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Design and Finite Element Analysis of Mini Star Tracker

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***Abstract*— A Star Tracker or Star Sensor is an imaging system that provides inertial reference for a spacecraft. It is an optical device that measures the position of stars using photocell or a camera.**

Most spacecraft steer by the stars, to make sure they are still on the course and pointed in the right direction, a Star tracker compares the position of stars with a celestial map and gives information to a gyroscope. Together the Star Sensor and gyroscope keep the spacecraft stable and oriented in the right direction in space.

The aim is to build a Micro star tracker, weighing less than 1Kg and as compact as possible. Also to carry out the Finite Element Analysis of the device to simulate the working condition in real time application.

The idea is to carry out structural analysis, to find out its vibrational, structural and dynamic characteristics during testing and the launch of the satellite till it's being ejected into its orbit, and to validate it with experimental results.

Keywords*— *StarTracker; Finite Element Analysis

I. INTRODUCTION

Star Tracker is an optical device that measures the position of stars using photocells or a camera. Most spacecraft steer by the stars to make sure they are still on course and pointed in the right direction, they may periodically check the position of the stars. A star camera often referred to as a Star Sensor.

A star camera or a Star Tracker is a celestial reference device that recognizes star patterns, such as constellations. Star patterns and even single stars are very helpful for navigation. The star camera will locate the positions of stars and report them to the spacecraft. The captured images will then be compared to a celestial map that resides in the spacecraft computer memory. The difference in the star position is sent to the gyroscope and the necessary action is carried out to restore the position and orbit of the spacecraft.

II. OBJECTIVES OF PRESENT WORK

The mechanical design of the Mini Star Sensor is generally driven by the constraints on the structural natural frequency.

When any object, vibrates at the same natural frequency of the second object, it forces that second object into vibrational motion. This is called resonance. The result of resonance is always a large vibration. Regardless of vibrating system if resonance occurs, a large vibration results.

Structural design optimization is a specialized utilization of numerical design optimization that has been adapted to cater especially for structural design problems. Some of the most common structural optimization applications include the mass minimization of a structure, Maximization of the stiffness, structure failure prevention and data matching. This report focuses on the specific application FEA methodology in the analysis of a Mini Star Sensor. The data of interest is the dynamic characteristics, specially the modal frequencies and mode shapes, of the structure.

III. METHODOLOGY

The geometric model is created using UG NX 7.5 from the design specifications obtained. The model consists of several components. Each component are modeled and assembled to form a Global model.

Modal Analysis, Quazi-Static Analysis, Dynamic Analysis were carried out for Mini star tracker consisting of several stacked PCB's optical lens, baffle and housings to safeguard the electronic package.

CAD model Mini Star tracker is developed in NX 7.5

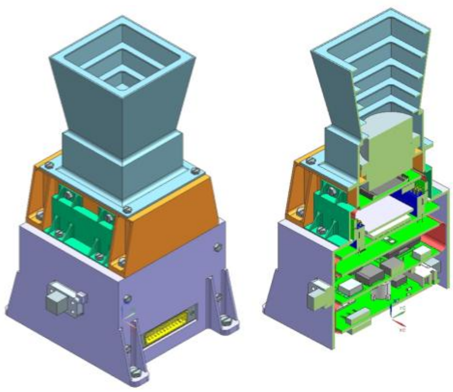

Fig. 1. Micro star tracker assembly model and sectional view

The bottom four bolted locations are fixed in all six degrees of freedom since it is mounted on spacecraft using screws.

The components on the PCB's are not considered while simulating the model. A lumped mass of the components is dumped in the CG of the PCB.

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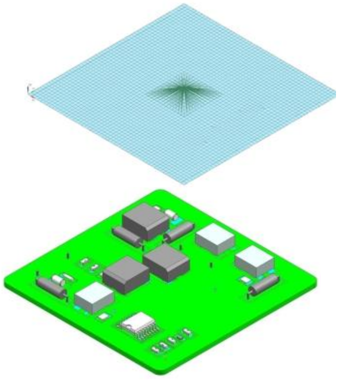

Fig. 2. Simplification of PCB components for simulation

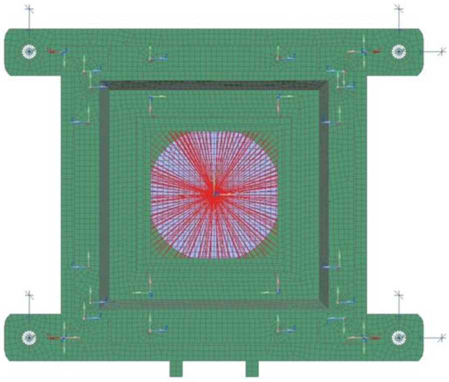

Fig. 3. Boundary condition location

A. Assumptions

- Structure is Homogeneous and Isotropic and all the material behaves linear.
- Structure is modelled using Shell elements because of its slenderness and uniform thickness.
- Screws are simulated using elastic beam element
- Optical device is modelled as a lumped mass, assuming its CG to be at a distance of 15 mm above the flange it is fixed

IV. FINITE ELEMENT SIMULATION

UG NX 7.5 is used to solve (NX Nastran solver) and post-process the simulation results.

The complete FE model is simulated using Quadratic Shell Elements by creating mid surface of each component and assembling it. The FE model of the Mini star tracker is as shown.

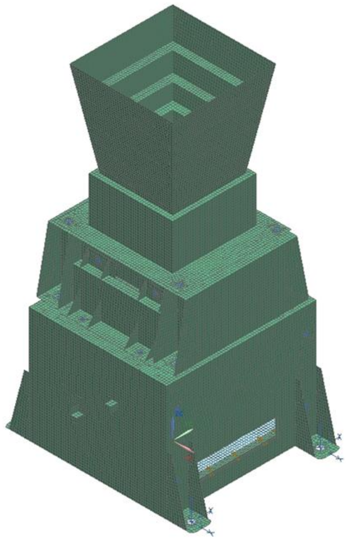

Fig. 4. Finite Element model of mini star tracker

The material properties that were used for the analysis is given below.

Table. 1. Material Properties

Material	Density	Young's Modulus	Poisson's Ratio
	Kg/mm3	*MPa*	
Al6061	2.7e-6	69000	0.33
FR4	1.9e-6	22000	0.136
RTV	1.29e-6	3.51	0.47
SS-304	7.92e-6	193140	0.3

Necessary quality checks like Aspect ratio, Jacobian, Element normal, were performed to see the elements are captured properly. Also surface operations like washer split was done around the screw holes to capture the stress value precisely around the holes.

V. RESULTS AND DISCUSSIONS

A. Modal Analysis

Determination of fundamental frequencies and mode shapes were carried out by performing modal analysis.

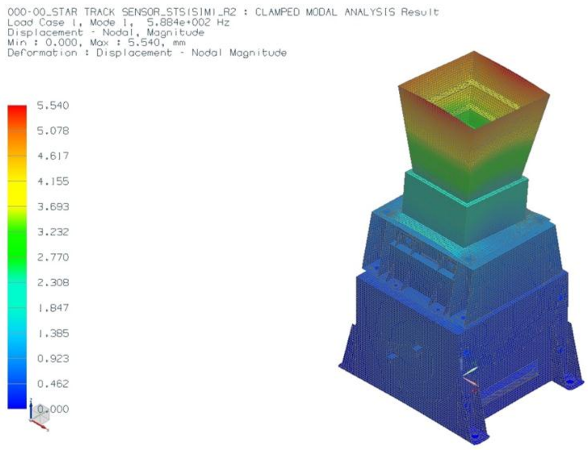

Fig. 5. First natural frequency, 588.4 Hz

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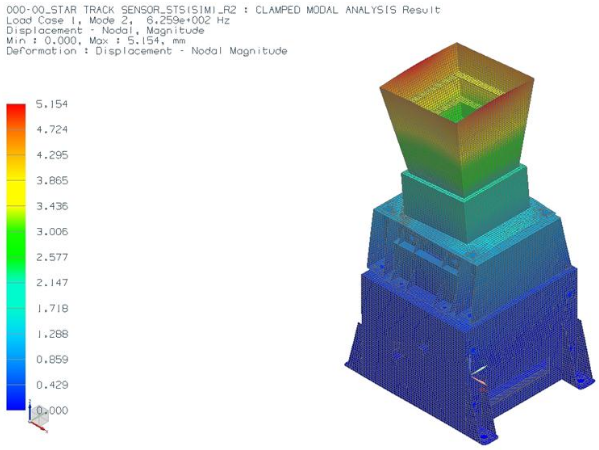

Fig. 6. Second natural frequency, 625.9 Hz

B. Quazi-Static Analysis

Quazi-Static analysis is carried out with 30g acceleration load applied on global model in three directions.

The plot of von-Mises stress in X, Y, Z direction is shown below. And the stress and displacement values for other directions are tabulated.

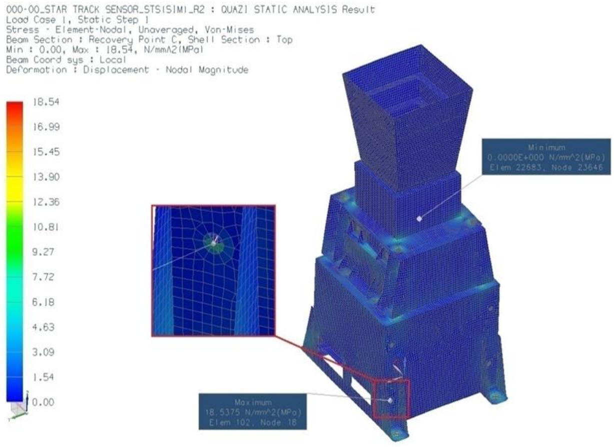

Fig. 7. Von-Mises Stress contour in X- direction

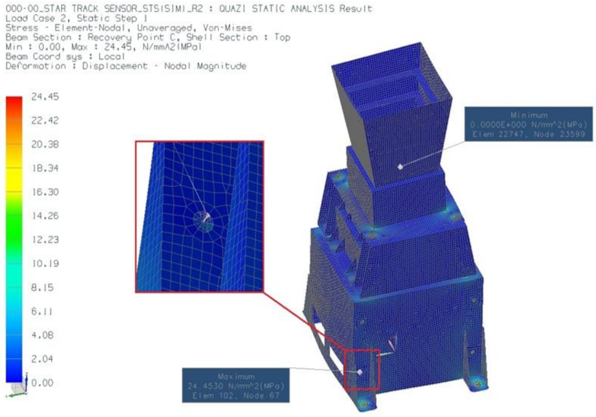

Fig. 8. Von-Mises Stress contour in Y- direction

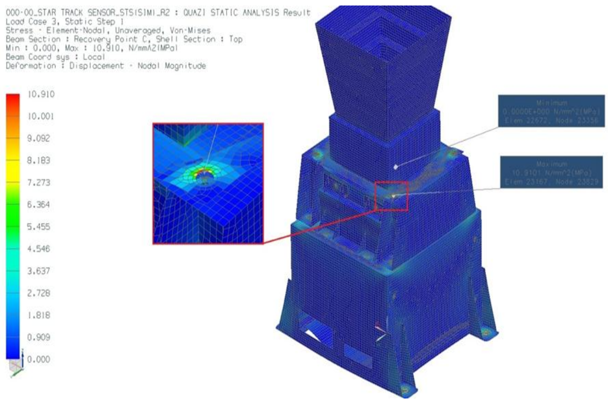

Fig. 9. Von-Mises Stress contour in Z- direction

Table. 2. Maximum values of displacements and Stress

Maximum values of Displacement and Von-Mises Stress			
	X-Dir	Y-Dir	Z-Dir
Displacement (mm)	0.04	0.05	0.02
Von-Mises Stress (MPa)	18.54	24.45	10.91

C. Dynamic Analysis

Sine response analysis was carried out to find the response at various probe locations for a given sine input curve which is a function of 'g'. The response in Z direction is of importance. Below image shows the von-Mises stress in the model.

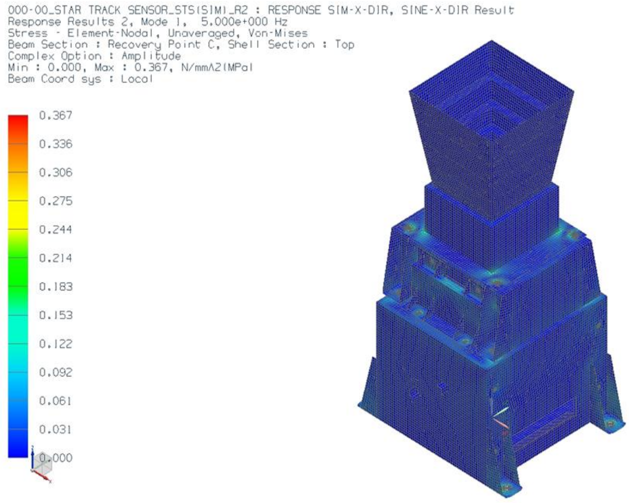

Fig. 10. Von-Mises Stress Contour in X- direction at 5 Hz

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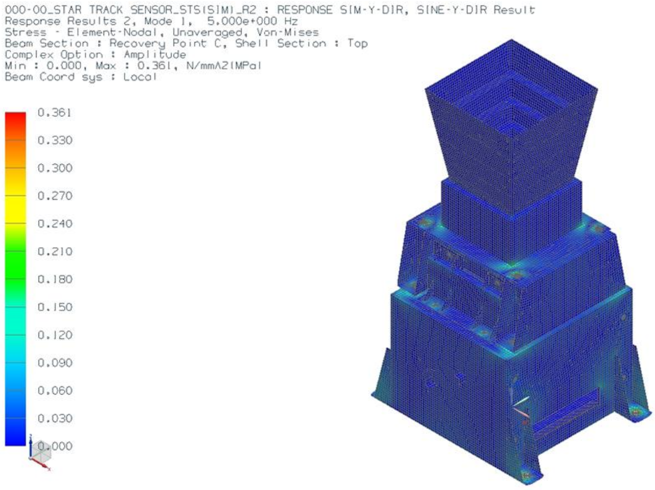

Fig. 11. Fig. 11. Von-Mises Stress Contour in Y- direction at 5 Hz

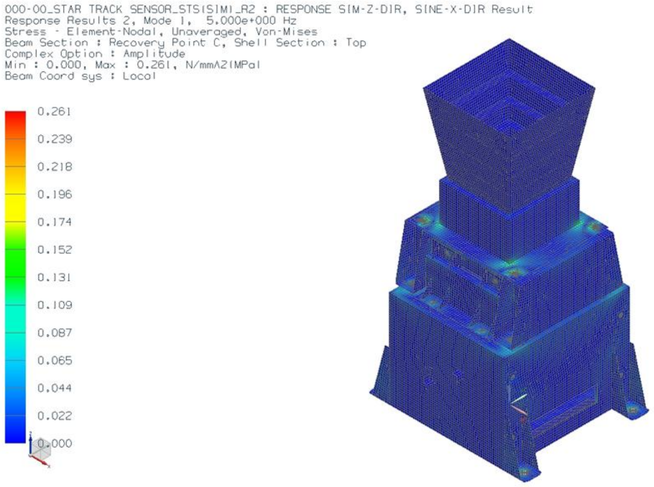

Fig. 12. Von-Mises Stress Contour in Z- direction at 5 Hz

VI. CONCLUSION

- The first natural frequency of micro star sensor assembly is 588.4 Hz, which is greater than 200 Hz, which is greater than the rocket frequency.
- The natural frequencies of the components in contact with each other are separated at least by one octave. So the effect of dynamic coupling is negligible.
- The von-Mises stress of maximum 24.45 MPa is occurring at one of screw, whose yield stress is 207 MPa. Which is safe with considerable factor of safety.
- The von-Mises stress in other components are well below its yield point.
- The von-Mises stress in sine response analysis is well within the margin of safety.
- The amplification factor of the components in the assembly is less than 10.

VII. ACKNOWLEDGMENT

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REFERENCES

[1] M. Lee, PHI. D., “Finite element modeling of printed circuit board for structural analysis”.

[2] Dave S. Steinberg, “Designing Electronics for High Vibration and Shock”.

[3] Anton V. Burmitskih, Aleksandr P. Lebedev, Alexey A. Levitskiy, “Printed Circuit Board Vibration Analysis using Simplified Finite Element Models”.

[4] T. Brady, S. Buckley, “The Inertial Stellar Compass: A Multifunction, Low Power, Attitude Determination Technology Breakthrough”.

[5] Practical Finite Element Analysis by Nitin S Gokhale.

[6] The Finite Element Method in Engineering by S S Rao.

[7] Vibration Analysis For Electronic Equipment by Dave S Steinberg.

[8] www.femci.gsfc.nasa.gov/.