DESIGN OF EXPANDABLE STRUCTURE FOR SPACEBORNE ANTENNA

[1]Shinde Krunal Manoj, [2]Hitesh Raiyani,

[1]M.E Scholar, [2]Assistant Professor,
[1]Mechanical Department of Post Graduation Section,
[1]L.J.Institute of Engineering and Technology, Ahmedabad, Gujarat, India

Abstract: Space expandable technology is upcoming necessity and has a very significant role in taking space exploration program to a new era of revolutionary future. With the increasing demand of communication so as to connect each and every remote location throughout the globe as well in the field of defense the need of expandable antenna as well as various other components is very significant. As there is various constraints involved for space vehicle in the form of mass and volume, it is not possible to carry more mass and volume of component exceeding the capability of launching vehicle. As per Indian space research organization is concerned sub meter length projects based on space expandable are under experiment phase, so the project that we are working upon is to deploy a helical antenna for certain submetered length. Initially the helical antenna would be in compressed state when situation demands helical antenna would deploy itself and would trap low frequency. There should be certain medium through which helical antenna can deploy itself. Thus it as a primary requirement of this project works to build a cylindrical expandable structure which has capability to deploy a compressed helical antenna.

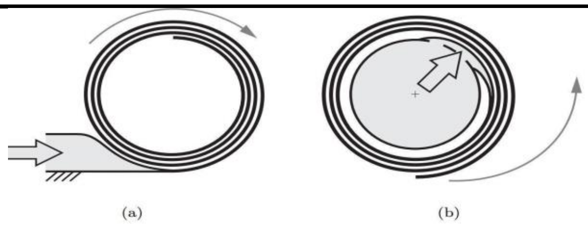
***IndexTerms* - space expandable, helical antenna**

I. INTRODUCTION

Space expandable structure is a technology which is having a significant role in the field of science and technology and its scope is going to increase in nearby future. Various space agencies will require this technology to launch and achieve their mass as well volume goal. This is essential for space missions that involve flight components and systems of large within orbit configurations. These involve solar arrays, solar concentrators, and telescope reflectors. At present, these external mechanical components make use of mechanically deployed structures to launch their required goal. In Comparison to mechanical deployable structures, space expandable structures do have various advantages, such as they are much lighter in weight as compared to that of mechanical deployment system, efficiency in packaging is higher, cost is much less as compared to that of mechanical system, simple design with less parts and higher deployment reliability. It is seen that expandable structures will be interchanged by mechanically expanded structures for lots of future space applications. Although the space expandable technology was not as famous in late 1950's but the disadvantage of launch vehicle payload carrying capacity refers that for a good launch of the payloads it is required to be space ultra-low-mass structures, such as space inflatables or any other forms of expendables. The use of expandable structures in space begins with the Mission Echo 1 in year 1960. In the 1960's, space agency of NASA put commendable effort into expandable space structures, including Echo I, ECHO II, PAGEOS and Explorer IX and XIX [9]. Overall, expandable in space have done a commendable job successfully, and are having various advantage to their demonstrated use in space. Expandable space systems actually require less packaged volume, are lower in weight and cheaper through both development and production

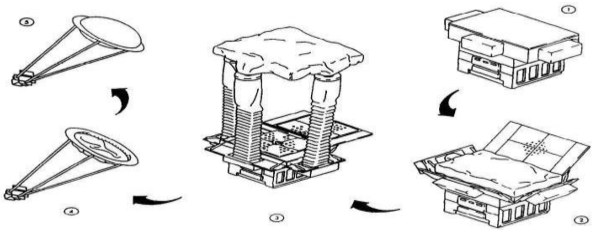
II. PROBLEM FORMULATIONS

In initial paper two important and different aspects of designing expandable cylindrical booms for actual space applications were studied which are, folding in the form of packaging methods that provides compact stowage and take under consideration reliable deployment, and techniques for rigidization that provide long-term structural rigidity after deployment. The brief literature in these two fields is elaborated for establishing state of the art. Also stowage method is to first compress the uninflated boom, before compressing by rolling it into a shape of coil or normally wrapping it around a hub [1]. Then on various properties of Mylar which is Polyethylene terephthalate (PET) were studied, Polyethylene terephthalate are trade names such as Mylar, melinax, hostophane, lumirror, tetoron, diafoil, terephane. Mylar is produced by E.I dupont de Numours and company Mylar is crystalline thermoplastic. Glass transition temperature of Mylar is 74 degree Celsius, Crystalline melting temperature Tm is 274 degree Celsius. Mylar is Flexible, resistant to creep, tears and puncture resistant. Elongation to break of Mylar is 50% to 130% at room temperature [2]. Information regarding large inflatable deployable antennae was studied. Since it was the first project that used space inflatable technology, thus various hardware technology were studied, with the help of large inflatable deployment space structures various designing and manufacturing of thin membrane structures for different classes of application were studied, the inflatable antennae experiment was pivotal in determining the future of inflatable space structures, technology development, and their subsequent applications [3]. Hardware components and systems commonly use mechanically deployed structures to meet their launch volume constraints. Compared to mechanically deployable structures, space inflatable structures have several distinct advantages, such as much lighter weight, higher packaging efficiency, lower life-cycle costs, simpler design with fewer parts, and higher deployment reliability. Depending on its configuration accuracy requirements, a space inflatable structure may fall into one of two roughly defined groups: hi-precision and low-precision [4].



The (a) coiling and (b) wrapping packing and deployment method.

(a) and (b)



(c)

Figure 1 (a) coiling (b) wrapping packaging and deployment method (c) deployment mechanism of space inflatable structure

III. EQUATION

mass flow rate is been calculated based on the fact that helical antenna is been compressed in initial stage then taking the cross section of undeployed antenna as rectangle angle and when the antenna deploy a circular cross section is obtained. Thus by comparing the perimeter of the rectangle and circumference of circle.

Radius of space inflatable is 80mm.

The area of circle = $20096mm^2$.

Volume of cylinder = $\pi r^2 \times (\text{Length of inflatable}) = 3.01 \times 10^7 mm^3$.

Mass flow rate $= 0.00418\ \text{kg/sec}$

Mass density $=1.390 \times 10^{-9}\ \text{tonne/mm}^3$.

Atmospheric pressure $=0.1\ \frac{\text{tonne}}{\text{mm s}^2}$.

Atmospheric density = $1.225 \times 10^{-2}\ \frac{tonne}{mm^3}$

IV. METHOD OF SOLUTION

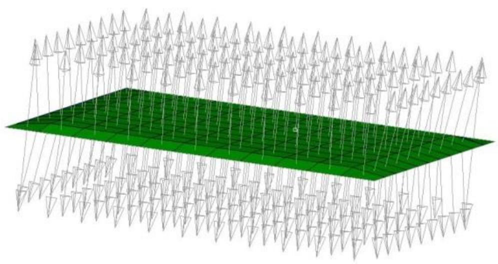
In order to study regarding the opening of space expandable structure software validation along with its hardware configuration is required, with the help of LS-DYNA tool various parameters could be judged along with their behavior.

4.1 SOFTWARE ANALYSIS

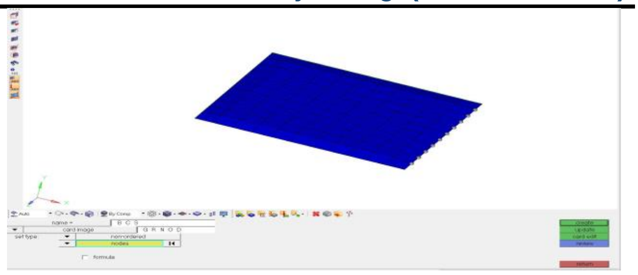
In order to know the behavior of deployment mechanism of helical antenna experiment various cards which are in the form of input cards need to be defined. Hypermesh is yet another nonlinear tool that is used to determine various parametric values with the help of which various behavior of mylar which is a suitable candidate for space expandable structure as of it is having several leading advantages that allows the simulation of actual model. LS-DYNA is a dedicated non linear software that is been specially designed for analyzing the behavior of the airflow inside the structure and to give an idea regarding the actual behavior of model in space.

4.1.1 SOLUTION PROCEDURE

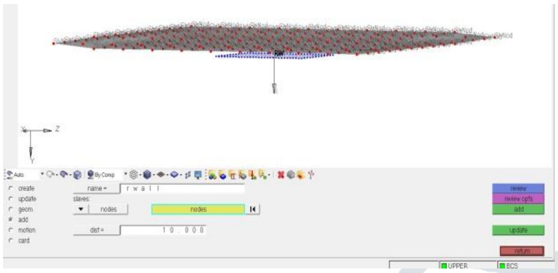
As per as solution procedure is concerned, initially modeling of space expandable structure in the software is required. Then the normal are checked and they need to be pointing outward. The edges of the surfaces should be translated as well as equivalence of the surfaces needs to be checked. Then interfaces need to be defined along with master and slave node, master node is a single node that control the slave node and also act as a boundary condition. A single edge of the surface need to be constrained be fixing all the degree of freedom such that we are providing boundary conditions to make sure that various parameters are defined properly. Then input parameters of gas are need to be given and the space expandable will act accordingly.



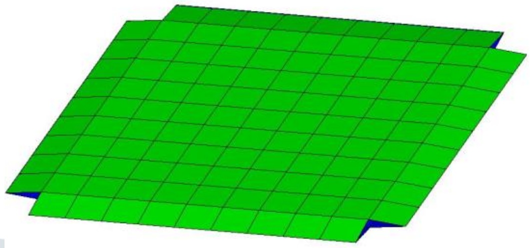
(a)



(b)



(c)

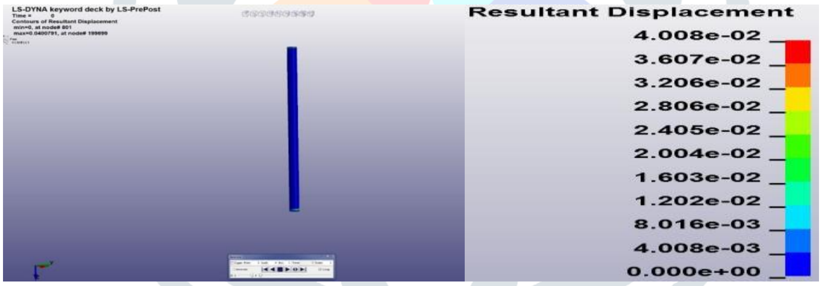


(d)

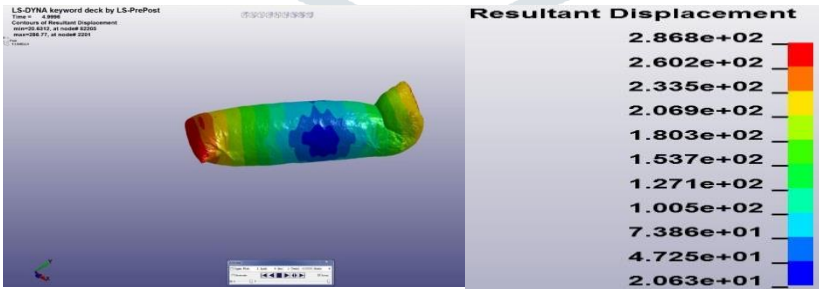
Figure 2: (a) normal pointing in outward direction (b) boundary conditions applied to edge (c) master and slave node (d) translating the surface.

V. RESULT AND DISCUSSION

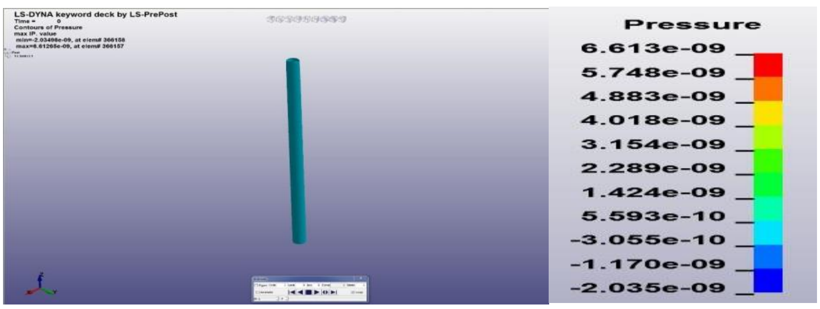
Various parameters were analyzed such as ,resultant displacement, pressure, surface stress, resultant velocity and with the help of results obtained from the software analysis , hardware configuration could validated.



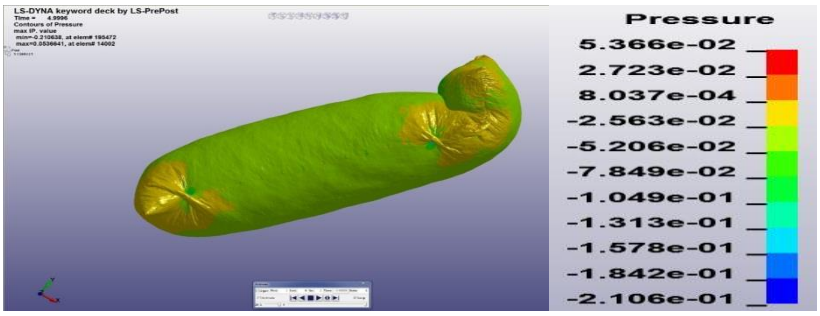
(a)



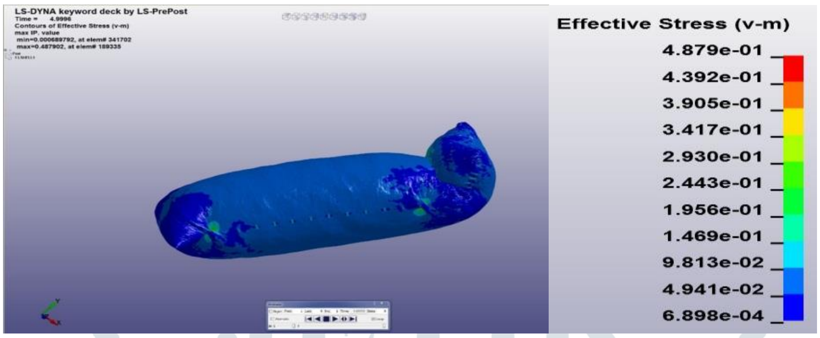
(b)



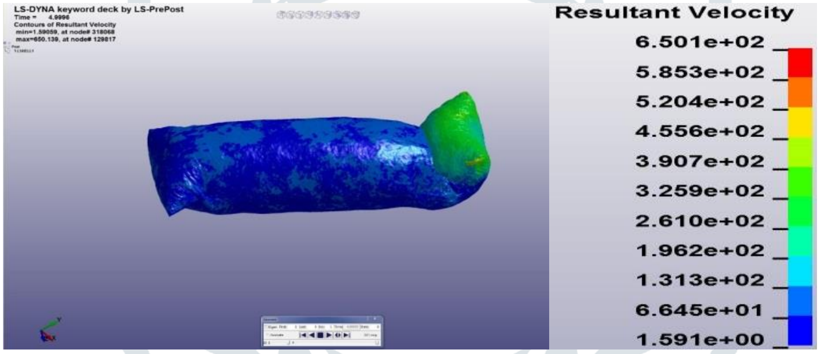
(c)



(d)



(e)



(f)

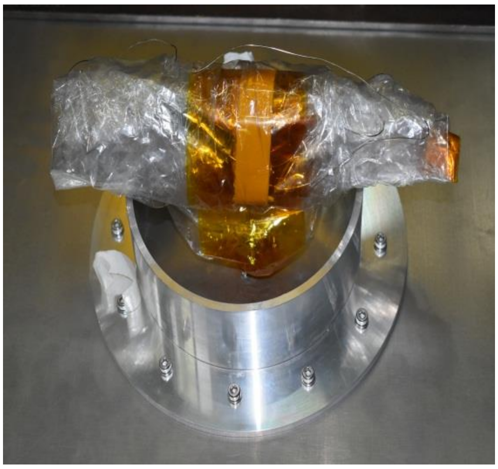
Figure 3: (a) resultant displacement step1 (b) resultant displacement step 2 (c) pressure step 1 (d) pressure step 2 (e) Effective stress (f) Resultant velocity.

Thus the resultant displacement is around 210 mm in radial direction, the pressure that we got is gauge pressure which in minus 70000 Pascal the value of absolute pressure would be of around 31325 Pascal, and the resultant velocity is around 455 millimeter per second, Thus this are various values that are been achieved in LS-DYNA and with all the value from the software analysis make the way of modeling actual deployable space expandable, and thus now the validation of the software model with the hardware configuration.

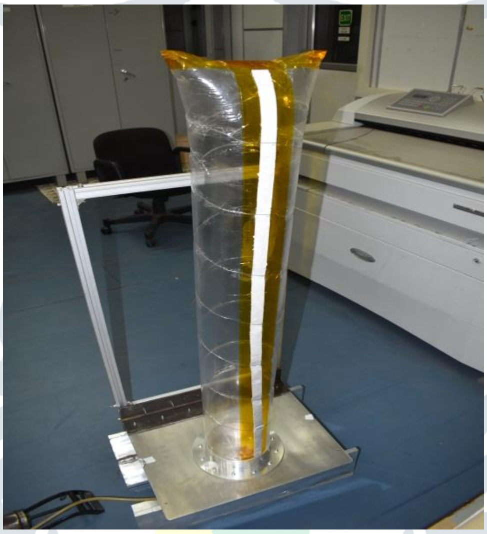
Resultant displacement	210 mm
Pressure	31325 Pascal
Effective stress	0.4 Mpa
Resultant velocity	455 mm/s

Table 1: values of various parameters and their values

Hardware model of space expandable antenna



(a)



(b)

Figure 4: (a) space inflatable structure in compressed stage (b)space inflatable structure in deployed stage.

VI. CONCLUSION

Space expandable structure was analyzed in software as well in hardware model, initially the software analysis of space expandable structure was performed then after its various parameters were observed and then based on the result obtained from the software analysis there were requirement of hardware model to be manufacture for validating the result. Thus the result of this paper would be that the validation of software data with the hardware model.

VII. ACKNOWLEDGEMENT

We take this opportunity to express our gratitude to our loving parents who are the center of our inspiration.

REFERENCES

[1] Review of Inflatable Booms for Deployable Space Structures: Packing and Rigidization Mark Schenk, Andrew D. Viquerat and Keith A. Seffen and Simon D. Guest Department of Engineering, University of Cambridge, Cambridge, CB2 1PZ, United Kingdom (2014).

[2] Materials for inflatables in space, John W. Connell – (November 25, 2015).

[3] LARGE INFLATABLE DEPLOYABLE ANTENNA FLIGHT EXPERIMENT RESULTS R.E.Freeland, Jet Propulsion Laboratory California Institute of Technology Pasadena, California, G. D. Bilyeu, G. R. Veal L'Garde, Incorporated Tustin, California M. D. SteineJ D. E. Carson, National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt, Maryland (1997).

[4] DEVELOPMENT AND APPLICATION OF SPACE INFLATABLE STRUCTURES Michael C. Lou 22"d International Symposium on Space Technology and Science Jet Propulsion Laboratory, California Institute of Technology Pasadena, CA 91 109, USA (2000).

[5] Resistive Deployment of Inflatable Structures Using Velcro M. Salama, H. Fang, and M. Lou Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109 JOURNAL OF SPACECRAFT AND ROCKETS Vol. 39, No. 5, September – (October 2002).

[6] DEPLOYMENT METHOD OF SPACE INFLATABLE STRUCTURES USING FOLDING CREASE PATTERNS Hiroaki Tsunoda, Yumi Senbokuya and Mitsunobu Watanabe NTT Network Innovation Laboratories, NTT Corporation 1-1 Hikari-no-oka, Yokosuka-shi, Kanagawa, 239-0847, JAPAN - (10 April 2003).

[7] New Design and Dynamic Analysis for Deploying Rolled Booms with Thin Wall, Ti Chen, Hao Wen, Dongping Jin, and Haiyan Hu Nanjing, University of Aeronautics and Astronautics, 210016 Nanjing, People's Republic of China- (January 2016).

[8] Design and Development of an Inflatable Reflectarray Antenna, H.Fang, M. Lou, J. Huang, L.-M. Hsia, and G. Kerdanyan, IPN Progress Report 42-149 - (May 15, 2002).

[9] Inflatable Boom Controlled Deployment Mechanism for the Inflatable Sunshield In Space (ISIS) Flight Experiment George H. Sapna III, John Folke, Charles R. Sandy, and David P. Cadogan 34th Aerospace Mechanisms Conference, (May 11-13 2000), NASA GSFC, Greenbelt, MD.