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MATERIAL SELECTION FOR LIGHT WEIGHT DELIVERY DRONE

Poras A. Nagmote[1], Dr. Prashant Kadu[2], Shantanu D. Munghate[3]

[1]*Student, Department of Mechanical Engineering, AGPCE Nagpur, Maharashtra, India,* ***porasn7@gmail.com***
[2]*Principal, Department of Mechanical Engineering, AGPCE Nagpur, Maharashtra, India,* ***pskadu3@gmail.com***
[3]*Student, Department of Mechanical Engineering, AGPCE Nagpur, Maharashtra, India,* ***shantanu.cci@gmail.com***

Abstract

Delivery using drones has been the prime talk in the domain of drone application. The Delivery drones are quite sturdy and require a strong as well as a light structure. There are different materials that are being used to design and manufacture the frame. Some of these materials include aluminium, composite materials and different plastics. In this paper four different materials viz. Ultrahigh modulus carbon fibre, Kelvlar-49 Aramid, S-glass composite and Aluminium are used and analyzed using a hexacopter drone frame designed in CATIA V5. The Aluminium has found to be having the highest strength while Kevlar-49 Aramid is selected since it has lower density and has all the stresses under the safety limit.

Index Terms: *Aluminium, Carbon Fibre, Composites, Drone-Frame, Hexacopter.*

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1. INTRODUCTION

Delivery using is one of the most trending topics. Designing the drone usually comes with the task of selecting the appropriate components. The light weight delivery drone like all multirotor drone is made up of a frame structure to support the payload; Propellers, motors and relevant electronic components; a power module; Receiver transmitter system and sensors to aid the delivery process. Considering the layout and number of rotors used the drone can be classified into a quadrotor, hexarotor, octarotor etc. Each motor/rotor is supported by an arm structure and hence the inference that the number of motors is equal to the number of arms holds true in most of the cases. Adding a certain number of rotors increases the thrust but it also increases the weight and power consumption. To find the right balance between number of rotors and required thrust is important.

After selecting these components, the design should be tested mechanically i.e. the strength of the design, optimum material for design etc. The frame is the most important element considering the structural and mechanical stability of the drone. The commonly used materials are Aluminium, wood and Composites such as Carbon Fibre Polymer Resin, Epoxy Glass, Kevlar etc. The Composites provide larger strength at more density but are expensive to create whereas Aluminium provides almost the same amount of strength and is comparatively cheaper. The density of Aluminium adds more weight to the structure which requires propulsion system to be re-selected. The reselected system might require more power as well as new components. Hence it requires a complete balance of both strength and density.

The materials usually used for the design of the drones requires to be light weight and of strength to support the entire structure of the drone. The Composites provide larger strength at more density but are expensive to create whereas Aluminium provides almost the same amount of strength and is comparatively cheaper. The density of Aluminium adds more weight to the structure which requires propulsion system to be re-selected. The reselected system might require more power as well as new components. Hence it requires a complete balance of both strength and density

2. LITERATURE SURVEY

Satra, M. K., & Shetty, S. (2017) [1] The author gives two designs for customized quad copter frame, carbon fibre tubes for hybrid frame and the pure 3D printed frame and parts. In this paper author discussed about the comparison between two approaches by comparing the weight and efficiency parameters. In this paper Author provides the relatable information to design a quadcopter frame using 3D printing technology. Author states that this research can be extended by using different materials in 3D printing technology.

Bowkett, M., Thanapalan, K., & Constant, E (2018) [2] In this paper the method of damage detection in carbon composites in drone frame is mentioned. During the flight if damage is detected in the quadcopter frame then a response is started in quadcopter flight control and the four-arm control is switched to three arm control system. Due to this quadcopter attains improved stability during flight. In this paper author gives the early error detection technique which offer minimal overhead approach and low cost by using flexible design. All the test performed on samples are 100% successful when failure occurred in the system. Benefit of damage detection helped in maintaining flight and lowers the damage caused by drone crash landing. Author also mentioned about the dual drone model which has similar properties as drone failure model. The test suggests that X frame is less prone to damage and the symmetrical weight distribution is favourable in case of impact. While H frame damage can be minimized using the technique enlisted by the author.

Sharma, P., & A, A. S. (2018) [3] In this paper the design of drone is proposed by checking its affinity with land, water and air. Physical contacts or drone and gravity is also considered. Weight carrying capacity of drones is also calculated by increasing the weight in drones in simulation until the drone fails to fly. Various other factors were also studied like structural integrity , landing capability and stress to make sure that drone don't fall from height. Author found that during the flight at any point thrust-rpm-speed plotter helps in getting exact value of thrust. This simulation gives a stress value of 34.3 MPa, while 42-45 MPa is the limit for ABS. When the weight is increased the rise in maximum stress can be seen but it is in the permissible limit. The analysis indicated that if we increase component on the drones it can easily handle this stress without any visual failure.

Eid, S. E., & Sham Dol, S. (2019). [4] In this paper author explained about the design and development of small sized drone which can be used to delivery floating device to the worker drowning during their offshore work like oil rigs. For this purpose, their drone gone through various frame test to get efficient frame design. For examining the structural integrity and flight endurance for a long period of time a computational study of this drone is done. As the location of this places are at remote areas so the flight endurance of the drone is highly tested. By using Acrylic material to design a drone with giving importance to the flight endurance and structural integrity. After passing the stress analysis this drone can be used to deliver flotation device.

Luke S. Dai et al (2016).[5] In this paper there are two objectives that the author is accomplish the first being to understand the physics of quad copter drone and 3d printing. The second objective is an attempt to find whether the 3d printing can be used to manufacture the drone. The author is using polylactic acid (PLA) and Acrylonitrile butadiene styrene (ABS).
The author found out ABS plastic is better than PLA .while designing frames , stress test is important to understand location of structural weak points where vibration and mechanical stress. hence these points must be of concern while design.

Suprapto, B. Y., Heryanto et al [6] In this paper while designing the hexacopter author used the stainless-steel frame. The conducted analysis shows the maximum displacement value of 0.302 mm and maximum von-misses stress is 14.149MPa which is quite less as compared to the values under factor of safety. While using this configuration, the hexacopter was could attain the height of 26m for the flight time of 15 min with payload weighing 15kg.

Likitha Thimmaraju Girijadevi et al [7] The subject of analysis of this paper is an hexacopter with a lifting requirement of 1.5 kg payload. The selected material for the analysis is Aluminium Alloy 2024. The design has RF values extending beyond 1.5 which is where author suggests the possibility of optimization in design and further weight reduction and the analysis validates the quadcopters capability of lifting heavier payload.
Alberto Martinetti et al [8] The paper simulates the mechanical stresses on the UAV quadcopter frame in order to predict failure and weak sections. After analysing the frame for mechanical stresses, the analysis is done for maintenance approach. Two materials were chosen for analysis Carbon Fibre and ABS plus plastic. For Carbon Fibre, stress value is 38 MPa. While the displacement is 3.2 and 6.5 mm for ABS plus plastic and Carbon Fibre respectively. Checking the connection between connectors of frame and arms and using shock absorbers on landing gears to reduce stresses and vibration isolation these were the suggested maintenance actions.

3. COMPONENT SELECTION

The component selection is an important step while considering the loading parameters and thrust requirement. The thrust requirement shall be satisfied by the motor propeller assembly and the necessary power should be provided by the battery. Also, the frame designed for this particular assignment shall not have any propeller interference and should be strong enough to support the loading. The selection process is followed in such a way that the components selected shall be able to satisfy the thrust criteria and the weight shall also be the part of thrust required.

Table 3.1 Component Selection

Component	**No. of Components**	**Aggregate Weight (in grams)**
T-Motor MN5212 420KV	4	1092
T motor Propeller 18x6 1CF	4	129
ESC Flame 60A HV	4	141
8S 29.6V 16000mAh LiPo	1	510

Battery		
Weight of Designed Frame	1	840
APM 2.8 Flight Controller	1	82
Electronics Components. Sensors and Wires	-	246
Landing Gear	4	200
	Total Weight	3240

Required Thrust per motor= (Thrust to Weight Ratio) (Weight of Assembly + Weight of Payload)/6

= 3 (3240+3000)/6

=3120g =30.61N

CAD Model:

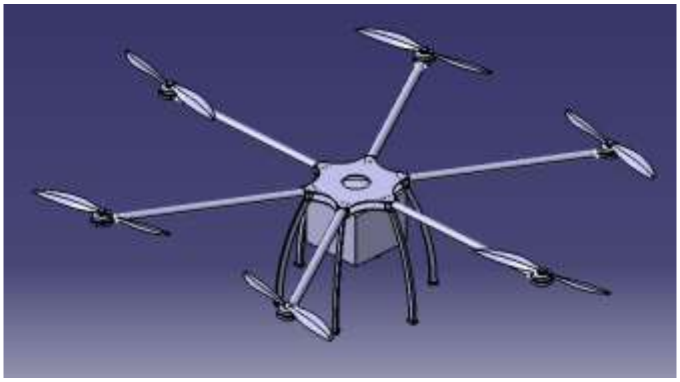

Fig.3.1 CAD model

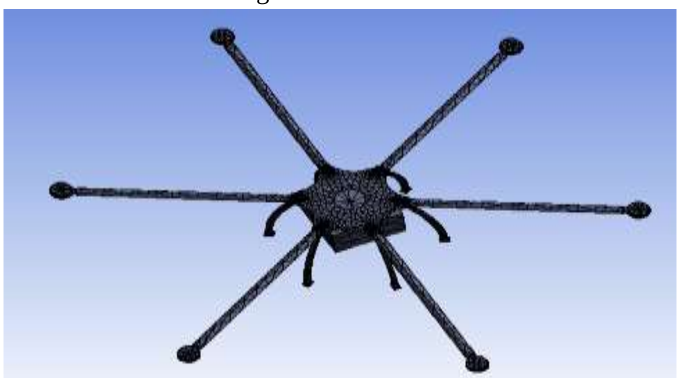

Fig.3.2 Meshed Geometry

The CAD model was prepared in CATIA V5. The geometry is simple and hence the meshing obtained was optimal with 51122 nodes and 24952 elements.

4. MATERIAL SELECTION AND ANALYSIS

Highly strong composites and 1 most commonly used metal was analyzed under the loading conditions of the currently adopted system to find out the optimally performing material. The Kevlar, Carbon Fibre and S-glass epoxy composites provide optimum amount of strength at less density and aluminium provides similar strength values at more density. The composites are known for their directional properties unlike the metals. The embedded fibre or elements within another substance enhances the directional properties of composites. That's why it becomes important to analyze the composites comparing that of metals in order to find out the optimally performing material.

The material properties were applied in the Ansys material database and the geometry was imported. Appropriate meshing was utilized for proper discretization which were refined in order to get necessary mesh quality and the boundary conditions were imparted. The loads were applied to the motor and propeller assembly in the direction of thrust and the weight of body was made to act through the centre of gravity. After applying boundary conditions, the solution was performed by the inbuilt solver. The results were obtained in 3 different quantities namely equivalent stress, equivalent strain and total deformation in order to analyze the pattern of effect of loads on the drone body.

Table 4.1 Material Properties

Constants	**Kevlar 49 Aramid/ Epoxy UD Composite**	**Ultrahigh Modulus Graphite/Epoxy UD Composite**	**S-Glass/Epoxy UD Composite**	**Aluminium**
Young's Modulus (GPa)	76	290	55	70
Bulk Modulus (GPa)	5.5	6.2	16	68.63
Shear Modulus (GPa)	2.1	4.8	7.6	26.32
Poisson's Ratio	0.34	0.25	0.28	0.33
Density (Kg/m^3)	1380	1700	2000	2700

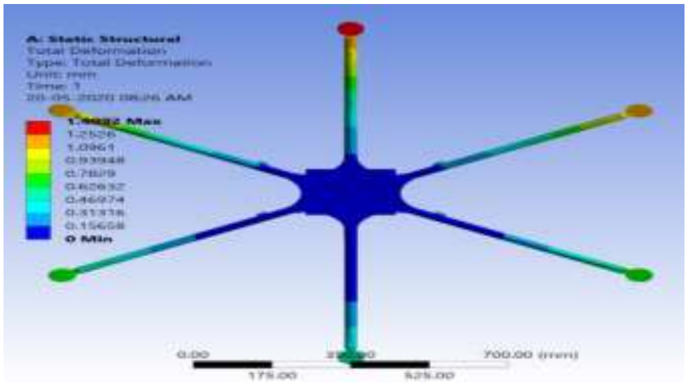

Fig 4. 1 Aluminium: Total Deformation

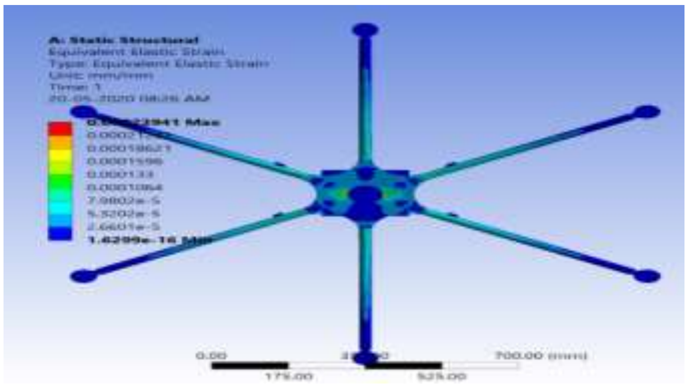

Fig 4. 2 Aluminium: Equivalent Elastic Strain

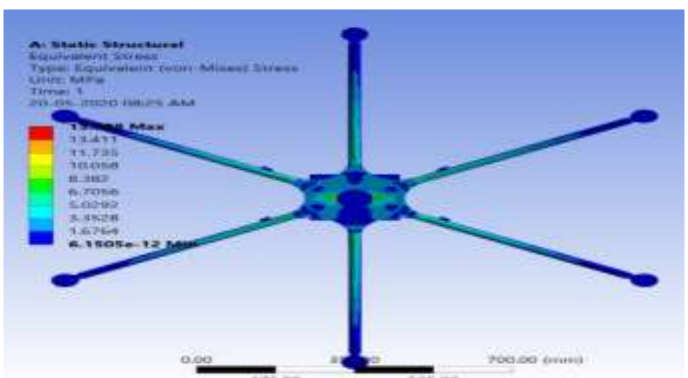

Fig 4. 3 Aluminium: Equivalent Stress

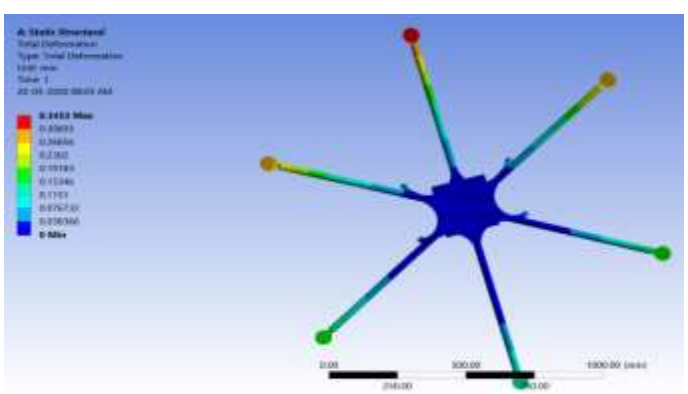

Fig 4. 4 Carbon fibre: Total Deformation

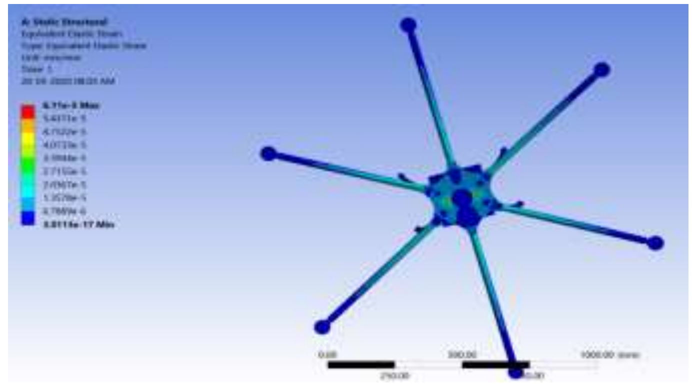

Fig 4. 5 Carbon fibre: Equivalent Elastic Strain

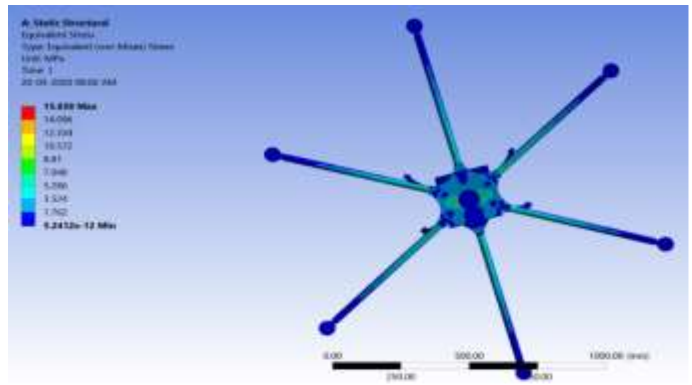

Fig 4. 6 Carbon fibre: Equivalent Stress

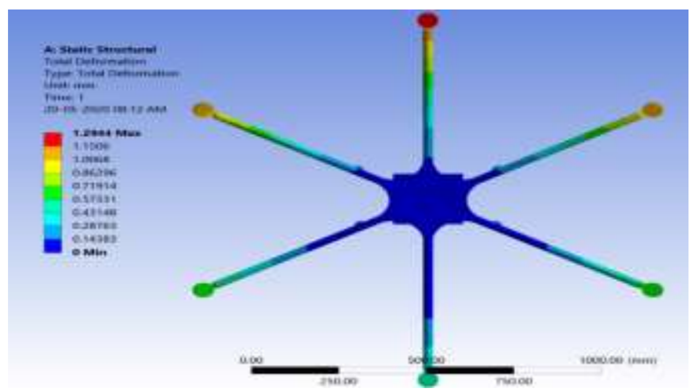

Fig 4. 7 Kevlar: Total Deformation

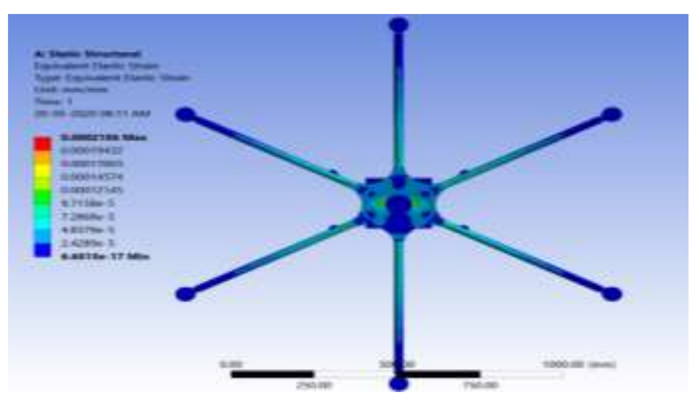

Fig 4. 8 Kevlar: Equivalent Elastic Strain

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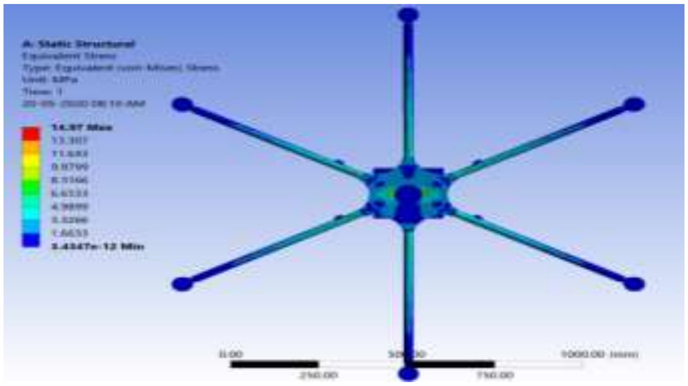


Fig 4. 9 Kevlar: Equivalent Stress

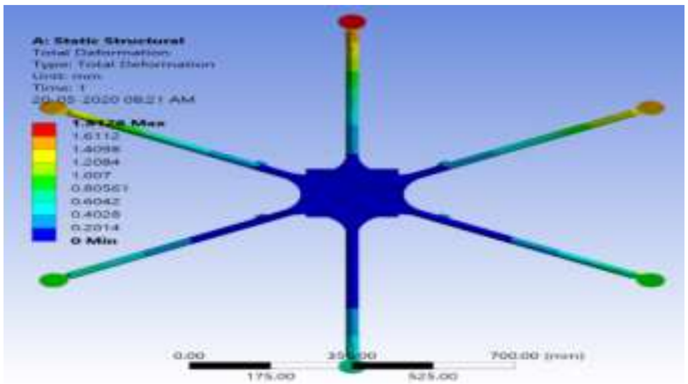


Fig 4. 10 S-glass: Total Deformation

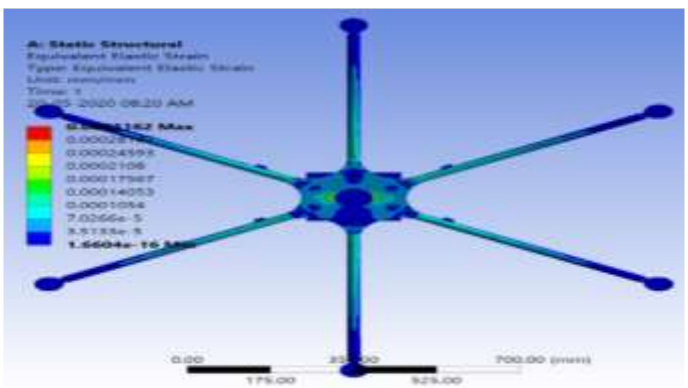


Fig 4. 11 S-glass: Equivalent Elastic Strain

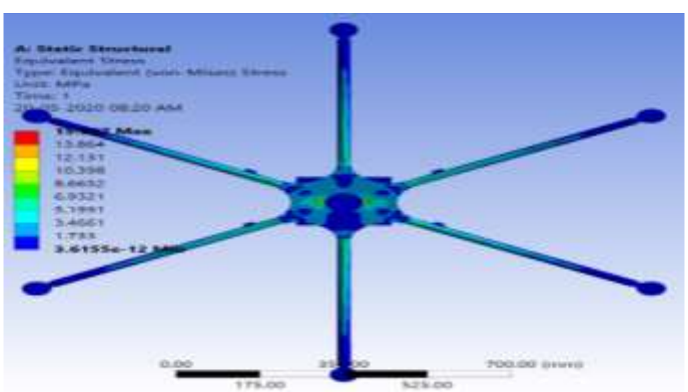
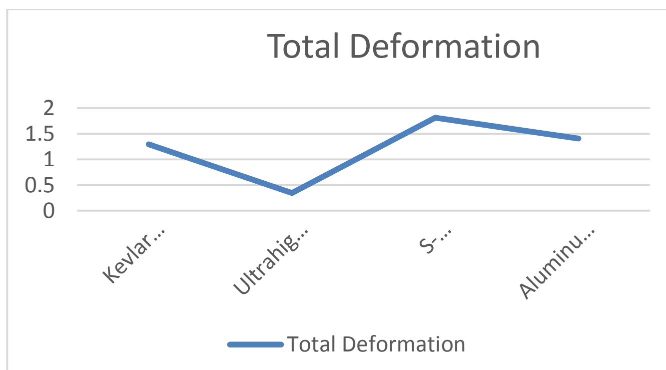


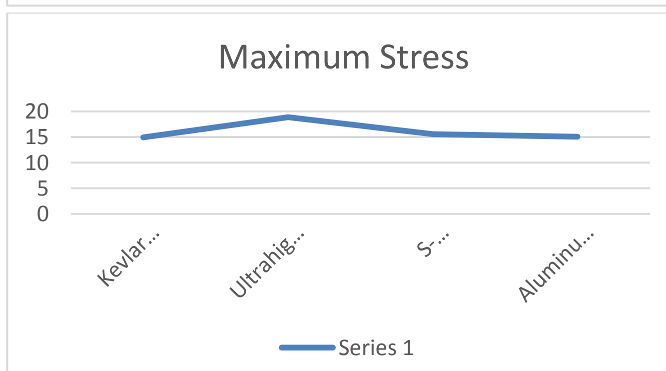
Fig 4. 12 S-glass: Equivalent Stress

Table 4.2 Structural Analysis Results

Material		Equivalent Stress	Equivalent Strain	Total deformation
Kevlar 49 Aramid/ Epoxy UD Composite	minimum	3.4347E-12	6.6815E-17	0
	maximum	14.97	2.186E-4	1.2944
	average	0.88795	1.802E-5	0.35436
Ultrahigh Modulus Graphite/Epoxy UD Composite	minimum	5.2412E-12	3.0113E-17	0
	maximum	18.858	6.11E-5	0.3453
	average	0.88768	3.6574E-6	9.4199E-2
S-Glass/Epoxy UD Composite	minimum	3.6155E-12	1.6604E-16	0
	maximum	15.597	3.162E-4	1.8125
	average	0.88758	1.9209E-5	0.4948
Aluminium	minimum	6.1505E-12	1.6299E-16	0
	maximum	15.088	2.3941E-4	1.4092
	average	0.88784	1.5002E-5	0.38553

5. RESULT AND DISCUSSION





Graph 5. 1 Total Deformation and Maximum Stress vs. Materials

The graph shows that Carbon fibre material even after having the highest stress which is almost near to the other 3 materials while the total deformation is minimum for the carbon fibre. The Kevlar 49 also shows the better properties also has the least density of the other selected materials. Hence Kevlar 49 shall be selected as the material for the drone.

6. CONCLUSION

The drone is designed and the design is found to be optimum under the mechanical loading. This particular configuration is designed for the particularly 3:1 thrust to weight ratio. This particular ratio can provide more mobility in this particular application which is essentially required considering the obstacles that may occur in the trajectory of drone travel.
Kevlar 49 Aramid/ Epoxy UD Composite that is selected for the drone assembly shows the most optimum results along with lower density. This can open new dimensions for the materials that are currently being used in the drone industry

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