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DESIGN AND ANALYSIS OF ENGINE MOUNTING FRAME OF AN UNMANNED AERIAL VEHICHLE

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Abstract

This paper basically deals with design and analysis of engine mounting frame. This frame provides an interface between engine and landing gear to the wing of an Unmanned Aerial Vehicle (UAV).
The structure basically comprises of three bulkheads namely front bulkhead, middle bulkhead and rear bulkhead along with connecting tubes, bushes and other necessary connecting components. The engine mounting frame is a mechanical structure which is supposed to carry various combinations of loads. The structural requirement of the interface is to carry engine weight under different load factors, transfer engine thrust to the wing and transfer landing gear loads to wings without any failure.
The present work also includes structural analysis using Finite Element Method (FEM). The structural analysis thus carried out involves familiarity with the pre and post processor DISPLAY-III that yield critical contour plots primarily due to static and frequency analysis for given loads and boundary conditions using NISA II package.
A close estimate of the static and dynamic behavior of Engine Mounting Frame is necessary right at the design stage, so as to have an optimum configuration with least weight that will meet the design requirements of strength, stiffness and natural frequency.

Keywords: Structure, Bulkheads, Engine mounting frame, Frequency Analysis, Landing gear.

1. Introduction

An Unmanned Aerial Vehicle's structural design involves many aspects ranging from clear aerodynamic shapes to its serviceability. The design must incorporate new materials and processes with advanced state of the art techniques. A good overall structural design can thus be obtained by incorporating a set of specifications consistent with the needs. An unmanned aerial vehicle (UAV); also known as a remotely piloted vehicle or RPV, or Unmanned Aerial System (UAS) is an aircraft that flies without a human crew on board the aircraft. Their largest uses are in military applications. An Unmanned aerial vehicle is defined as a reusable, uncrewed vehicle capable of controlled, sustained, level flight and powered by a jet or reciprocating engine or battery source.

Unmanned aerial vehicles (UAVs) have become a hot research topic in the last decade worldwide. Their great potential has been explored in numerous military and civil implementations. Among various UAVs, small scale UAV is especially attractive to the academic circle due to its small size, unique flight capacities, outstanding manoeuvrability and low cost. Many research groups have constructed their own UAV for research purposes. Success has been achieved in many research areas such as software design and integration, modelling and simulation of the structure and engine mounting frames of the UAV's [1-3].

An aircraft structure in the modern UAV's usually consists of a thin layer of skin covering a frame which strengthens and improves the ability of skin to take more loads. Basically an UAV structure is designed to resist the aerodynamic loads acting on them during the flight and provide an aerodynamic shape so as to reduce the drag during flight. The framed structure of an UAV basically consists of bulkheads with formers, stringers and tubes that are interconnected to form a skeletal structure and it also comprises of an engine mounting bushes which bear the engine mount and its corresponding components [4].

An engine mount is a frame that supports the engine and holds it to the fuselage or nacelle. It may be made of formed sheet metal, welded steel tubing, or some other suitable material. Engine mounts vary widely in appearance and construction, although the basic features of construction are similar and well standardized. They should be designed so that the engine and its accessories are accessible. In case of reciprocating engines which are often built as individual units and commonly used in UAV's, the engine mounting frame should necessitate easy and quick detachment from the supporting structure. In many of the large transport aircraft, the engine mount, the engine, and its accessories are removed and replaced as a single, complete power unit assembly. This makes maintenance and overhaul simpler as well as shortening the time required for engine change.

Henceforth the present paper aims at simplifying the task of designing engine mounting frames of UAV's to the extent that an engine change can be accomplished very quickly. The liquid lines, electric cables, and control linkages have to be provided with quick disconnect joints, which makes it possible to uncouple all connections in a matter of minutes.

2. Design Consideration of an UAV Structure

To ensure safety, structural integrity and reliability of flight vehicle along with optimality of design, International Civil Aviation Organization (ICAO) has established definite specification and requirements in regards to magnitude of loads to be used in structural design of various flight vehicles.

The limit loads used by civil agencies (or) applied loads used by military agencies are the maximum anticipated loads in the entire service life span of the vehicle. The ultimate loads commonly referred to as design loads are the loads which are obtained by multiplying applied load with Factor of Safety (FS).

$$FS = \frac{Ultimate\ Load}{Applied\ Load} \tag{1}$$

Generally a factor of safety which varies from 1.5 for missile structure to 2.0 for aircraft structure is used practically in every design because of uncertainty involving

a) The simplifying assumptions used in theoretical analysis.
b) The variations in material properties and in the standards of quality control.

c) The emergency actions which have to be taken by the pilot resulting in loads on vehicle that are more than the specified load limit.

The applied loads and ultimate loads quite often are prescribed by specifying certain load factor. The applied load factor is a factor by which basic loads on a vehicle are multiplied to obtain applied loads. Likewise the ultimate load factor is a factor by which basic vehicle load are multiplied to obtain the ultimate loads, in other words it is product of the limit load factor and factor of safety.

3. Design Methodology Followed

i. Stating the problem with a detailed description of the intricacies involved in the design of engine mounting frame.
ii. Analyzing the frame for all external and internal forces acting upon it.
iii. Determination of forces and moments acting upon it.
iv. Modelling of the structure and engine mounting frame.
v. Discretization of the Model generated in solid works.
vi. Finite element analysis of the engine mounting frame by specifying appropriate boundary conditions and corresponding constraints to the framed structure.
vii. Natural frequency and mode shape analysis of the engine mounting frame.

4. Modelling of Interfacing Frame

The whole structure basically comprises of three bulkheads namely front bulkhead, middle bulkhead and rear bulkhead along with connecting tubes, bushes and other necessary connecting components. The modeling of the frame was carried out using ‘SOLID WORKS’ package.

4.1 Configuration of Interfacing Frame

The bulkheads are main components of frame which are rigid in nature and carry concentrated loads; hence these structures are designed to withstand the loads without rupture.

The configurations of interfacing frame and the corresponding assembly of different components are as shown in Fig 1.

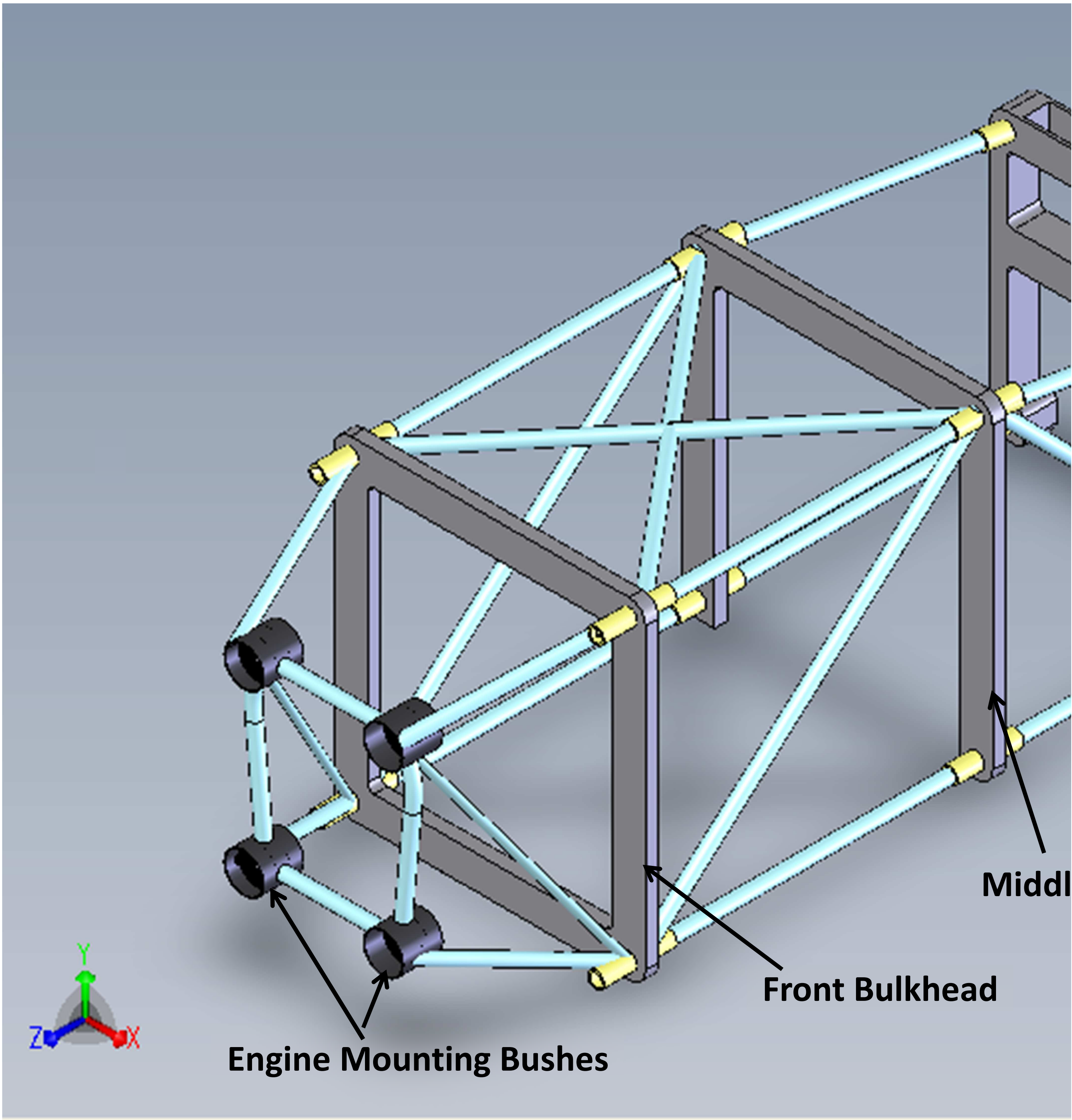

Fig 1 Model of the Interfacing frame

5. Finite Element Analysis of Engine Mounting Frame

The engine mounting frame as shown in Fig 1 was analyzed with the help of an evolved Finite element method using NISA II Package.

The analysis of the structure involved three major steps namely Pre-Processing, Processing and Post-Processing stages with the following information being input to the NISA II Processor Package.

- Geometry of the system.
- Elements connecting the nodal points.
- Mass properties.
- Boundary conditions.
- Loading detail.

NISA II Software also necessitated specifying material properties which was input to the Processor in Pre-Processing stage. Table -1 gives information of the material properties input to the processor during Pre-Processing Stage.

Table 1: Material Properties

Sl. No.	Material	Young's modulus (Kgf/mm^2)	Density (Kg/mm^3)	Poisson's Ratio
1	Stainless Steel	2.10×10^4	7.8×10^{-6}	0.3

The main reasons for carrying out this work of finite Element analysis are:

- **Linear static analysis** of the system is carried out in order to determine the stresses and deflections during the steady flight condition. This analysis can be used to determine the deflection of interfacing frame due to operational loads because of structural flexibility. If the deviation is not within the permissible limits then the structural stiffness has to be increased to minimize this deflection.

- **Normal modes analysis** is mainly carried out to determine the natural frequency of the system .The requirements to be satisfied are that the natural frequency of the system in translation mode should be beyond the natural frequency of the vibration isolators in order to achieve better isolation. Also the natural frequency in rotational mode for all the modules of the system should be above the control system bandwidth.

6. Results

6.1 Results on Linear Static Analysis

Static analysis is done using finite element structural analysis software NISA II with the given loads and boundary conditions under two load cases.

6.1.1 Load Case – 1

The Stress Contour Plot and Displacement Plot for load case – 1 are as shown in Fig 2 and Fig 3 respectively,
The actual stress obtained for Load case – 1 varies from 0 to a maximum of 49.91808 kg/Sq mm, while the displacement varies from 0 mm to 8.6 mm.

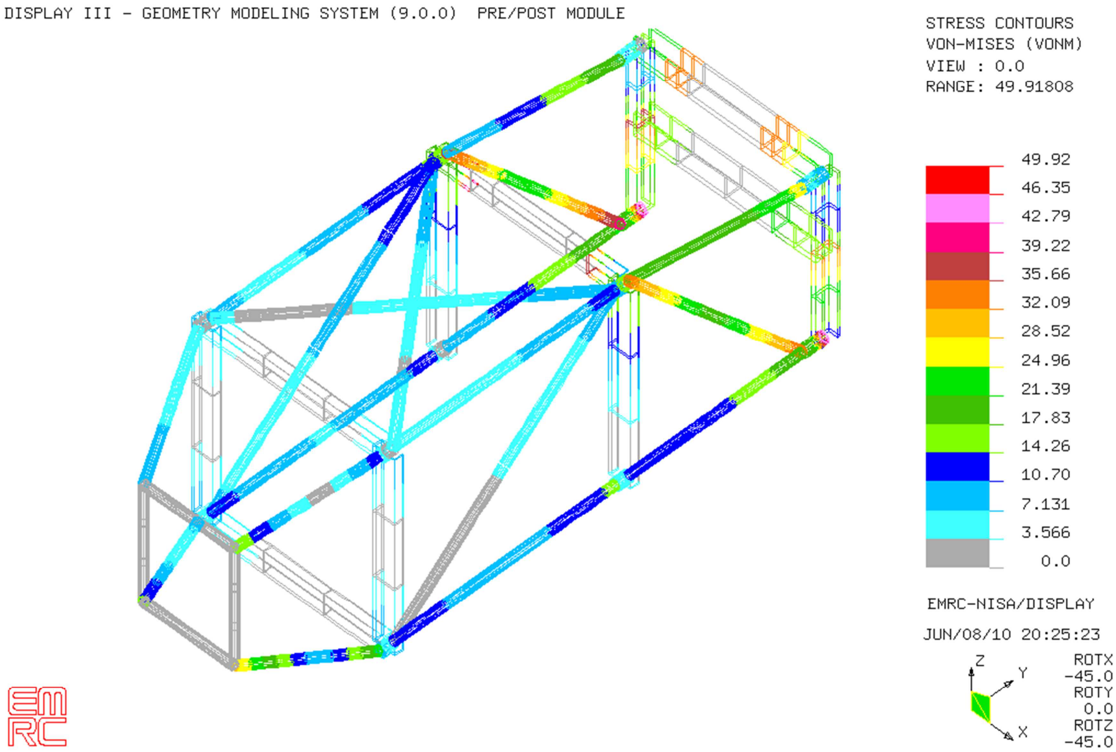

Fig 2 Stress Contour Plot for Load Case – 1

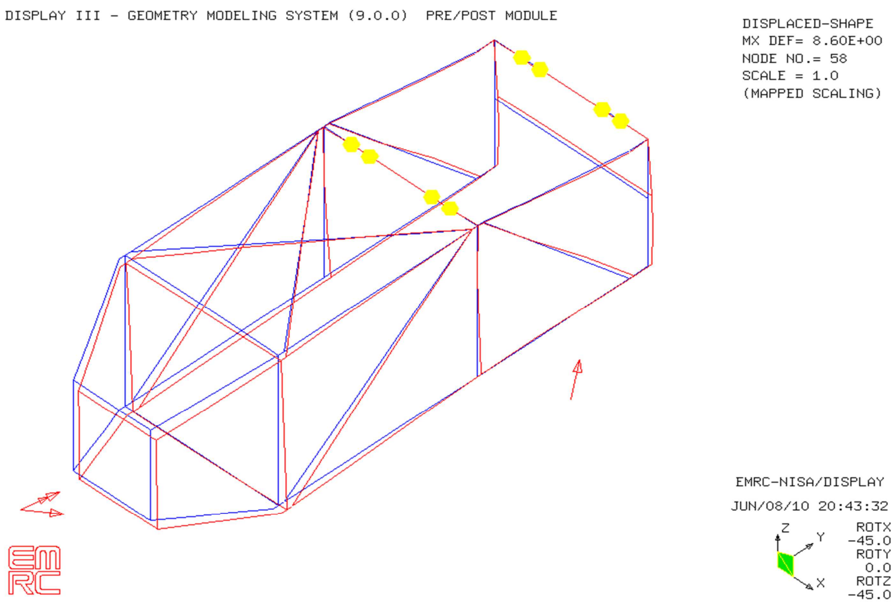

Fig 3 Displacement Plot for Load Case – 1

6.1.2 Load case – 2

The Stress Contour Plot and Displacement Plot for load case – 2 are as shown in Fig 4 and Fig 5 respectively, the actual stress obtained for load case – 2 varies from 0 to a maximum of 54.32 kg/sq mm, while the displacement varies from 0 mm to 16 mm.

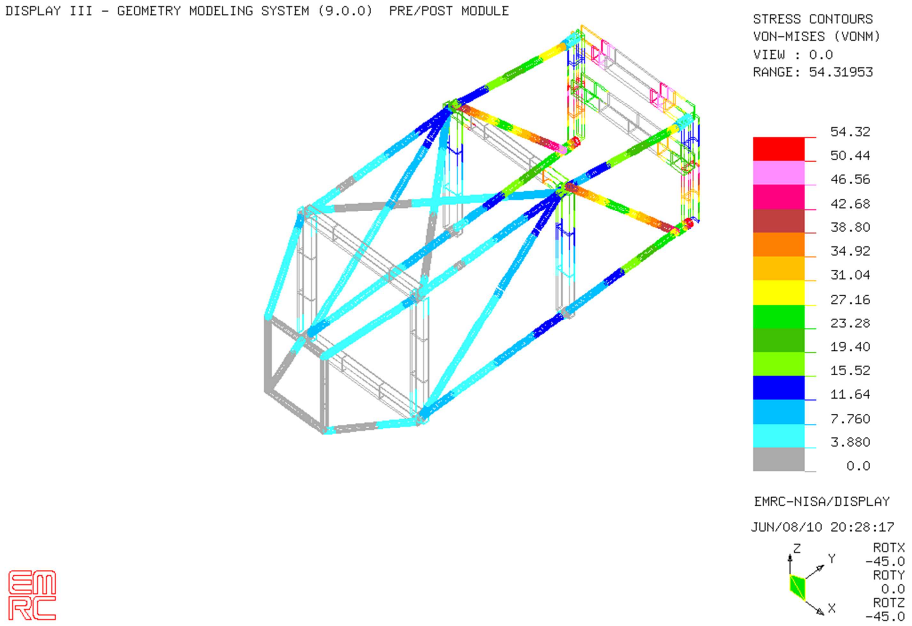

Fig 4 Stress contours plot for load case – 2

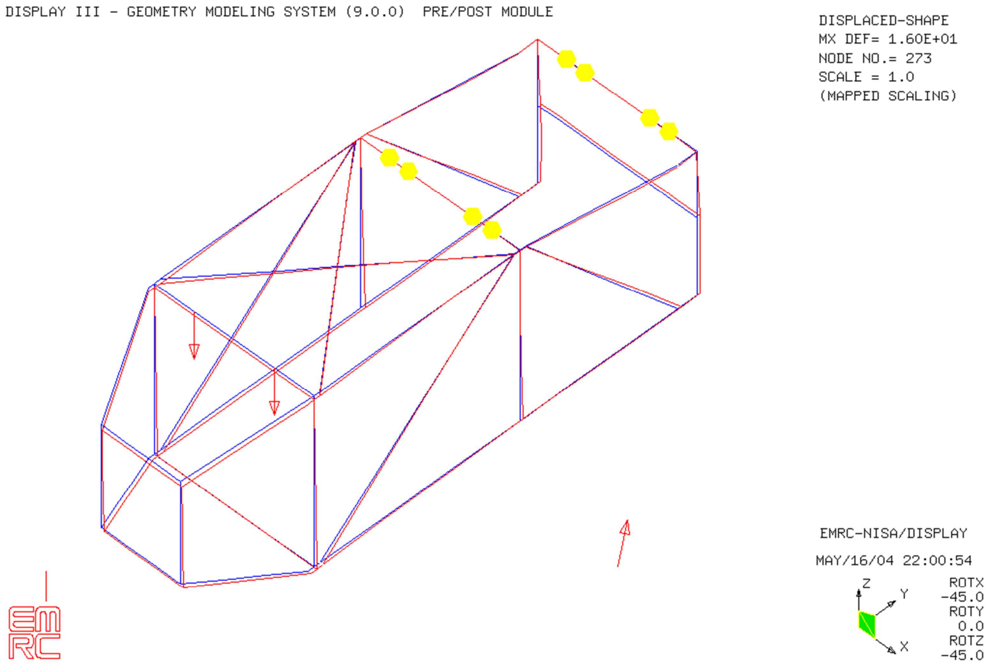

Fig 5 Displacement plot for Load Case – 2

6.2 Results on Natural Frequencies and Mode shape

Normal mode analysis is carried out in NISA II Software to determine natural frequency for 10 different mode shapes as shown in Fig 6. The natural frequencies for different mode shapes are tabulated as shown in table – 1.

MODE NUMBER	FREQUENCY (CYCLES/SEC)
1	1.727722E+01
2	1.806157E+01
3	3.263030E+01
4	3.671007E+01
5	3.841202E+01
6	1.041444E+02
7	1.280067E+02
8	1.557057E+02
9	1.645914E+02
10	1.983670E+02

Table – 1 Natural Frequencies for different mode Shapes

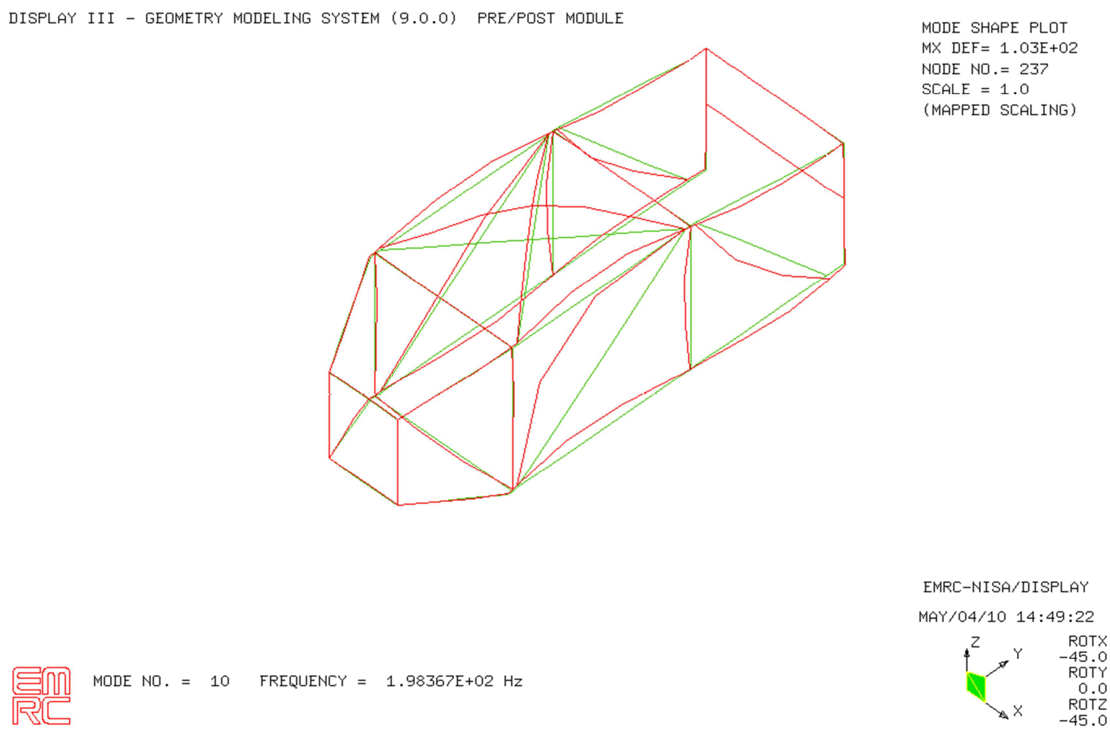

Fig 6 Frequency Mode shape – 10

7. CONCLUSION

7.1 Stress

The actual stress obtained for the load case-1 is 49.92 kg/sqmm and for load case-2 is 54.32 kg/sqmm, which is less than the ultimate stress 68.00 kg/sqmm of the material used (SAE4130). Hence design is safe.

7.2 Deflection

- The deflection obtained for load case-1 is 8.6 mm which can be neglected.
- The deflection obtained for load case-2 is 16.00 mm at landing gear loading point; hence frame is safe for both load cases.

The result obtained from our project serves as a reference for the future model gap calculations and also deciding the scale of the test model. Since methodology and our approach are well documented it serves as a database for further research activities in Design and Analysis of Engine mounting frame for an UAV.

8. REFERENCES

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