Design and Static Structural Analysis of Plus Configuration Octa-copter

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Abstract— There are various requirements which should be satisfied by the structure and is best rigid body as light as possible, capability of carrying heavy payload, mounting the electronics components such as sensor, ESC, motor etc., which can be achieved by the various modification & optimization of various structural parameters, structural design and analysis of multi-rotor for integration into whole system for the best result. Design of a novel acrobatic holonomic multi-copter UAV is carried out using CAE tools to produce desired design concept. Analysis of multi-copter is executed using analysis tools. By design optimization; number of motors, type of propeller & design of airframe has been sketched conceptually. In this type of drone, payload weight is an important factor which have been taken into consideration.

Keywords: Octa-copter, Stress, Displacement, ANSYS, CATIA, Static Analysis

I. INTRODUCTION

Multi-copters are most probably used wireless drones used for various purposes. The multi-copters are one of the most complex flying machines due to its versatility to perform many types of tasks. The first multi-rotor helicopter with fixed pitch blades rotors was proposed in 1923 by De Bothezat, but technology at that time was not ready for applicable construction of such type of machine. The main problem was an instability of the vehicle and thus pilot workload which was too high. Since then the development of light batteries, brushless actuators and MEMS sensors allowed considerable improvement in construction and control of this type of helicopter.

Today's multi-copters are not only radio-controlled toys but they are robust which are able to lift higher payload. They have started to be used as UAV (Unmanned Aerial Vehicles) or aerial robots mainly for identification purposes. Also, they are used for military applications. Multi-rotors are to be considered as most stable wireless drones. It becomes most popular research platforms for UAVs. Since a hexa-copter or an octa-copter can carry heavier payload than a quadrotor, they are used for aerial photograph, broadcasting, carrying heavier payload and even surveillance.

They are available in various different types such as bi-copters, tri-copters, quad-copters, penta-copters, hexa-copters, octa-copters, out of all these copters hexa and octa copters are considered to be the most stable drones. Octa-copter appear to pre-dominate the current commercial and recreational markets for vertical take-off and landing UAVs. This configuration offers much higher flexibility in size and location of rotors and payload when compared with other single rotor configuration. The detail study of rotor-rotor and rotor-body aerodynamic interactions of multi-rotor is important for design optimization to push beyond the current performance limitations.

Fig. 1: Overview of an Octa-copter

II. LITERATURE SURVEY

The international journal paper by “Hyeonbeom Lee, Suseong Kim, Hyon Lim, H. Jin Kim, 2013”[1] carried out research on control of an octa-copter from modelling to experiments which can carry heavier payload than quadcopter. That paper presents modelling and stabilization of an octa-rotor using the simple motor mixing concept considering the octa-copter as the sum of two quadrotors, the motor control input can be computed from the thrust, roll, pitch, yaw commands. Also, using the adaptive sliding mode controller, the uncertainty problem for the octa-copter can be solved, which can be more crucial to the octa-copter than quad-rotor considering the modelling error and the ground effects. The experimental results show satisfactory hovering performance within about 0.4 m^2 area.

The international journal paper by “Tao Du, Adriana Schulz, Bo Zhu, Bernd Bickel, 2016” [3] presents computational multi-copter design. They had shown multiple examples to demonstrate the effectiveness of their design system, physical simulator, control loop and optimization method with the two classic multi-copters: X-frame quadcopter and Y6 hexa-copter. A penta-copter demonstration for correctness of their controller and its ability to handle nonstandard copters with odd number of motors. A more challenging penta-copter with tilted motors, which is optimized for the payload metric. And finally, provide a rectangular quadcopter optimized for longer flight time and compare it with a standard quadcopter. They proposed a new pipeline for users to efficiently design, optimize, and fabricate multi-copters.

III. OCTA-COPTER DESIGN

After a detailed background study, with appropriate dimensions the 3D modelling of a multirotor is done using CAE tools. The design is optimized by various structural parameters in order to achieve the main payload criteria.
Overall view of the model is shown in below figure 2:

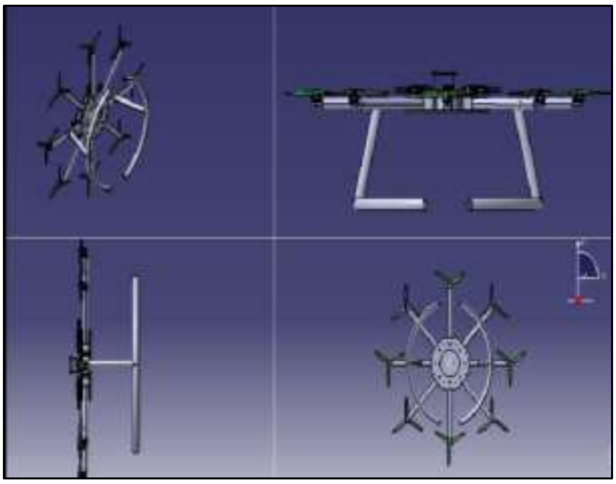

Fig. 2: Designed Octa-copter

Here the octagonal shape of mount is chosen with circular filled arms and landing skit for main frame design of an octa-copter. The tri-propeller is selected for producing more thrust with appropriate motor which will be able to lift higher payload and longer endurance. Loads, speeds, temperature, mating materials, cost constraints and critical factors to be kept in mind when selecting materials.

A. Material Selection: Carbon fiber

Material used for designing the multirotor is carbon fiber because of its several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion.

Material properties	Values
Young's Modulus (GPa)	27.6
Poisson's ratio	0.23
Density (Mg/m3)	2.49
Elastic limit (MPa)	76
Modulus of Rupture (MPa)	110

Table 1: Properties of carbon fiber

Source: Materials World, Vol. 4, no. 12 pp. 707-8, December 1996[10].

B. Weight Estimation for Analysis

The weight estimation of an octa-copter is carried out after applying carbon fiber on its airframe components like: mount, arms, landing skit, propeller etc.

Weight estimation of an octa-copter is shown in below table:

S.N.	Components	Weight (Kg)	Number of Component used	Total Weight (Kg)
1	Mount	0.879	1	0.879
2	Propeller	0.013	8	0.104
3	Motor	0.131	8	1.048
4	Landing skit	0.176	2	0.352
5	Arms	0.228	8	1.824
6	Battery	1.3	1	1.3
7	Allowances	0.493	1	0.493

Table 2: Weight Estimation of an Octa-copter

The self-weight of the structure, which we have estimated is about nearly 6kg and the payload weight is about 10kg. Hence, total weight of the octa-copter with payload is approximately 16kg.

IV. Results and Discussion

The 3D CAD model of an Octa-copter frame with 250mm and 300mm armlength having zero-degree, 5-degree and 8-degree inclination is imported into ANSYS Workbench and material is applied as carbon fiber to do structural analysis, whose meshed part is shown in below figure:

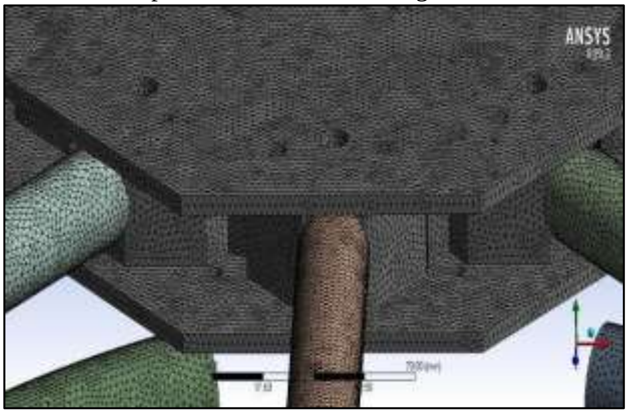

Fig. 3: Meshed model

Mesh quality obtained is between 0.18-0.9

Self-weight	6 kg
Payload weight	10 kg
Total weight	16 kg
Load experienced by each arm	16/8=2 kg

Table 3: Overall weight estimation

Load experienced by each arms (N)	FOS	Total load Experienced Upward (N)
2*9.81=19.62	3	19.62*3=58.86
2*9.81=19.62	3	19.62*3=58.86
2*9.81=19.62	3	19.62*3=58.86
2*9.81=19.62	3	19.62*3=58.86
2*9.81=19.62	3	19.62*3=58.86
2*9.81=19.62	3	19.62*3=58.86
2*9.81=19.62	3	19.62*3=58.86
2*9.81=19.62	3	19.62*3=58.86
Load experienced by Mount with payload	FOS	Total load experienced Downward (N)
11*9.81=107.91	2	107.91*2=215.82

Table 4: Boundary Conditions

The boundary conditions are applied as shown in below figure:

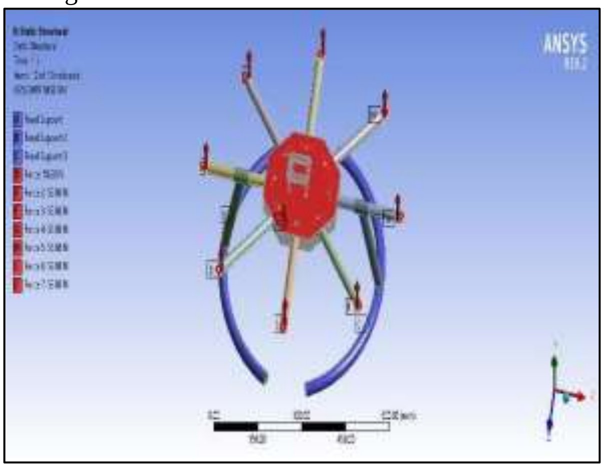

Fig. 4: Applying loads and supports

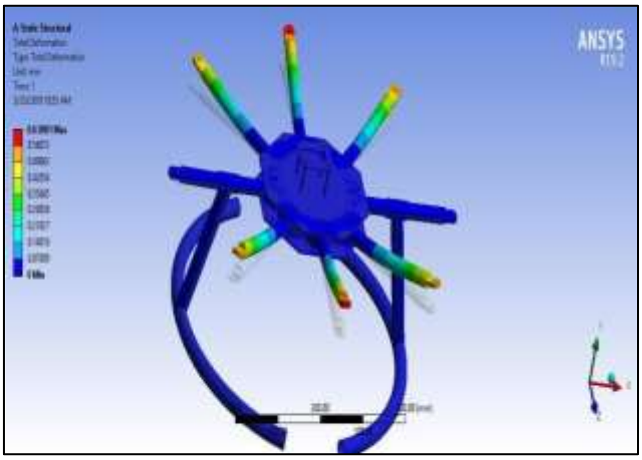

Fig. 5: Total Deformation

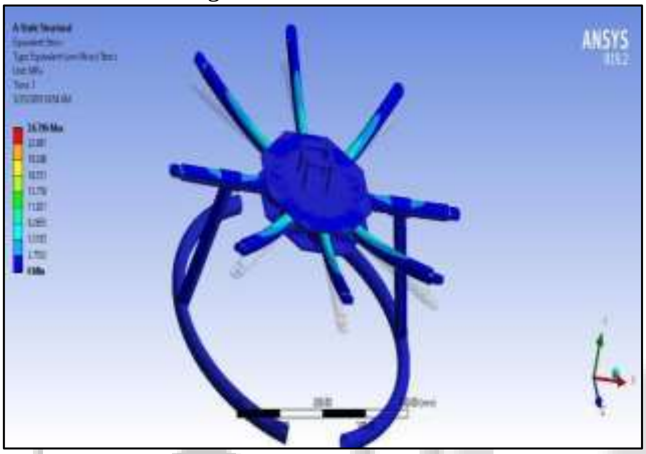

Fig. 6: Equivalent Stress

After applying the boundary condition, Equivalent stress and total Deformation is calculated through static structural analysis and results are tabulated below:

S.N.	Arm length (mm)	Angle of Inclination (deg)	Max. Deformation (mm)	Max. Stress (MPa)
1	250	0	0.62445	32.713
2	250	5	0.63081	24.796
3	250	8	0.62963	25.62
4	300	0	1.092	34.166
5	300	5	1.081	44.033
6	300	8	1.081	48.139

Table 5: Results of various octa-copter design with payload

V. CONCLUSION

This paper presents the design and static structural analysis of plus-configuration octa-copter. The design of octa-copter is carried out with CAE tools as per demand where as the main factor of consideration for our design is carrying higher payload. The design is mainly focused on lifting heavier warhead which can be used for carrying fire extinguisher, camera mount for photography & cinematic world, agricultural purpose, in war for carrying warheads, delivery activities, medical supplies during emergency, mapping of landscape etc. By analysis results of all the design, the Octa-copter with 250mm horizontal arm is undergoing less total deformation i.e. 0.62445 mm and maximum stress experienced by model is 32.713 MPa. Whereas the Octa-copter with 250mm arm having 5 degrees inclination is also having almost same total deformation i.e. 0.63081 mm and maximum stress experienced is 24.796 MPa which is comparatively very less. Hence, we can conclude that octa-copter with 250mm arms having 5-degree inclination is the best design for carrying heavy payload of 10 kg.

VI. REFERENCES

[1] Hyeonbeom Lee, Suseong Kim, Hyon Lim, H. Jin Kim "Control of an octa-copter from modeling to experiments which can carry heavier payload than quadcopter", National Research Foundation of Korea (NRF), No: 2013013911,2013.

[2] Sravan Kumar N, Ram Kishore "The design and control implementation of quadcopter", International Journal of Mechanical and Production Engineering, ISSN: 2320-2092, Volume- 4, Issue-5, May-2016.

[3] Tao Du, Adriana Schulz, Bo Zhu, Bernd Bickel "Computational multi-copter design", Air Force Research Laboratory's, MIT Award ID:024831-00003,2016.

[4] R Nallappan, CasindraHellanMaxim, P Barath Kumar "Design and analysis of quadcopter", International Conference on Systems, Science, Control, Communication, Engineering and Technology, ISBN:978-81-929866-6-1, 2016.

[5] Kanaiya Agrawal, Punit Shrivastav "Multi-rotors: A Revolution in unmanned aerial vehicle", International Journal of Science and Research (IJSR), ISSN: 2319-7064,2014.

[6] Endrowednes Kuantama, Dan Craciun, Radu Tarca "Quadcopter body frame model and analysis", ANNALS OF THE UNIVERSITY OF ORADEA, May 2016.

[7] Oscar Oscarson "Design, modeling and control of an Octocopter", Royal Institute of Technology, SCI School of Engineering Sciences, Sweden, 2015.

[8] Bhakti Yudho Suprapto, M Ary Heryanto, Herwin Suprijono, JemieMuliadi, "Design and development of heavy-lift hexa-copter for heavy payload", International Seminar on Application for Technology of Information and Communication, 2017.

[9] Ethara Bala Vyshnavi, Amareswari Ambati, Gorantla Chamundeswari, Garre Vineetha, "Automatic CO2 extinguisher fire fighter drone", International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE) Vol 4, Issue 12, ISSN: 2394-6849, December 2017.

[10] Materials World, Vol. 4, no. 12 pp. 707-8, December 1996.