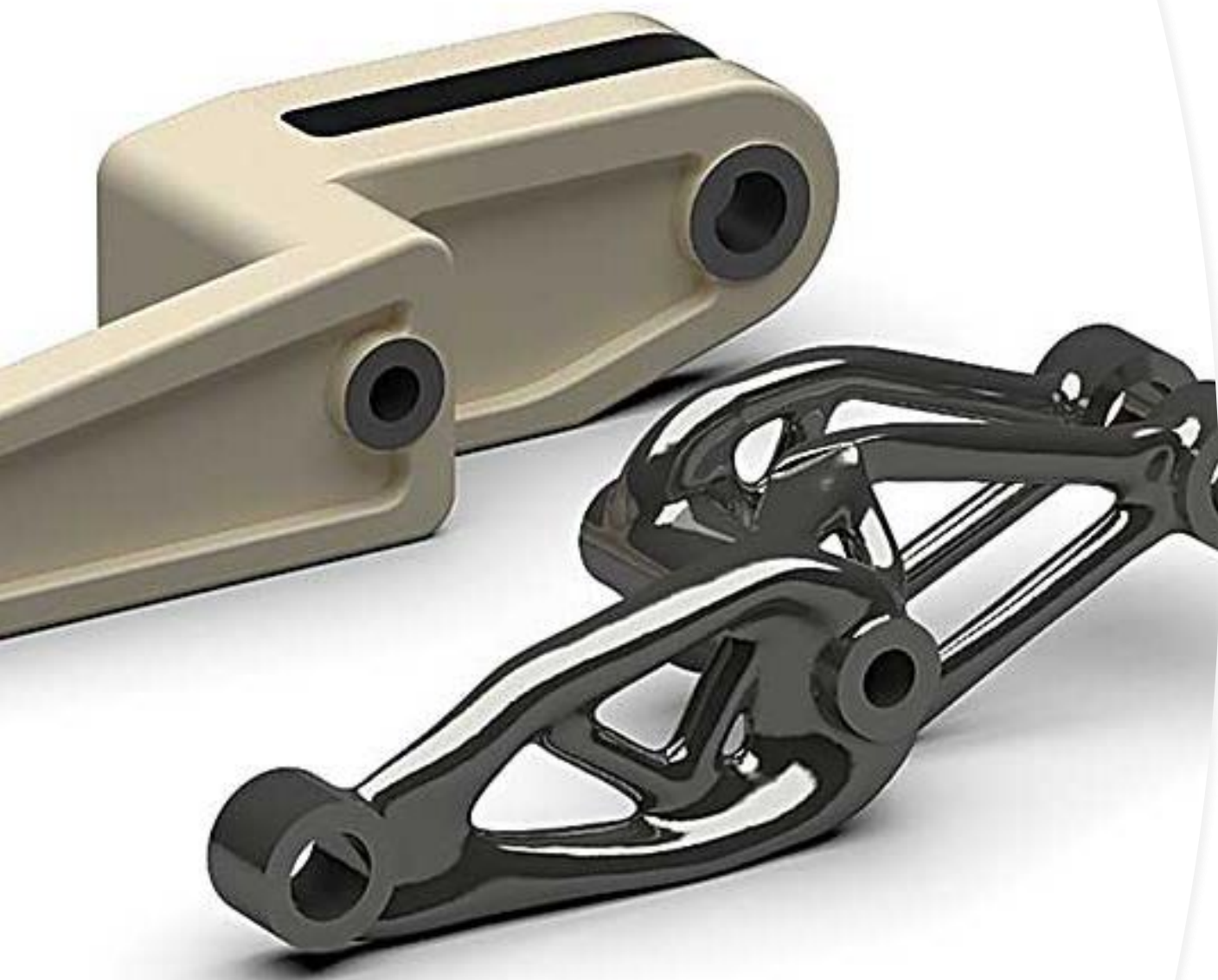
What is Generative design?

⚙️ Iterative Design exploration process

🧠⚙️ Uses AI to generate multiple Design in a single computation

🧠 GAN is used to generate surfaces between constraints

🎚️ Mainly used for mass reduction and structural optimization

Steps involved in Generative Design

Define

- Define preserved Boundaries
- Define obstacle boundary
- Define Fixed Geometry
- Define material
- Define AM technique

Generate

- Define the loading conditions
- Generate All possible outcomes
- Remove all Under defined outcomes

Explore

- Check for the best possible design with optimized properties
- Smoothen the surface using form tools

Loading conditions

Component	Number of individual components	Weight of individual component (g)	Net Weight of individual component (g)
RS2205S Motor	4	28.8	115.2
Pixhawk FC	1	73	73
M8N GPS	1	32	32
5" Propeller	4	4	16
BL Heli ESC	4	14	56
PC Hub PDB	1	8.5	8.5
Camera	1	12	12
Telemetry	1	15	15
IA6B Receiver	1	14.6	14.6
LIPO Battery	1	200	200
TOTAL	19		542.3

- Approx. weight of Frame 250g

- By 15% buffer we get a total mass of 1000g

- M=1000g=1Kg

- F=M*g=10N

- So for hovering condition we need a minimum of 10N thrust from 4 Motors
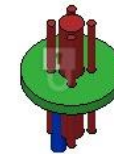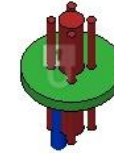
# Defining a Generative design model
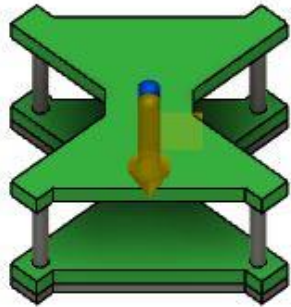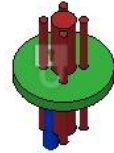
MODEL-1
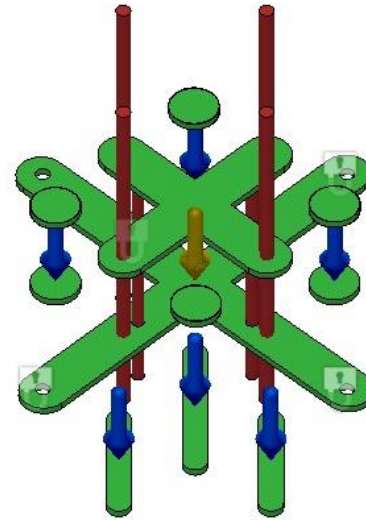
MODEL-2

DRONE SPECS:
- 450 mm Size
- True X
- Centre of mass maintained at the exact center
- Symmetric in nature

RED COLOUR OBSTACLE BOUNDARY
GREEN COLOUR PRESERVED BOUNDARY

ITERATIONS

- GAN creates surfaces and overhangs

- The iterative mechanism removes mass from the surfaces while optimizing mechanical properties

- Final model is converged when no mass can be removed while having maximum mechanical strength
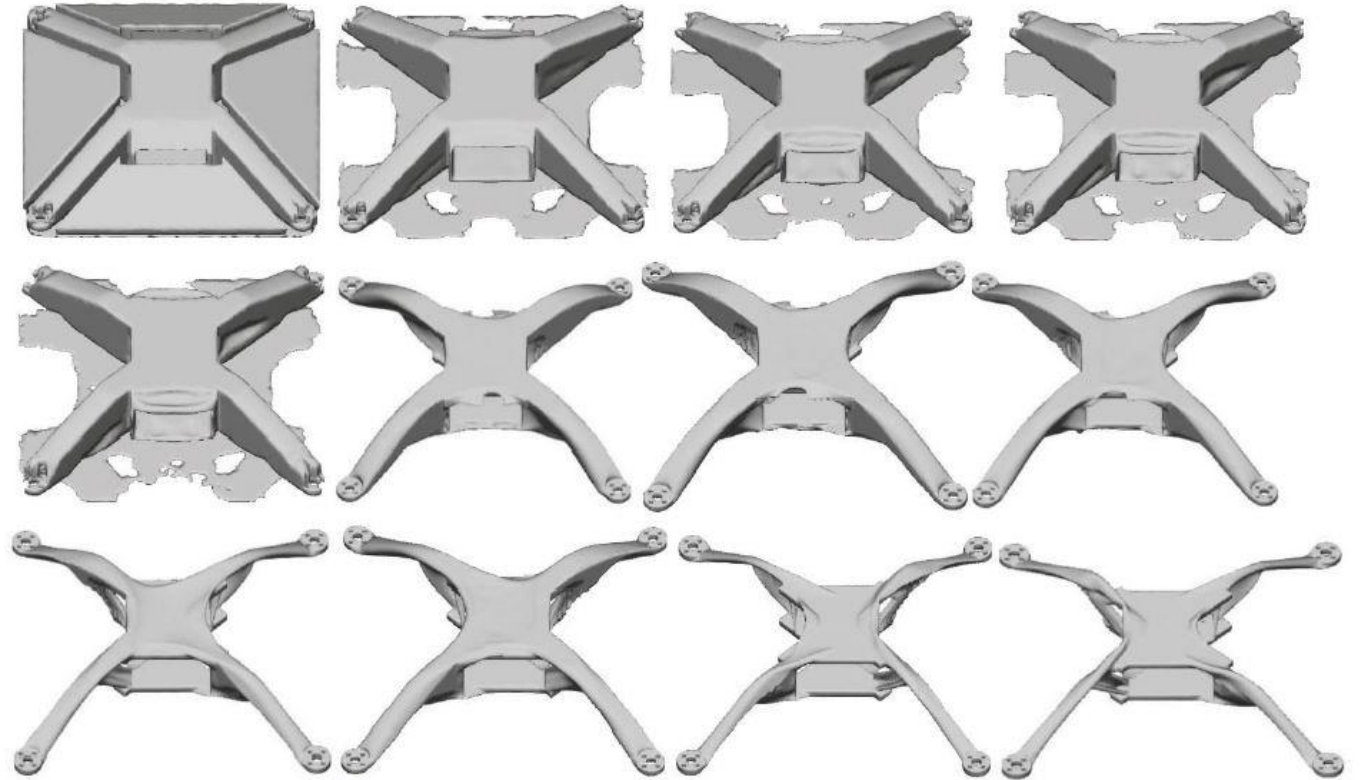
OUTCOMES

- Total of 74 designs were generated throughout the experiment

- Fusion 360 autonomously classifies the models based upon mass ,FOS, Von Misses Stress Etc.

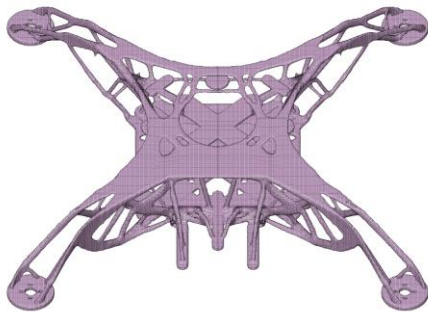- Best model is chosen based upon the mechanical properties
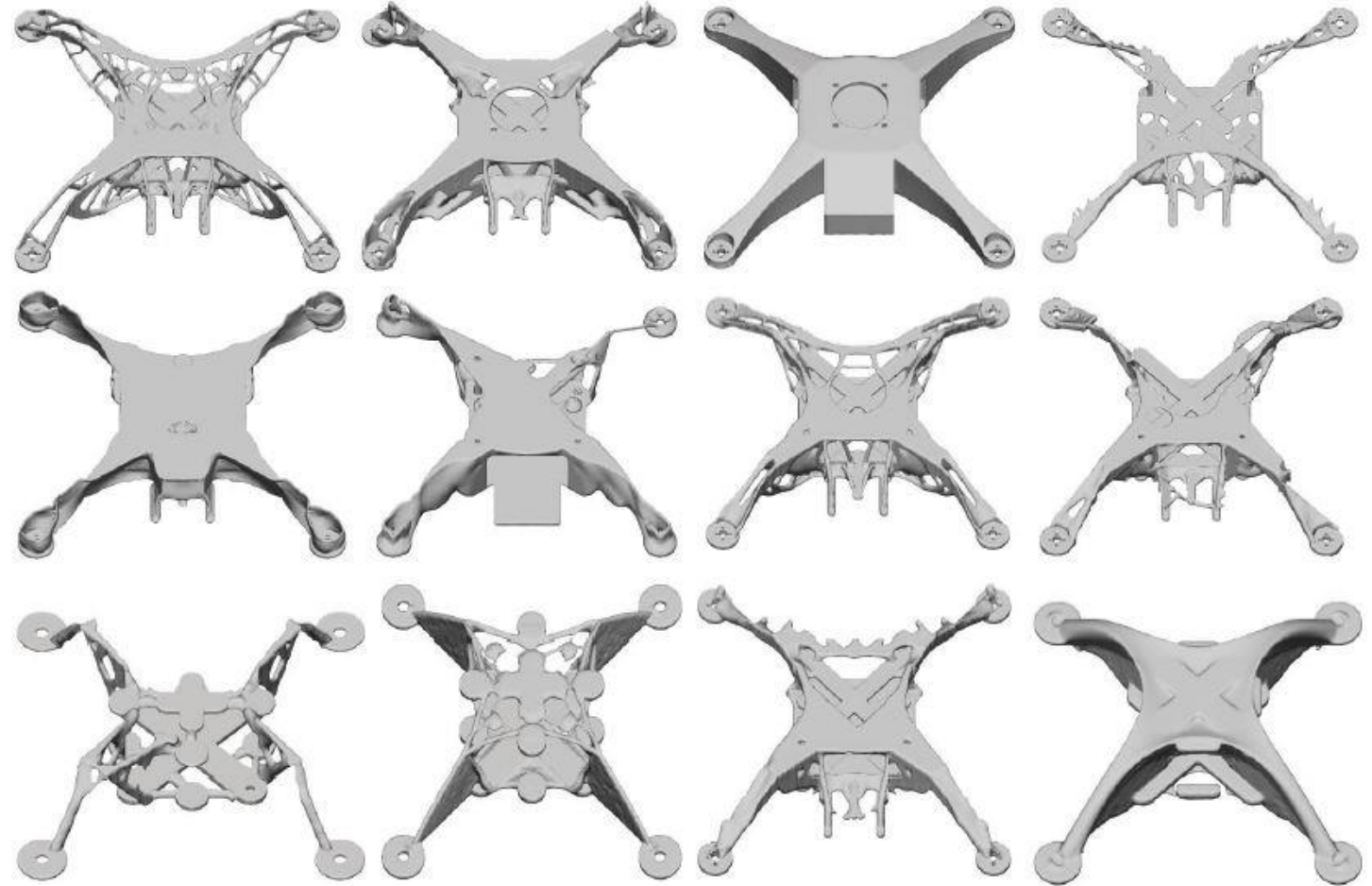
RESULTS

- Mechanical properties of generatively designed frame in comparison with DJI F450 Drone frame

- ABS plastic is used for Additive manufactured Drone frame
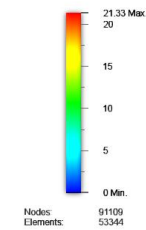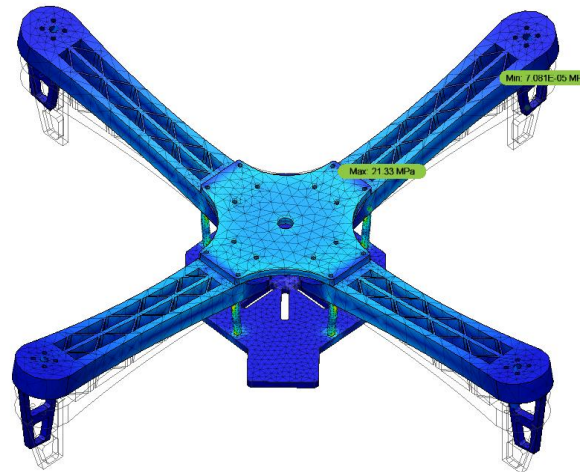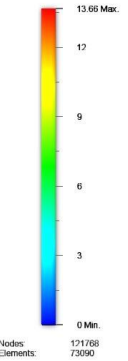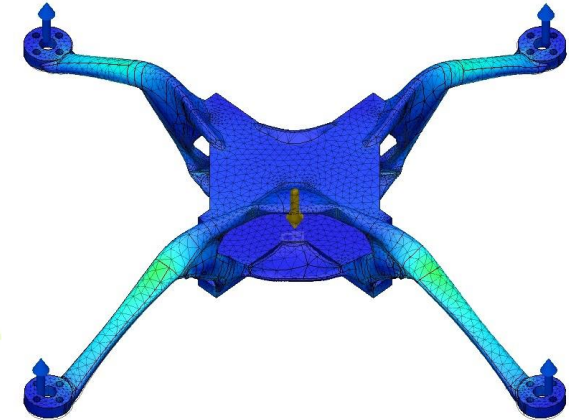

Model 1

Model 2

DJI F450 FRAME

| FACTORS	MODEL 1	MODEL 2	DJI F450
Mass of the frame(g)	267	227	330
Minimum FOS	133	13.3	3.301
Manufacturing Method	Additive Manufacturing	Additive Manufacturing	Advanced Manufacturing
Maximum Von Mises stress(MPa)	17.11	1.5	21.33
Maximum Displacement Global(mm)	0.01	6.22	4.016
Material used	ABS	ABS	Polyamide Nylon

STRESS ANALYSIS
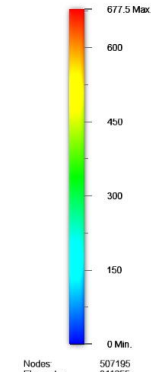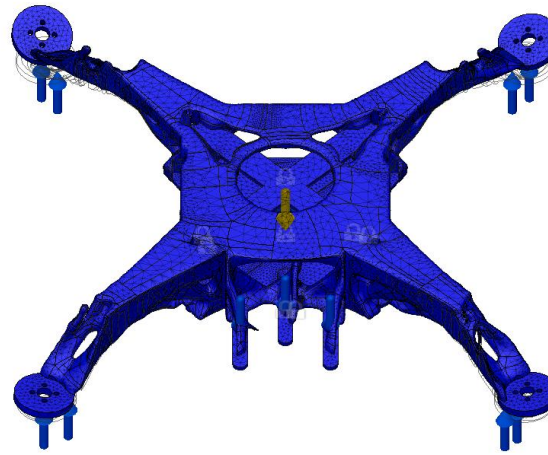
STRAIN ANALYSIS
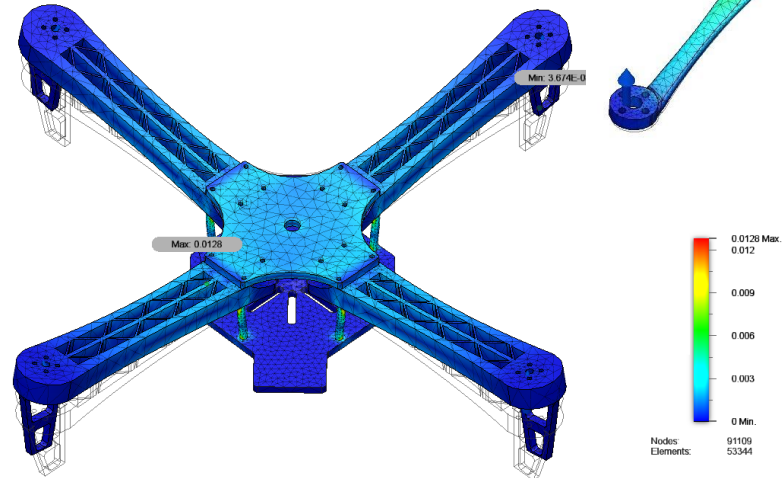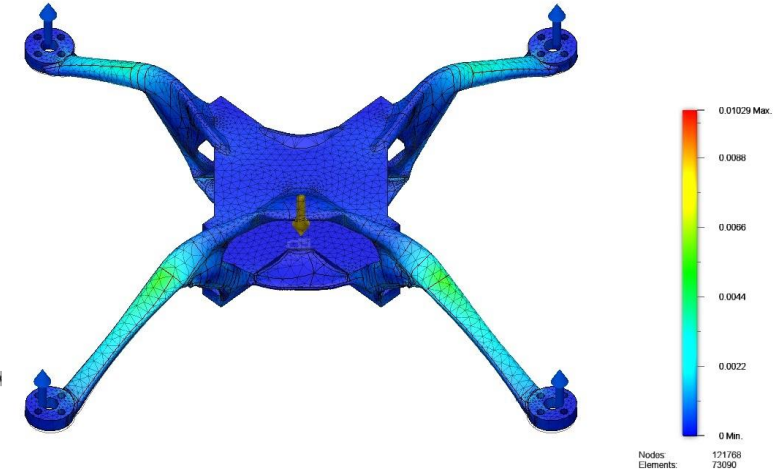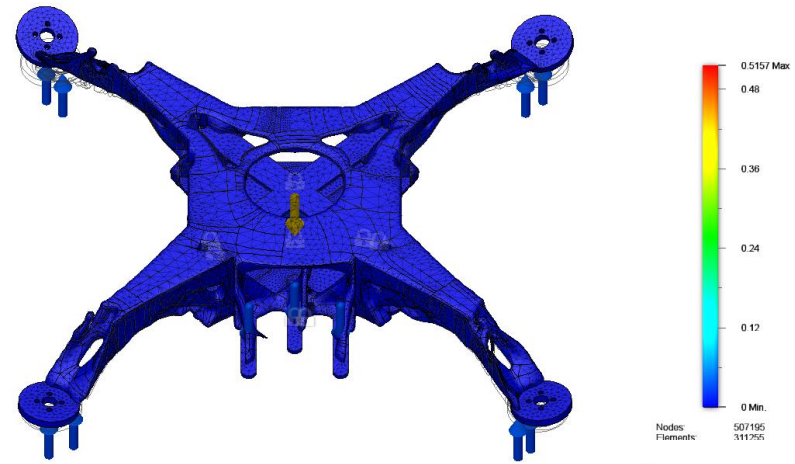
DISPLACEMENT ANALYSIS
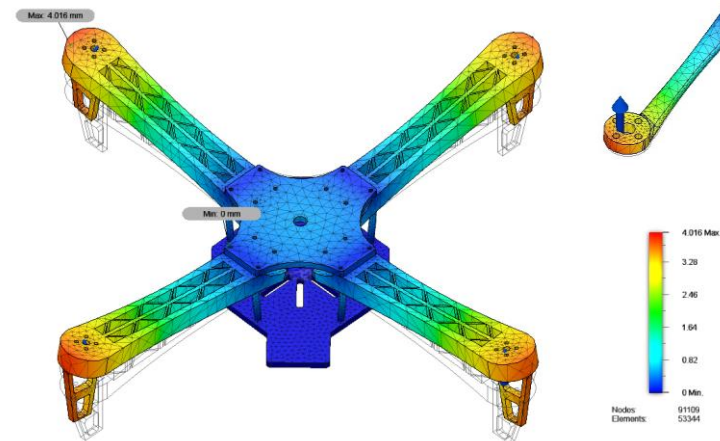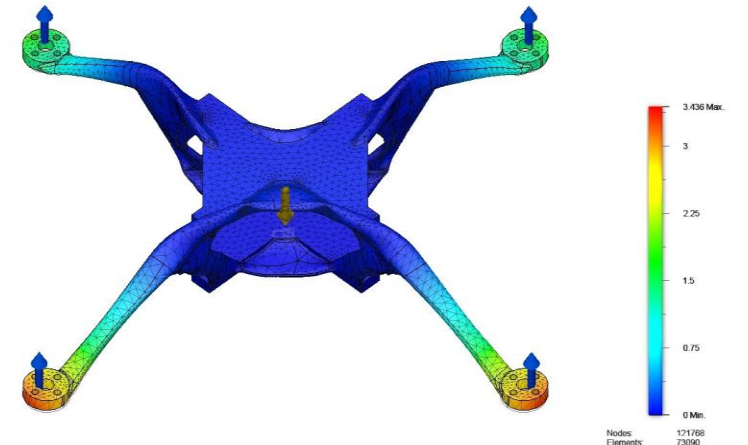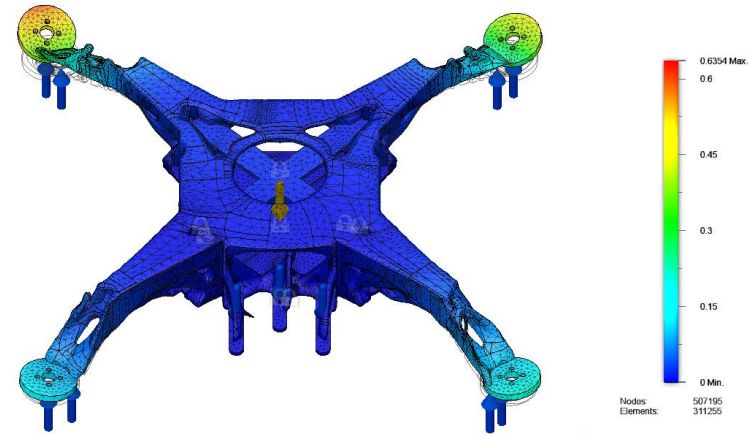
FREQUENCY ANALYSIS AT 300 Hz
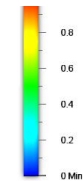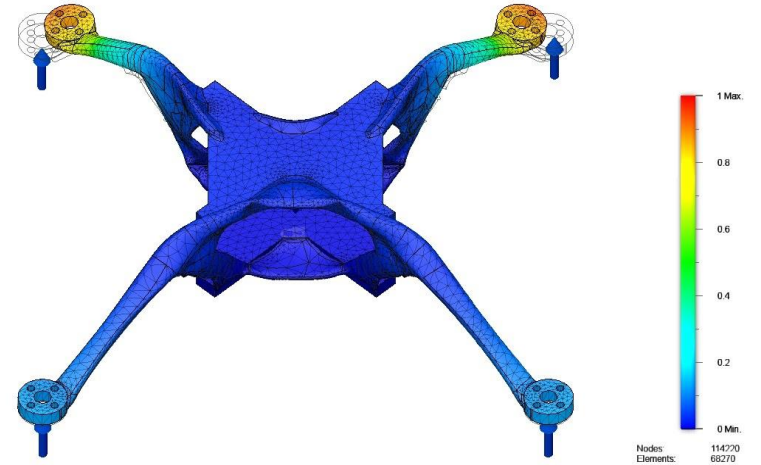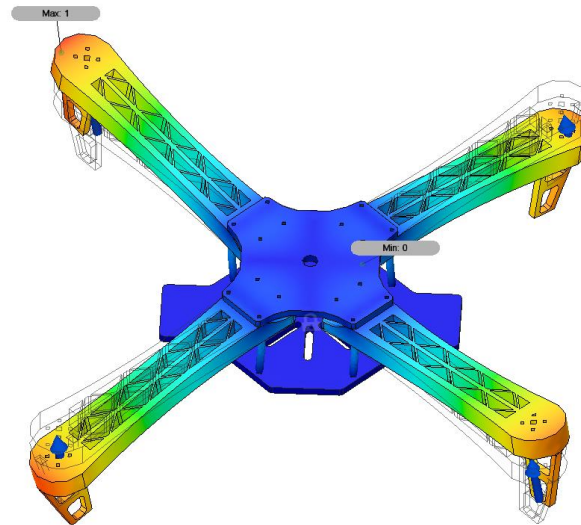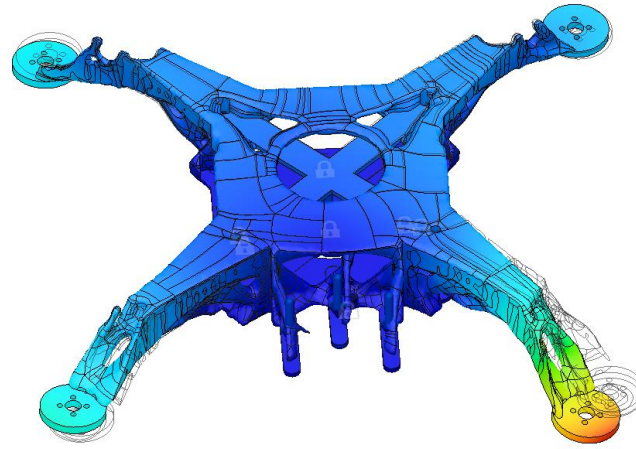
Conclusions

All the designs generated are within the saftey limit

Mass is comparitively less for generatively designed frames when compared to Traditionaly designed drone frame

Factor of safety of model 1 is almost 40 times of DJI F450 Drone frame

Maximum displacement of model 2 is just about 0.1 mm under the loading conditions which is 400 times when comparedto DJI Drone frame

Von misses stress is 11.4 times less for the model 2 frame in comparison to DJI F450 Frame

Model 1 and 2 can withstand cyclic load and can survive from failure for a longer period of time

REFERENCES

- Buelow PV. (2002) Using evolutionary algorithms to aid designers of architectural structures. p. 315–36.

- McKnight, M. (2017) Generative Design: What it is? How is it being used? Why it's a game changer. KNE Eng., 2, 176–181.

- Wu, Jun & Qian, Xiaoping & Wang, Michael. (2019). Advances in generative design. Computer-Aided Design. 116. 102733. 10.1016/j.cad.2019.102733.

- Ahmed, Md & Zafar, Mohd & Mohanta, Jagadish. (2020). Modeling and Analysis of Quadcopter F450 Frame. 196-201. 10.1109/IC3A48958.2020.233296.

- Sun, H.; Ma, L. (2020) Generative Design by Using Exploration Approaches of Reinforcement Learning in Density-Based Structural Topology Optimization. Designs 2020, 4, 10.

- Janssen P. A generative evolutionary design method Digital Creativity 2006; 17(1):49–63.

- Sosnovik, I.; Oseledets, I (2019) Neural networks for topology optimization. Russ. J. Numer. Anal. Math. 34, 215–223.

THANK YOU!