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Develop the Communication Satellite Structure under Space Environments

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Abstract

This research is studies the simulation of Iraqi communication satellite under space environments. The satellite operates on a low earth orbit at circular (500,500) Km, and subjected to the different torque in space environments. The purpose of this paper is to develop the satellite structure design and change the geometry and inertial characteristics of space structural systems to meet the torque stability requirements. The satellite used so far is spin – stabilized, is rotating about one axis in 10 rpm. The configuration to structure was suggested hexagonal. The dimension of structure is 110 cm in diameter and 85 cm high. The general dynamics of the system are modeled by using the finite element method and analyzed by the NASTRAN programming to find the distribution (stress, strain, and vibration) on the structure.

Keywords: Simulation, Communication, Satellite, Structure, Space.

Nomenclature

LEO = Low Earth Orbit.

GEO = geosynchronous Earth Orbit.

FEM = Finite Element Method.

DOF = Degree of Freedom.

1. INTRODUCTION

Design of any system demands consideration of the environment in which it must operate, to ensure proper system functions, reliability and lifetime, space system is no exception to this rule. Indeed, because of the difficulty and cost repair, environmental compatibility is particularly critical in space.

For present purposes, the space environment to be considered is that of near – Earth space, i.e., orbits ranging in altitude from low Earth orbit (LEO) to geosynchronous (GEO) and beyond, and including all inclinations.

The natural near – Earth space environment is complex and dynamic. Its features are determined partially by the characteristic of the Earth itself, partially by the interactions between the Earth and the sun, and partially by processes occurring in interplanetary and interstellar space.

The various environment components, or factors, interact in different ways with space systems and produce a variety of effects.

Because the physical processes of interaction depend on the type of environment factor under consideration. It is usual to ' sort ' environmental interactions and effects by environment factor.

Following this approach a list of environment factors and their effects on space system near – Earth space is provided in table (1).(see the Ref. [1])

Table 1: The terrestrial space environmental and Effects on space system

Environmental Factor	Effects
a- Sunlight and Earthshine.	-Heating, thermal cycling, material Damage, Drag, Torque's, Photo - mission, power.
b- Gravity	-Acceleration, Torque's, (stabilization).
c- B and E Field.	-Torques, drag, surface changes, potentials.
d- Neutral Atmosphere.	-Drag, Torque's, material Degradation, vacuum contamination, H. V Breakdown.
e- System generated.	-System dependent: Neutrals, plasma, fields, forces and torque's, particles, Radiation.

In additional to above torque there is thruster torque but to the spacecraft to correction the tragedy of spacecraft. [2]

The general motion of a spacecraft under the influence of both gravitational and other forces is somewhat involved, and the problem can be solved analytically only if summations are made about the magnitude time behavior of the applied forces. [3]

A brief survey of the environmental torque's and their influences on the orbit dynamics (10-N) Thruster performance is given by Razag. [2].

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Modeling of gravity gradient and solar radiation pressure torque may be found in References (3, 4.5). Spacecraft are not point masses as Kepler assumed in the analysis of planetary bodies. They have finite size and hence inertia. [3]

In general, there are many torqueses which affecting the spacecraft found in References, [4] - [6]:

a. Gravity – gradient torque.

b. Solar radiation pressure torque,

c. Magnetic torque,

d. Aerodynamic and atmospheric,

e. Thermal analysis, and

f. Thruster's impulsive torque

2. FINITE ELEMENT MODELING ANALYSIS

The FEM package in most widespread is used in space engineering in NASTRAN (developed initially by NASA). The analysis options invoked in this work by FEM are:-

a. Static analysis

Deals with displacement, forces, and stress under steady state loads. The analysis is performed to study the system under various load cases and under its weight at integration and ground test phases.

b. Normal Mode

Computes system resonant frequencies and mode shapes.

c. Transient response

Analyze time – varying displacement, forces, and stresses for time variable loads.

d. Frequency response analysis deals

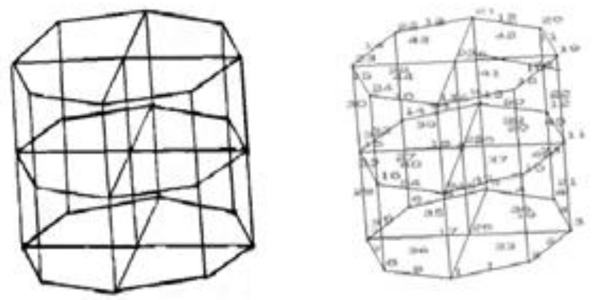
With the steady state displacement and phase angles for frequency dependent loads. The analysis being used to study the response of the structure at deployment to various sources of vibration at wide band of disturbances that might occur at maneuver and ADCS activities of the satellite on orbit.

The FEM implementation procedure starts with discretization, nodal point's definitions and coordinate system, then element generation and connection analysis options requirements are determined for particular results.

3. DISCRETIZATION

The structures were represented as plates and bar elements. The package being used offers isoperimetric element with four nodal points for plat and two nodes for bar, each nod has 6 DOF.

Figure (1) shows the discretization of the structure of satellite. Number of nodes (27) and number of elements (54), the type of plate element is quadrate plane with uniform thickness; all elements have the same material properties (Al – dure). For all nodes there are three transnational and three rotational DOFs about the Y – axis of all nodal points on the central axis.



(a) before (b) after

Fig. 1 Structure of satellite before and after Modeling analysis.

4. COORDINATE SYSTEM

The coordinate system is fixed because the structure assumed to be rigid body. A local and global coordinate system is defined to assist geometrical definition. The nodal points is chosen at the end bar and corner of plate. Where x, y, z – axes of the Cartesian coordinate chosen I lies in plane of their element. The global coordinate system is located in center of structure.

5. LOADS AND BOUNDARY CONDITION

To study the structure stresses and deformations of structures, loads must be determined. The loads being subjected to the structure in space environments divided into two main sources:-

1. External loads.

2. Internal loads.

The structure can be assumed rigid body (hinged or clamped) in the two nodes of the center (25, 27). The weight of the components acts as uniformly distribution loads on the structure.[7] External moment arise on the structure due to space environment subjected to the all nodes of structure, was calculated from different torques, for all we assumed to be about (1 N). Because the all torques of external load assembly don't reach to (1 N).

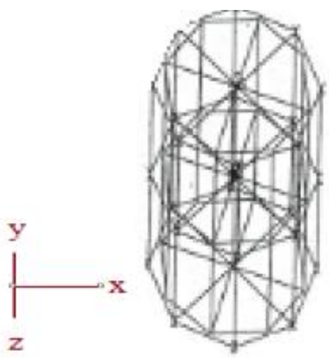
The internal loads arise on the structure due to thruster force subjected to the structure is (10 N) at nods (2, 6) in two direction of Y – axis, again subjected thruster force at nodal (18, 22) in two direction of X – axis. [3].

6. RESULTS AND DISCUSSION

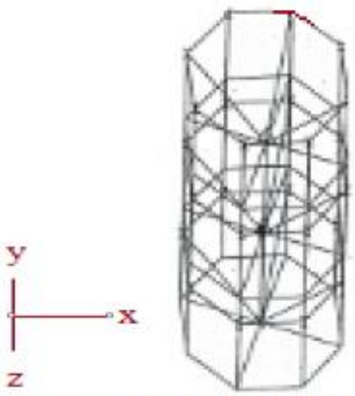
Normal analysis computes the natural frequencies and mode shapes of a structure. The eign vectors for selected modes are shown in figure (2). The eign vectors with its mode given in table (2). Each mode shape is similar to a static displaced shape in that mode shape and the static displacement. In static analysis the displacement is the true physical displacement due to the applied load. Element forces and stresses and reaction forces are computed in the same manner as for static analysis. Figures (3, 4, and 5) show the Von Mises stresses at different element on structure and distribution of Von misses stresses along X & Y – coordinate of structure at subjected the structure to torque (1 N).

Table 2: The eign vectors with its mode.

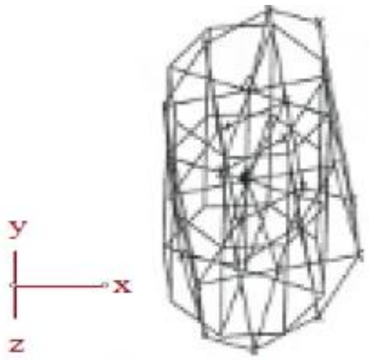
Mode	Eign Vector Hz
1	1.935890
2	3.490028
3	46.620144
4	49.285206
5	178.635757
6	187.859039



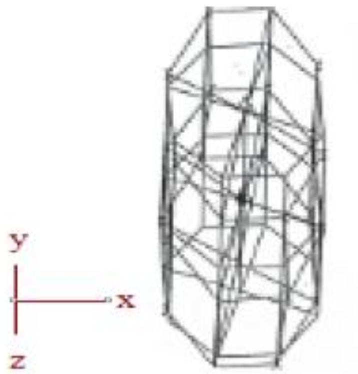
Out Set 1 Mode 1.935890 Hz Deformed (0.0405) : Total Translation



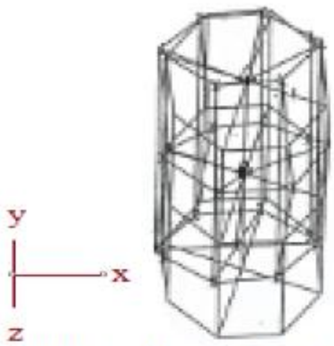
out set case 2 mode 3.4900 Hz Deformed (0.0405) : total translation



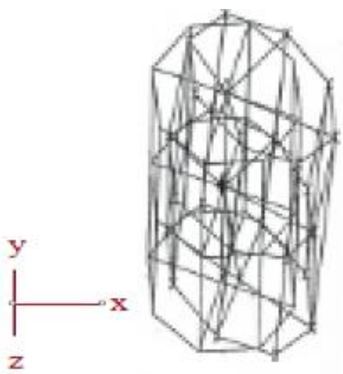
Out Set Case 3 Mode 46.620144 Hz Deformed (0.0591 : Total Translation



Out Set Case 4 Mode 49.285206 Hz Deformed (0.0625): Total Translation



Out Set Case 5 Mode 178.635757 Hz Deformed (0.0488): Total Translation



Out Set Case 6 Mode 187.859039 Hz Deformed (0.0544) : Total Translation

Fig.2 Structure mode Shapes for six cases mode.

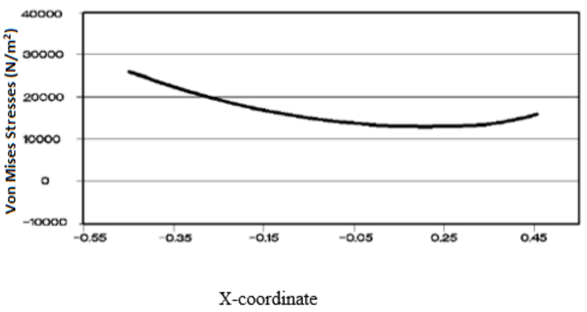


Fig. 3 Von Mises stresses a long x – Coordinate

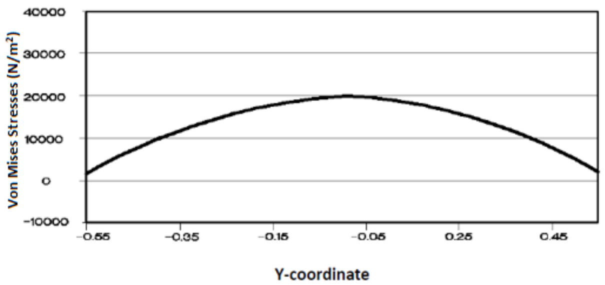


Fig. 4 Von Mises stresses a long y – Coordinate

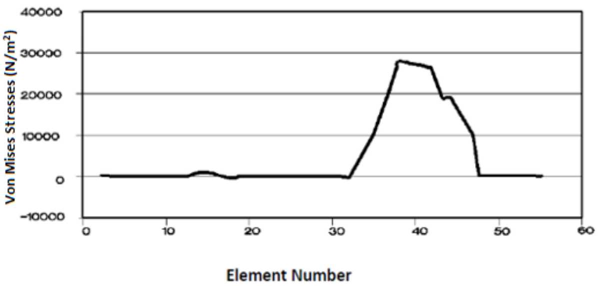


Fig. 5 Von Mises stresses Viruses Element Number

Figures (6, 7, and 8) show the displacement at different nodes on a structure and along X&Y – coordinate of structure at subjected the structure to torque (1 N). Figures (9, 10,11,12,13, and 14) show the Von Misses stresses at different elements on structure and distribution of Von Mises stresses along X&Y – coordinate of structure at subjected the structure to the thruster load (10 N) in X&Y – direction.

Figures (15, 16, 17, 18, 19, and 20) show the displacement at different nodes on a structure and along X&Y – coordinate of structure at subjected the structure to the thruster load (10 N) in X&Y – direction.

From the stress levels it is that at deployment configuration the lower plate at element (34) suffers higher stress levels than another element for plate and bar. The critical areas were at hinge position, and (314714) N/m stress was detected for Von Mises stress; a level of (3432) N/m was observed at hinges and (element 53) plate.

It is clear that the maximum displacement occurs at node (3) and the minimum at the node (25, 27), these nodes represent the between structure and antenna tube by ball bearing.

At subjected structure to thruster force in x-coordinate, maximum stress occurs at the element (49), and minimum at (38), because the element (49) is bar and (38) is plate type. The maximum displacement occurs at node (12) respectively at two directions. At subjected structure to thruster load in y-coordinate, maximum stresses occur at element (42), and minimum at (49), and the maximum displacement occurs at node (4) respectively at two directions.

It is clear that the stress in elements (1-32) is less than the stresses in elements (33-54) because the element in (1-32) is bar and (33-54) is plate type.

The satellite suffers acceleration load environment at space. To determine the displacement and stresses of different nodes and elements along the load variation, a transient response analysis is required. The configuration model of FEM was used for analysis and loads were applied. Figure (21) gives the displacement verses time. The stress distribution also was determined. Maximum Von Mises stress was detected of structure. Figure (22) gives Von Mises stress at different elements.

The direct method solves the coupled equation of motion in terms of forcing frequency. A frequency range (0 – 200 Hz) in step (1 Hz) applied to structure. Figure (23) shows the displacement versus frequency.

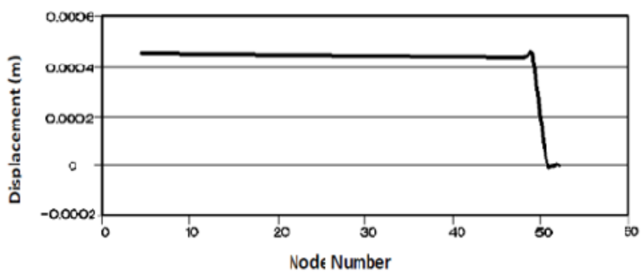


Fig. 6 Displacement Viruses Node Number.

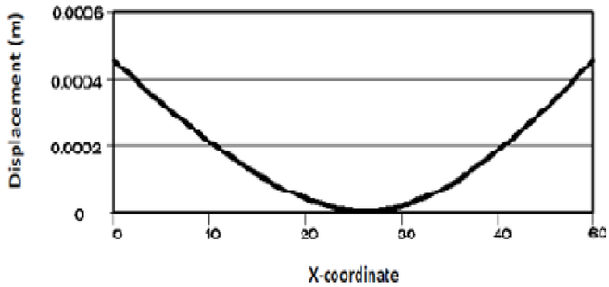


Fig. 7 Displacement a Long x – Coordinate.

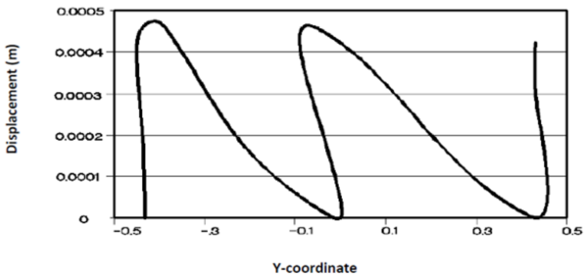


Fig. 8 Displacement a Long Y – Coordinate.

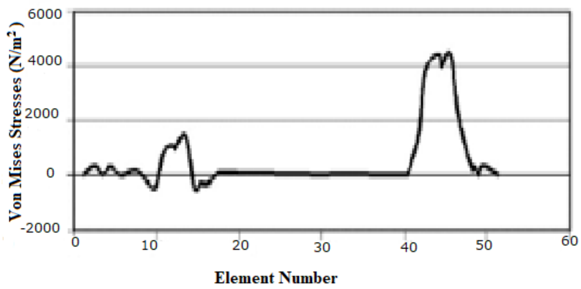


Fig. (9) Von Mises Stresses Viruses Element Number at thruster Load in x – direction.

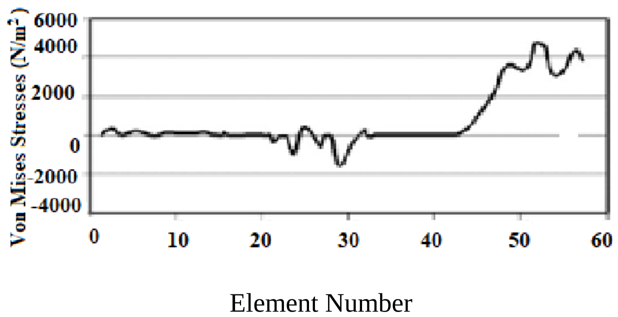


Fig. (10) Von Mises Stresses Viruses Element Number at thruster Load in x – direction.

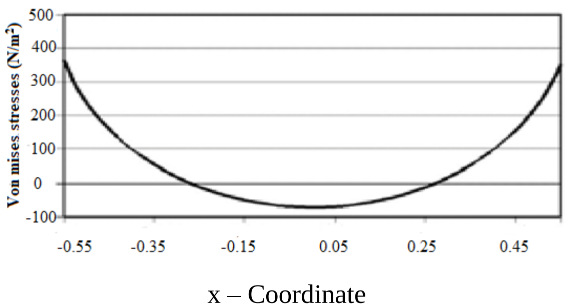


Fig. (11) Von Mises stresses along x-coordinate at thruster Load in x – direction.

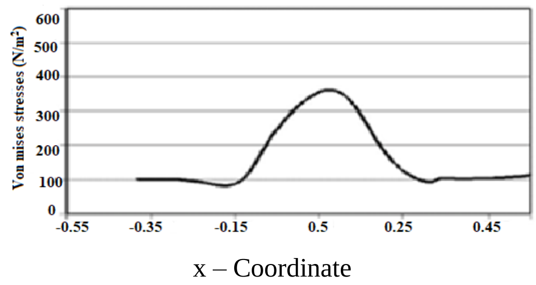


Fig. (12) Von Mises stresses along x-coordinate at thruster Load in y – direction.

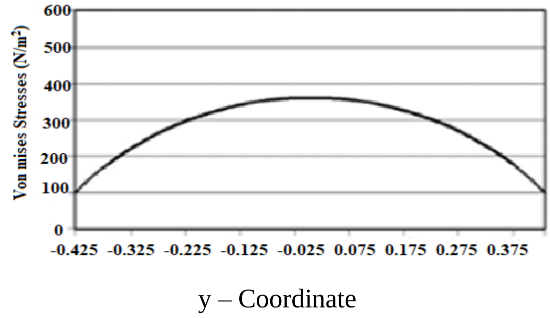


Fig. (13) Von Mises Stresses along Y-coordinate at thruster Load in x – direction.

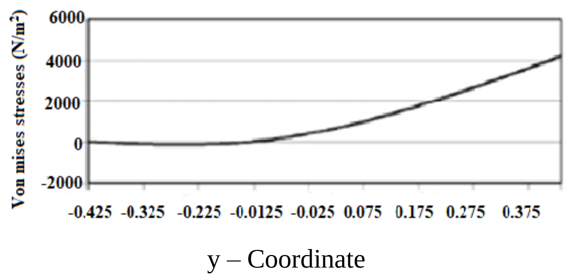


Fig. (14) Von Mises Stresses along Y-coordinate at thruster Load in y – direction.

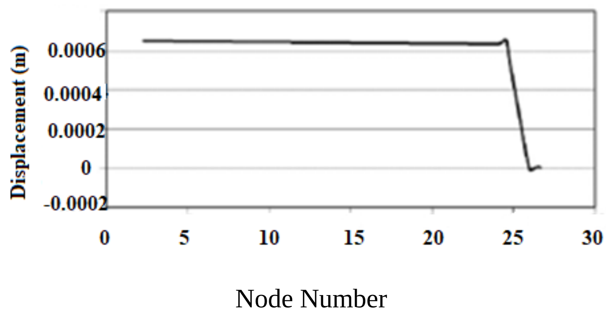


Fig. (15) Displacement viruses Nodes Number at thruster Load in x – direction.

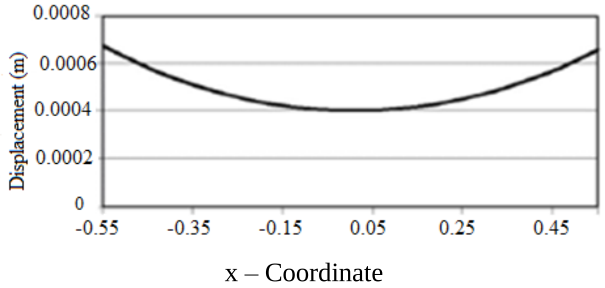


Fig. (16) Displacement along x - coordinate at thruster Load in x – direction.

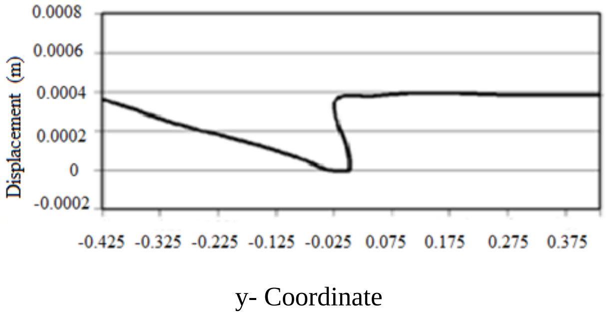


Fig. (17) Displacement along Y-coordinate at thruster Load in y – direction.

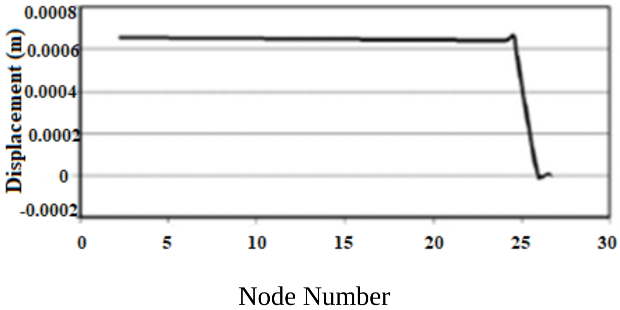


Fig. (18) Displacement viruses Nodes Number at thruster Load in y – direction.

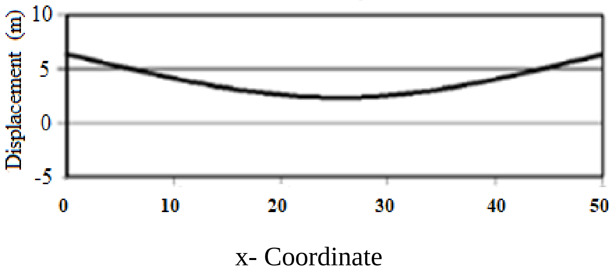


Fig. (19) Displacement a long x – coordinate at thruster Load in y – direction.

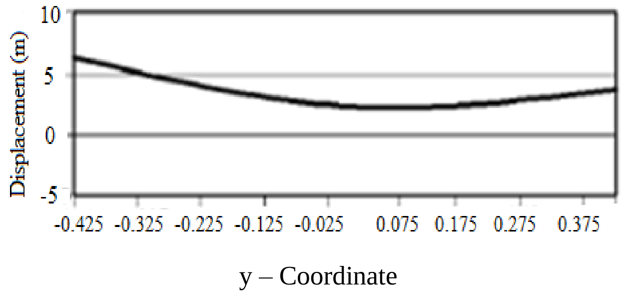


Fig. (20) Displacement a long y - coordinate at thruster Load in y – direction.

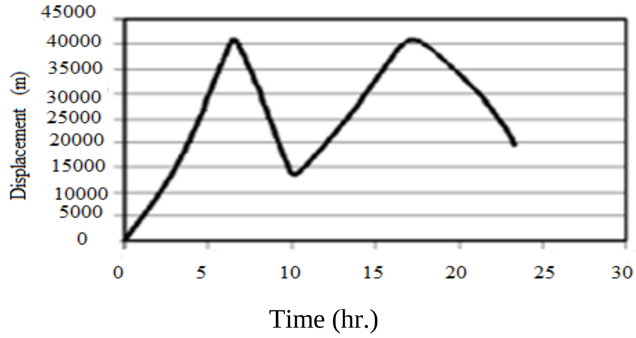


Fig. (21) Displacement versus Time.

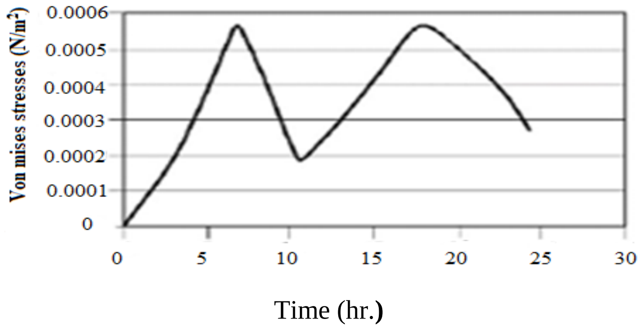


Fig. (22) Von mises Stress Versus Time.

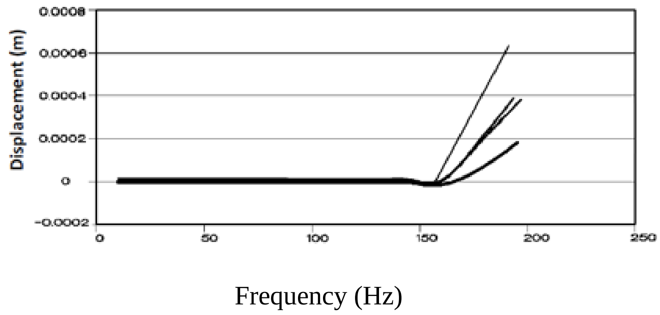


Fig. (23) Displacement versus Frequency

7. CONCLUSION

The FEM suggested in this work was analyzed the level of system design. The operational parameters were obtained and verified for space environments. From the static and dynamic analysis performed, the following advantages can be concluded.

The natural environmental of near-earth space is complex and dynamic and contains many components, some of which are strongly influenced by the systems presence and operations.

The mode shapes of the system shows that the structure is stable to six modes, after this the deformation due to change the configuration of structure.

The stress consideration on the lower plate in element (34) at subjected to (1 N) and at thruster in element (49) there for cannot put the pay load on this plate.

The torque's of spacecraft is variable with time, because of the change in the spacecraft position through 24 hr. At subjected the satellite to vibration, the structure become stable to rang (0- 150) Hz after this rang the system due to unstable.

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