Development of Thermal Compensating Mechanism for Spacecraft Component

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Development of thermal compensating mechanism for cavity filter, A cavity filter is apart of spacecraft component. Temperature compensation mechanism based on material differential co-efficient of thermal expansion (CTE).Most of time spacecraft component operate in thermally varying environment. When satellite components made of dissimilar materials and made to operate in thermally varying environment shows tendency to develop stresses and strains at joint and cause change in functional performance of sub-system. Aim of this paper is to replace invar cavity filter with aluminum and to develop temperature compensation mechanism. Thermally compensated aluminum high power cavity filter provide major optimization in cost and mass. This work proposes a compensating mechanism with a development of prototype. Development of compensating technique is made possible with the use of various experimental methods. Validation of developed mechanism is done by using FEA simulation with the help of CAE tool. The correlation has been developed between the measured data and the FEA result for validation purpose.

1. Introduction

This paper on cavity filters which is part of the Multiplexer (MUX). The Mux contains of circular cavity filter, irises, input adapters, output adapters, manifold, rigid bracket, flexible bracket, base plates. All these components are assembled to meet a defined functional performance. A cavity filter is made of invar material, Invar is used as special alloy for spacecraft component for vary specific properly of low CTE (1 to 1.5E-6 1/˚c) but this metal is very hard to machine and undergoes a calculate set of stress reliving by heating during difference stage of machining, these stress if not relieve properly will have a bearing on dimensions of sub system most spacecraft have their function performance and geometry tolerance. A mass penalty is also incurred when using Invar over aluminum, which is especially costly in satellite applications. For launch costs of $25000 per kilogram, so it will be very useful for reduced overall weight of satellite. However, constructing a component from Invar is more costly than using aluminum, both in terms of material and machining costs. The Mux assembly also huge amount of heat dissipate into the system is addition to the temperature excursions which happens during satellite operation. The functional performance is depending upon the physical dimension of all the component constraint simultaneously. Any change in the size of component will have in effect on the performance. This performance is also of effected by stress / strain created by various constraints in the assembly. This stress varies with respect to variation in the temperature during satellite operation. To curtail this special metal like invar is used where CTE (α) is low and expansion and contraction minimum. But invar having very poor thermal conductivity, very hard material, and poor machinability during machining stress reliving cycle must be carried out; its CTE (α) is temperature dependent. It is highly disadvantage. To developed solution for these aluminum alloys is used to get advantage of light weight, strength to weight ratio is higher and easy machinability and high conductivity but aluminum alloy has high CTE (α) 24*10-6 mm/mm/˚c these property of aluminum will cause higher expansion when subjected temperature excursion and these for very severely effect the functional performance of sub-system. So that development of thermal temperature compensation mechanism will help when expansion occurs at that time compensation mechanism produce contraction by country effect of expansion [1].

2. Existing cavity filter

The Mux is combination of two or more cavity filter channels connected with help of single input manifold.

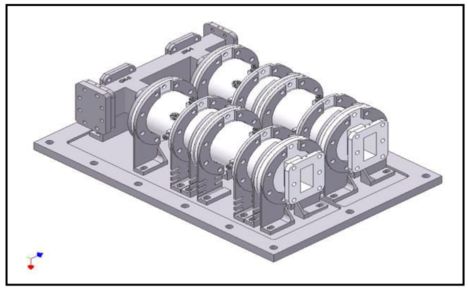


Figure 1 MUX Assembly (2 Channels)

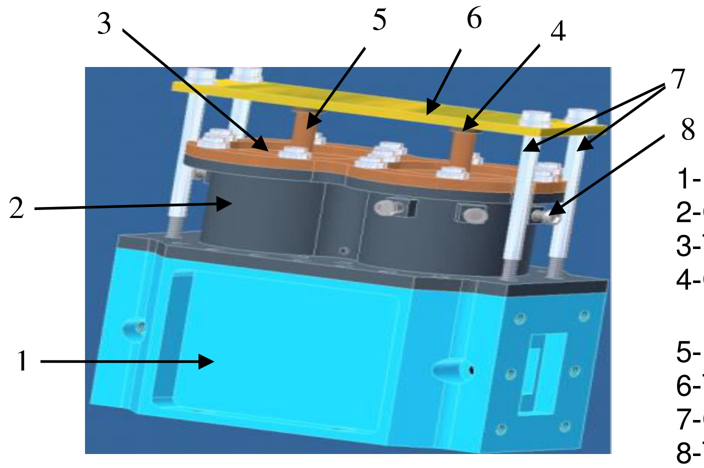
Cavities filter which is composed of hollow cylindrical cavities of precise dimension and the iris between the cavities. MUX consists of mainly two types of brackets depending upon the functionality. Supporting Brackets (Rigid brackets), Brackets for heat conduction (Flexible brackets).These channels are made of invar material. Invar having higher CTE (α) so that MUX assembly is too much bulky and overall mass of satellite will increase. Aim of paper is invar cavities replace with aluminum alloys so the overall mass optimization of subsystem [2].

3. Requirement of temperature compensation mechanism

Existence cavity filter made of invar. Invar is replace with aluminum alloys so that aluminum having higher CTE (α) it is expand more and inside volume of cavity will increase and cavity filter frequency will swift these is not allowed into the system. Therefore to maintain initial volume of cavity filter, the thermal temperature compensation mechanism is required [2, 3].

4. Working of proposed cavity filter

This is assembly of the cavity filter, which made up of aluminum alloy .when microwave energy pass and it dissipate some heat in cavity which will cause temperature of cavity rise and being aluminum cavity expand 24 ppm. When cavity expand volume of cavity increase which will change microwave frequency which depend upon volume of cavity this will cause the microwave frequency swift because change in volume this is not allowed in system. Therefore it is required to maintain volume of the cavity as its initial volume even at temperature change. To design such system this type of mechanism is proposed this mechanism will try to compensate change in volume. When cavity expand diaphragm also being expand so plunger expand which push top plate but top plate being rigid and not more expand therefore country effect on to the plunger. This will apply retracting force on to the plunger which in turn pushes diaphragm into the cavity and thus changes the volume of cavity to its original volume so that compensating volume change [3, 4].



1-Bottom body
2-Cavity filter
3-Thin diaphragm
4-Circular piece

5-Plunger
6-Top plate
7-Control rods
8-Tunning screw

Figure 2 Cavity filter

4. Simulation under two Different Conditions

1. Simulating condition of the assembly under free-free condition with thermo-structural analysis.
2. Simulating condition of the assembly under compensation with thermo-structural analysis.

Thermal and structural boundary condition

Thermal contact conductance between metal to metal=3000 (W/m^2 ^{o}C).

Thermal contact conductance between metal to nonmetal=2000(W/m^2 ^{o}C).

Heat flow into the bottom body=7 (W).

Convection at all surfaces.

Ambient temperature =25 ^{o}C

All parts are constraint as per the assembly sequence.

Grounding all four holes is fixed supports.

4.1 **Simulating under free-free condition with thermo-structural analysis**

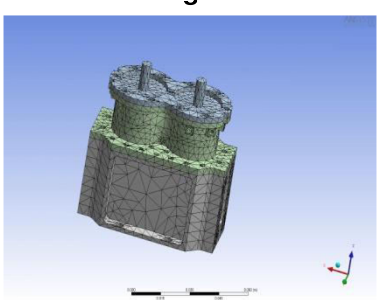


Figure 3
Mesh model of free-free condition

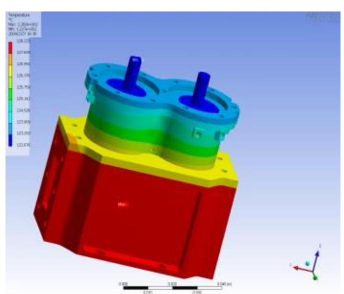


Figure 4
Temperature profile

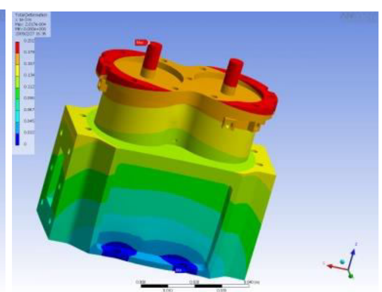


Figure 5
Deformation profile

The applied thermal boundary condition with free-free condition that gives the temperature distribution profile for the system as shown in Figure 4, Than after loading all structural boundaries condition that give deformation of system as shown in Figure 5.

Maximum temperature at bottom body =128.225 ^{o}C

Minimum temperature at plunger and diaphragm =122.676 ^{o}C

Maximum deformation on plunger and diaphragm =202 µm.

Minimum deformation on four mounting holes=0

4.1.1 Experimental under the free-free Condition

Experimental setup as shown in Figure 6 input heat is supply with help of resistive heaters. Heaters are attaching on to the circumferences of bottom body. Input heat 7watt supply with help of voltage variance to bottom body. Parts are expanding due to the heat supply and expansion measure with help of two dial gauges. A body temperature is measure with help of two temperature sensor which are attaching on bottom body and cavity.

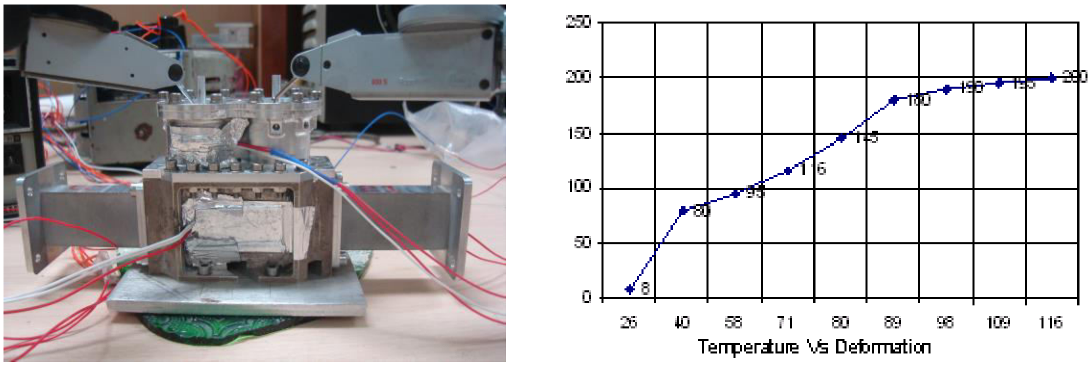


Figure 6 Experiment setup under free-free condition

4.2 Simulating under compensation with thermo-structural analysis

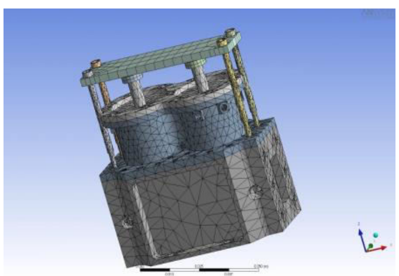


Figure 7

Mesh model-compensation mechanism,

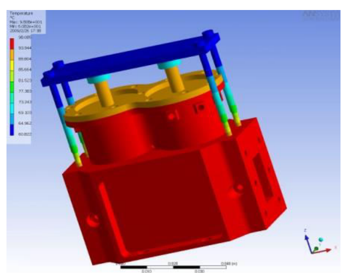


Figure 8

Temperature profile

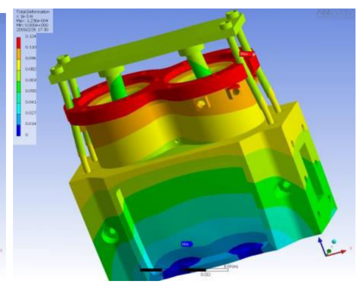


Figure 9

Deformation profile

The applied thermal boundary condition with compensation that gives the temperature distribution profile for the system as shown in Figure 7, Than after loading all structural boundaries condition that give deformation of system as shown in Figure 8.

Maximum temperature at bottom body and cavity =98.085 ^{o}C

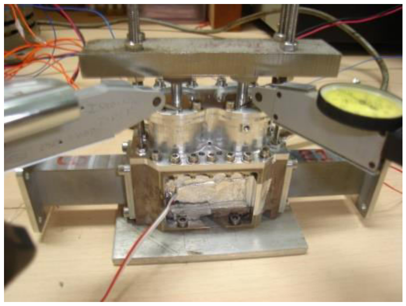
Minimum temperature at invar plate and control rods =60.822^{o}C

Maximum deformation on diaphragm flange =124 µm.

Minimum deformation on four mounting holes=0

4.2.1 Experimental under the compensation condition

Experiment setup deflection measurement on to the diaphragm and diaphragm flange with help of dial gauges. When input heat supply start thin wall diaphragm is continuous expanding but at particular stage it will start contacting even temperature rise. It means retracting force on to the plunger and it transfer to diaphragm. But incase measurement on to the diaphragm flange Continuous Deflection increase because there is no retracting force acting.



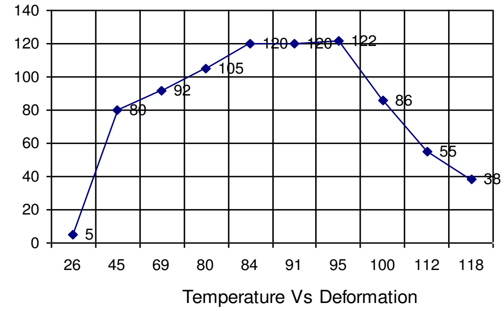


Figure 10 Experiment setup under compensation

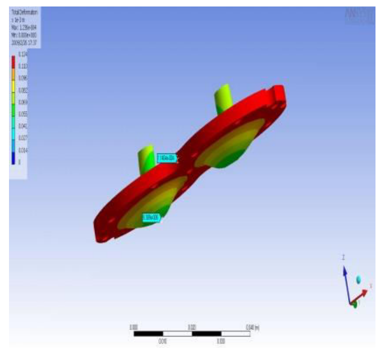


Figure 11 Deformation (Practical)

Figure 12 Deformation (simulation)

5. Conclusion

Condition	Free-free	Compensation
Expansion(µm)	200-8 = 192	122-5 =117
Contraction(µm)	0	122 – 38= 84
Percentage of Compensation (%)	0	71.79

Practical result shows that increases in temperature cause diaphragm to expand. At particular temperature deformation becomes stable and after inspite of increase in temperature it start contraction because of retracting force is transferred from plunger to diaphragm.

6 References

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