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Structural Simulation of Flexure Compliant Mechanism for Stress Reduction for Space Payload System

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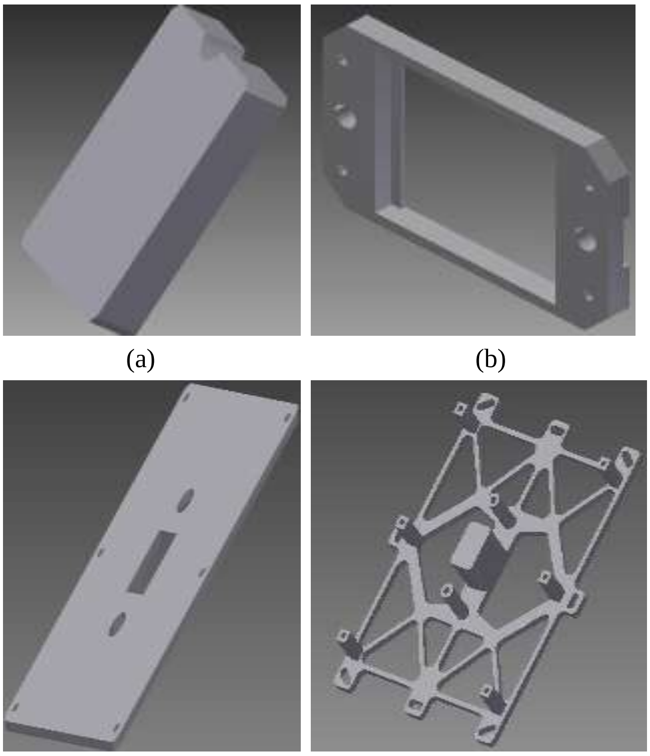
Abstract

Detector Head Assembly (DHA) is a one of the most important assembly in the optical space payload. DHA consist the detector, detector mount, PCB and DHA frame. However detector malfunction was identified as most critical failure of DHA. Due to the temperature changes the thermal stresses are develop on detector and results in the malfunctions or cracks are generating on the detector. To reduce the thermal stresses on detector by providing flexure compliant to detector mount, so detector is thermally expandable or contract able. We proposed kinematics synthesis approach for concentrated or lumped compliant in which various geometries are optimized to develop a compliant detector mount for payload. There are number of different iterative compliant mounts are modeled using the modeling software package and also using ANSYS, to check the equivalent or von-misses stresses on the detector and total deformation level of DHA.

Keywords-*Flexure compliant mechanism, Detector, Detector mount, PCB, DHA frame, Equivalent stress, Total deformation.*

I. INTRODUCTION

The detector along with its processing electronics, mechanical mounting and thermal control system is known as Detector Head Assembly (DHA) of an imaging system. DHA consists the detector, detector mount, PCB and DHA frame which are shown in figure1.



(a) (b) (c) (d)

Figure1. (a) Detector (b) Detector mount (c) PCB (d) DHA frame

Detector is an important part of the DHA and it is infrared based detector. DHA frame provide structural integrity and thermal balance. The detector mount is used to hold the detector. The PCB (printed circuit board) is electronic circuit for operate the detector. Assembly of the components that is Detector Head Assembly (DHA) is shown in figure2.

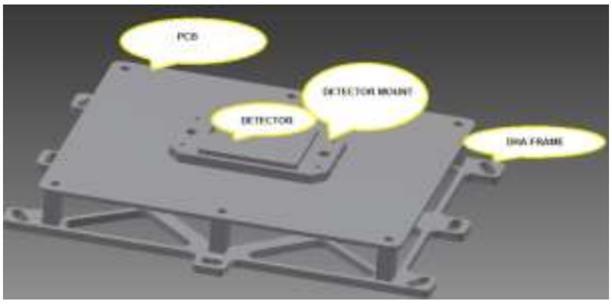


Figure2. Assembly of components-DHA

DHA is an important part of the imaging system, performance of DHA has major impact on the quality parameters of the imaging system. The detector is placed at focal plane of the imaging system thus, it receive useful electromagnetic (light) signals and transforms it in an electronic charge & finally in digital format which is read by the detector electronics. Optics captures the signals in the form of light coming from planet surface.

Detector is mounted on the mount made up of kovar material. As kovar has matching co-efficient of thermal expansion with alumina, it will minimize the thermal stresses caused by the temperature gradient. Detector id directly screwed to the DHA frame at two lugs through mount. The power is controlled and supplied to the detector by PCB card. The detector is connected to the PCB card by the kovar pins. The PCB card is then mounted on the DHA frame at six points. The frame acts as heat sink to remove heat from highly heat dissipating electronic components.

1.1 Thermo-Structural Stress

Thermal stresses are the stresses induced in a body due to changes in temperature. Thermal stresses are set up in a body, when the temperature of the body is raised or lowered and the body is not allowed to expand or contract freely.

In the field of space technology, the combinations of different materials are frequently used. Due to the temperature changes, thermal stresses are develop into components & which causes the malfunctions on it. Thermal stresses can be reduced by the flexure compliant mechanism, which provides the flexibility in the components. This flexibility makes the components/materials easy to expandable or contactable according to temperature changes.

II. PROCESS METHODOLOGY

In DHA, the detector mount works as rigid member. Due to the temperature changes, the thermal stresses are generating. Generation of thermal stresses, results in cracks are formed on the detector. To reduce the stresses on the detector by the flexure compliant is provide to detector mount. The flexure compliant mechanism provides flexibility to detector, which is easily thermally expandable or contract able according to temperature changes, so the stresses on detector can be reduce.

2.1 Compliant mechanism

Compliant mechanisms are flexible mechanisms that transfer an input force and displacement from one point to another point through elastic body deformation. A flexible structure that elastically deform without joints to produce a desired force and displacement. These are usually monolithic (single-piece) or joint less structures with certain advantages over rigid-body or jointed mechanisms.

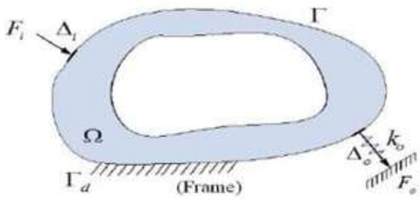


Figure3. A monolithic compliant mechanism

A compliant mechanism can be defined as a single piece flexible structure, which allows elastic deformation to achieve force and motion transmission. It gains motion from relative flexibility of its members rather than from rigid-body. Compliant mechanism is a combination of a structure and a mechanism, since the jointless feature resembles a structure, while the function of structure resembles a mechanism.

The main advantages of compliant mechanisms over the classical one are: no joints, no friction or wear, monolithic, no assembly etc. Because of these advantages compliant mechanisms are used in many applications including manufacturing, product design, aerospace, robotics, biomedical devices, MEMS, gripper, motion amplifier, positioning devices, adaptive structures, shape morphing structure, surgical tools etc. It has several disadvantages like small displacements and forces, limited by fatigue, hysteresis and creep, difficult to design. [1-4]

2.1.1 Synthesis of compliant mechanism

Compliant mechanisms can be classified into two groups: mechanisms with concentrated compliance and mechanisms with distributed compliance. Mechanisms of the first group are obtained from their conventional classical joints with so-called flexure hinges. Usually, flexure hinges are realized as short-length regions with reduced cross-section and therefore low bending stiffness. Mechanisms with concentrated compliance realize their mobility due to elastic deformation of flexure hinges. It is also called mechanisms with lumped compliance or partial compliance mechanisms.

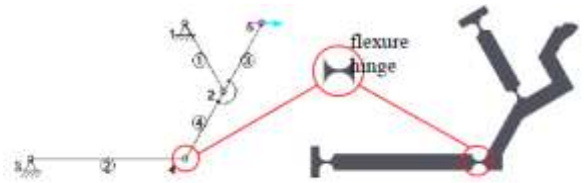


Figure4. Mechanisms with concentrated compliance

Whereas mechanisms with distributed compliance make use of longer and thicker bending elements with the objective of better distributing the strain and stress over the structure. It is treated as a continuum mechanics design methods are used instead of rigid body.

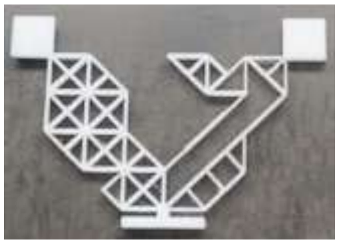


Figure5. Mechanisms with distributed compliance

2.1.2 Approaches for synthesis

Because of significant differences exist between these two groups of compliant mechanisms; two fundamentally different approaches are used: kinematics synthesis approach and continuum synthesis approach.

Kinematics synthesis approach is used for the design of concentrated or lumped compliant mechanisms and is based on rigid-body kinematics. Since a lumped or concentrated compliant mechanism can be seen as a traditional mechanism with flexure pivots (flexure hinges) replacing the classical joints and in consequence methods conceived to design rigid body mechanism can be modified and applied successfully in this case.

Where continuum synthesis approach used for design of distributed compliant mechanisms. It is focused on the topology, shape and size of the mechanism. In distributed compliant mechanisms, the topology and shape of the material continuum give these mechanism ability to deform and hence the motion and force transmission capability. Topology is defined as the pattern of connectivity or spatial sequence of members or elements in the structure. Once the topology and shape of the mechanisms are defined, the last step is size optimization where the design variables are the

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cross-section, thickness dimension of element segments. [1-4]

Here in our problem the kinematics synthesis approach is well suited for concentrated compliance to develop flexure compliant detector mount. Based on design, position etc. of the mount the mechanism with concentrated compliance fit for solving our real problem to reduce stress on the detector.

2.2 Material selection

Material properties of components are illustrated in table1.

Table1. Material Properties

Components	DHA Frame	Detector Mount	PCB	Detector
Material	Al 6061 T6	kovar	FR4	alumina
Density in kg/m^3	2770	7850	1900	3960
Coefficient of expansion in $°C^{-1}$	2.3E-5	5.8E-6	20E-6	5.6E-6
Modulus of elasticity in pa	7.1E10	2E11	15E10	37E10
Poison ratio	0.33	0.3	0.42	0.22

2.3 Process flow chart

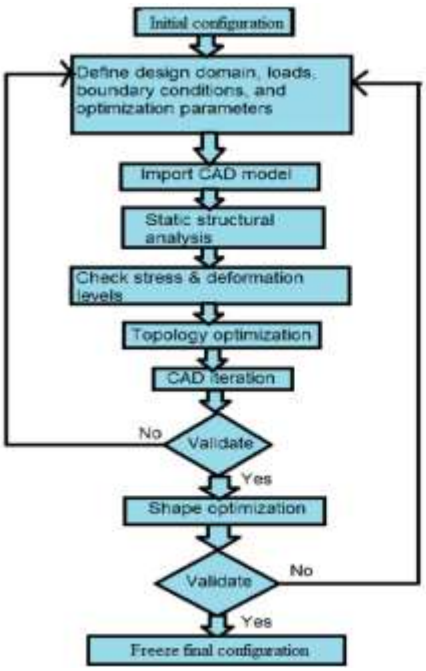


Figure6. Process chart

2.4 Consideration

(1) All the bolted connections are considered as bounded or constrained in analysis.

(2) The thermal condition: reference temperature is 22Ċ and final temperature is 50Ċ.

(3) Fixed support condition: DHA frame integrates all the components and 8 faces are at bottom of DHA frame are fixed.

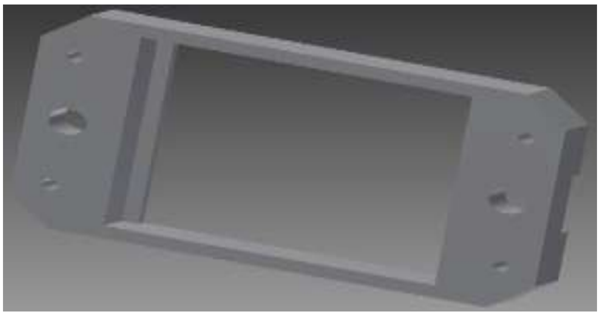
III. MODELING CONFIGURATION & ANALYSIS

There are number of iterative different flexure compliant detector mounts are modeled in CAD software package and then imported in to ANSYS for analysis; to observe the equivalent or von-misses stresses on the detector and deformation of the assembly.

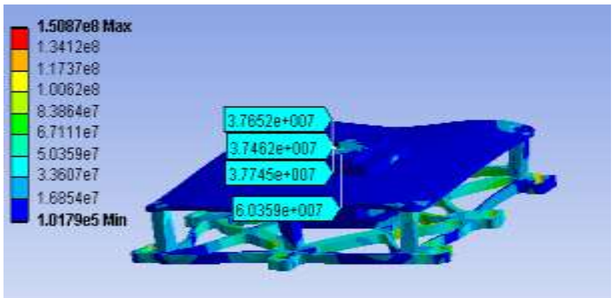
The modeling configurations and analysis (von-misses stress) result have shown in figure 7 & 8.

3.1 Analysis of DHA without flexure compliant detector mount:

Initial configuration:



(a)



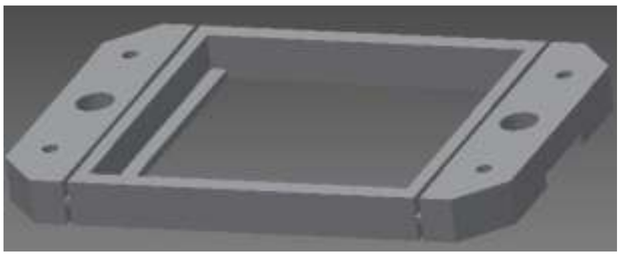
(b)

Figure7. (a)Detector mount configuration (b) stress result on detector

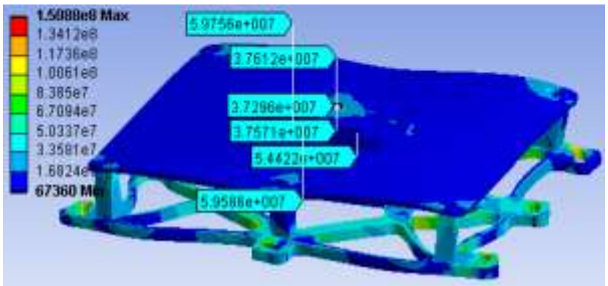
3.2 Analysis of DHA with flexure compliant detector mount:

At various steps, we achieving different configuration of detector mount and corresponding stress results on detector which are illustrated in figure 8.

Step 5:

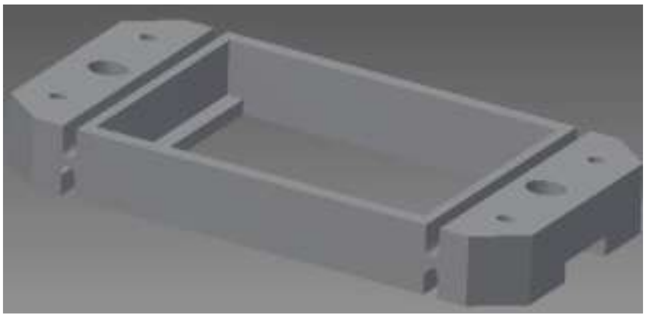


(a)

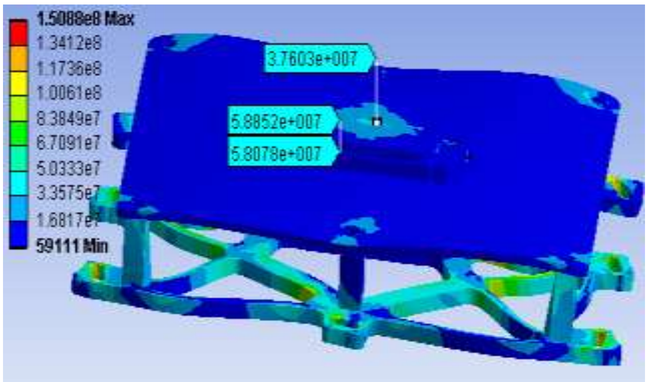


(b)

Step 10:

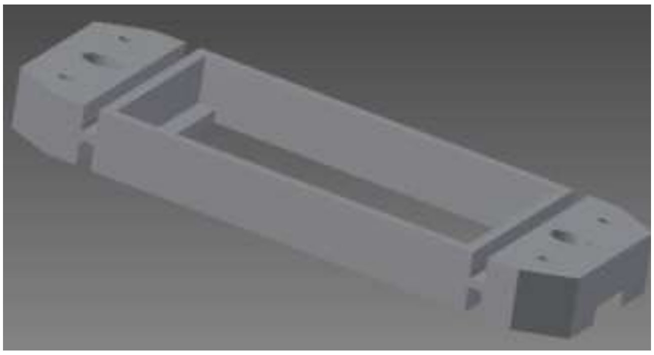


(a)

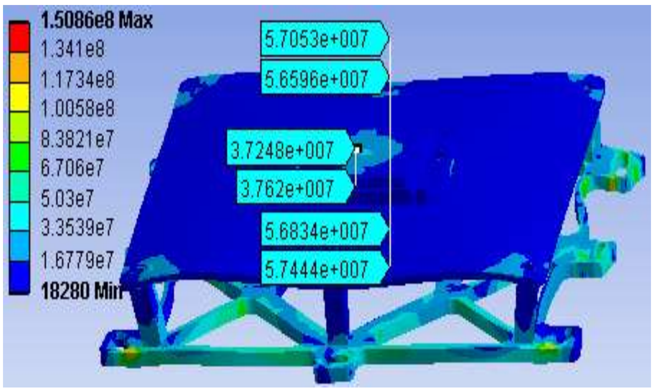


(b)

Step 15:

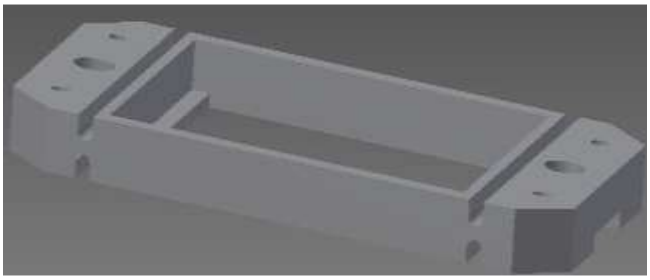


(a)

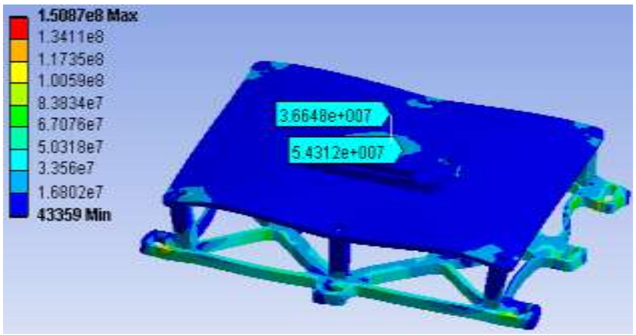


(b)

Step 20:

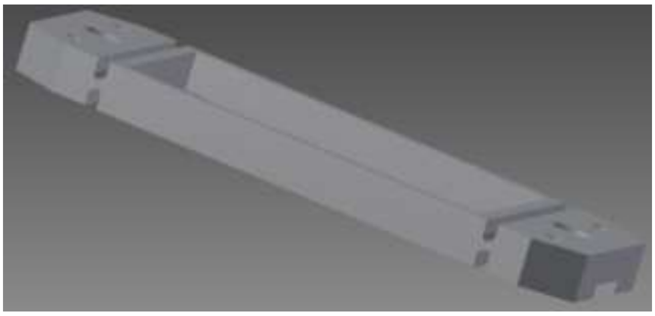


(a)

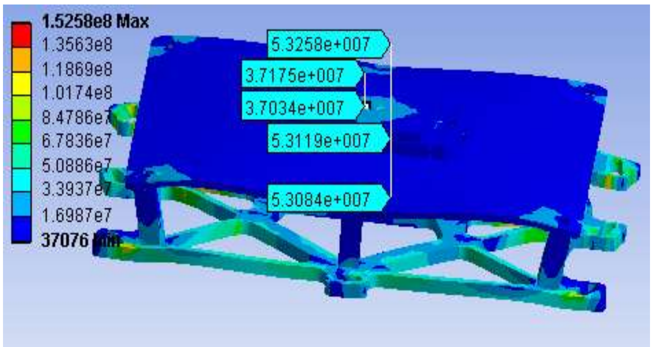


(b)

Final configuration:



(a)



(b)

Figure8. (a) Detector mount (b) stress result

IV. RESULTS & DISCUSSION

For the given thermal and fixed support conditions, observe the von-misses stresses on the detector of DHA. The simulation results carried out in below table2.

Table2. Results

Sr no.	Descriptions	Von-misses stress on detector
1	Initial configuration of detector mount without flexure compliant	60.36Mpa (6.0359E7 pa)

2	final configuration of detector mount with flexure compliant	53.26Mpa (5.3259E7 pa)

Initial configuration without flexure compliant detector mount the stress result is 60.36Mpa. Stresses are reducing by application of compliant mechanism. The final configuration with flexure compliant detector mount the stress result is 53.26Mpa.

V. CONCLUSION

In this paper, the flexure compliant mechanism is modeled in CAD software package and the analysis is carried out using ANSYS simulation package. The flexure compliant detector mount is used for reduce the thermal stresses on the detector; which generates due to temperature changes. Here design and position of mount, the kinematics synthesis approach used for develops the concentrated flexure compliant detector mount. Different iterative compliant detector mounts are modeled and imported into ANSYS for analysis; to observe the equivalent or von-misses stresses on the detector. Results are shown that the thermal stresses on detector reduce from 60.36Mpa to 53.26Mpa, so problem of malfunctioning or cracks generation on detector is tackle.

ACRONYMS

CAD: Computer Aided Design
DHA: Detector Head Assembly
MEMS: Micro Electro-Mechanical System
PCB: Printed Circuit Board

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