Available online at: http://www.ijmtst.com/vol6issue05.html

International Journal for Modern Trends in Science and Technology

ISSN: 2455-3778 :: Volume: 06, Issue No: 05, May 2020

Design and Analysis of Avionic Structures For Aircraft Applications

P H J Venkatesh[1] | M S R Viswanath[2]

[1,2]Department of Mechanical Engineering, Vignan's Institute of Information Technology (A), Vizag, A.P., India

To Cite this Article

P H J Venkatesh and M S R Viswanath, "Design and Analysis of Avionic Structures For Aircraft Applications", *International Journal for Modern Trends in Science and Technology*, Vol. 06, Issue 05, May 2020, pp.: 78-83; https://doi.org/10.46501/IJMTST060513

Article Info

Received on 21-March-2020, Revised on 23-April-2020, Accepted on 29-April-2020, Published on 04-May-2020.

ABSTRACT

The Avionic enclosure is a electronic packed setup which are used in aircrafts and spacecrafts. Avionic enclosure is used for mechanical support to all the system elements and this is mechanically interfaced with the aircrafts. The avionic enclosures is a key role for the system performance. The avionic package has to be designed to withstand high dynamics. FINGS(FIBRE OPTIC GYRO BASED INERTIAL NAVIGATION SYSTEM) is a unit of aircraft for finding the navigation. In this paper the FINGS + GPS SYSTEM (FINGS) unit designed using SOLID WORKS and The Modal Analysis on these parts was carried out using ABAQUS FEA software and a random vibration experimental analysis is tested under both static and dynamic analysis. The obtained results are compared other for the design optimization of FINGS package.

KEYWORDS: *Avionic,FINGS, SOLID WORKS,ABAQUS FEA,GPS*

DOI: https://doi.org/10.46501/IJMTST060513

I. Introduction

The Designing of avionic enclosures aims to achieve the ability to withstand vibration, shock and sustained acceleration, without any effect on the performance in the environment. It is a part of an aircraft package, It is designed for small size and less weight.Fings consists of Fibre Optic Gyros (Fogs) andaccelerometers to give the total navigation information.The Fog IMU consists of sensors (Fogs andaccelerometers) mounted in an oblique configuration at an angle of 55^0.This IMU is mounted in a casing. Processor card is mounted on inside the casing for processing the information obtained from the gyros,accelerometers and Gps and casing is enclosed with a cover.

Fig 1: FOG IMU

Navigation: Navigation is about travel and finding the way from one place to another and there are different means by which this can be achieved. The simplest form of navigation is to follow the instructions and directions.Navigation depends on the observation and recognisation of known features or fixed objects in our surroundings and moving between them.The navigation process follows a map ,in this case ,the navigator will determine the position by observation of geographical features like roads, rivers, hill stations and valleys which are shown on the map.

INS (inertial navigation system): Inertial navigation system is a self-contained navigation technique in which measurements provided by accelerometers and gyroscopes are used to track the position and orientation of an object relative to a known starting point, orientation and velocity. Inertial measurement units (IMUs) typically contain three orthogonal rate-gyroscopes and three orthogonal accelerometers, measuring angular velocity and linear acceleration respectively. By processing signals from these devices it is possible to track the position and orientation of a device.Inertial navigation is used in a wide range of applications including the navigation of aircraft, tactical and strategic missiles, spacecraft, submarines and ships. Recent advances in the construction of MEMS devices have made it possible to manufacture small and light inertial navigation systems. These advances have widened the range of possible applications to include areas such as human and animal motion capture.

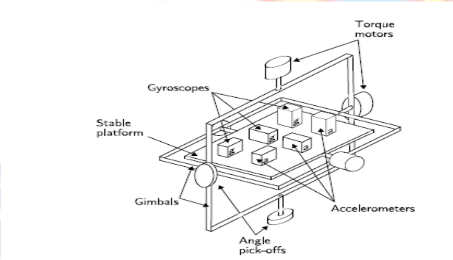

Fig 2: A stable platform IMU

GPS: Global positioning system (GPS) is a space based global navigationsatellite system(GNSS)that provides reliable location and time information in all weather and at all times and anywhere on or near the earth when and where there is a unobstructed line of sight to four or more GPS satellites.GPS allows land, sea, and airborne users to determine their exact location, velocity, and time 24 hours a day, in all weather conditions, anywhere in the world.

II. METHODOLOGY

Random Vibration Analysis: The most important characteristic of a random vibration is that it is non-periodic.Knowledge of the past random motion is adequate to predict the probability of occurrence of various acceleration and displacement magnitudes, but it is not sufficient to predict the precise magnitude at a specific instant.

Pure sinusoidal vibration is composed of a single frequency. On the other hand, random vibration is composed of a multitude of frequencies. In fact, random vibration is composed of a continuous spectrum of frequencies. Random vibration is somewhat analogous to white light. White light can be passed through a prism to reveal a continuous spectrum of colours. Likewise, random vibration can be passed through spectrum analyzer to reveal a continuous spectrum of frequencies.On the other hand, sinusoidal vibration is analogous to a laser beam, where the light wave is composed of single frequency.Random vibration can be represented in the frequency domain by a power spectral density function. The typical units are acceleration [G^2/Hz] versus frequency [Hz]. The acceleration can also represented by metric units such as [$(m/sec^2)^2$/Hz].Note that the amplitude is actually [$GRMS^2$/Hz]. Where RMS is root mean square. The RMS notation is typically omitted for brevity.The RMS value of a signal is equal to the standard deviation, assuming a zero mean.Apure sinusoidal function has the following relationship.Peak =$\sqrt{2}$ RMS.The power spectral density (PSD is simply the (overall level)^2 divided by the band width.Again the unit [$GRMS^2$/Hz] is typically abbreviated as [G^2 / Hz].

Table 1: Critical Frequency

Elements	Critical frequency
Accelerometer	1090 Hz
Gyro	62 to 78 KHz
IMU structure	1650-1700 Hz

Random Vibration Testing Experiment: Electronic and mechanical components may be mounted on an electromagnetic shaker table for the purpose of vibration testing. The design of a electromagnetic shaker is somewhat similar to an audio speaker. There are common types of vibration testing such as to verify the component can withstand simulated vibration environments and for the Stimulation of latent parts and workmanship defects and Identification of natural frequencies, transmissibility functions, and other parameters. The shaker provides a base input to the test item. A control computer applies a random vibration signal to the shaker via a power amplifier. The shaker applies mechanical vibration to the test item. The shaker vibration is monitored by accelerometers. The accelerometers provide a feedback signal to the control computer.

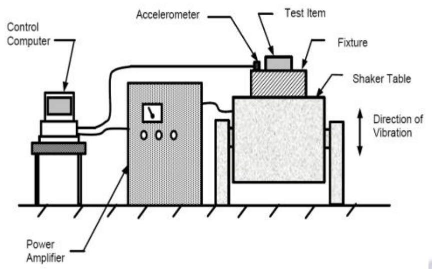

Fig 3:Random Vibration Analysis Experiment

Inputs for Random Vibration Analysis: This model is solved for the random vibration analysis with linear perturbation method using Random response method. All mode shapes up to 2000 HZ are expanded. As the frequency increases, the stress levels in the structure also decreases. In this random vibration analysis it will give the response graphs of each component for the given inputs.

Modelling of FINGS Unit:

Table 2: Input Profile for Random Vibration

Start Mode	End Mode	Critical Damping Fraction
1	6	0.17
7	9	0.01

Table 3: Inputs for Random Vibration Analysis

Lower Frequency	Upper Frequency	Number of points	Bias
20	2000	20	3

Table 4: Damping

Type of test	Random vibration
Acceptance test	0.04 G^2/Hz, MIL SPEC
Qualification test	0.06 G^2/Hz, MIL SPEC

The material choosen for the fing is aluminium alloy and the properties are shown in the following table 5

Table 5:Materials

MATERIAL	YOUNGS MODULUS Gpa	POISSSONS RATIO	DENSITY Kg/m^3
Aluminium Alloy	70	0.3	2770

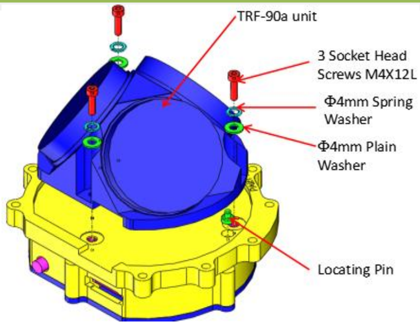

Fig 4:Solid Model of FINGS Unit

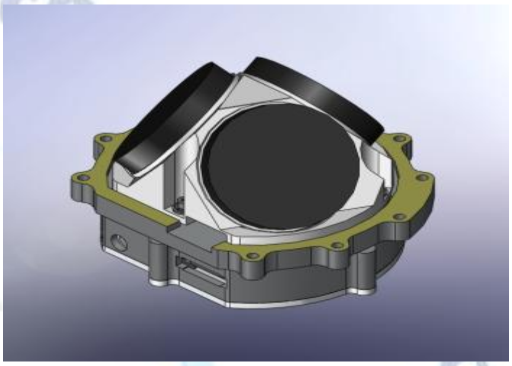

Fig 5: 3DSolid Model of FINGS Unit

Modal analysis: Primary aim of Modal analysis is to determine Natural frequencies, Damping coefficient and Mode shapes of the structure. Modal Analysis offers a vibrant and powerful method of estimating the modal parameters. Modal analysis is the study of dynamic characteristics of a mechanical structure. Structures encountered in practice are continuous, in homogeneous and posses infinite degrees-of-freedom (DOF). However, for the simplicity of analysis, often they are approximated to only a finite number of DOF. This choice of the model is determined by several parameters such as frequency range of interest in the vibration of the structure and the types of vibration modes that are of significance. In general, any Multiple-DOF system can be interpreted as an extension of single-DOF systems. . Modal analysis is performed to either validate or adjust a finite element model or to build an experimental model for use with one of the structural dynamics packages available. As such, the above methods are used to investigate the effects of structural dynamics and they provide opportunity to improve the structural dynamic properties of the system. The weighting, often called the Modal participation factor, is a function of excitation and mode shape coefficients at the input and output DOFs.

Meshing: The mesh element for Connectors, PCB and SMPS Casing, Bottom cover, IMU skeleton is First order Hexahedral element (8 noded)

No.of Elements :85925
No.of Nodes: 149016
The mesh element for Mass element Gyros and accelerometers is Second order is Tetrahedral element (10nodes)
No.of Elements: 3878
No.of Nodes: 5750

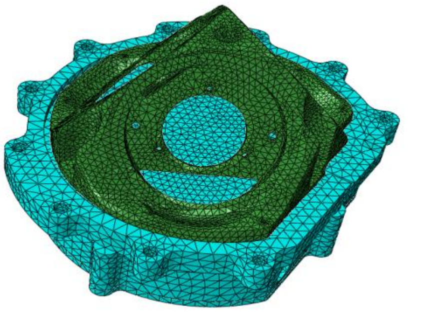

Fig 6:FINGS Unit With Mesh

Fig 7:FINGS Assembly with Boundary Conditions

III. RESULT AND DISCUSSION

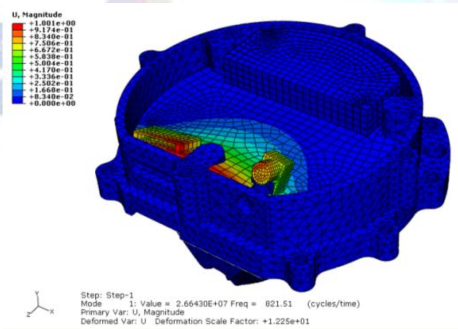

Fig 8: printed circuit board (PCB) frequency of 821 HZ

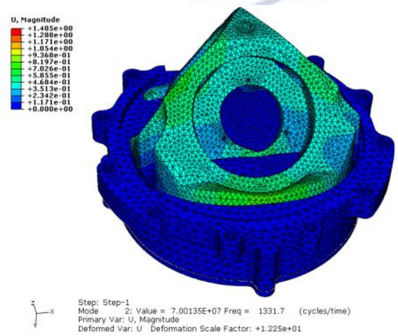

Fig 9:Inertial measuring Unit (IMU) is effecting and giving the frequency of 1331 HZ

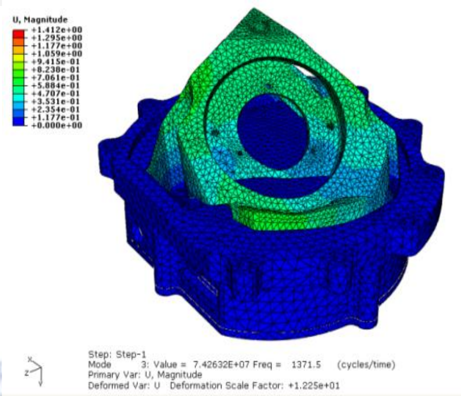

Fig 10:Inertial Measuring Unit (IMU) is effecting and giving the frequency of 1371 HZ

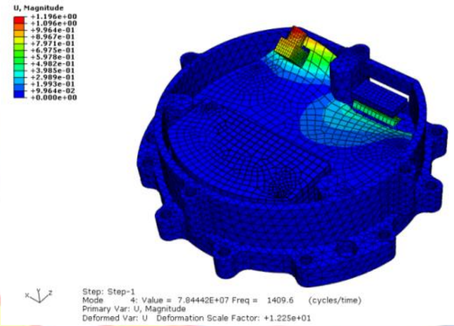

Fig 11:printed circuit board (PCB) is effecting and giving the frequency of 1409 HZ

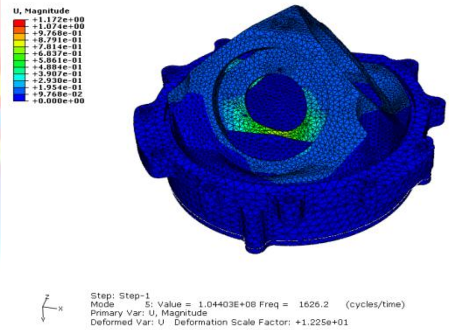

Fig 12:Inertial Measuring Unit (IMU) is effecting and giving the frequency of 1626 HZ

Table 6: Mode No and Frequency Values

Mode no	Frequency(Hz)	Mode
1	821	PCB Mode
2	1331	IMU Mode
3	1371	IMU mode
4	1409	PCB Mode
5	1626	IMU Mode

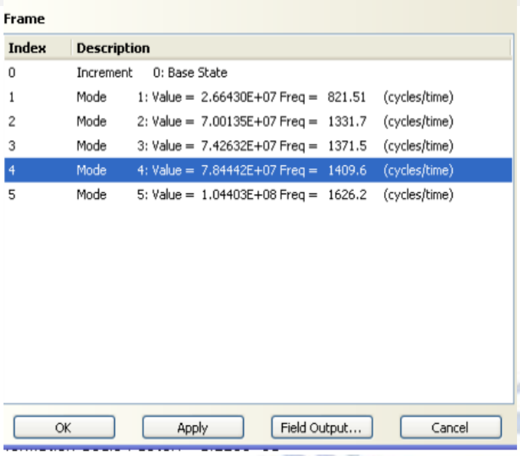

Fig 13: Mode Frequency

Random Vibration Analysis of FINGS in X, Y & Z directionss

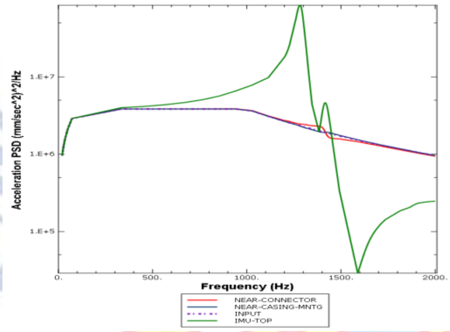

Fig 14:Response Graphs at Important Locations in X-Direction (vibration)

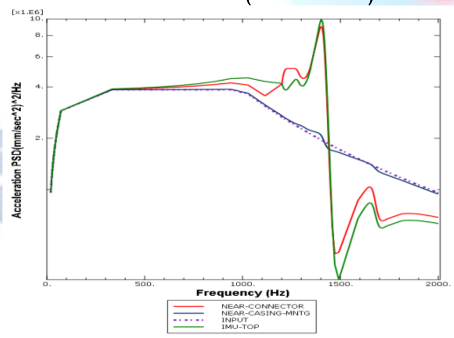

Fig 15:Response Graphs at Important Locations in y-Direction (vibration)

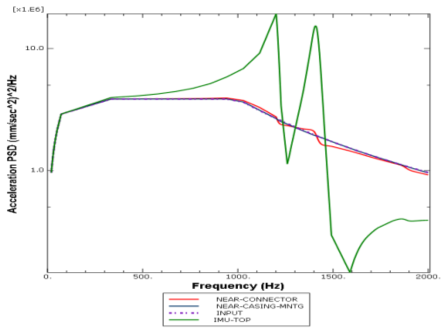

Fig 16: Response Graphs at Important Locations In z-Direction (vibration)

Table 7: Random Vibration Analysis Results

S.no	Location	X	Y	Z
1	Input	7.53	7.53	7.53
2	Near Connector	7.54	8.01	7.54
3	IMU TOP	11.50	8.05	9.09

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

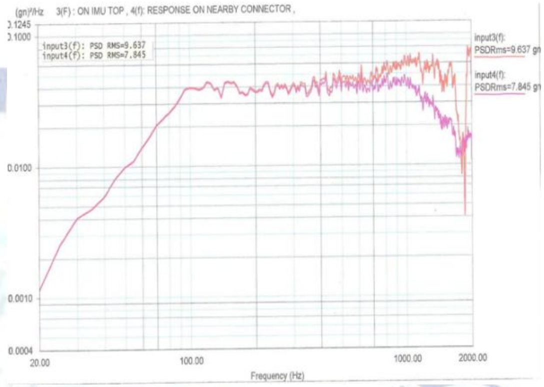

Fig 17:Random Vibration Response in X-Axis

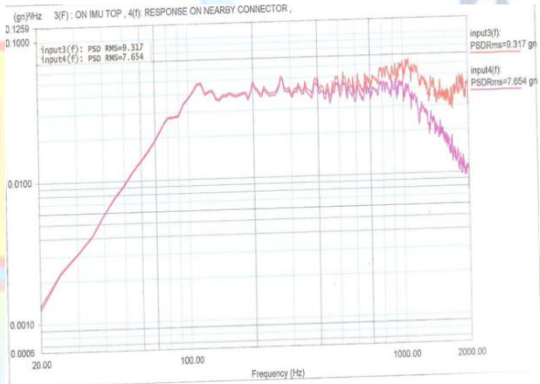

Fig 18:Random Vibration Response in Y-Axis

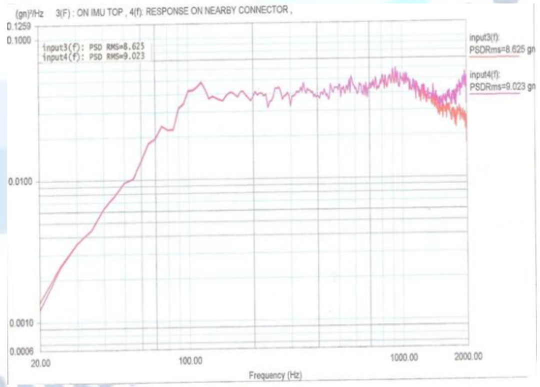

Fig 19: Random Vibration Response in Z-Axis

Table 8: Experimental Random Vibration Results

S.no	Location	X	Y	Z
1	INPUT	7.57	7.57	7.57
2	CONNECTOR	7.84	7.65	9.02
3	IMU TOP	9.63	9.31	8.62

IV. CONCLUSION

The FINGS unitis designed with sold modeling and Model Analysis performed using ABAQUS FEA and the maximum frequency is found to be 1626 HZ.The FINGS unit is also tested in the dynamic environment(randomvibrations) analysis and compared with the experimental results.When both the results are compared The values obtained with a small marginal difference errs and optimum design has been archived within given conditions.The Performance of FINGS Mechanical system can be simulated for higher dynamic environment at 0.07G^2/Hz.The same analysis can be conducted by considering suitable composite materials and a correct material for optimum design can be achieved.

REFERENCES

[1] The theoretical formulation for the random vibration analysis of surface mounted devices is developed by Pittarresi, James M.akanda, Anab. The 1993 ASME international electronics packaging conference ;Binghamton,NY,USA;29,sept: 02 oct.1993.

[2] Inertial Attitude Heading Reference System (AHRS) for General Aviation Applications Demoz Gebre-Egziabher, Roger C. Hayward and J. David Powell.Department of Aeronautics and Astronautics, Stanford University.

[3] Dr. George A. Pavlath Fiber-Optic Gyro DirectorNorthrop Grumman, Electronic Systems, Navigation Systems Division.

[4] Oliver J. Woodman An Introduction To Inertial Navigation, August 2007

[5] Fundamentals of GPS by P.L.N. Raju, Geoinformatics Division, Indian Institute of Remote Sensing,Dehra Dun

[6] Inertial Navigation Sensors by Neil M. Barbour,Charles Stark Draper Laboratory Cambridge.

[7] Random vibration test control of inverter-fed electro dynamic shaker by Chang-Ming Liaw; Wen-Chin Yu; Thin-Huo Chen; Dept. of Electr. Eng., Nat. Tsing Hua Univ., Hsinch

[8] Application of an Inertial Navigation System to the Quad-rotor UAV using MEMS Sensors by Tin Thet Nwe, Than Htike, Khine Myint Mon, Dr.Zaw Min Naing and Dr.Yin Mon Myint.

[9] Anderson e.w. The Principles Of Navigation(Hollies and Carter 1966).

[10] J. B. Kosmatka and S. L. Liguore,"Multi-disciplinary Design of Aircraft Structures "Journal of Aerospace Engineering, Vol.6, s No.3, July 1993.

[11] Hand book of Fibre Optic Gyroscope Sensing Technology,edited by Jose Miguel lopez, higuer 2000, John Wiley&Sons ltd.

[12] Globalpositioning System AR journal ,dec 2007 by kyle Holdmeyur, Paul j,Alisha D

[13] Aerospace CoatingOperations First Edition Contributing ARB Staff Steven Giorgi Randy Guensler.

[14] Applied Finite Element Analysis By G.Rammurthy