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Finite Element Analysis of Payload for Space Applications

Pranav Mahamuni[1], Amol Kamthe[2], Rohit Cholke[3], Sachin Velapure[4], Yash Parikh[5]

[1, 2, 3, 4] **Department of Mechanical Engineering, Sinhgad Institute of Technology and Science, Pune, Maharashtra, India.**

[5]**Department of Mechanical Engineering, Symbiosis Institute of Technology, Pune, Maharashtra, India.**

Abstract
For aircraft or launch vehicles, its carrying capacity is defined as a Payload. It is usually measured in weights. For a rocket, payload can be satellite or scientific instruments. The design of the payload is a challenging task as it has to withstand space environment and launch loads. Due to launch vibrations, there are possibilities of failure of design of payload so it is very important to reduce these vibrations by alternative techniques. This paper studies the effect of different materials on the natural frequency of payload which helps in the reduction of the natural frequency of the payload and for safe functioning of satellite.
Keywords: *Payload, Satellite, Launch Loads, Natural frequency.*

1. Introduction

Mechanical vibrations into the system can cause many problems resulting in degradation of sensitive systems [1]. The static and dynamic unbalanced forces of rotary equipments placed near payloads generate vibrations which affect the pointing of precision payloads and devices in space platforms [2]. In a Spacecraft, vibrations are produced by on board equipments such as boosters, electric motors, reaction wheels. They propagate through the satellite structure towards payloads. Due to these vibrations, there are possibilities of failure of the payload due to fatigue stresses. So it becomes necessary payload to withstand these vibrations so as to avoid the structural failure of the payload.

The natural frequency of a payload changes with the change in material [3], it becomes necessary to choose such a material which will itself damp the vibrations and also be light in weight so that it will reduce the payload mass. As mass plays an important role in payload carrying capacity of a space craft, it is necessary to reduce the mass of a payload. With the reduction in the mass the propulsive thrust required at the time of a launch is reduced thus reducing the fuel for combustion.

In this article, Finite Element Analysis has been done to see the effect of change in natural frequency as a result of change in mass and material.

2. Design Requirements for Payload

Payload 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.

3. Design of Payload

For aircraft or launch vehicles, its carrying capacity is defined as a Payload. It is usually measured in weights. For a rocket, payload can be satellite or scientific instruments. The satellite consists of different subsystems like structural subsystem, telemetry subsystem, power subsystem, thermal control subsystem, altitude control subsystem and communication payload [6].

The scope of this paper is limited to designing of payloads. As mass plays an important role in the design of the payload, which directly or indirectly affect the frequency of the payload. This paper shows the effect of change in different material on frequency because the frequency of an object changes with change in material.

To study this effect, an arbitrary model of transponder casing was prepared using CAD software. The overall size of payload is 250 mm * 175 mm * 122.2 mm (height). Fig. 1 shows the CAD layout of the model.

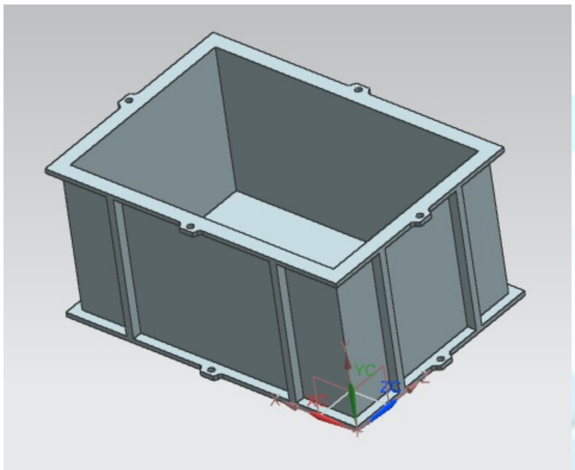

Fig. 1 CAD layout of the model

4. Simulation through Finite Element Analysis

4.1 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 number of elements are17161 with 17328 nodes. Total number of quad elements are 17153 while total number of tria elements are 8. So, the number of tria elements is less than 5% of total elements. Total number of rigid elements are 4. Fig. 2 shows the final meshed model.

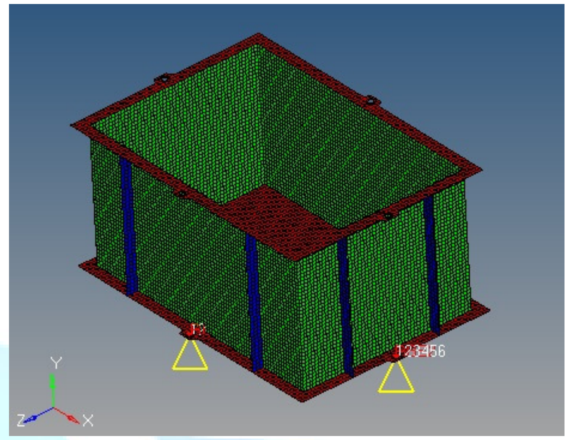

Fig. 2 Final meshed model

In Fig. 2 different colours has been assigned to different elements having different thickness. Green, Blue and red colours have been assigned to elements having thickness 4.3mm, 6mm and 3.6 mm respectively.

4.2 Finite Element Analysis with Aluminium T6-6061 as a Material

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

The properties of Aluminium T6-6061 are as follows

Modulus of Elasticity – 70000 N/mm^2
Poisson Ration – 0.33
Density – 2.7*10^{-9} Ton/mm^3

After applying the material and properties the mass of the payload obtain was 1719gm.

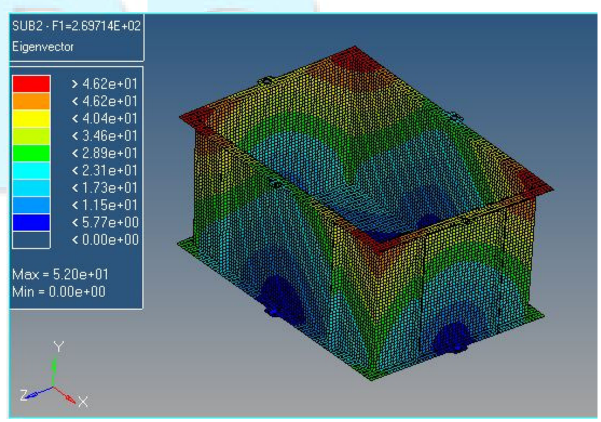

Fig. 3 Modal analysis result for first mode

Fig. 3 shows the modal analysis result of model for the first mode with aluminium T6-6061 as a material. The Table 1 shows the next modes obtained from the analysis.

Table 1: Modal analysis result

Mode	*Frequency (Hz)*
1^{st}	269.71
2^{nd}	547.98
3^{rd}	611.61
4^{th}	788.17
5^{th}	941.60

4.3 Finite Element Analysis with Titanium as a Material

Titanium has been selected for model as it has high strength, stiffness, toughness and resistance to corrosion.

The properties of Titanium are as follows

Modulus of Elasticity – 120000 N/mm^2
Poisson Ration – 0.33
Density – $4.5*10^{-9}$ Ton/mm^3

After applying the material and properties the mass of the payload obtain was 2865gm.

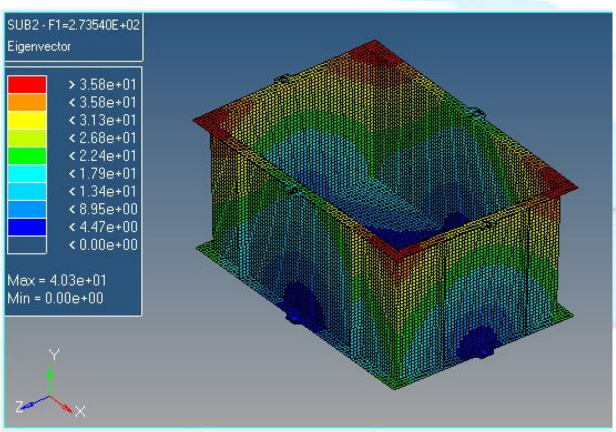

Fig. 4 Modal analysis result for first mode

Fig. 4 shows the modal analysis result of model for the first mode with Titanium as a material. The Table 2 shows the next modes obtained from the analysis.

Table 2: Modal analysis result

Mode	*Frequency (Hz)*
1^{st}	273.54
2^{nd}	555.75
3^{rd}	620.28
4^{th}	799.35
5^{th}	954.59

4.4 Finite Element Analysis with Epoxy Carbon as a Material

Epoxy Carbon has been selected for model as it has high strength to weight ratio. They are extremely strong and light in weight.

The properties of Epoxy Carbon are as follows

Modulus of Elasticity – 70000 N/mm^2
Poisson Ration – 0.3
Density – $1.6*10^{-9}$ Ton/mm^3

Here the material properties considered are of Epoxy Carbon sheets. After applying the material and properties the mass of the payload obtain was 1019gm.

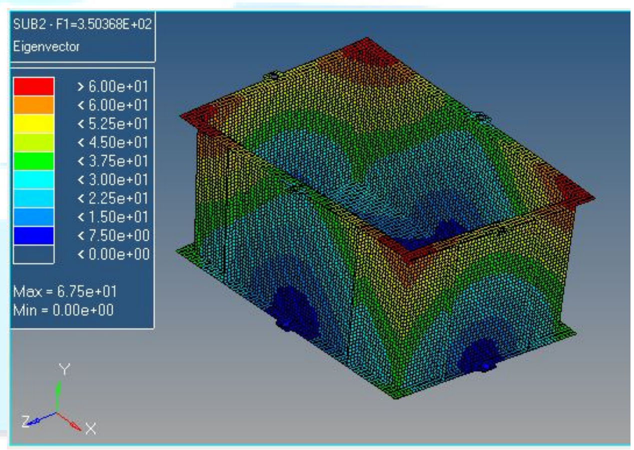

Fig. 5 Modal analysis result for first mode

Fig. 5 shows the modal analysis result of model for the first mode with Epoxy Carbon as a material. The Table 3 shows the next modes obtained from the analysis.

Table 3: Modal analysis result

Mode	*Frequency (Hz)*
1st	350.36
2nd	711.85
3rd	794.50
4th	1023.87
5th	1223.18

4.5 Comparison of Frequencies for Different Materials

From Finite Element Analysis, it is observed that natural frequency modes changes with change in material of the model. The first mode of the model having Aluminium T6-6061 as a material is obtained at 269.71 Hz. The first mode of the model having Titanium as a material is obtained at 273.54 Hz. The first mode of the model having an Epoxy Carbon as a material is obtained at 35036 Hz.

Fig. 6 shows the comparison of modal analysis results for different materials.

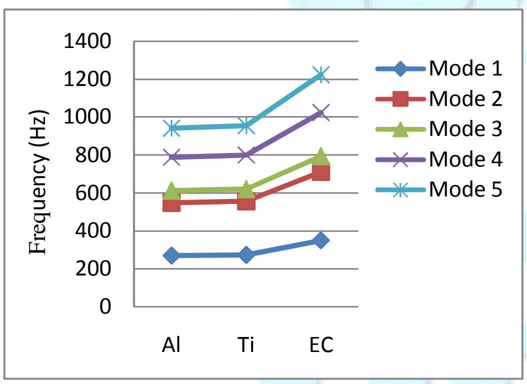

Fig. 6 Comparison of frequencies for different materials

From Fig. 6, it can be seen that the first mode frequency for Aluminium T6-6061 is least while it is maximum for the Epoxy Carbon.

5. Conclusions

The different results obtained in this paper are hopeful and from these results, it is clear that change of material lead to change of frequencies. For these reasons, material selection plays a vital role in designing of spacecraft components. It is also observed that Aluminium T6-6061 is a suitable material for designing of payloads. This work can give a hint for the researchers in the design of payloads.

Acknowledgments

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