“DESIGN AND ANALYSIS OF STABLE PLATFORM FOR SATELLITE OPTICAL PAYLOAD”

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Abstract: -This paper constitutes the study good earth imagery from the optical sensors and camera of the satellite in space, good dimensional stable structure is required for supporting the payloads. A small deflection in the support structure of optical payload causes large deviation of focus area from the required target image. To avoid this the selection of material for the structure is important and the material should have a low thermal coefficient of expansion and low density for this we have selected CFRP (Carbon fibre reinforced polymer) as a material, and we have designed a tripod for the supporting structure for the optical payload and sensors. This consumes less space, less material and increased strength as compared to other truss members. This consists of mainly three parts upper deck, pod, and end caps, increasing the strength and stability for the supporting structure. We have assigned and stacked various layers of CFRP with required properties and independent orientation of fibres. The temperature variation in space ranging from -170ºC to +100ºC. The thermal control system will control these temperatures to the working range of $+80^{0}$c to -30^{0}c. Due to this temperature variations in the spacecraft structure material gets expanded and contracted. The effect of these temperature variations, on the dimensional stability of the structure thermo-elastic deformation analysis also carried out for extreme temperature ranges. During launching, spacecraft will experience vibration loads at the spacecraft interface to the launch vehicle. These vibration loads are further amplified at the subsystem level within the spacecraft. The low frequency vibration loads added to the steady state acceleration of the launch vehicle impart the combined dynamic and static loads on the spacecraft. This loading is called as Quasi-Static loading and the static analysis is carried out with inertial loading conditions. The stresses and failure indices on the composite materials are calculated for above different analyses types. The change in the orientation of the mounting plane of the optical payload is also estimated for extreme temperature conditions.

***Index Terms*:** CFRP, Optical payload, Tripod Support, Pod, Platform and Tripod.

1.Introduction:

ISRO mainly has 2 categories of satellites, namely Communication satellite and Indian Remote Sensing satellite (IRS class). IRS satellites quickly enables India to map, monitor and manage its natural resources at various spatial resolutions. IRS satellites carry out the operation with the use of its optical payloads (High capacity camera and optical sensors). IRS satellites are of 3 different series: Resoursat, Cartosat, Oceansat.

The IRS system is one of the largest constellations of the remote sensing satellites for which civilian use in operation today in the world, with 11 operational satellites. These all are placed in the polar sun-synchronous orbit and provide data in a variety of spatial, spectral and temporal resolutions. Indian Remote Sensing Program completed its 25 years of successful operations on March 17, 2013. Optical Payload are either fixed or only have limited yaw movements from its structure, hence they need to be properly aligned to function accurately. RS satellite which will be placed at around 800 – 900 kms altitude (Sun Synchronous polar orbit) travelling at a speed of 10 – 11 km/sec, at these circumstances the satellite has to point correctly to its target so even the minute deflections can result in very large displacement. Hence even deflections in angstrom are also considered for designing. Satellite undergoes various temperature changes (-170°c to +100°c) and also faces high vibrations during lift off.

The material used is composite material (CFRP). A composite material is study of material which is being made from two or more materials with different physical and chemical properties, the individual components remains separate and thus distinct within the complete structure. New materials are preferred for many reasons such as materials which are stronger, lighter and expensive when compared to traditional materials. Composite materials are basically used for aerospace applications, satellites, automotive industries buildings purpose, structures, bridges, swimming pool panels, racing car bodies and airlines.

Table 1.1: Comparison of CFRP with aluminium.

Aluminium	**CFRP**
Density: 2700 kg/m^3	Density: 1550 kg/m^3
Thermal expansion Co-eff: 23 E-6/ºc	Thermal expansion Co-eff: 2.15 E-6/ºc
Tensile Strength: 650 Mpa	Tensile Strength: 1600 Mpa
Thermal Conductivity: 250 W/(mk)	Thermal Conductivity: 24W/(mk)
Compression Strength: 390 Mpa	Compression Strength: 700 Mpa

2.Objectives:

- Designing a stable platform for optical satellite payload, achieving the dimensions, parameters, materials, selection of design criteria.
- Improve the design to minimize the effect of deformation due to temperature changes.
- The aerospace structure generally requires lightweight designs. The goal of these designs is to optimize the strength per weight ratio, or efficiency of the design.
- To improve the total structural strength of the support system.
- To have good damping effect, to eliminate the vibrations to payload. High vibrations occur during lift off.
- To minimize the total space for the support structure.
- To maximize the stability of payload to stay stable even under the 30 G's (G-Force).

3.EXPERIMENTAL WORK:

3.1: Model generation and Designing work.

For the need of a stable platform for a satellite optical payload. We created a design model i.e. TRIPOD. The model is being created by using UGNX Software in the ISRO industry premises. The upper deck consists of honeycomb structure in the centre and two layers of composites on either side of the deck.

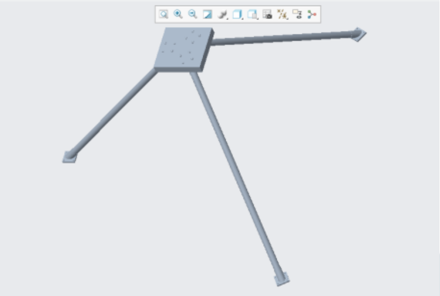

Fig 3.1a: Tripod structure.

For the good strength and density to the weight ratio, material preferred is CFRP (Carbon fibre reinforced polymer) as a composite material. For the reduction of the weight in the tripod we selected honeycomb structure platform for the upper deck of the tripod. Titanium bolts have been used for the connection of upper deck and the pod.

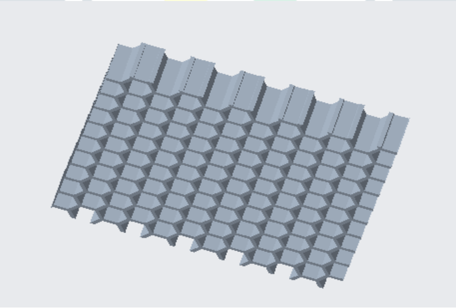

Fig 3.1b: Honeycomb structure.

3.2: Design parameters:

Table 3.2.1: Material properties.

Parts	Fibre Orientation	Material	Properties
Upper Deck	Bi-directional	CFRP	• Young's Modulus E11=E22=E33=1.5*10^4 N/mm^2 • Poisson's ratio μ=0.3 • Rigidity Modulus G12=E11 G13=1.5*10^8 N/m^2 G23=8.9*10^7 N/m^2 • Density = 32 kg/m^3 • Co-efficient of thermal expansion α11=α22=23*10^-6/degcels
Pod	Uni-directional	CFRP	• Young's Modulus E11=2.6*10^11 N/m^2 E22=6*10^9 N/m^2 • Poisson's ratio μ=0.23 • Rigidity modulus G12=3.4*10^9 N/m^2 G23/G13=G12/2 • Co-efficient of thermal expansion α11=-2.3*10^-6/ deg Celsius α22=3.2*10^-5/ degcelsius

The assembled part consists of majorly three parts, Upper deck, Supporting pod, platform. The upper deck consists of two different materials. On either side of the deck there is two layers of CFRP material and middle core consists of aluminium honeycomb structure material. The Upper deck consists of 4 layers, Each Layer thickness of: 0.1 mm. The pod consists of 24 layers composite fibres, each layer thickness of 0.1mm, the fibre orientation of 24 layers is given below.

Table 3.2.2: Fibre orientation.

Layer	1	2	3	4	5	6	7	8
Orientation	0	45	90	-45	-45	90	45	0

- 2kg lumped mass applied for the platform.
- The load applied is 90mm apart from the platform.
- The connection between the platform and support is given by titanium bolted joint.
- The connection between the support and pod is given by bond joint.
- Gravity loading conditions, along x-direction is 20g and y-direction is 15g.

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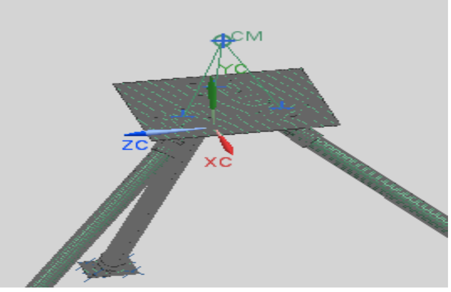

Fig 3.2a: Loading condition.

Gravity release:

Most of the space optics are aligned over the ground in an 1g environment, and should function in a 0g environment. The systems with heavy large optics, thus the gravity release can occur to misalignments. Even the surface shape of mirrors can be affected by slump effects. If it is polished in one orientation, hence surface errors can be introduced when it is tested over the other orientations.

Temperature changes:

The Space based optical instruments are invariably be required to operate at the temperatures other than that of which are assembled and need to be aligned over the ground. The change in the temperature can result in recoverable and is non-recoverable deflections in structure. Cycling of the temperature of the instrument can generate additional non-recoverable deformations and some of the materials may display coefficients of thermal expansion (CTE) hysteresis and the mechanical joints may spin into a position that can relieve the inbuilt strains. Deformations due to the temperature changes transpire during imaging are also an issue. Typically, the optical requirements for a stability is much higher during imaging than that between alignment and the operations.

4. Results and discussions:

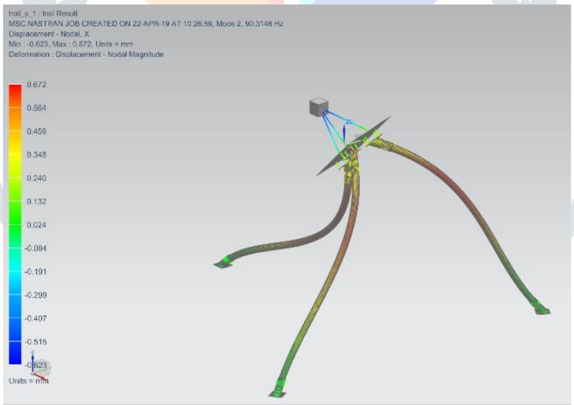

Fig 4.1a: Displacement in structure due to vibration in Mode 1.

Table 4.1: Structural free vibration analysis results.

Mode Numbers	Frequency (Hz)	mass in x-direction	mass in y-direction	mass in z-direction	MI about x	MI about y	MI about z
1	8.92E+01	9.90E-02	1.14E+00	1.05E-05	2.85E-02	2.49E-03	1.52E-05
2	9.03E+01	1.12E+00	9.71E-02	6.27E-05	2.49E-03	2.89E-02	1.73E-04
3	1.70E+02	3.59E-06	3.35E-04	1.99E-07	4.65E-06	2.33E-07	2.17E-02
4	2.11E+02	1.13E-01	9.48E-01	1.39E-03	1.12E-02	1.41E-03	4.87E-05
5	2.13E+02	9.66E-01	1.18E-01	2.05E-03	1.40E-03	1.13E-02	1.40E-04
	Total	2.304602	2.30E+00	2.33E+00	4.46E-02	4.44E-02	2.98E-02

Table 4.2: Static analysis result.

Test	Direction	Displacement in mm		Reaction in N		Max ply failure index
Static Analysis	Lateral X direction (25G)	X	5.85E-04	X	00	0.183
		Y	5.56E-05	Y	0.061	
		Z	4.34E-04	Z	0.078	
	Lateral Y direction	X	6.42E-5	X	0.072	0.155
		Y	6.03E-4	Y	0.0054	
		Z	3.8E-4	Z	0.137	
	Lateral Z direction	X	4.64E-5	X	0.0391	0.0406
		Y	6.7E-5	Y	0.0491	
		Z	1.04E-4	Z	0.00	

Table 4.3: Thermal analysis result.

Test	Displacement in mm		Reaction in N		Ply failure index
Thermal Analysis	X	5.37E-5	X	6.158	+0.409
	Y	6.83E-5	Y	6.37	
	Z	1.07E-4	Z	0.0200	

Table 4.4: Structural analysis result.

Test	Displacement in mm		Stress in N/mm^2	Ply failure index	Reaction in N		Frequency in Hz
Structural Analysis	X	0.184	6.68E-07	10192.06	X	86.52	89
	Y	0.645			Y	90.41	
	Z	0.607			Z	236.16	

Table 4.5: Finding the displaced location from the original location by creating normal plane in the platform by varying temperature.

Original locations	X	Y	Z
	0.0229793	0.052489	0
	-0.045162	0.0114032	0
	0.0222168	-0.025734	0

Table 4.6: Displaced locations at minus 20^0 temp.

Grid	minus 20^0 temps		
23391	0.0229783	0.052476	-0.000053
23999	-0.045157	0.0114012	-0.00006
25642	0.0222108	-0.025736	-0.000048

Table 4.7: Displaced locations at 70^0 temp.

Grid	70^0 temps		
23391	0.0229803	0.052507	0.000073
23999	-0.045168	0.0114062	0.000082
25642	0.0222258	-0.025731	0.000066

Conclusions:

- High strength and good stability to withstand 30G-Force.
- Minimum thermal distortion.
- Successfully created the support structure for optical payload which can withstand the load up to 2kg.
- The composite material is taken into consideration while manufacturing of a satellite is mainly based upon their properties, cost, and complexity.
- It increases the fuel efficiency of the rocket.
- It can be used on any of the IRS class satellites.
- It is most suitable to operate in a sun-synchronous orbit.

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