Modeling and Analysis of Quadcopter

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Abstract: *Quadcopter is high performance with its simple design and model. It has the characteristics of a high carrying capacity. The Quadcopter is one of the UAVs (Unmanned Aerial Vehicles) used to transport, track, record and collect information from one place to another in a short time without using too much space and cost. The quadcopter differs from other aircraft such as vertical take-off and landing (VTOL) and has features that make it a leader in applications in combat, transportation, inspections, festivals and more. The area is crowded. Quadcopter design is an essential part of its aerodynamics, and modeling and analysis are two key factors in the manufacturing process. This article focuses on the modeling and analysis of the quadcopter frame. Modeling is done in CATIA V5 software and all parts are analysed using ABAQUS software. Compare the results with the output in the quadcopter support. Although there are many negative factors affecting the performance of the Quadcopter, our work is limited to optimizing, specifying, modeling and evaluating the framework and integrating them into the whole process to achieve good results*

Keywords: Quadcopter, Aerodynamics, Design, Structural Analysis, Optimizing

I. INTRODUCTION

Demand for drones / quad helicopters is increasing in the aviation industry. In order to overcome failure in flight, it is necessary to make them strong so that they can operate in a heavy-capacity environment. The design and structure of the fuselage model play an important role in an unmanned aerial vehicle (UAV) or quadrotor that can hover vertically in a small area. The quadcopter is equipped with four engines and locked propellers to create lift. Four motors driving the fan are mounted on the end beam of the frame, which usually consists of two beams like a cross. In a quadcopter, two motors fixed in opposite directions rotate clockwise and the other two counter clockwise to take off from the ground. Each stationary motor produces the desired thrust and rotational force used to propel and propel the quadcopter. The coordination of the motors in the direction of rotation will remove all forces and maintain the same speed. While hovering on the quadcopter, some points must be observed to steer it in the desired direction. If the speed of the motors on both sides (left / right of the frame) changes while keeping the direction of the two motors the same, then there will be a "bias" in direction. Therefore, two movements, "rolling" and "pitching", are created by the rotation of the motor.

Unlike most helicopters, quadcopters use two equal amounts of constant noise; two clocks (CW) and two cycles (CCW). These use changes in RPM to control lift and power. Control of the bicycle is achieved by varying the rotational speed of one or more rotor discs, thereby changing the torque load and thrust / lift characteristics. Drones can be classified on various basis according to their "use" such as photographic drones, aerial mapping drones, surveillance drones. However, the best categorization of "drones" can be based on aircraft platforms. There are 4 main types of drones according to the type of aircraft used.

- Multi Rotor Drones
- Fixed Wing Drones
- Single Rotor Drones
- Hybrid VTOL

MULTI ROTOR DRONES

Multi-rotor drones are the most common type of drone used by professionals and hobbyists alike. Aerial photography, aerial video surveillance, etc. are used in most applications. There are many types of products in this segment of the market-for example, multi-rotor drones for professional use like aerial photography (which can cost anywhere from

$500 to $3000) and different types for hobbies like amateur drone racing or recreational flying (prices from $50 to $400). ranges from $). Among the 4 types of drones (air platform-based), multi-rotor drones are the easiest to build and also the least expensive.

FIXED WING DRONES

Fixed-wing UAVs are completely different from multi-rotor UAVs in terms of design and construction. They use "wings" like conventional airplanes. Unlike multi-rotor drones, fixed-wing drones never use energy to hover against gravity (fixed-wing drones cannot hover). Instead, they will follow the path, either on their own or with a control system (perhaps a human-operated remote) as long as their power source allows. The average flight time for most fixed-wing drones is several hours. Gas-powered drones can fly for up to 16 hours or longer. Because of their longer flight times and better fuel consumption, Fixed-wing UAVs are ideal for long-duration operations (mapping or surveillance). However, they cannot be used for aerial photography that requires the drone to stay in the air for a period of time. Other disadvantages of fixed-wing drones are the high cost and technical training required to fly them. It's not easy to blow up a winged drone. You will need a "runner" or a catapult launcher to keep the drone in the air. Again, they need a track or a helmet or a net to get them back to the ground safely. On the other hand, multi-rotor drones are inexpensive-anyone with a few hundred dollars can buy a decent quadcopter. Flying a quadcopter requires no special training. Take them out into the open air and let them fly. Learn how to steer and control your quadcopter on the go.

SINGLE ROTOR DRONES

Single rotor drones resemble helicopters in their design and structure, consisting of one large rotor and a smaller tail rotor for controlling heading. They are known for their efficiency, with longer flying times and the potential to be powered by gas engines. Aerodynamically, a lower rotor count results in less spin, making single rotor drones more stable than their multi-rotor counterparts. However, single rotor drones are also more complex and pose greater operational risks than multi-rotor drones. The large rotor blades can be dangerous if mishandled or involved in an accident, and they require special training to operate effectively. Multi-rotor drones, on the other hand, have smaller rotor blades and are less likely to cause fatal injuries, although they can still cause harm. Single rotor drones are commonly used in agriculture, surveying, and construction due to their high lift capacity of up to 40kg and greater efficiency in lifting heavy payloads while using less battery or fuel life. They can also fly faster than multi-rotor drones. While multi-rotor drones are more manoeuvrable and can hover in place, single rotor drones are better suited for lifting heavy payloads and flying longer distances. The choice between single rotor and multi-rotor drones ultimately depends on the specific needs and requirements of the user, as well as their level of training and expertise in operating these machines

HYBRID VTOL

Hybrid VTOL drones combine the benefits of fixed-wing and rotor-based models, allowing for both hovering and longer flying times. While this concept was first explored in the 1960s, it has seen renewed interest with the development of new sensors such as gyros and accelerometers. Hybrid VTOLs operate using a combination of automated stabilization and manual control. They typically use vertical lift to take off and rely on gyroscopes and accelerometers to maintain stability in the air. Manual control is then used to guide the drone along a desired course.

There are various versions of hybrid fixed-wing models available in the market, but the most well-known is likely the drone used in Amazon's Prime delivery service commercials. These types of drones are highly versatile and can be used for a range of commercial and military applications. The hybrid fixed-wing/VTOL configuration combines the benefits of both fixed-wing and rotary-wing UAVs in one model.

VTOL, or vertical take-off and landing, refers to the ability of an aircraft to take off, hover, and land vertically. This can be achieved using a helicopter design or a multirotor design with four or more propellers. Examples of VTOL aircraft include the F35B fighter jet and various types of UAVs.

II. LITERATURE REVIEW

D. Deva Prakash discusses the design of a quadcopter using the PID control algorithm. Here, a low-cost hover control mechanism is designed and implemented on a microcontroller. Because the quadcopter is hovering by itself at a fixed level on the ground, flight control is easier while also making it much easier to manoeuvre at high altitudes and work like photography. A PID control method has been developed for quadrotor flight stability. The model has four power inputs, the main input being the thrust provided by each propeller connected at an angle to each rotor. We will get the pitch, roll and yaw sound of the quadcopter by changing the speed of the front and rear motors. Improvements may be made in the future to improve the design to demonstrate its ability to produce small UAVs that can meet the needs of the military as well as industry and business.

D. Hanafi Simplified GUI Wireless Quadcopter Controller Remote Operated Quadcopter Development. The quadcopter is controlled by a Graphical User Interface (GUI) where communication between the GUI and the quadcopter is established using wireless communication. Quadcopter stability is detected by the FY90 controller and the IMU 5DOF sensor.All signals from the sensors are processed by the Arduino Uno microcontroller board, and the output of the Arduino Uno microcontroller board is used to control the quadcopter propellers. The GUI was developed using Visual Basic 2008 Express as an interface between the proportional, integral and derivative (PID) controller and the quadcopter system. Tests show that the quadcopter system can move and maintain balance, and stability is guaranteed. In addition, the construction process can withstand impact loads of up to 250 g in the suspended position. With a 2200 mAh Li po battery, the Quadcopter has a maximum operating time of 6 minutes, and the operating time can be increased by using the maximum capacity.

K.Sowjanya and S.Suresh presented a research paper on the analysis of unmanned aerial vehicles. A drone is an activity for the movement of the body. Drones are made of either cast iron or aluminium composite. These are selected by performing various tests on software such as Pro/E (Creo-Parametric) for good modelling and static analysis is done by CAD/CAE software.

Vivek Singh Negi examines the concept of using different parameters in a system, the design and the rationale behind choosing the right approach. The UAV system mechanics model includes the evaluation of many situations and uses it to arrive at the ideal but forced UAV. Determining the data used to eliminate the usual estimates of the design makes assumptions that are in some cases considered as reasonable as possible.

III. MAIN OBJECTIVES

- To study Quadcopter
- Modeling of Quadcopter frame using Catia V5
- Carrying out analysis on quadcopter frame with Carbon Fibre Composition and Aluminium in ABAQUS software.

IV. HARDWARE COMPONENTS OF QUADCOPTER

The different components mounted on quadcopter are:
- DC Motors
- Propellers/ Fans
- Electronic Speed Controllers (ESC's)
- Lithium-Ion Polymer (LiPo) Battery
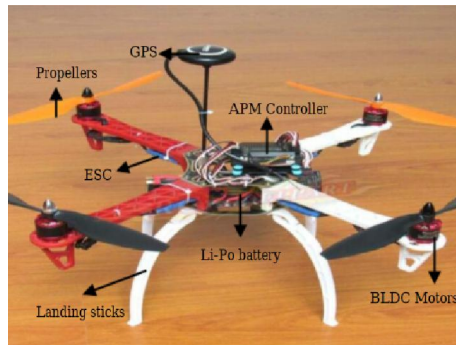- Radio transmitter and receiver
- APM Controller

FIGURE 1. Components of Quadcopter

V. MODELING OF QUADCOPTER

The modeling of Quadcopter frame is carried in Catia V5by taking into considerations the safety requirements, smooth functioning and optimum utilization of propellers, motors and electrical equipment. Central Hub and Bracket is given with 10mm thickness and Arm is given with 6mm thickness.
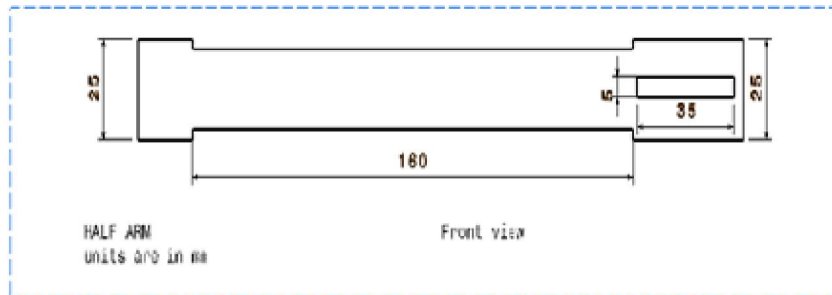
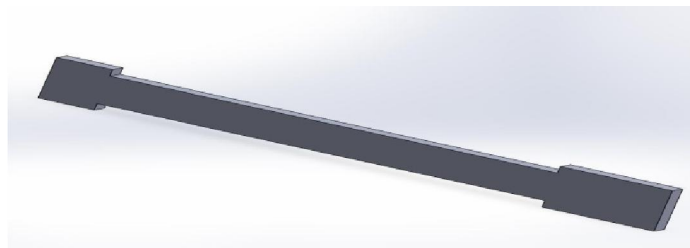

FIGURE 2. Sketch of Quadcopter Arm in CATIA V5
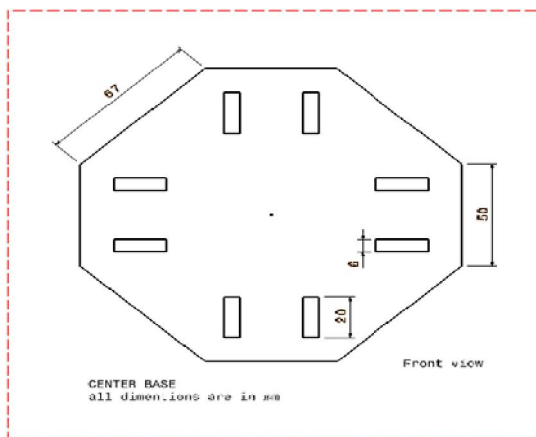

FIGURE 3. Model of Quadcopter Arm in CATIA V5

FIGURE 4. Sketch of Quadcopter Central Hub   **FIGURE 5.**Model of Quadcopter Central Hub
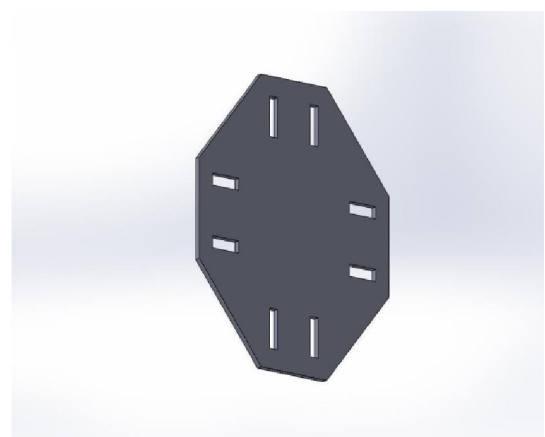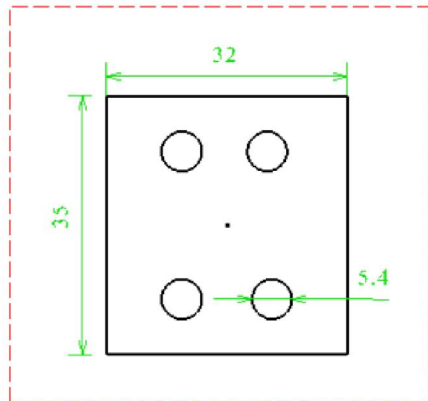
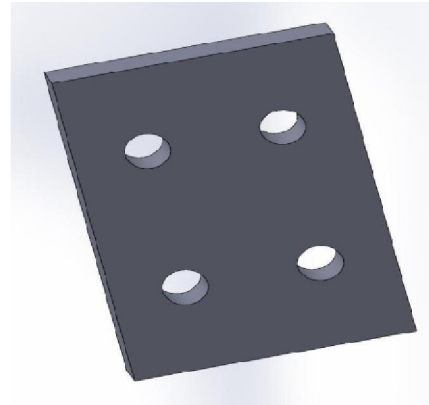**FIGURE 6.**Sketch of Quadcopter Bracket

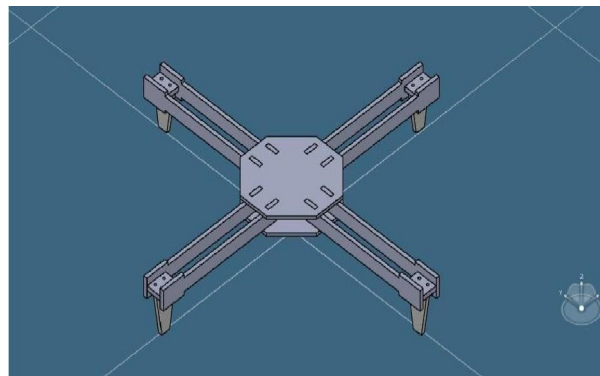**FIGURE 7.**Model of Quadcopter Bracket

FIGURE 8. Assembly of Quadcopterin CATIA V5

VI. ANALYSIS OF QUADCOPTER

The manuscript describes the various subsections that are present in the Abaqus/CAE workspace. These sections include:

- The Viewport: This is the primary output screen of Abaqus/CAE which is used for visualizing pre- and post-processing data.
- The Model Tree View: This section displays all the essential modeling steps in the form of tree nodes. Each node is further divided into multiple sub-nodes that offer corresponding functionalities.
- The Toolbar Section: Each node in the Model Tree View has a related toolbar that allows the user to access relevant forms.
- The Prompt Region: When the user selects a function, command buttons and tips appear on the prompt region to assist in carrying out the task.

Steps to perform Static analysis in Abaqus software:

STEP 1: FILE DEFINITION

To begin working on Abaqus, open the software and create a new model database. It's important to save your work at regular intervals during your session.

STEP 2: GEOMETRY DEFINITION

To import a part into Abaqus, first, go to the "File" option in the status bar and select "Import". Then, select "Part" and choose the "STEP" file format in the file filter to view all the parts saved in the STEP format. Next, select the desired file and click "OK" to import the part into Abaqus.

STEP 3: MATERIAL DEFINITION

To define a new material in Abaqus, follow these steps:

1. Double-click on the "Materials" node in the model tree.

2. Right-click on the material library and select "Create Material" from the drop-down menu.

3. Enter a name and description for the new material.

4. Click on the "Mechanical" tab and select "Elasticity" from the drop-down menu.

5. Select "Elastic" from the list of available models.

6. Enter appropriate values for the Young's Modulus and Poisson's ratio for the material.

7. Click "OK" to save the new material.

S.NO	MATERIAL NAME	YOUNGS MODULUS(MPa)	MASS DENSITY (t/m m3)	POISSONS RATIO
1.	Carbon fibre composite	90500	1.55×10^{-9}	0.25
2.	Aluminium	6900	2.7×10^{-9}	0.30

TABLE 1. Material Properties

STEP 4: SECTION ASSIGNMENT

To assign a section to the model, follow these steps:

1. Double click on the Parts node in the Model Tree.

2. Double click on Section Assignments.

3. In the model viewport, select the elements to which the section will be assigned.

4. Choose the section created earlier from the combo box.

5. Click OK.

By completing these steps, each line entity in the model will be attributed with the section property that was assigned.

STEP 5: MODEL INSTANCE

Under the Build node in the Model Tree, double-click Instances. Select Independent for the instance type, then click OK.

STEP 6: MODEL MESH

To begin meshing, double click on the Mesh node under the Part in the Model Tree. Next, click on the Assign Element Type icon in the toolbar and select Standard for the element type. Choose 3D stress for the element and Linear for the element shape to define a four-node element. Click OK to confirm. In the toolbox area, click on the Seed Edge: By Number icon (hold down the icon to bring up other options), and select the entire geometry. Click Done in the prompt area and define the number of elements along the edges as 1. Press Enter in the prompt region and then click Done in response to the next prompt. In the toolbox area, click on the Mesh Part icon and then click Yes in the prompt area to mesh the instance.

STEP 7: ANALYSIS TYPE DEFINITION

To define the analysis type in Abaqus/CAE, start by double-clicking on the Steps node in the Model Tree. This will open the Create Step form where you can select the appropriate analysis type. For a linear static analysis, select "Static, General" from the list box. Click on "Continue," and then name the step before clicking "OK" to close the form. If you are performing a large displacement analysis, make sure to check the "Nlgeom" radio button.

STEP 8: BOUNDARY CONDITIONS

Double-click the BC node in the Model Tree to open the Create Boundary Condition form. Assign a name to the boundary condition and select Displacement/Rotation as the type. Click Continue and then select the nodes where the boundary conditions should be applied. Read the messages appearing in the prompt area and click Done. In the form,

choose the degrees of freedom that you want to restrict and set their values to zero. The boundary condition will be applied by clicking on the OK button.
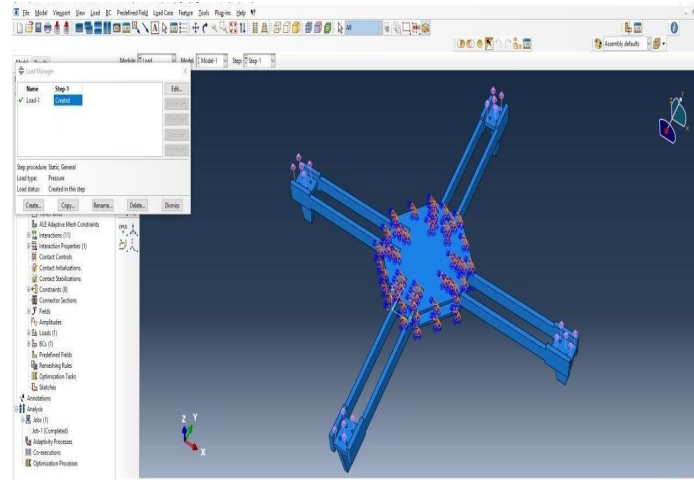

FIGURE 9. Boundary Conditions

STEP 9: LOADS

Double-click on the Loads node in the Model Tree, name the load, and select the appropriate load type (e.g., pressure, force, moment). Click Continue and select the appropriate geometry to apply the load to, then click Done in the prompt region. In the next form, specify the magnitude and direction of the load and click OK to apply it.

Loads: Total load to be applied on quadcopter can be mentioned here. Here we applied 10 N at each free end of the quadcopter arm for the experiments.
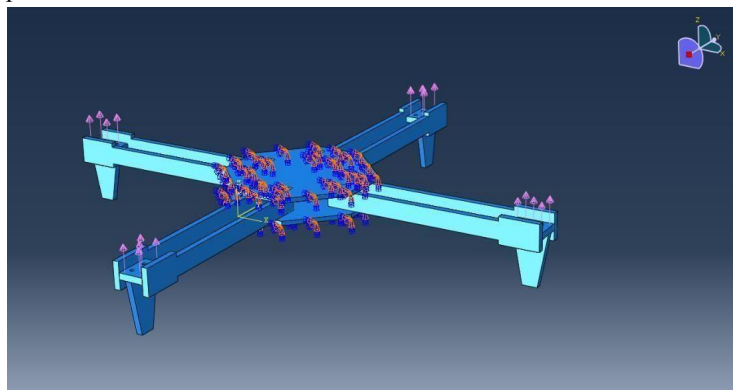

FIGURE 10. Loads applied on arms

STEP 10: CREATE JOB AND RUN ANALYSIS

To start the analysis in Abaqus, double click on the Job node in the Model Tree, name the job, and click on Continue and then OK. Then, click on the Job Manager in the toolbar and press Submit to start the analysis. During the analysis, you can monitor the progress by right-clicking on the submitted job and selecting Monitor. Once the analysis is complete, you can view the results by clicking on the Results tab to open the Visualization module of Abaqus
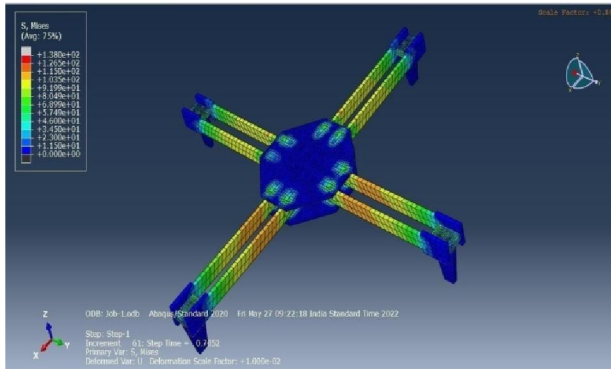
VII. RESULTS

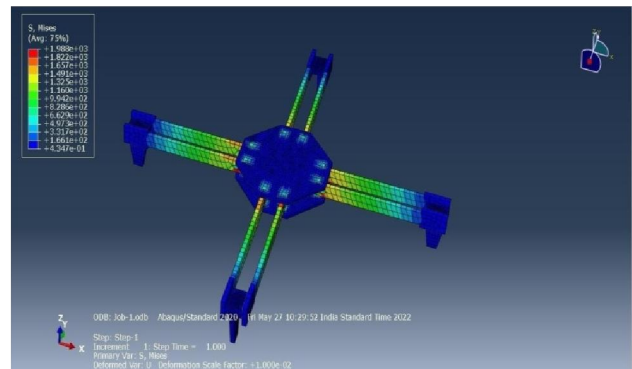**FIGURE 11.**Stress generated in Carbon Fibre Composition

FIGURE 12. Stress generated in Aluminium

After comparison of stresses in both materials, the stresses generated in carbon fibre composite is lesser than the aluminium.
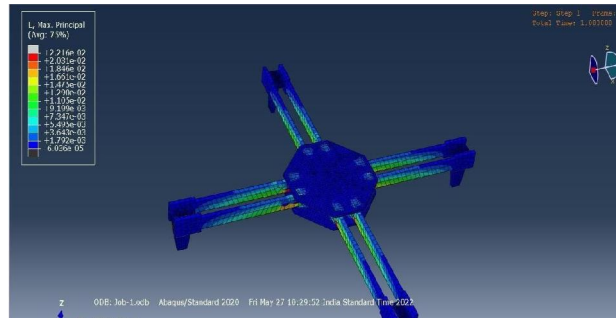

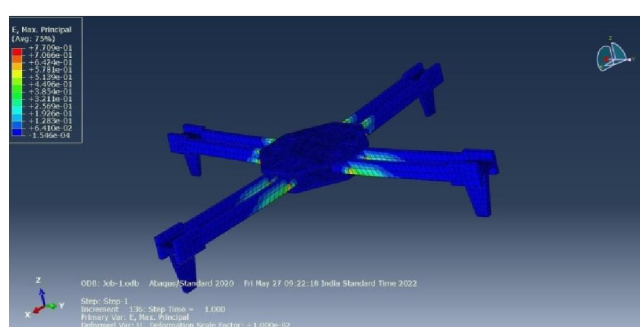**FIGURE 13.**Strain generated in Carbon Fibre Composition

FIGURE 14. Strain generated in Aluminium

After comparison of strains in both materials, the strains generated in carbon fibre composite is lesser than the aluminium.
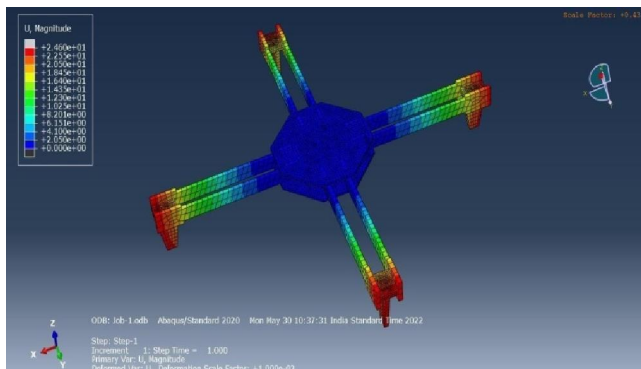

FIGURE 15. Deformation in Carbon Fibre Composition
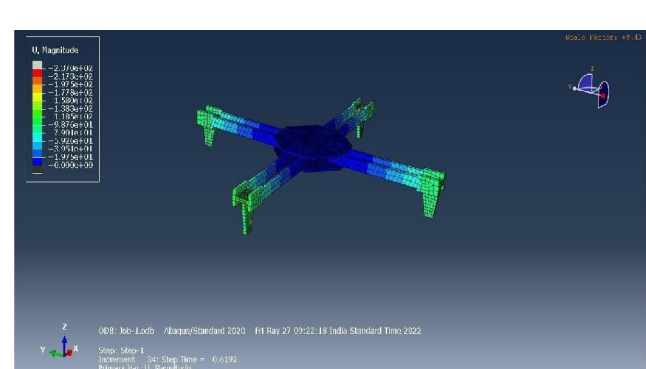

FIGURE 16. Deformation in Aluminium

After comparison of deformation in both materials, the deformation in carbon fibre composite is greater than aluminium.

COMPARISON OF RESULTS

S.NO	MATERIAL	STRESS(N/mm2)	STRAIN	DEFORMATION (mm)
1.	Carbon fibre composite	1.380×10^2	2.216×10^2	2.460×10^2
2.	Aluminium	1.988×10^3	7.709×10^2	2.370×10^2

TABLE 2.Comparison of results

VIII. CONCLUSION

In this work, the quadcopter of having parts of central hub, arms, bracket has been designed by using CATIA-V6 software. Furtherly, we did analysis by using Abaqus software. Finally, we calculated static stress, strain and deformation generated in quadcopter. This Structural Analysis of the carbon fibre leads to the following conclusions:

- Vibration got reduced when compared to the plastic UAVs.
- There is no effect to the rotor's propellers and other electrical components by using this design.
- The strength and resistance capacity are increased.

REFERENCES

[1] D. Deva Prakash and P. Ananthachristu Raj Design Of A Quadcopter Using PID Control Algorithm, vol-1 , 2014.

[2] D. Hanafi, M. Qetkeaw, R. Ghazali, M. Than, W. Utomo and R. Omar, "Simple GUI Wireless Controller of Quadcopter," International Journal of Communications, Network and System Sciences, Vol. 6 No. 1, 2013.

[3] K. W. Weng, "Quadcopter," Robot Head to Toe Magazine, Vol. 10, 2011. • Quadcopter design and Implementation, Gaponov. I, TALE, IEEE International conference, 2012.

[4] L. Salih, M. Moghavvemil, H. A. F. Mohamed and K. S. Gaeid,"Flight Pid Controller Design for A UAV Quadcopter," Scientific Research and Essays, vol 5(23), pp.3660-3667,December 2010.

[5] 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.

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

[7] 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 Advanced Intelligent Mechatronics, 2012, Kaohsiung, Taiwan, PP.916-921.

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