Design and Analysis of CFRP Boom for Supporting TTC antenna

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Abstract: Telemetry Tele-Command (TTC) antenna is an essential part of every spacecraft used to track and guide the spacecraft during launch phase and attitude control of the spacecraft in-orbit. As it is very clear from its functional requirements, the antenna should be always in line of sight of ground control stations. To maintain such continuity requirements of line of sight, this antenna generally mounted on any of the external deck of spacecraft with the help of long tubular (typically) structure. Usually, these kinds of structure are made of metallic alloys like Aluminium Alloys. Aluminium alloys are preferred choice because of availability and easy machinability. But in cases, considering the longer arm length required for TTC antenna structure; aluminium alloy is not a good choice for meeting the stiffness requirements. Hence, an option with CFRP composite tubular structure is considered in this study. Being orthotropic material CFRP has an added advantage of tailorability of its properties in the direction of benefit over and above high specific modulus and high specific strength. This thesis presents a comparative study of analytical aspects, fabrication aspects and tests results of both metallic and composite TTC antenna support structure

Index Terms— CFRP boom, antenna

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1 INTRODUCTION

Laminated composites exist of layers of atleast two different materials that are bonded together. Lamination is fundamentally used to combine the best aspect Antenna is a part of satellite communication sub-system. The antenna on board the satellite serves a intersection between earth stations on the ground and various satellite sub-systems during trading operations. Antennas perceives the transmission signal and transmits the downlink signals. In add-on that they provide one- onone link for the telemetry, telecommunication and com- mand system which is in coincidence with attitude control subsystems provides tower tracking signals for precise pointing of the antenna towards the earth. Demands for improved spacecraft RF performance in terms of enlarged gain, wider bandwidth and more accurated beam shaping have led to the large, precision antenna.

In order to meet the above mentioned requirements an antenna should (a) remains steady in orbit under suitable geographical area conditions (b) lies on the desired direction (c) resist loads on the structure during launch period of time. The antenna support construction helps the antenna in order to meet the above necessity. The present work handles with design and analysis of a fixed tubular structure antenna support boom.

The support structure shall be configured in such a way that it meets all above mentioned necessity with minimum possibili- ties. Therefore, reinforced plastics (FRP) materials are obvious choice for aerospace construction.

The basic structure block of laminate is a lamina which is a flat arrangement of unidirectional fibers or woven fibers in a ma- trix as shown in Fig.1.1. A flat lamina has two principal mate- rial axes which are parallel and perpendicular to the fiber di- rection. The fibers are the principal reinforcing of load- carrying and are typically stronger and stiffer. The matrix phases can be organic, metallic, ceramic, or carbon. Matrix is a enclosed layer of reinforcement, the purpose of the matrix is to support and protect the fibers from surrounding conditions and to provide a means of distressing load among and trans- mission load between the fibers. The execution for load trans- fer is the shearing stress formed in the matrix, the shearing stresses resist the pulling out of the broken fiber.

2 LITERATURE REVIEW

G. Kamli, N. Ashok Kumar, K. Sugesh, V. Magesh are discussed about the development of refined and specialized materials such as composite materials. Selection of material is a very critical content when it comes to Aerospace Engineering. Now-a-days, composite materials are becoming important because to its increased strengths at lower weights, corrosion resistance, stiffness etc. This paper investigate the advantages and disadvantages of using composite materials in airframe manufacturer and also reviews the advanced development in composites as structural materials. Development and produc- tion of materials to either improve physical properties or to allow their applications in new areas and roles for further us- age in future were also discussed.

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Christoph SICKINGER, Lars HARBECK are discussed about the development of ultra light weight deployable CFRP booms within in the scope. After the functional performance of the design was proven during successful demonstration under 0g environment on the ground. Then, the concept being further developed with the aim of an application under environmen- tal space conditions. The refinement of the boom analysis methods is one main objective because of its importance for overall light weight design. The manufacturing concept of the booms is based on a conventional prepreg technology in which extremely thin walled prepregs are used. Later, by con- ducting some tests such as tension test, outgassing test, ther- mal tension test.

Giangiacomo Minak, Daniele Ghelli conducted low velocity and low energy impact tests on CFRP circular laminated plates, in order to investigate the effect of specimen dimension and boundary conditions on dynamic behaviour and material behaviour and material damage. Two different diameters and constraints were tested. Numerical simulations of specimen impact response were performed by a finite element program and compared to experimental results. Tests indicated that both dimensions and boundary conditions affect response and damage, higher target stiffness resulting in greater energy absorption and more extended delamination. The main features of contact force history were correctly predicted by numerical analysis, although disagreement was observed between numerical and experimental results due to damage.

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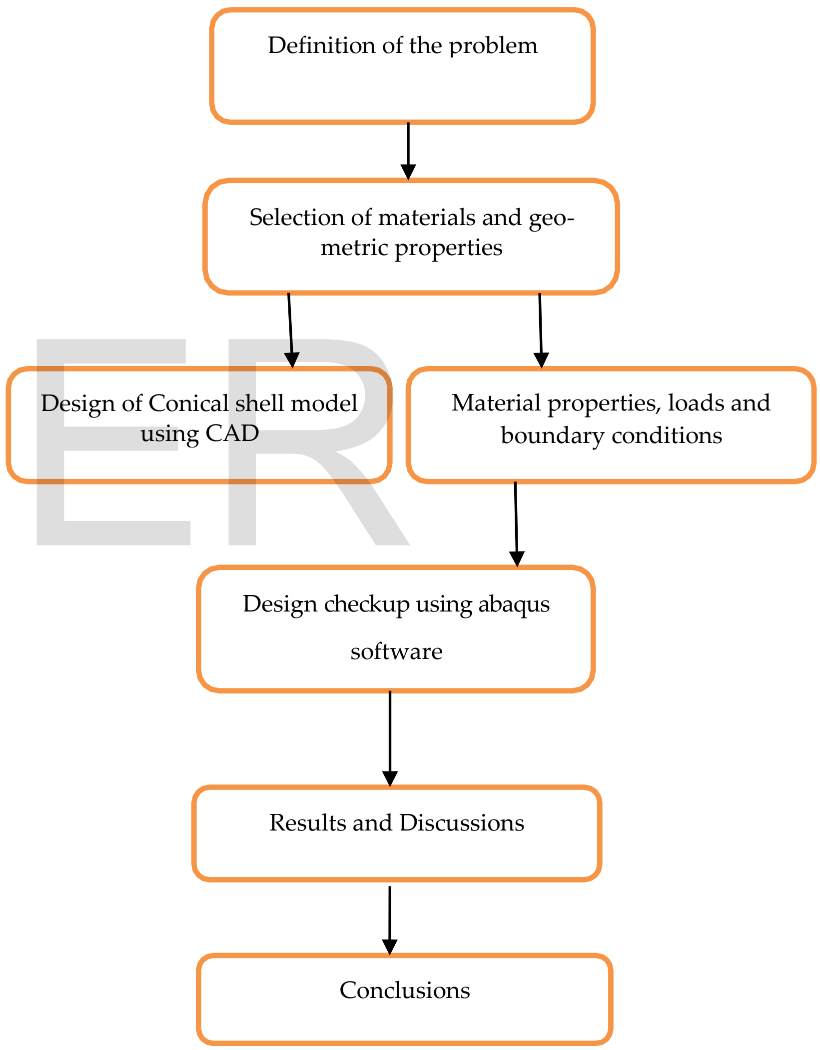
Abderrahim EI Mahi, Mustapha Assarar, Jean-Marie Berthelot analysed the damping of unidirectional fibre composites, orthotropic composites and laminates. Damping parameters are investigated using beam test specimen and an impulse technique. Damage modelling is developed using a finite element analysis which evaluated the different energies dissipated in the material directions of the layers. The results obtained show that this analysis describe fairly well the experimental results. The finite element analysis can be applied to complex shape structures.

Won-Kyun Lim, Woo-KilJeong, Elmar K. Tschegg developed and demonstrated a failure criterion for anisotropic materials under combined stress. The generality and accuracy of the present theory are illustrated by examination through the use of material systems under various loading conditions. Calculated results were compared with the experimental data. It agrees with observations quite well at high values of shear stress, where the Tsai-Hill theory becomes too conservative. The present criterion is also compared with other criteria. The comparison shows that this criterion has a good agreement with the experimental data even when the shear stress com- ponent is greater than the shear strength.

3 METHODOLOGY



4 DESIGN OF CFRP BOOM

Design a CFRP boom construction for a load of 600gms. The configuration of the boomis shown in figure

Upper Diameter = 67 mm
Lower diameter = 63mm
Height = 570mm
Axial Load = 600gms

ISSN 2229-5518

Design Approach

Basic considerations for design are:

- Stiffness
- Strength
- Low mass

Modelling

The geometric modelling of the antenna support boom was done in CATIA software using Part Design and Genera- tive Shape Method.

Materials Used

The materials used for antenna support boom are listed in following sections. The tube structure is made up of 24 layered symmetric laminates with CFRP. The top and bottom end fit- tings are made up of Ti-6Al-4V.

Tubular structure

The tubular structure is a 24 layered symmetric lami- natesmade up of high modulus carbonfiber/ epoxy composite material (M55J/M18 With 0.1 mm ply thickness). These are used to provide extra stiffness, strength and to decrease the mass to the system.

Top End Fitting

The top end fitting consists of frustum conical shape and flat plate on its top. The materials used for top end fitting is Ti- 6Al-4V alloy.

Bottom End Fitting

The bottom end fitting consists of cylindrical structure sur- rounded with gussests and flat plate on its base. The materials used for bottom end fitting is Ti-6Al-4V.

Gussets:

These gussets are made up Ti-6Al-4V material. This gussets are located aroung the bottom end fitting.these gussets gives more strength to the whole support structure.

FIG .1. ANTENNA SUUPORT BOOM

Fig.2. Top End Fitting

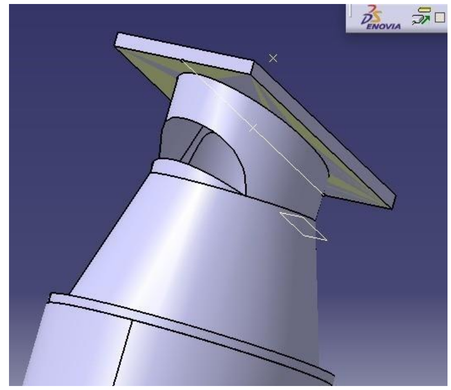


FIG.3. BOTTOM END FITTING

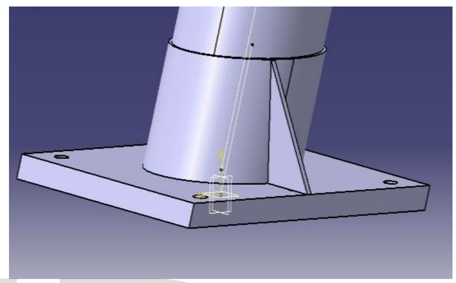


FIG.4.GUSSETS

Table.1. Properties of CFRP material used

Property of Composites	CFRP
Density (g/cc)	1760
Cured Ply Thickness(mm)	0.1
Tensile Strength (GPa)	22
Shear Strength (GPa)	48
Poisson's Ratio	0.33
Modulus of Elasticity (GPa)	294

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Table. 2. Propeties of the material

Property of metals	Ti-6Al-4V
Density(kg/m^3)	4400
Modulus(Gpa)	100
Ultimate Tensile Strength(Mpa)	930
Poissons Ratio	0.3
Shear Strength(Mpa)	490

5 Results and Discussion

Layup Sequence $(0/30/0/0/-30/0/0/-30/0/0/30/0)_2$

Substituting the material constants in above equations

Q_{11}= 2.5x10^{11} N/m^2

Q_{12}= 1.89x10^{10} N/m^2

Q_{22}= 1.26x10^{10} N/m^2

Q_{66}= 2.20x10^{10} N/m^2

The above values can be substituted in above equations to find reduced transformed stiffness terms.

The reduced stiffness matrix for 0^0 and 30^0

Resultant forces:

E_{11}= 2.2x10^{11} N/m^2 N_1 = -1.1x10^3

E_{22}= 1.12x10^{10} N/m^2 N_2 = 1.52X10^3

E_{33}= 0 N_{12} = 0

Moment forces:

N_{12}= 1.5 M_1 = -8.9x10^{-8}

N_{23}= 0 M_2 = 1.49x10^{-7}

N_{31}= 0 M_{12} = -5.9x10^{-8}

G_{12}= 2.2x10^{10} N/m^2

G_{23}= 0

G_{31}= 0

By using above all values we can find [A], [B], and [D] matrices.

$$A=\begin{bmatrix} 59.9 & 4.53 & 0 \\ 4.53 & 3.02 & 0 \\ 0 & 0 & 5.27 \end{bmatrix} \times 10^7$$ = Extensional Stiffness matrix

$$B=\begin{bmatrix} 0.586 & 2.73 & -1.96 \\ 2.37 & 2.81 & -0.24 \\ -1.9 & -0.24 & 2.69 \end{bmatrix} \times 10^3$$ = Bending Stiffness Matrix

$$D=\begin{bmatrix} 28.8 & 2.15 & 6.57 \\ 2.15 & 1.44 & 2.31 \\ 6.57 & 2.31 & 2.5 \end{bmatrix} \times 10$$ = Coupling Stiffness Matrix

6 Conclusions

The design of CFRP Boom structure to meet structural stability requirement in space has been presented. The concepts of finite element method (FEM) as an analysis tool have been discussed in detail. Steps involved in analysing an engineering problems using FEM were also elaborated. Composites as an engineerig materials in space applications have been discussed. Configuration of a CFRP Boom and its construction features are detailed. The properties of materials used in Tubular structure are presented. Principles of modelling (Geometric and finite element) design and analysis have been discussed frequency of a beam element was found out by analytical method using beam deflection equation and this result was validated using FEM analysis. Studies on effect of changing various parameters like element size on frequency were conducted. Frequency analysis and static load analysis were done and compared, was chosen to be the best model as it meets all the design requirements.

7 Acknowledgment

I would like to thank VSSC for giving me opportunity to un-

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dergo research work and also I would like to thank Mr. VINU VISWANATHAN, VSSC for providing encouragement and valuable suggestions to carry out my research work.

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