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OPTIMIZATION OF AVIONIC STRUCTURE IN DESIGN AND ANALYSIS FOR SPACE CRAFT APPLICATION

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Abstract
Avionic enclosures are electronic packed setups used in aircrafts and spacecrafts. The avionic enclosure provides mechanical support to all system parts and is mechanically interfaced with the aircrafts. Avionic enclosures have a critical role in system performance. The avionic package must be built to endure high dynamics.Fibre optic gyro based inertial navigation system is an aviation navigation device.In this work, the Fibre optic gyro based inertial navigation system and Global Positioning System unit was created utilizing Solid Works and The Modal Analysis on these parts was performed using FEA ABAQUS software, and a random vibration experimental analysis is tested under both static and dynamic conditions.The collected findings are compared to others in order to optimize the design of the Fibre optic gyro based inertial navigation system package.
Keywords : Avionic,ABAQUS, FEA,high dynamics,Fibre optic, navigation

1.Introduction

The avionic enclosure's goal is to provide mechanical support to all system parts and to mechanically interact with the aircrafts. Avionic enclosures are critical to system performance. The goal of designing avionic enclosures is to achieve the capacity to tolerate vibration, shock, and continuous acceleration without compromising performance in the environment. Because it is an aeroplane kit, it has been designed to be tiny and light. The packaging should be designed to be serviceable, maintainable, and simple to assemble and disassemble.To provide entire navigation information, FINGS is made up of three Fibre Optic Gyros (FOGS) and three accelerometers.The FOG IMU is made up of three sensors (3 FOGS and 3 accelerometers) positioned at an angle of 45 degrees.A processor card is installed on lugs within the case to process data from the gyros, accelerometers, and GPS, and the covering is covered.Inertial navigation uses gyros rather than radios to compute aircraft location by comparing acceleration readings with stored data. .

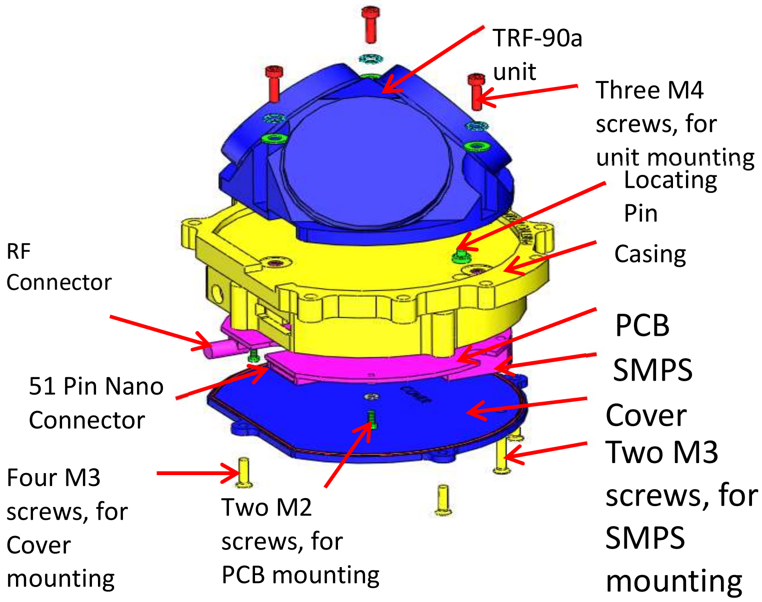

Figure 1:View of FINGS Unit

Table 1: Weight Distribution

S .no	Elements	weight in grams	quantity
1	FOG IMU	430	1
2	Casing	345	1
3	Cover	60	1
4	Pcb, smps and connectors	094	1
5	Screws	25.4	13
	total weight	954 grams < 1000grams	

2.Design and Methodology

Nominal major diameter of the bolt =4mm

Pitch of the bolt =0.7mm

Tensile stress area of the bolt $= \pi /4x \text{ (core dia)}^2$

$= 8.78 mm^2$

Joint separation load coming on the joint coming on the joint will be shared by the bolt and joining material. The following relation gives the amount of load shared by the bolt.

$$F_b = K_b/ (K_b + K_m) F + F_i$$

$$F_b = C * F + F_I$$

Where,

K_b and K_m are the stiffness of both and joining material respectively

F is the separation force

F_i is preload given to the bolt

For the bolt,

Material : En-24

Young`s modulus : E = 210 Gpa

Total length of bolt : L = 30mm

K_b = A x E / L = $(8.78X210X10^3)/30$

K_b = 61460 N/mm

Case-1:

(a) For FINGS Mechanical Housing,

Material : Al. Alloy HE-15
Young`s modulus : E = 70 GPa=70000 N/mm2
Bolt Outer dia : d= 4mm
Bolt Head dia : D=7mm
Thickness of lug : t=10mm

K_{m1} = (π x E x d) / In (2t+D-d)/(2t+D+d) (D+d)/(D-d)

= π x 70,000 x 8/ in (20+7-4)/(20+7+4)(7+4)/(7-4)

= 7,12,969 N/mm

(b) For missile bracket(Astra INS Mounting Disc)

Material : Al. Alloy HE-15
Young`s modulus : E = 70 GPa=70000 N/mm2
Bolt Outer dia : d=4mm
Bolt Head dia : D=7mm
Thickness of lug : t=10mm

K_{m2} = (π x E x d)/In (2t+D-d)/(2t+D+d) (D+d)/(D-d)
= π x 70,000 x 8 / In (20+7-4)/(20+7+4) (7+4)/(7-4)
= 7,12,969 N/mm

Equivalent stiffness,

K_m = K_{m1}xk_{m2} / (K_{m1} + K_{m2})
= 7,12,969 x 7,12,969 / (7,12,969 + 7,12,969)
= 3,56,484.5N/mm

Joint constant, C= K_b / (K_b + K_m)
= 61,460 / (61,460+ 3,56,484.5)
= 1.472

Preload required by the bolt

F_i = 0.75 x A x S_p

= 0.75 x 8.78 x (**0.85 x 780**) (proof strength, $S_p=0.85\sigma_y$)

= 4197.9 N

No of bolts used N = 10

Load on the bolt,

a) Weight of FINGS = 1kg
b) Axial acceleration = 40 G

Total load = 40x10x1

= 400N

Load on each bolt due to acceleration of missile = 400/10

= 40 N

Therefore final load on each bolt

F_b = (C ×F) + F_I

= (1.472 x 40) +4197.9

= 4256.78 N

Tensile stress on the bolt, = F_b /A_b

= 4256.78/8.78

= 484.82 N/mm^2

Factor of safety = Yield stress of bolt/working stress

= 900/484.66 {yield strength=900N/mm^2}

Minimum preload required for getting a sound joint

$F_{I\,(min)}$ = F(1-C)

= 40 (1- 1.472)

= 18.88 N

This value of minimum preload requirement is less than the preload given to the bolts.
Therefore, bolts are sufficient preloaded to avoid any joint separation.
Torque required to get the preload of 4197.9 N will be

T = 0.20 x F_i x d (where F_i is in KN, d in mm)

= 0.20x4.1979 x 4

T = 3.35 N-m

Therefore, all bolts should be given 3.35 N-m torque to get sound joint.

Table 1: Material Properties for FINGS with Disc

Sl.No	Material	Young's Modulus, MPa	Poisson's ratio	Density Kg/m^3
1.	Aluminium alloy	75,000	0.4	2790

3.Results and discussions

3.1 Modal Analysis of FINGS

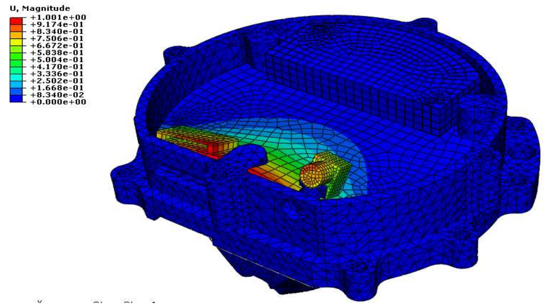

Figure 2 : First mode Analysis

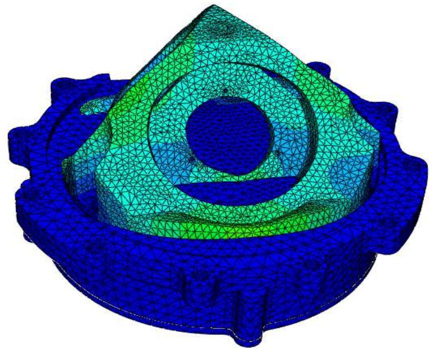

Figure 3 :Second mode Analysis

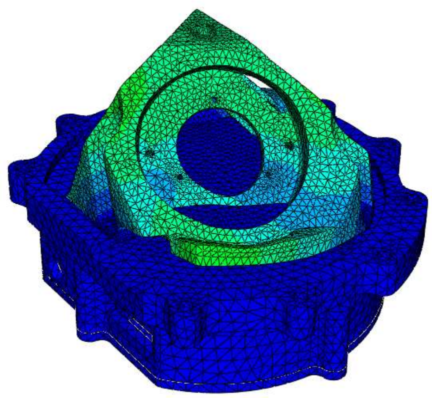

Figure 4 :Third mode Analysis

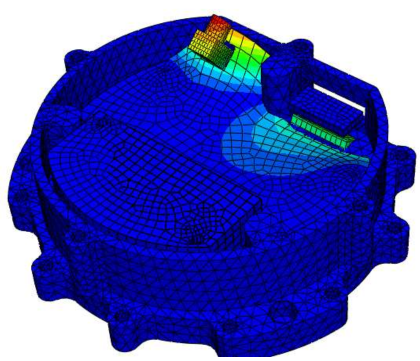

Figure 5: Fourth mode Analysis

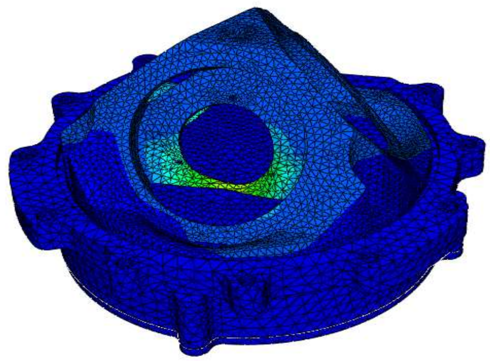

Figure 6: Fifth mode Analysis

Table 3:Frequency values with different modes

Mode no	Frequency(Hz)	Mode
1	965	PCB Mode
2	1389	IMU Mode
3	1474	IMU mode
4	1580	PCB Mode
5	1695	IMU Mode

3.2 Random Vibration Analysis of FINGS in X,Y & Z Direction

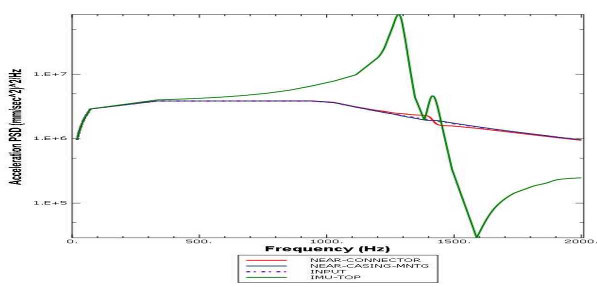

Figure 7: Response Graphs at Important Locations in X-Direction (vibration)

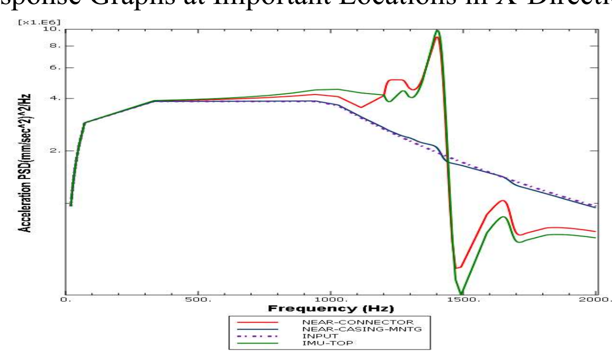

Figure 8:Response Graphs at Important Locations in y-Direction (vibration)

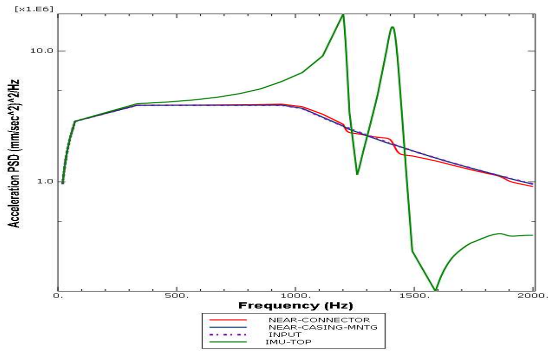

Figure 9:Response Graphs at Important Locations In z-Direction (vibration)

3.3 Experimental Random Vibration Analysis of FINGS in X,Y & Z Direction

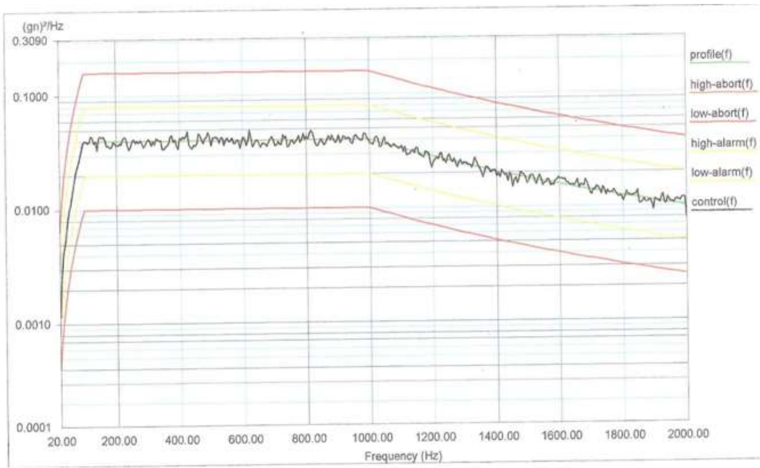

Figure 10**:** Input Profile for X-Axis

Similar way for Y axis and Z axis are plotted and tabulated

From the graph it can be observed that the vibrational response graphs for connector and IMU unit is gradually increasing from 0 to 100 HZ and is stable from 100 HZ to 1000HZ and then decreasing there on.

Analysis of Fibre optic gyro-based inertial navigation system With Disc

The boundary conditions are applied and obtained the needed frequency in four 4mode shapes with regard to supplied input the counter plots of frequencies and stress, displacement

Table 4: Comparison of Experimental and Theoretical Random Vibration values

S.no	Location	Random vibration Analysis Values			Random vibration Experimental values		
		X	Y	Z	X	Y	Z
1	Input	9.34	8.31	8.67	8.43	8.62	9.21
2	Near connector	9.57	8.87	8.17	8.07	8.76	9.76

3	Imu top	12.4	9.07	10.87	9.63	10.2	9.58

3.4 Modal Analysis of printed circuit board

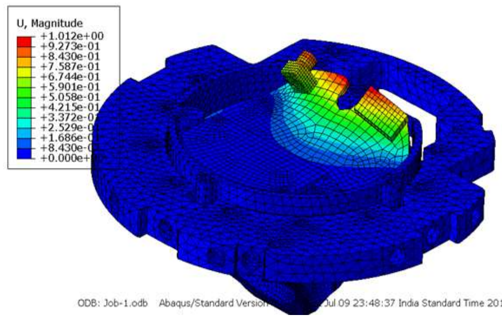

Figure 11 First Mode

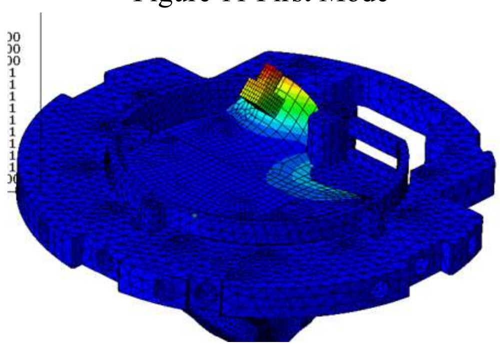

Figure 12 Second Mode

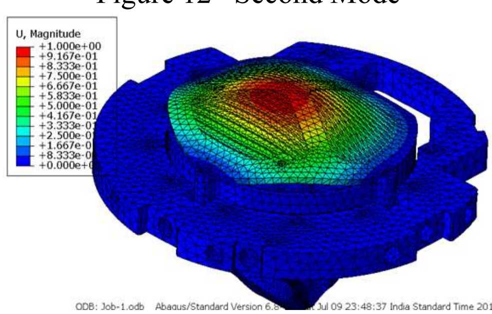

Figure 13 Third Mode

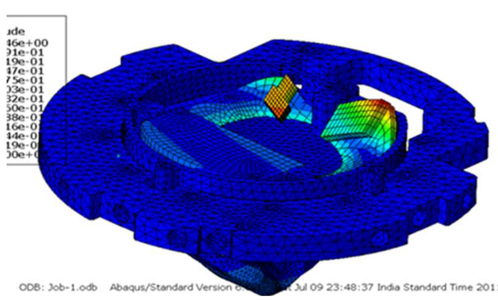

Figure 14 Fourth Mode

Table.5 Frequency Mode Values

Mode No.	Frequency in (Hz)	Mode
1	821	printed circuit board Mode
2	1404	printed circuit board Mode
3	1657	Bottom Cover
4	2001	printed circuit board Mode

4.Conclusion

The Fibre optic gyro-based inertial navigation system unit for aircrafts and spacecrafts is designed, and model analysis is performed the maximum frequency is found to be 1690 HZ, and it is tested in a dynamic environment (random vibration) analysis, and the experimental results are compared.It has been shown that FEA analysis findings and practical outcomes capture the same pattern with minor differences that are acceptable and the constraints that were set, the best design was accomplished.Fibre optic gyro-based inertial navigation system mechanical hardware performance will be approximated for a greater dynamic environment (0.05 g^2/Hz).Weight may be reduced to less than 820 grams by lowering the weight of the IMU device and housing.

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