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Microwave Packaging for Space Communication Payload

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Abstract

The purpose of a microwave package is to integrate all the components of a sub-system in such a way to minimize size, mass, complexity and cost. This paper addresses the design, modeling and analysis of transponder casing for satellite communication payload. The design was checked for its performance under all critical loading conditions and was found to meet all requirements including stiffness and stability. The casing was fabricated and it showed compliance to dimensional accuracy requirements. The new improvised casing weighed 1.275 kg achieving a mass saving of around 22% on the existing structure.

Keywords–*Microwave Package, Payload, Satellite, Stability, Stiffness.*

I. INTRODUCTION

In aerospace industries, the most important factor considered while designing of a spacecraft is weight. To improve the payload carrying capacity of spacecraft as well as to reduce the launch cost, it is necessary to reduce the weight of a spacecraft [1]. In many industrial applications, reducing the weight of a structure without compromising its strength and stiffness is considered as one of the most important design criteria [2]. D. Shah et al. [3] achieved the 37% of mass reduction of Ku band channel amplifier with help of microwave packaging. Microwave packaging deals with the reduction of size, mass and cost of the product without compromising its performance under critical loading conditions. This paper shows the microwave packaging of transponder casing with help of Computer Aided Design (CAD) and Computer Aided Engineering (CAE).

II. DESIGN REQUIREMENTS OF MICROWAVE PACKAGE FOR SPACE USE

Package should fulfill following design requirements.

1. It should have high strength in order to withstand environmental and launch loads. The range of Random Vibration is 20 Hz to 2000 Hz [4].
2. The natural frequency of it should be above 100 Hz. It should not couple with spacecraft structure to avoid resonance [5].
3. The mass of the payload should be low to reduce the fuel consumption or to increase the payload carrying capacity of spacecraft [4].

III. DESIGN OF PAYLOAD

The important design goal while designing spacecraft or satellite is to reduce mass as it helps to increase payload carrying capacity of spacecraft and also helps to reduce the launch cost. This paper is about the mass reduction of payload. For this study, model of transponder casing was prepared using CAD software. The overall size of payload is 260 mm * 185 mm * 124 mm (height). Fig. 1 shows the CAD layout of the model.

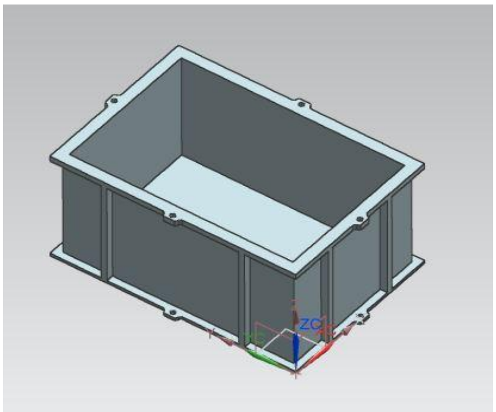

Fig. 1 CAD layout of the model

Aluminium T6-6061 has been selected for the model as it is light in weight and has high strength. It has good machinability.

The properties of Aluminium T6-6061 are as follows

Modulus of Elasticity – 72000 N/mm^2
Poisson Ration – 0.33
Density – $2.7*10^{-9}$ Ton/mm^3

IV. FINITE ELEMENT MODEL OF CASING (PAYLOAD)

Hypermesh has been used for Finite Element Analysis. Combination of automesh and manual mesh has been taken with "tria" and "quad" shell elements. Total numbers of elements are 17395 with 17546 nodes. Total numbers of quad elements are 17349 while total numbers of tria elements are 42. So, the number of tria elements is less than 5% of total elements. Total numbers of rigid elements are 4. Fig. 2 shows the meshed model.

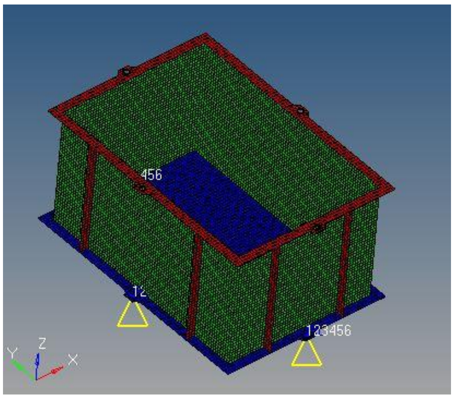

Fig. 2 Meshed model

In Fig. 2 different colors has been assigned to different elements having different thickness. Green, Blue and Red colors have been assigned to elements having thickness 4mm, 3mm and 6mm respectively.

After applying material properties and thickness to the model, the mass of the model was obtained as 1637 gm.

V. FINITE ELEMENT ANALYSIS OF CASING (PAYLOAD)

The casing is mounted by 4 numbers of screws. All 4 numbers of screw defined as a constraint for Finite Element Analysis. Finite Element Analysis is done by solver optistruct.

The Finite Element Analysis is done for random vibration condition ranging from 20 Hz to 2000 Hz and gravity load of 10g.

The results of modal analysis and stress analysis are as follows.

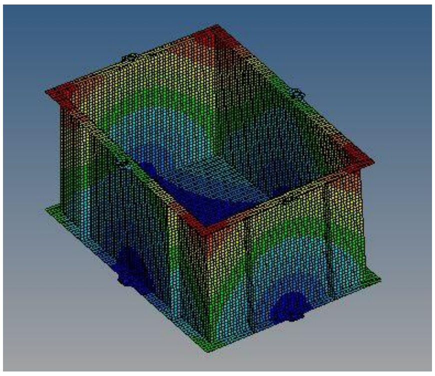

Fig. 3 First mode of natural frequency

From Fig. 3, it is observed that first mode of frequency is obtained at 264.83Hz.

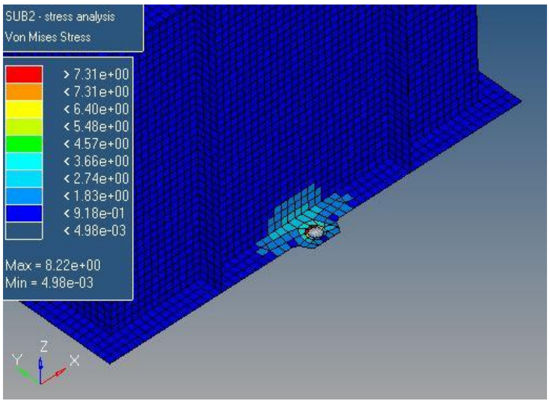

Fig. 4 Stress analysis

From Fig. 4, it is observed that the maximum stress induced at constraint is 8.22 Mpa which is well within the permissible limit of material.

VI. IMPROVISATION OF CASING (PAYLOAD)

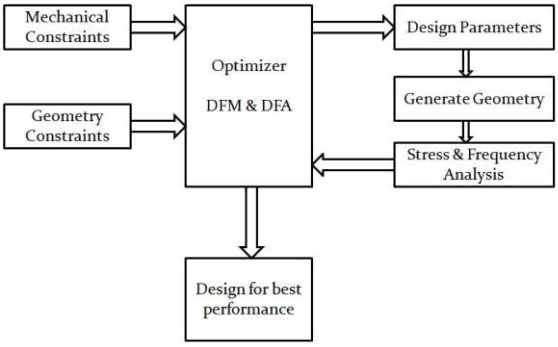

Fig. 5 Overview of microwave packaging

Fig. 5 shows the overview of Microwave Packaging. At the very first step the mechanical and geometrical constraints are given to an object based on the basis of the design parameters. Using these constraints and parameters geometry is prepared using CAD software. After this step analysis was carried out to measure stress and frequency. From this step the best and cost effective design from Design for Manufacturing and Design for Assembly point is selected and the resulted design is the best among all the design for its performance.

The design changes are given below:

Base Plate

Thickness of base plate is reduced to 2.5 mm from 3 mm.

Top Plate

Thickness of top plate is reduced to 5 mm from 6 mm.

Wall Plate

Thickness of wall plate is reduced to 3 mm from 4 mm.

Ribs

Thickness of ribs is reduced to 5 mm from 6 mm.

After microwave packaging, the mass of casing is reduced by 362 gram.

VII. FINITE ELEMENT ANALYSIS OF IMPROVISED CASING (PAYLOAD)

Hypermesh has been used for Finite Element Analysis. Combination of automesh and manual mesh has been taken with “tria” and “quad” shell elements. Total numbers of elements are 17602 with 17747 nodes. Total numbers of quad elements are 17530 while total numbers of tria elements are 68. So, the number of tria elements is less than 5% of total elements. Total numbers of rigid elements are 4. Fig. 6 shows the meshed model of improvised casing.

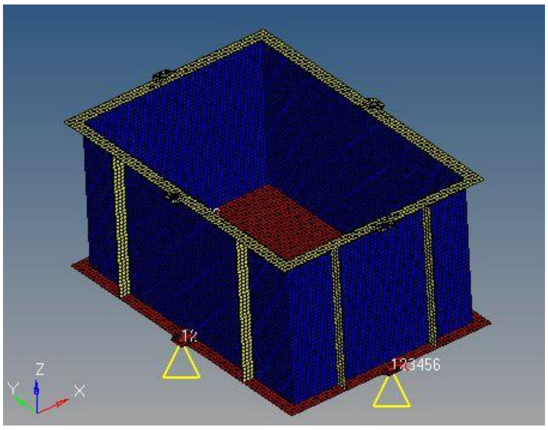

Fig. 6 Meshed model of improvised casing

Different colors have been assigned to different elements having different thickness. Red, Blue and Yellow colors have been assigned to elements having thickness 2.5 mm, 3 mm and 5 mm respectively.

After applying material properties and thickness to the model, the mass of the model was obtained as 1275 gm.

The Finite Element Analysis is done for random vibration condition ranging from 20 Hz to 2000 Hz and gravity load of 10g.

The results of modal analysis and stress analysis are as follows.

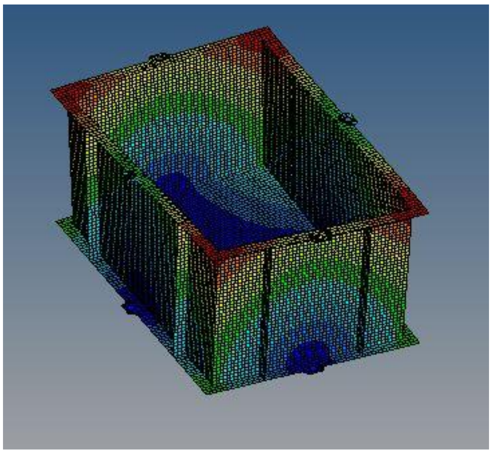

Fig. 7 First mode of natural frequency

From Fig. 7, it is observed that the first mode of natural frequency is obtained at 240.12 Hz. From the results, it is also observed that the first mode of frequency is greater than 100 Hz hence resonance is avoided. So the design is safe.

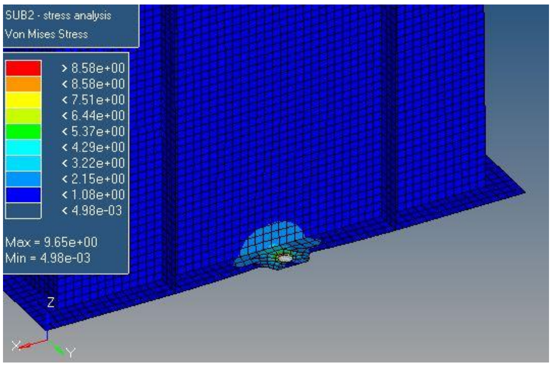

Fig. 8 Stress analysis of improvised casing

From Fig. 4, it is observed that the maximum stress induced at constraint is 9.65 Mpa which is well within the permissible limit of material. Hence the design is safe.

VIII. CONCLUSION

Some of the main positive aspects of this paper are as follows:

After microwave packaging the outcome is the reduction in mass of the current model by around 22%.

Stresses acting on the model after microwave packaging are less than the yield strength of the material. So the design is safe and it can withstand various stresses in the environment, forces during launching of satellite.

As the mass of the transponder casing is reduced, the payload carrying capacity of the launch vehicle is increased and also the efficiency of the space program increases. This work can give a hint for the researchers in the design of payloads.

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