DESIGN AND STATIC STRUCTURAL ANALYSIS OF AN AERIAL AND UNDERWATER DRONE

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ABSTRACT - Drones have been implemented for several application around the world due to its robust technology and ease of operation. In this project we would like to implement drones for underwater as well as aerial surveillance at our coastline and further extend its application for detection of underwater air crashes and ship wrecks. Underwater drones must consider important factors such as floatability and buoyancy which challenges the structural integrity and power requirements of the drone. This project uses an innovational quadcopter design with a new streamlined structural geometry. The entire frame is designed using CATIA. The new design is validated for its successful implementation through stress analysis using ANSYS, also suitable material for fabrication is selected by comparing five other materials.

Key words: Drones, Simulation, Structural Integrity, Surveillance, Underwater Vehicles.

I. INTRODUCTION

Drones are now being implemented in various fields such as agriculture, mining, surveillance, mapping, reconnaissance, etc. The versatility of drones has been expanding due to the highly advanced electronics available today. Imaging sensors, thermal sensors, passive infrared sensors, obstacle detection are some of the most commonly used ones today. Infrastructure surveillance and maintenance is done with less use of manpower using drones. Critical structures that require a lot of energy and time for inspection such as cable towers, wind mills, solar farms, industrial buildings walls and dams, can be easily inspected with the help of drones. In this paper drones are to be implemented for underwater as well as aerial surveillance. The innovation for this paper is based on the underwater drone developed by Johns Hopkins University [1], the Corrosion Resistant Aerial Covert Unmanned Nautical System — or CRACUNS. The two challenges CRACUNS faced was water pressure and corrosive environment. They have used a composite frame to resist underwater pressure and special coatings have been provided to resist corrosion in harsh saltwater environment. Following the above mentioned innovation, this paper uses a new streamlined geometry which has been designed to be fully sealed to carry the components and all the circuits. This is done in order to fully protect the circuits. The model will be designed based on a basic quadcopter. The frame size, position and angle of arms will all be decided based on the propeller size to prevent interference between propellers and with the propeller and the frame. The entire frame will be modeled using CATIA. Once the frame is modeled a suitable material that can withstand variable pressures in air and water will be chosen. Using the chosen material's properties the weight of the structure will be estimated. The structural stability of the drone plays an important role as its application involves exposure to different pressure environments. The stability of the frame will thus be validated using analysis through software. The entire frame of the drone is subjected to static structural analysis using ANSYS workbench.

Figure 1: CRACUNS by John Hopkins University.

II. MISSION REQUIREMENTS

The main requirements for a drone to be able to travel both in aerial and underwater is to have the ability to withstand the hydrostatic pressure which will be experienced in underwater and the electronic components should also not be exposed to the water as it may damage it. So the design should be made in such a way that the electronic components like ESC, FC, battery, etc., are not exposed to water and the frame should be able to withstand hydrostatic pressure till certain depth.

III. ANALYTICAL METHOD

Design of the Frame

The drone was designed using CATIA software by taking the mission requirements into consideration. The bottom and top part of the frame was designed separately and they are to be attached with screws. The motors for operation of the drone will be fit securely within the motor holders which were also designed.

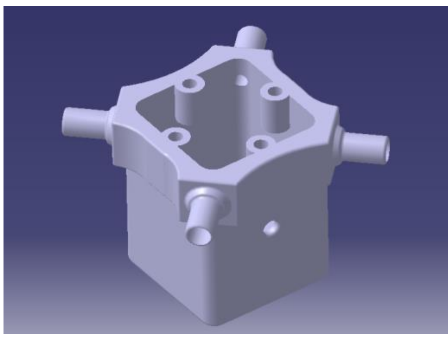

Figure 2: Bottom part of the model.

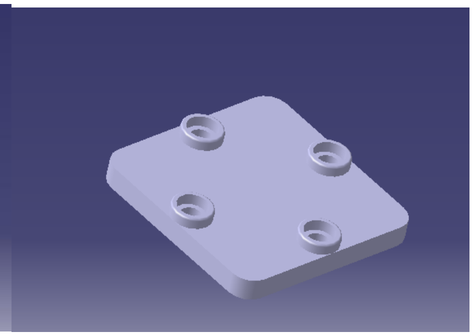

Figure 3: Top part of the model.

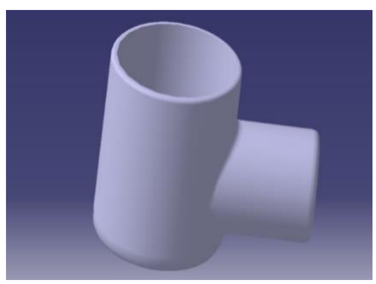

Figure 4: Motor holder.

The assembly design for the frame of the drone is shown in fig 5.

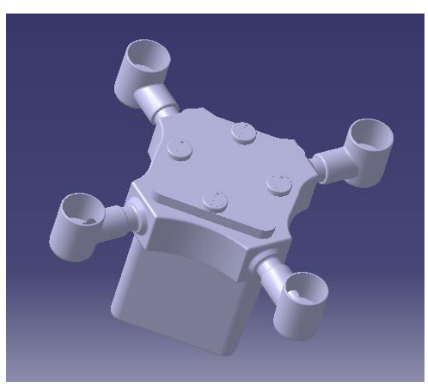

Figure 5: Isometric view of the design model.

Measurement of Center of Gravity

Centre of Gravity is defined as the point in which the whole mass of the body acts upon. This Centre of Gravity is calculated for the model using CATIA software.

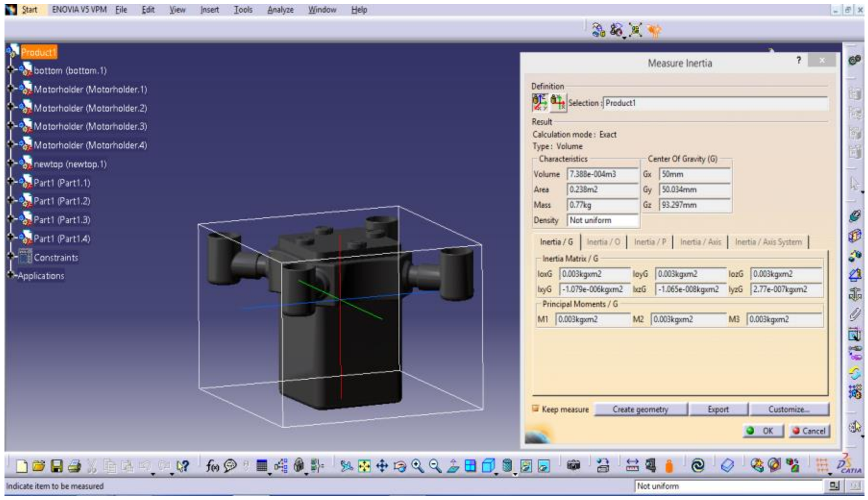

Figure 6: Depicting the measurement of Centre of Gravity using CATIA.

Structural analysis

The frame that has been designed must now be validated for it strength and rigidity under immense pressure under water and in air. The design model has been imported into ANSYS workbench from CATIA where the static structural analysis has been performed. The loads acting on the drone in air and water are given in table 1. In addition to these loads the motor weight and the payload weight are also applied.

Condition	Air	Water
Pressure- condition	Standard atmospheric condition	Fluid pressure at a depth of 5m
Pressure- magnitude	101325 Pa	151795 Pa
Density	1.225 kg/m^3	1030 kg/m^3

Table 1: Loading conditions.

The analysis was performed for different materials to choose the best material for fabrication of the drone. The weight of the frame plays an important part in the power requirements of the drone. The materials chosen and the weight estimate of the frame for the chosen materials are shown in table 2.

Material	Weight estimate (kg)
ABS- Acrylonitrile butadiene styrene	0.814
PMMA- Poly methyl methacrylate	0.9195
PETG- Polyethylene terephthalate glycol	0.9896
PLA- Polylactic acid	0.9662
EOS Aluminium- AlSi10Mg	2.08

Table 2: Weight estimate for different materials.

The lightest material is ABS plastic. The entire weight of the drone is estimated using this material.

Weight Estimation

The weight of each component was taken into consideration. The weight of the bottom part, top part and the motor holder was computed in CATIA software. The weight estimation procedure is adopted from [2].

COMPONENTS	WEIGHT
Bottom part	0.55 kg
Top part	0.104 kg
Arm & Motor holder	0.160 kg
Battery	0.096 kg
ESC	0.127 kg
Motor	0. 212 kg
Camera and circuits	0. 250 kg

Table 3: Weight of each components.

$$W_0 = W_{st} + W_{pp} + W_{sys} + W_{bat} + W_{pay} \quad (1)$$

Where,

W_0 = Takeoff gross weight

W_{st} = Frame weight

W_{pp} = Powerplant weight (motor)

W_{sys} = Systems weight

W_{bat} = Battery weight

W_{pay} = Payload weight

Also, the empty weight can be defined as:

$$W_e = W_{st} + W_{pp} + W_{sys} \quad (2)$$

The Takeoff weight will remain constant as the drone is electrically powered [3]. So the takeoff gross weight is:

$$W_0 = W_e + W_{bat} + W_{pay} \quad (3)$$

Empty weight,

$$W_e = W_{st} + W_{pp} + W_{sys}$$

$$= 0.814 + 0.212 + 0.127$$

$$= 1.153 \text{ kg}$$

Takeoff gross weight,

$$W_0 = W_e + W_{bat} + W_{pay}$$

$$= 1.153 + 0.096 + 0.250$$

= 1.5 kg (approx.)

Empty weight fraction,

$$\frac{W_e}{W_o} = 0.769$$

IV. RESULT & DISCUSSION

The total deformation for the above mentioned loading conditions and materials were obtained using structural analysis tool in ANSYS for air and water separately. The deformation results are shown in the figures below. The deformation values are shown in table 4.

Material	Total deformation (mm)	
	Air	Water
ABS- Acrylonitrile butadiene styrene	0.35	0.53
PMMA- Poly methyl methacrylate	0.25	0.37
PETG- Polyethylene terephthalate glycol	0.324	0.49
PLA- Polylactic acid	0.32	0.48
EOS Aluminium- AlSi10Mg	0.009	0.014

Table 4: Total deformation for different materials.

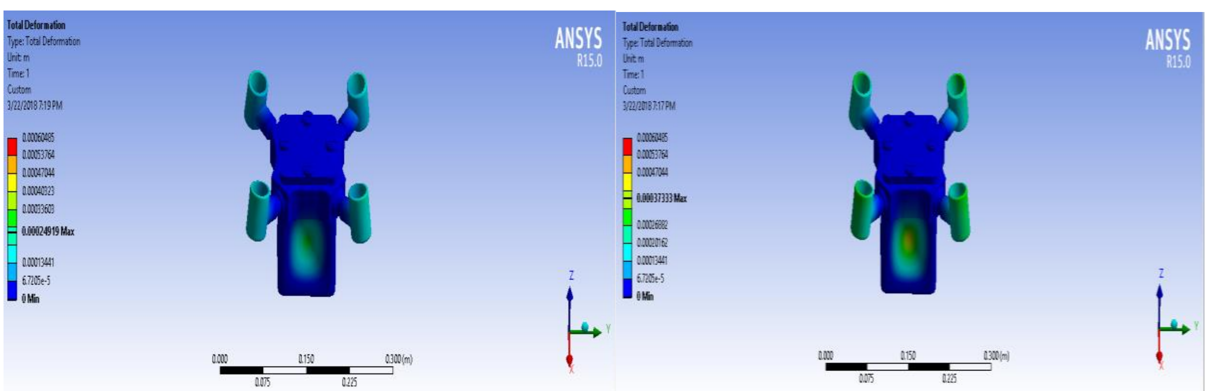

Figure 7: Total deformation of the frame in case of PMMA, air (left) and water (right).

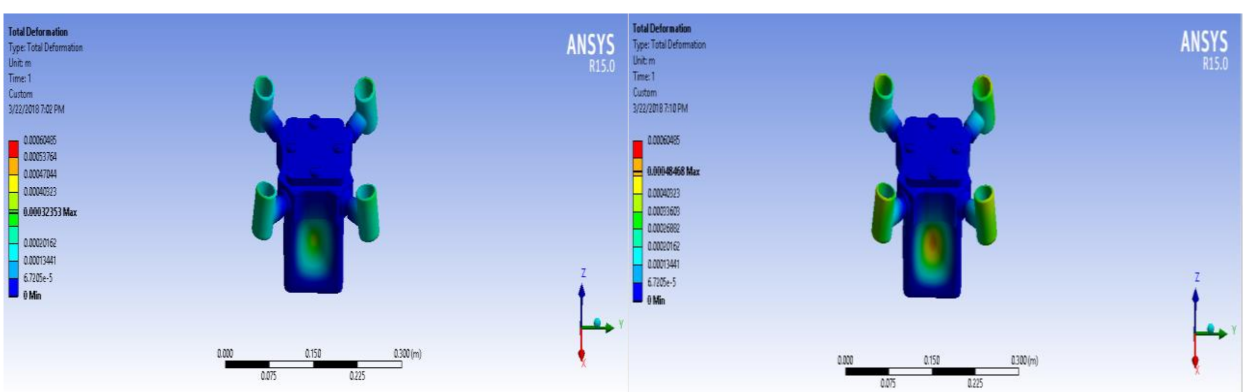

Figure 8: Total deformation of the frame in case of PETG, air (left) and water (right).

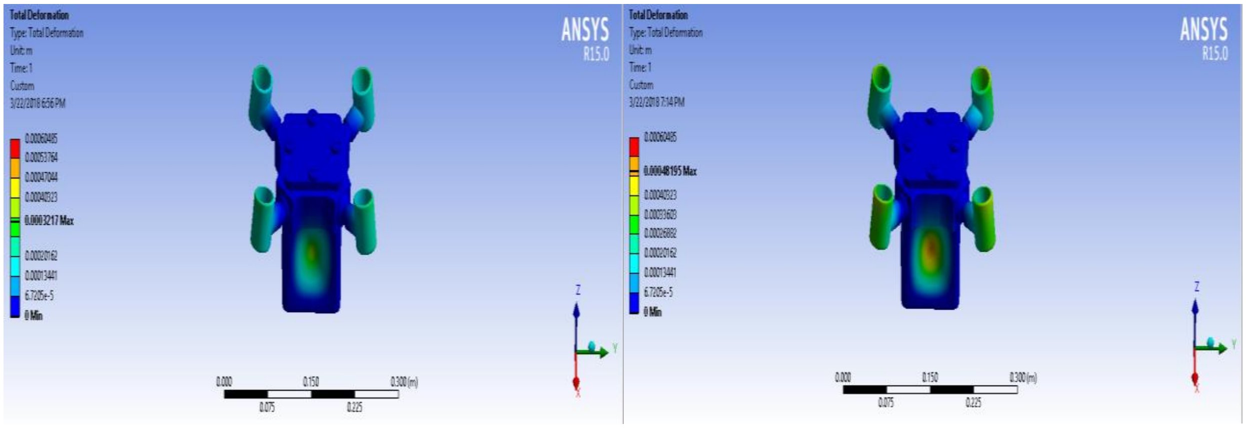

Figure 9: Total deformation of the frame in case of PLA, air (left) and water (right).

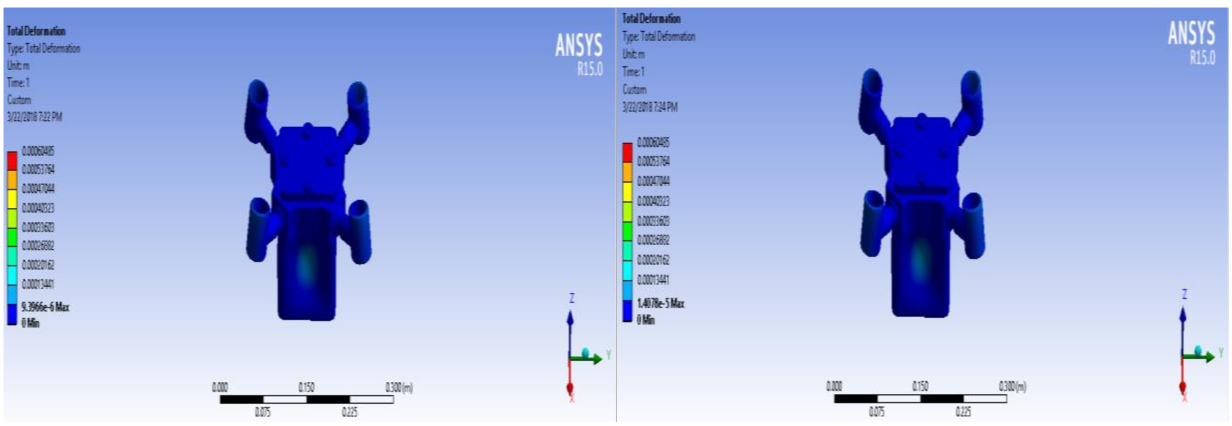

Figure 10: Total deformation of the frame in case of EOS Aluminum- AlSi10Mg, air (left) and water (right).

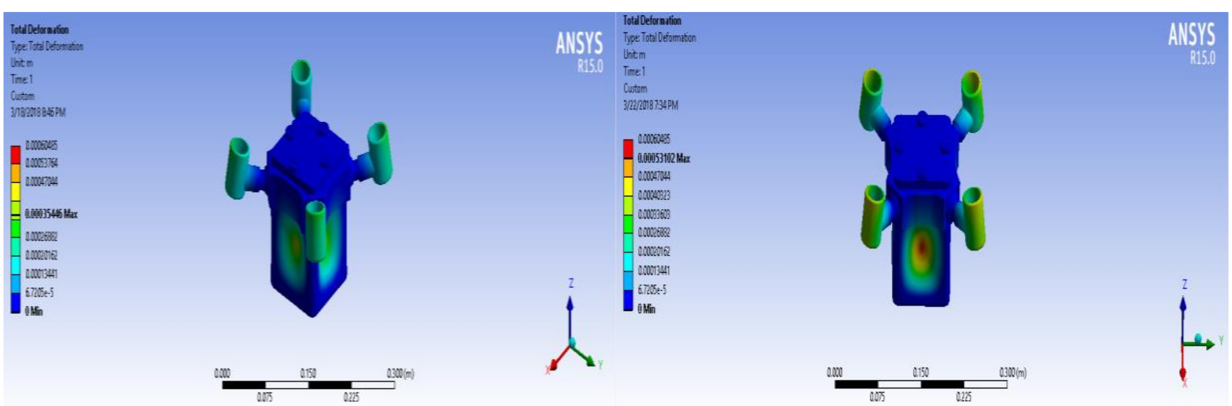

Figure 11: Total deformation of the frame in case of ABS, air (left) and water (right).

V. CONCLUSION

The center of gravity was calculated and it was found to satisfy the balancing condition for this case. From the total deformation results obtained in ANSYS we inferred that the deformation for all the chosen materials was within negligible limits. Therefore the most suitable material was chosen based on the weight of the frame. Since ABS plastic gives a lighter structure compared to the others it was chosen for fabrication of the drone. ABS plastic not only gives a lighter and stronger structure, it additionally proves to be corrosion resistant for the harsh saltwater, sea environment.

VI. FUTURE SCOPE

- The model will be fabricated with the chosen material and subjected to flight tests in air and water.
- GPS technology with geometrical reasoning can be implemented to remove limitations due to remote operation [4].
- Improved underwater imaging can be provided with acoustic imaging [5].

REFERENCE

[1] Geoff Brown. (2016). New UAV that can launch from underwater by Johns Hopkins University. Retrieved from http://www.jhuapl.edu/newscenter/pressreleases/2016/160317.asp

[2] Daniel P. Raymer. (1989). Aircraft design: A conceptual approach: AIAA Education Series.

[3] Gian Luca Foresti, Stefani Gentili, Massimo Zampato. (1999). "Autonomous underwater vehicle guidance by integrating neutral networks and geometric reasoning". International Journal of Imaging and Processing, Vol 10, Issue 5, pp: 385-396.

[4] Mauro Gatti and Fabrizio Giulietti. (2013). “Preliminary Design Analysis Methodology for Electric Multirotor”. IFAC proceedings, Vol 46, Issue 30, pp: 58-63.

[5] Kamgar-Parsi.B, B. Johnson, D.L. Folds, E.O. Belcher. (1997). "High-Resolution Underwater Acoustic Imaging with Lens-Based Systems". International Journal of Imaging and Processing, Vol 8, Issue 4, pp: 377-385.