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Modeling, Analysys & Fabrication of Quadcopter (Uav) With Payload Drop Mechanism

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Abstract: A quadcopter also called a quadrotor helicopter or quadrotor is a multi-rotor helicopter that is lifted and propelled by four rotors. In recent years, research and development in quadrotor (i.e., unmanned aerial vehicles, UAV's) has been growing at an unprecedented speed. This paper is focused on modeling, analysis and fabrication of the quadrotor in terms of improving the payload capacity of the quadrotor. To validate this proposal, we considered many different structures of UAV's considering several literature surveys and choose Quadrotor. The payload of our Quadrotor is around 5 kg which adds function of weight lifting in military operations as well as industrial applications. "CATIA V5 R19" software was used for modeling and "ANSYS Workbench" was used for Static and dynamic analysis. The static analysis results revealed that the maximum deformation in the model is 3.5835e-5 m and maximum stress developed is 7.341e6 Pa. CFD analysis revealed that the maximum & minimum pressure are 5.325e+001 & -1.560e+002 Pa respectively and maximum & minimum velocity are 1.440e+001 & 000 m/s respectively for the applied input velocity of 10 m/s.

Index Term s- Quadcopter, UAV, Frame, Airflow, Aerodynamics, CAD, Finite Element Analysis, etc.

1. INTRODUCTION

1.1 Unmanned Aerial Vehicle (UAV)

Over the last few years we have seen a massive growth in the manufacture and sales of remote airborne vehicles known as unmanned aerial vehicle (UAV), since the application of UAV can apply to many areas such as salvage mission, military, filmmaking, farming, and others. An unmanned aerial vehicle (UAV) is an aircraft without a human pilot aboard. UAV's are a component of an unmanned aircraft system (UAS). The flight of UAV's may operate with various processes: either under remote control by a human operator or autonomously by onboard computers. A UAV is defined as a "powered aerial vehicle" that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable.

1.2 Quadcopter

Quadcopter is one of the rotary wings UAV that is major centers of dynamic explores in the recent years. Quadcopter is one of type of multirotor that is lifted and propelled by four rotors as shown in Fig. 1.1. It is also known as quadrotor. It works according to the force or thrust generated by four rotors connected to its body. It has four input and six yield or output states (x, y, z, θ, ψ, ω), and it is an under-activated framework, since this empower quadcopter has to convey more load. A quadrotor is a four-rotor helicopter. It is an under actuated, dynamic vehicle with four input forces and six degrees of freedom.

Unlike regular helicopters that have variable pitch angle rotors, a quadrotor helicopter has four fixed-pitch angle rotors. A quadcopter is a flying vehicle which utilizes quickly turning rotors to push air downwards, subsequently making a push energy keeping the helicopter on high. Its control is very difficult to achieve. With six degrees of freedom (three translational and three rotational) and just four free inputs (rotor speeds), quadcopter are extremely under actuated. Quadcopter are classified as rotorcraft, as opposed to fixed-wing aircraft, because their lift is generated by a set of revolving narrow-chord air foils.

Fig. 1.1 Quadcopter

1.3 Working mechanism

A quadcopter is a multi-rotor craft that is lifted and propelled using four rotors. The propellers of a quadrotor are vertically oriented and each of them works in varying speeds, giving the aerial vehicle some speed, desired thrust and turning force, required in moving the quadcopter on the air. Typically, the quadcopter has the following configurations; two rotors turning clockwise and the other two turning counter clockwise, helping the quadrotor respond to controls of its pilot when flying. The multi-copter uses its propellers to rise up in the air (upward lift). The four motors are therefore designed to rotate in the following directions; CW, CCW, CW, CCW. This enables the cancelling out of a motors intention to cause a spin of the craft when on air, cementing Newton's Third Law of Motion; for every action, there is an equal and opposite reaction. What is unique about multi-copter is their vertical takeoff and landing. In order to attain this, the pilot needs to control the pitch, yaw and roll the quadcopter in variable thrusts on each motor.

2. MATERIALS

The frame of quadcopter can be made from aluminium, carbon fibre or balsa wood. The comparison among various properties of these materials are listed below-

Table 1.1 Comparison of mechanical properties of Aluminium, Carbon fiber and Balsa wood

Property	**Al(6061)**	**Carbon Fibre**	**Balsa wood**
Young's modulus (GPa)	70	70	3
Poisson's ratio	0.33	0.1	0.229
Ultimate Tensile strength (MPa)	550	600	14
Ultimate compressive strength (MPa)	469	570	7
Density (gram/cc)	2.86	1.6	0.13

Aluminium (6061) is light and strong material, which dissipates heat well, and is relatively inexpensive compared to the other available options. It is having high malleability. No sparking, so it's ideal for use near flammable substances. Resistant to corrosion, this makes it ideal for use outdoors. Nonmagnetic, hence it is not affected by electromagnetic forces. Thus Aluminium is a material which is used for arms and the supporting plate. Fig. 2.1 shows the fabricated frame of quadcopter.

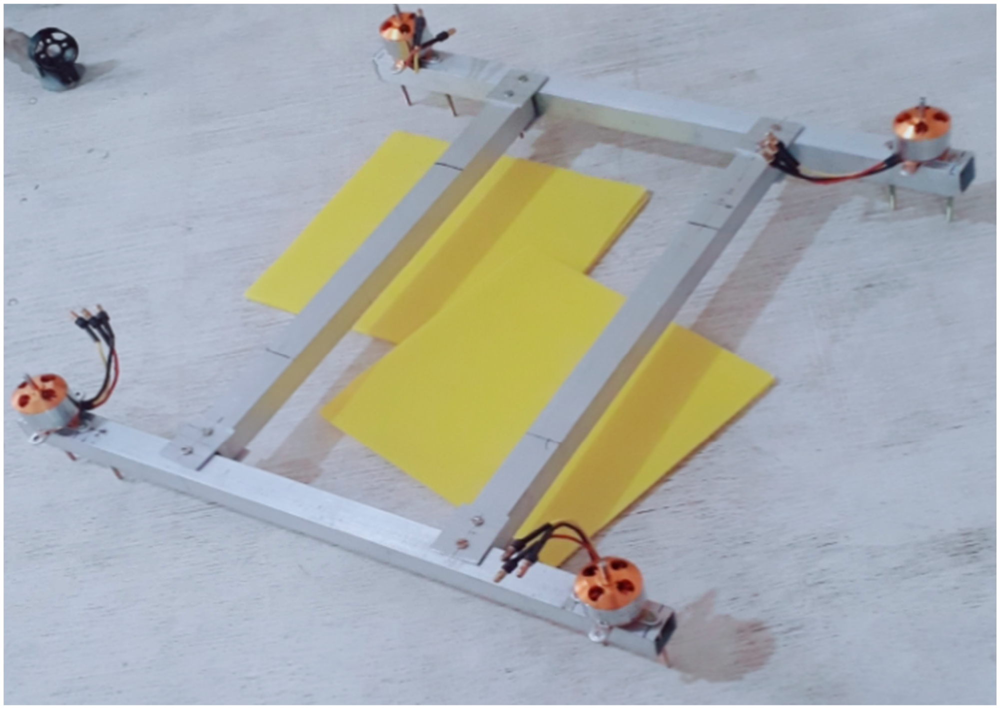

Fig. 2.1 Frame of quadcopter

3. CAD MODELLING

The 3D modeling is done in "CATIA V5 R19" software. The various parts modeled are Frame, Supporting Plate, Motor Plate, Motor, Propeller wing. These parts are assembled. Fig. 3.1 shows 3-D modeling of quadcopter frame with motor plate and Fig. 3.2 shows an Assembled quadcopter.

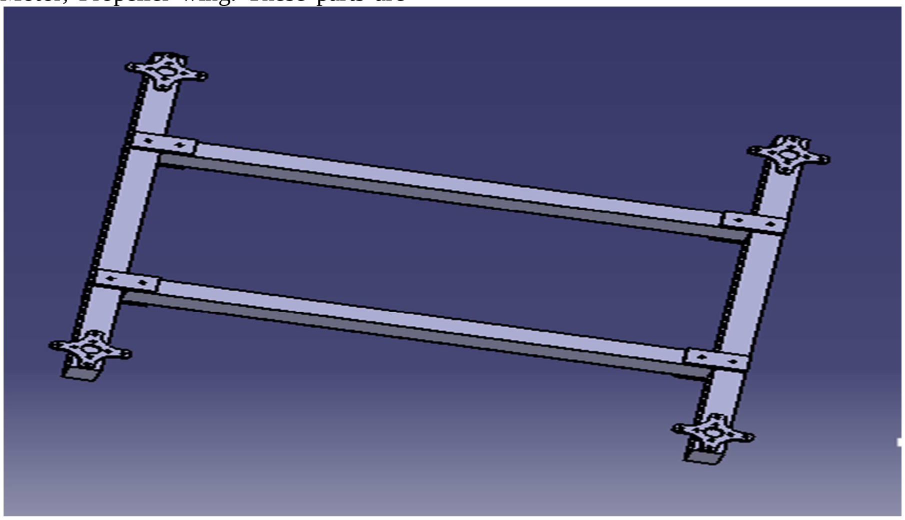

Fig. 3.1 3-D CAD model of quadcopter frame with motor plate

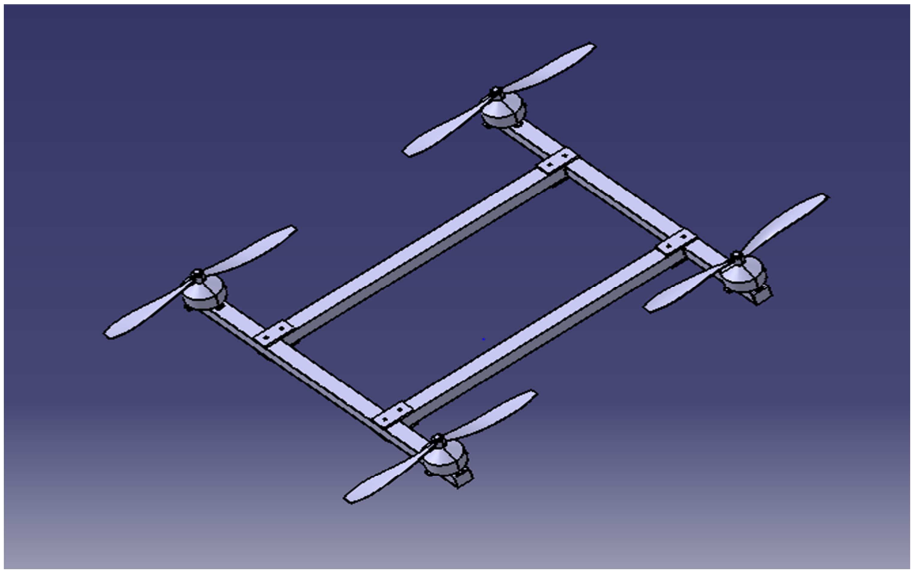

Fig. 3.2 Assembly of quadcopter

4. CALCULATIONS:

i. Max. Power of motor

P = V * I = 11.1*2.2 = 24.42 W

Where,

V= Battery voltage in volts.

I = Current in Ah.

ii. Selection of Electronic speed controllers (ESC)

4* ESC > C * Ah

120 A > 55 A

iii. Amount of power by motor to rotate propeller

W = k * $R^2 * D^4$ *P

Where,

$K=5.3 \times 10^{-15}$

R=Rpm of motor

D=Diameter of propeller

P=Pitch of propeller

$W= 5.3 \times 10^{-15} \times (2775)^3 \times 10^4 \times 4.5$

=5.096 W

iv. Thrust from propeller

$F = 4.392399 * 10^{-8} * R * D^{3.5}/\sqrt{4.5} * (4.2333 * 10^{-4} *R *P - V_1)$

Where,

R = Rpm of motor.

D = Dia. of propeller.

P = Pitch of propeller.

V_1= Inlet velocity of fluid.

$F =4.392399 * 10^{-8} * 2775 * 10^{3.5}/\sqrt{4.5} * (4.2333 * 10^{-4} *2775 *4.5 - 10)$

F = 0.8564 lbh

F = 3.8102 N

OUTPUT

i. Propeller sweep area

$A = 0.25 \times \pi \times (D^2)$ $inch^2$

$A = 0.25 \times \pi \times (10^2)$ $inch^2$

A = 78.539 $inch^2$

- **Conversion of units**

A_{ft} = A * 0.0694444

A_{ft} = 78.539 * 0.0694444

A_{ft} = 0.545 ft^2

ii. Power Loading

$$P.L = \frac{P_{in} \times n}{A_{ft}}$$

Where,

P_{in} = Input power in Hp

Ƞ = Average efficiency of Motor

P_{in} = Voltage * Amps.
= 11.2 * 2.2 = 24.42 W
= 24.42 * 1.340 x 10^{-3}
= 0.0327 Hp

$$P.L = \frac{0.0327 \times 0.75}{0.5454}$$

$$= 0.0450 \frac{HP}{ft^2}$$

iii. Thrust Loading

T L =8.6859×$PL^{-0.3107}$×1
$= 8.6859 * (0.0450)^{-0.3107} * 1$
$=2207646 \frac{lb}{hp}$

iv. Lift Per Motor

Lift=T.L * (P_{in} x Ƞ)
=22.7646 * (0.0327*0.75)
=0.558 lbh
=2.482 N

v. Total Lift Generated

$Lift_{total}$= Lift * N
Where, N = no. of motors
$Lift_{total}$=0.558*4
$Lift_{total}$=21.89 lbh
$Lift_{total}$=97.403 N

vi. Total Lift Required (No Load)

$Lift_{total}$=2* W
Where, W= weight of quadcopter
=2*9.81 (1kg = 9.81 N)
=19.62N

vii. Total Lift Required (With Payload)

$Lift_{total}$= 2 * W * Payload
= 2 * 9.81 * 4.905
= 29.43 N

viii. Total UAV Current

$$I_{total}=I_{motor}*N$$
$$=12*4$$
$$=48Amps$$

ix. ESC Requirement Current

$$ESC_{req}= I_{motor}*1.2$$
$$=12*1.2$$
$$=14.4A$$

x. Throttle Time

$$T_{full}\ \text{Throttle}=\frac{60*\left(\frac{c}{100}\right)*N_{Batt}}{I_{tot}}$$
$$=\frac{60*\frac{733.3}{1000}*3}{48}$$
$$=2.7498\ \text{min.}$$

5. ANALYSIS

The model is subjected to static analysis and aerodynamic analysis.

5.1 Static Structural Analysis

Static structural analysis provides data of directional deformation under static loading of 50 N containing various forces like weight of the assembly & thrust force generated by rotors. The boundary conditions for static structural analysis are shown in Fig. 5.1. Fig. 5.2 shows a frame on which 50 N of load is applied.

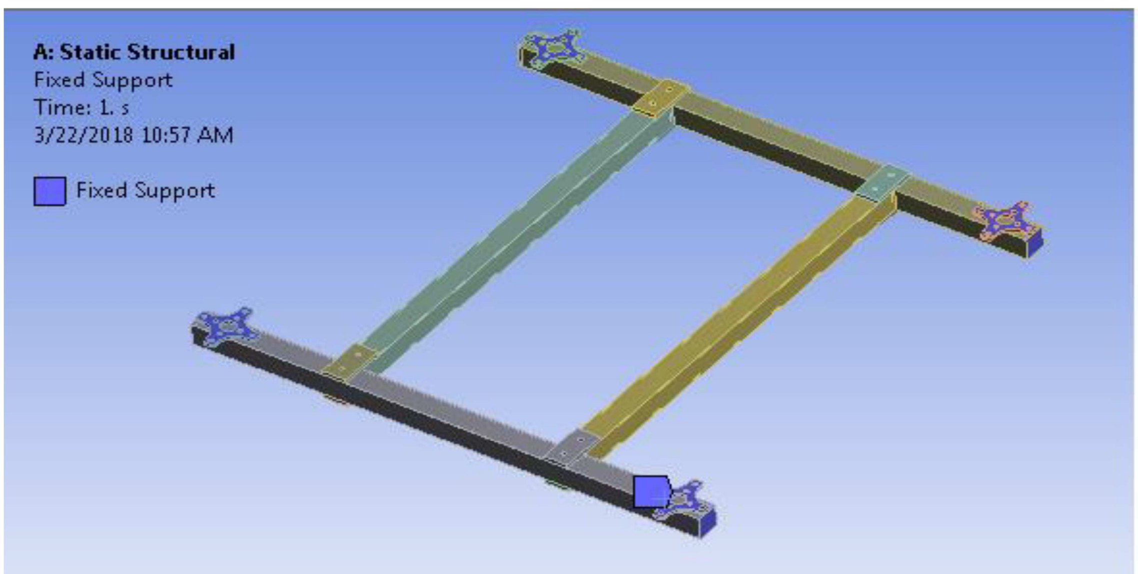

Fig.5.1.Application of boundary conditions

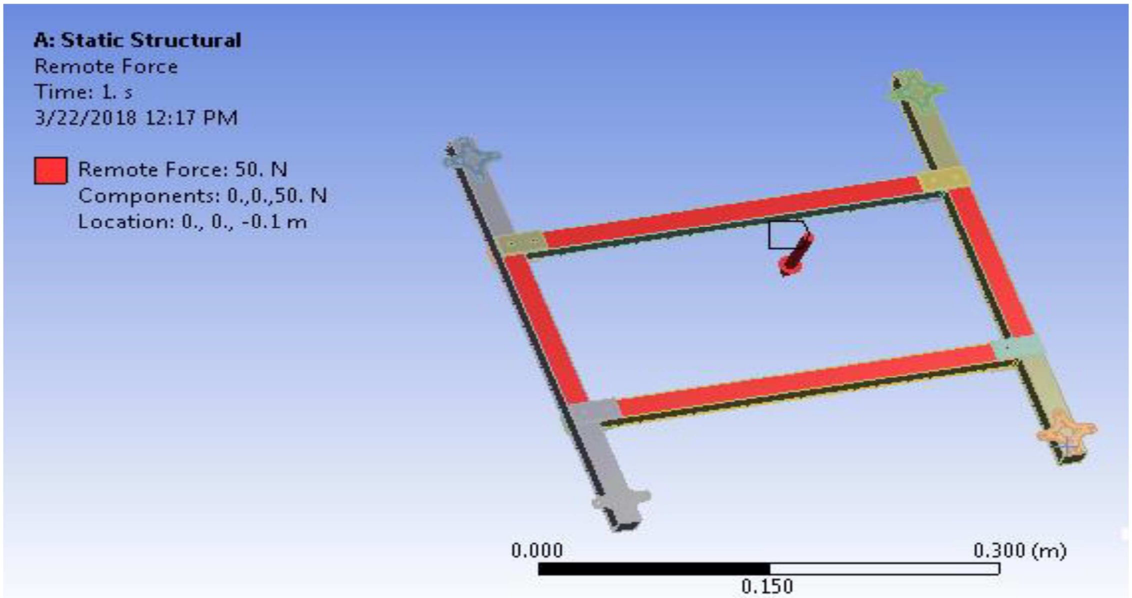

Fig. 5.2 Application of Load on quadcopter frame

5.2. Aerodynamic Analysis

Boundary conditions play key roles in CFD simulations. It is the state of fluid at which fluid enters the computational domain. Appropriate boundary conditions lead accurate results. In our work the boundary condition is taken as the fluid medium, air enters the domain with a velocity of 10 m/s.

6. RESULTS AND DISCUSSIONS

In static structural analysis, on applying a load of 50 N at the center of the frame, there is a maximum deformation of 3.5835e-5 m as shown in the Fig. 6.1. Also Fig. 6.2 shows that stress developed in quadcopter frame is 42.446 Pa (minimum) and 7.341e6 Pa (maximum).

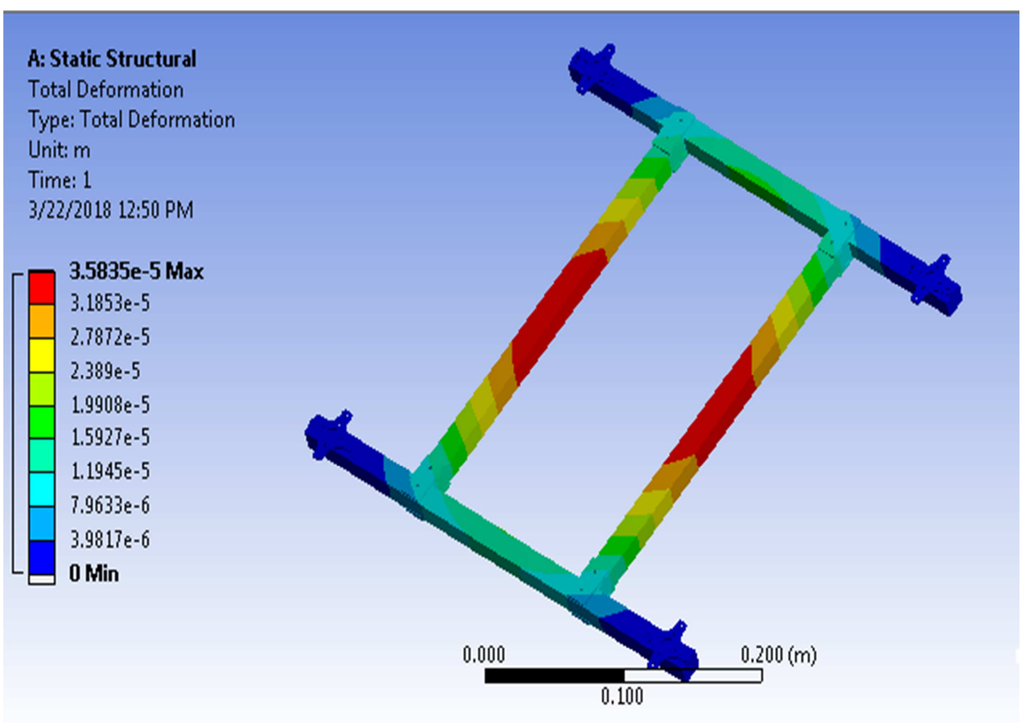

Fig.6.1 Total deformation of quadcopter frame

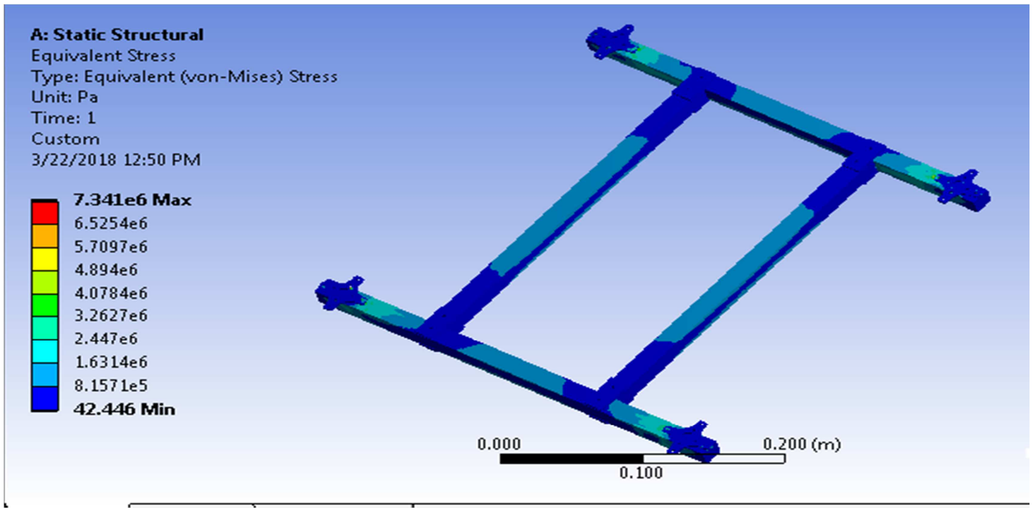

Fig.6.2 Equivalent stress of quadcopter frame

In Aerodynamic analysis; the plots for pressure, velocity and turbulence kinetic energy are very helpful to understand the behavior of air flow. The velocity, pressure and turbulence kinetic energy contours are shown in the Fig. 6.3, 6.4 and 6.5 respectively.

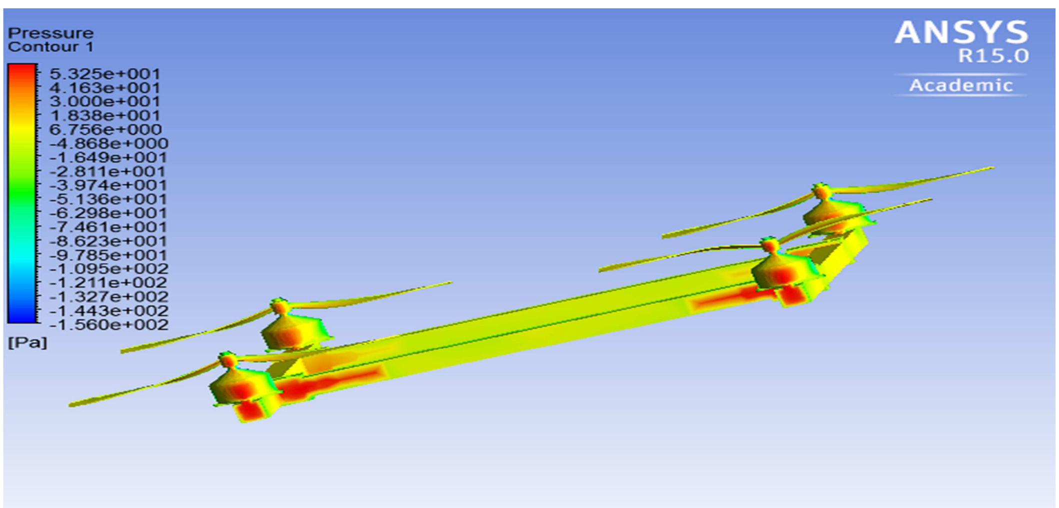

Fig.6.3 Pressure contour

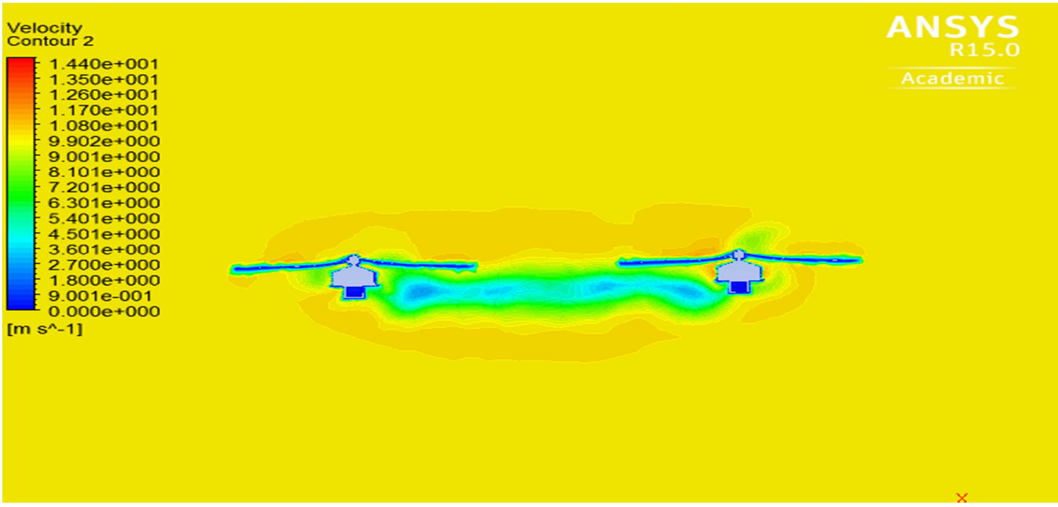

Fig. 6.4 Velocity contour

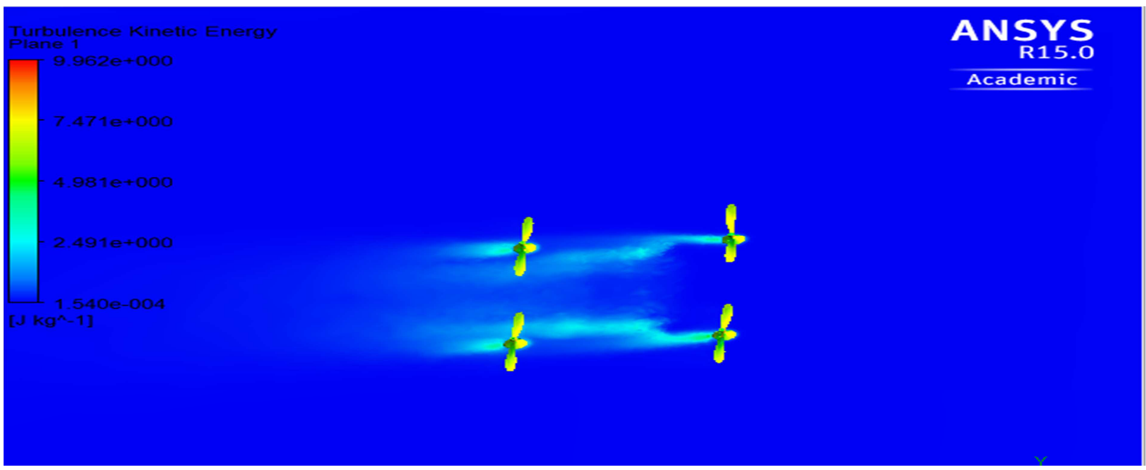

Fig.6.5 Turbulence kinetic energy contour

6.1 Graphs

The below graph, shows that coefficient value of lift in different iterations and solution converged at174 iterations with value of 0.01572 as shown in Fig. 6.6

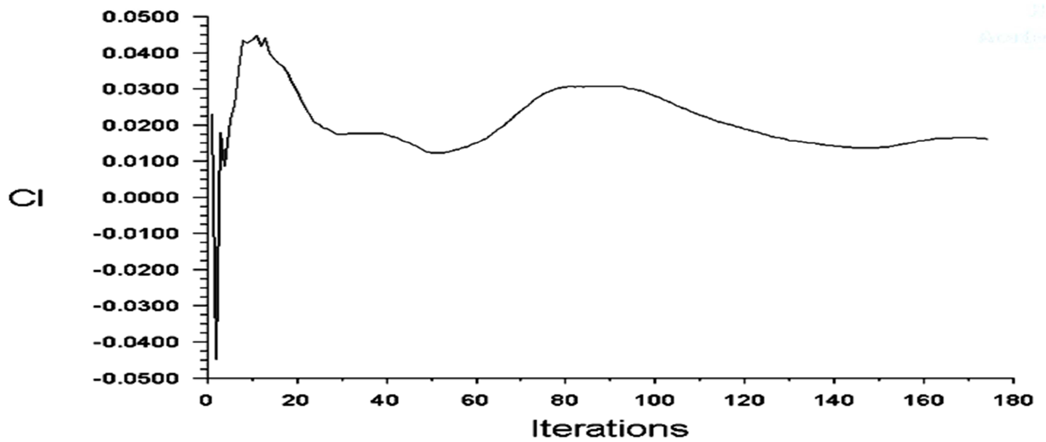

Fig. 6.6 Cl v/s Iterations

The below graph shows that coefficient value of drag in different iterations and solution converged at174 iterations with values of 1.3073 as shown in above Fig.6.7

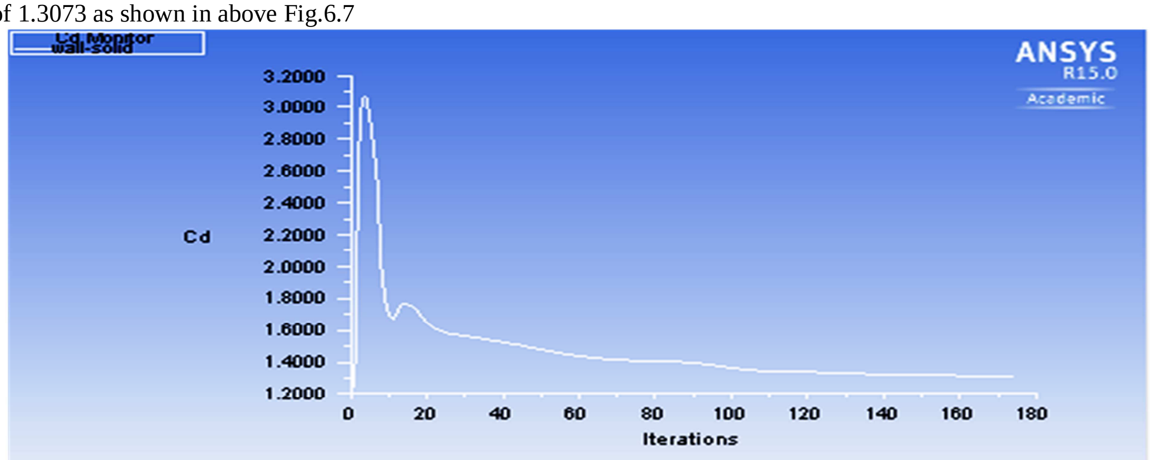

Fig. 6.7 Cd v/s Iterations

7. CONCLUSION

In our project, we have modeled the quadcopter in CATIA V5 R19 and performed both static and CFD analysis in ANSYS Software. We found that the deformation and stress results are within the permissible limit and quite satisfactory. So it is concluded that the design for quadcopter is safe.

After completing the simulation and calculation, the physical model is constructed. We have used the good avionics for fabrication of quadcopter with payload drop mechanism. Finally, the fabricated quadcopter is tested and it is confirmed that the quadcopter can fly in a stable manner.

REFERENCE

[1] Shah, K.N., Dutt, B.J., Modh, H.,"Quadrotor–An Unmanned Aerial Vehicle", International Journal of Engineering Development and Research, (IJEDR), March 2014, ISSN: 2321-9939, Volume.2, Issue 1, pp.1299-1303.

[2] Kivrak, A.O.,"Design of control systems for a quadrotor flight vehicle equipped withinertial sensors", Master's thesis,Atilim University, December 2006.

[3] Seung H. Jeong, Seul Jung, Tomizuka, M., "Attitude control of a quad-rotor system using an acceleration-based disturbance observer: An empirical approach", International conference on AdvancedIntelligent Mechatronics, 2012, Kaohsiung, Taiwan, PP.916-921.

[4] Madani, T., Benallegue,A.,"Backstepping control for a quadrotor helicopter. "BacksteppingContol for a Quadrotor Helicopter", October 2006, Proceeding of International Conference on Intelligent Robots and System, pp. 3255-3260.

[5] Hoffmann, G. M., Huang, H.,Waslander, S. L., & Tomlin, C. J.,"Quadrotor Helicopter Flight Dynamics and Control: Theory and Experiment", Proceeding of

American Institute of Aeronautics and Astronautics, 20-23 August 2007, Hilton Head, South Carolina, pp.1-20.

[6] Achtelik, M., Zhang, T., Kuhnlenz, K., Buss, M.,"Visual tracking and control of a quadcopter using a stereo camera system and inertial sensors". InternationalConference on Mechatronics and Automation, 2009, pp. 2863-2869.

[7] Santos, M., Lopez, V., Morata, F., "Intelligent fuzzy controller of a quadrotor", International Conference on Intelligent Systems and Knowledge Engineering, November 2010, pp. 141-146.

[8] Erginer, B., Altug, E.,"Modeling and PD control of a Quadrotor VTOL Vehicle", Intelligent Vehicles Symposium, June 13-15, 2007, Istanbul, Turkey, pp. 894-899.

[9] Nemati, A., Kumar, M.,"Modelling and control of a single axis tilting quadcopter", American Control Conference, June 2014, Portland, Oregon, USA, pp. 3077-3082.

[10] Bouabdallah, S., Murrieri, P., Siegwart, R.,"Design and Control of an indoor MicroQuadrotor", International Conference on Robotics and Automation", 2004, vol. 5, pp. 4393-4398.

[11] Javir, A.V., Pawar, K.,Dhudum, S., Patale, N., Patil, S., "Design, Analysis and Fabrication of Quadcopter", Journal of Advance Research in Mechanical and Civil Engineering, March 2015, ISSN: 2208-2379, Vol-2, Issue-3, Paper-3, pp. 16-27.

[12] Saharudin, M.F., "Development of tilt-rotor unmanned aerial vehicle (UAV): material selection and structural analysis on wing design", IOP Conference Series: Materials Science and Engineering, 2017

[13] Zhong, L., Yuqing, H., Liying, Y., Jianda, H., "Control techniques of tilt rotor unmanned aerial vehicle systems: A review," Chinese J. Aeronaut., 2017, vol. 30, no. 1, pp. 135–148.

[14] Franke, U.E., "Civilian Drones: Fixing an Image Problem?", ISN Blog, International Relations and Security Network, March 2015.