# Design of Tank Simulator for Side-mount Support Structure for a Spacecraft

**Nagarjuna B G[1], Dr. H.C. Chittappa[2]**

*[1]PG student, Dept of Mechanical engineering, UVCE Bengaluru, Karnataka, India*
*[2] Associate professor, Dept of Mechanical Engineering, University Vishveshvaraya Collage of Engineering, Bengaluru, Karnataka, India*

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**Abstract**: *The GSAT satellites are India's indigenously developed technologies of communication satellite, used for digital audio, data and video broadcasting. GSAT satellite mainly consists of central cylinder as a primary structure. Normally both oxygen tank and the fuel tank are mounted inside the central cylinder. When we do so the L/D ratio for the satellite increases and this results in less stability and more deflection of the spacecraft. To reduce the deflection we need to increase stiffness i.e. we need to add more material to the structure and this will increase the weight of the satellite. In this study we have developed a new concept of tank support system which can effectively reduce L/D ratio for spacecraft. Here we take out the fuel tank and mounted it on both side of the satellite as two small tanks, whose total capacity is same as the earlier fuel tank, by using 'side mount configuration'. Side mount configuration consists of side mount bracket in the centre which will connect the tank simulator to the central cylinder. The configuration also has four struts and four wedge brackets which will support the simulator on top and bottom side with the help of flex plate. In this study we designed a tank simulator for side mount configuration. And the tank simulator is simulated for 'static test qualification'.*

## 1. INTRODUCTION

A spacecraft is defined as the physical platform that supports and integrates subsystems and payload and as such it is of fundamental part of any spacecraft. Since, it is an assembly of many components, structure takes up any load as a single entity. The spacecraft structure consists of platforms, cylinders and rods, where sandwich structures are often used because they combine low weight with high stiffness. Structure is an important part since it supports its instruments and subsystems. A geosynchronous satellite revolves in an orbit of 36,000 km from the earth where it can see the rotating earth as almost stationary and it can take clear images of earth which will be helpful is communication, weather forecasting, management of natural resources etc. The GSAT satellite is heavy as compared to polar satellite and is launched by using powerful heavy lifting, GSLV. These launch vehicles can take satellite only up to 800-900 kms height from the earth. After the separation of the spacecraft from the launch vehicle the orbit rising of the spacecraft is carried out by firing the LAM. The orbit raising is done in steps starting from smaller elliptical orbit to finally 36,000 km orbit. The spacecraft consists of a central cylinder which is the primary structure. It takes all major loads like axial, bending, torsion, and vibration and transfers it to the launch vehicle through LV adapter. Normally the oxygen tank and fuel tank is mounted inside the central cylinder. In such case the length of the spacecraft will be more and it will face stability problem. And also when length of the satellite is more it will deflect more. To reduce deflection and increase stiffness we can't add more material because every single unit mass that we add to the system will cost us in all kind of design prospective. So to reduce the length of the satellite, if we take out the fuel tank outside the cylinder and mount it on the both side of the satellite as two separate tanks by using side mount configuration we can effectively reduce the length of the satellite. So a suitable configuration has to be designed for the required stiffness and strength In this study we have designed a tank simulator which consists of central ring with attachment setup, top and bottom plates, and the peripheral ribs which connect the ring and top, bottom plates. This simulator is mounted on spacecraft by using side mount configuration which consists of flex plate, spacer, struts, wedge brackets and simulated it for static test qualification. Requirements for tank simulator are as follows:

 Static analysis:

1. 18g load taken in Z direction independently. Minimum margin of 0.5
2. 8g load taken in X and Y directions independently. Minimum margin of 0.5.

## 2. FEA AND CONFIGURATION STUDY

### 2.1 Geometric Modeling

Tank simulator assembly consists of a Central ring is the main part of the simulator because it has a attachment which will directly connect the simulator to the central cylinder (primary structure). In the vicinity of the central ring the centre of gravity of the whole model is concentrated. Top and Bottom plates are supporting the simulator for the connections in top and bottom. These plates have connector in the centre which will connect the spacer and simulator. The peripheral ribs are hollow tubes of circular cross section which will connect the central ring to the top and bottom plates. Spacer will help to maintain the space between top and bottom plate and the flex plate. This is also circular hollow component which can able to take bending loads. Flex plate will connect spacer and struts. It is also called boomerang. It is plate of almost similar to triangular shape which is connected to struts at both opposite vertices and another corner is connected to spacer. Struts are the circular cross section hollow tubes, which will connect flex plate and wedge brackets. Wedge brackets are in the shape of a triangular wedge. These will connect the struts to the shear webs on one of their face and to the respective decks on the other face. Side-mount bracket will connect the tank simulator to the central cylinder (primary structure). This bracket will take the maximum load of tank.

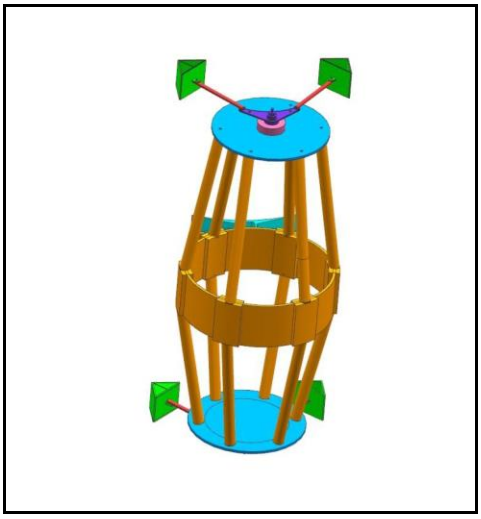

Figure 1 Tank simulator assembly

### 2.2 FINITE ELEMENT MODELLING

A finite element model is a complete idealization of the entire structure, including the node locations, element's physical and material properties, loads and boundary conditions. The model is mainly defined for linear static analysis. The accuracy of the resulting solution will depend on how well the structure was modelled, the assumptions made for the load boundary conditions and accuracy of the elements used for a given problem. In general, the solution will be more accurate; as the model is subdivided into smaller number of elements. The finite element model is built by using MSC/Patran (pre-processor and post-processor) and MSC/Nastran (solver).

#### 2.2.1 Meshing

The surface model is generated using points and curves according to the dimensions specified in the geometric model. The Patran software has automated meshes like Isomesh, which is used for meshing the square and rectangular surfaces of the model and Paver mesh is used to mesh the inclined vertical and horizontal surfaces and surface which has holes. The model is meshed with 4 noded quad element, shell elements and also beam elements.

#### 2.2.2 Material Properties

Many available metal alloys are suitable for spacecraft; each has desirable characteristics for a specific design. Aluminium alloys are light and strong, and are used for virtually every type of structure, including skins, truss members, and brackets. But titanium, beryllium, magnesium, and stainless steel often appear somewhere in a spacecraft because of their unique properties. Aluminium 2024 is assigned to struts, wedge brackets & side-mount bracket. Titanium is assigned to flex plate. Rest of the parts like central ring, peripheral ribs, top and bottom plates are assigned with mild steel.

### 3. ANALYSIS AND RESULTS

#### 3.1 Linear Static Analysis

In case of static structural analysis the loads are assumed to be applied slowly and the model is constrained to prevent rigid body motion. That is, Static equilibrium exists for the model.

Linear static analysis was carried out to compute the response of structure for 8g load in X & Y directions and for 18g in Z direction (along the axis of the tank) independently.

#### 3.1.1 Inertia Load of 8g in X Direction.

In X-direction inertia load of 8g is applied. The stress values and the displacement values for each component of the model is shown below. These values are in the allowable limits (0.5 margin of safety is considered).

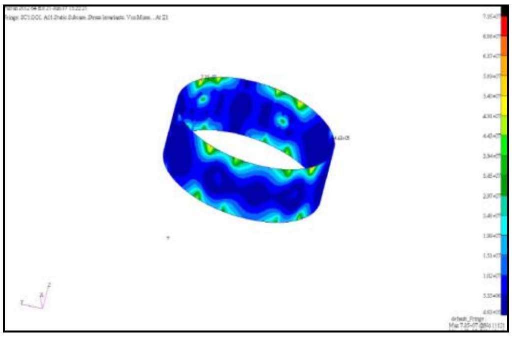

Figure 2 Stress plot of ring in X direction

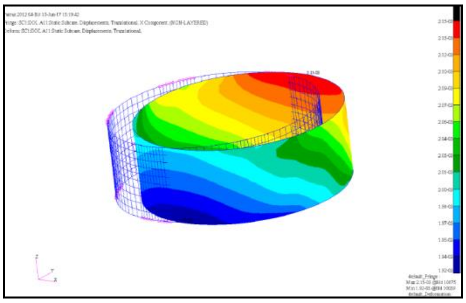

Figure 3 Displacement plot of ring in X direction

Table 1 Stress and displacement values for tank simulator assembly parts.

| S. N. | Component | X-Direction (8G LOAD) | | | |
|---|---|---|---|---|---|
| | | Stress (Mpa) | Margin | Disp (mm) | Margin |
| 1 | Central Ring | 81.1 | 0.672 | 2.6 | 0.25 |
| 2 | Ring Attachment | 255 | 0.71 | 2.55 | 0.27 |
| 3 | Side Mount Bracket | 216 | 0.46 | 2.7 | 0.22 |
| 4 | Peripheral Tubes | 40.2 | 0.84 | 2.6 | 0.23 |
| 5 | Top & Bottom Plates | 152 | 0.4 | 1.08 | 0.69 |
| 6 | Flex Plate | 496 | 0.45 | 1.79 | 0.48 |
| 7 | Struts | 45.3 | 0.88 | 1.67 | 0.52 |
| 8 | Wedge Bracket | 218 | 0.46 | 0.81 | 0.76 |

### 3.1.2 Inertia Load of 8g in Y Direction.

In Y-direction inertia load of 8g is applied. The stress values and the displacement values for the model are shown in the fig 3.3 and 3.4 respectively. These values are in the allowable limits (0.5 margin of safety is considered).

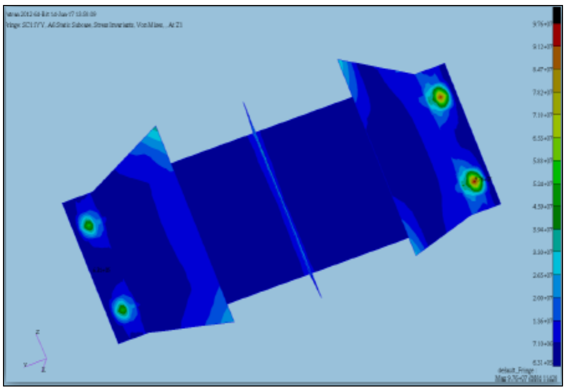

Figure 4 Stress plot of ring attachment Y direction

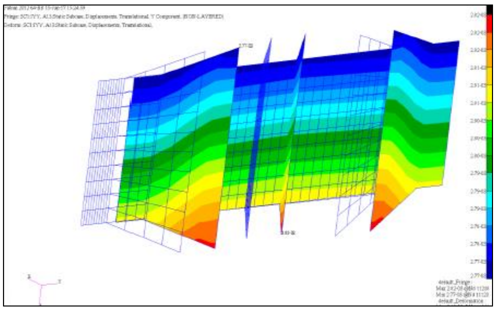

Figure 5 Displacement plot of ring attachment Y direction

Table 2 Stress and displacement values for tank simulator assembly parts.

| S.N. | Component | Y-Direction (8g load) | | | |
|---|---|---|---|---|---|
| | | Stress (Mpa) | Margin | Disp (mm) | Margin |
| 1 | Central Ring | 76.6 | 0.69 | 3.3 | 0.05 |
| 2 | Ring Attachment | 97.6 | 0.89 | 3.3 | 0.05 |
| 3 | Side Mount Bracket | 227 | 0.43 | 3.09 | 0.11 |
| 4 | Peripheral Tubes | 33.6 | 0.86 | 3.29 | 0.05 |
| 5 | Top & Bottom Plates | 138 | 0.44 | 1.81 | 0.48 |
| 6 | Flex Plate | 401 | 0.55 | 3.25 | 0.07 |
| 7 | Struts | 38.9 | 0.90 | 3.02 | 0.13 |
| 8 | Wedge Bracket | 226 | 0.43 | 1.11 | 0.68 |

### 3.1.3 Inertia Load of 18g in Z Direction.

In Z-direction inertia load of 18g is applied. The stress values and the displacement values for the model are shown in the fig 3.3 and 3.4 respectively. These values are in the allowable limits (0.5 margin of safety is considered).

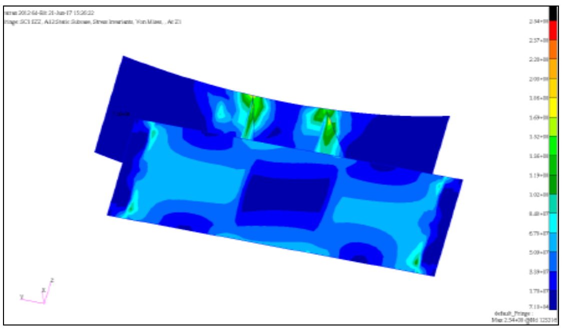

Figure 6 Stress plot of side mount bracket in Z direction

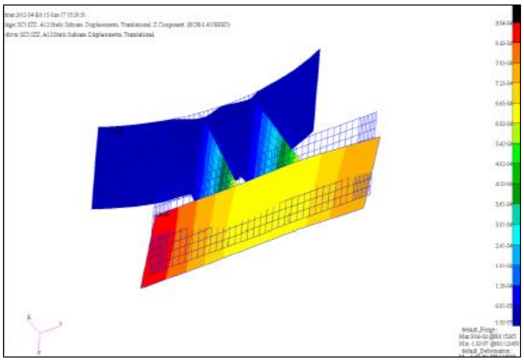

Figure 7 Displacement plot of side mount bracket in Z direction

Table 3 Stress and displacement values for tank simulator assembly parts.

| S. N. | Component | Z-Direction (18g Load) | | | |
|---|---|---|---|---|---|
| | | Stress (Mpa) | Margin | Disp (Mm) | Margin |
| 1 | Central Ring | 135 | 0.46 | 2.82 | 0.24 |
| 2 | Ring Attachment | 103 | 0.88 | 1.22 | 0.61 |
| 3 | Side Mount Bracket | 245 | 0.38 | 1.16 | 0.52 |
| 4 | Periferal Tubes | 56.5 | 0.77 | 2.73 | 0.22 |
| 5 | Top&Bottom Plates | 146 | 0.41 | 2.81 | 0.21 |
| 6 | Flex Plate | 410 | 0.4 | 2.15 | 0.24 |
| 7 | Struts | 59.6 | 0.85 | 2.16 | 0.24 |
| 8 | Wedge Bracket | 208 | 0.48 | 0.715 | 0.78 |

## 4. CONCLUSION

From above results which we obtained from the static analysis for 8g loading in lateral directions and 18g load in longitudinal direction, the stress and displacement values are within the allowable margin. Also the required modifications in dimensions for the brackets have been done to take the load conditions in all three directions by multiple iterations. From the results we can get to know, the configuration which we designed as tank simulator for side mount support structure is safe. So we can use this configuration of side mount of fuel tank in the spacecraft. By the study we have reduced the length and diameter of the central cylinder. Hence the main purpose of the project is achieved.

## 5. REFERENCES

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