DEVELOPMENT OF LARGE INFLATABLE SPACE ANTENNA STRUCTURE

Sumio Kato[+1], Yoshinori Sakai[+1], Osamu Muragishi[+2]
Yuzo Shibayama[*], Tomomi Obuchi[*], Michihiro Natori[**]

[+1] Kawasaki Heavy Industries,LTD. Aircraft Engineering Division
[+2] Kawasaki Heavy Industries,LTD. Technical Institute
[*] NEC Corporation,Space Development Division
[**] Institute of Space and Astronautical Science

ABSTRACT

This paper presents the recent research and development of a large inflatable antenna structure that is composed of modularized inflatable elements and back-up truss structure. An appropriate antenna structure including inflatable elements and back-up truss is investigated. Inflatable elements and back-up truss models are manufactured and tested. It has been cleared that the inflatable modularized surface structure has potential for high precision antenna missions.

1 INTRODUCTION

Large inflatable space antenna structures have a feature that its packaging efficiency and surface accuracy are good and well-balanced compared with other types of antennas(rigid and mesh types). The inflatable antenna structure has two types. One is an entire type[1], that is composed of one entire inflatable element, and the other is a modular type[2][3],that is composed of many modularized inflatable elements. Although the former type has good packaging efficiency, very accurate manufacturing process is required. Shape control of the surface is difficult because it has no hard points inside. The surface rms(root mean suare) error increases more as the size of the structure becomes larger. On the other hand the latter, which uses back-up structure, can avoid various difficulties mentioned above and is a good candidate for high precision antenna missions. In this paper basic concept of the modularized inflatable antenna structure is briefly described. Test results on inflatable elements and back-up truss models are presented and discussed.

2 BASIC CONCEPT [2][3]

A modular type structure consists of modularized inflatable elements and back-up truss structure. In orbit, it is deployed from the stowed configuration and the reflecting membrane surface is rigidized by solar heating etc. During the membrane rigidization, the appropriate internal pressure and tension are applied to inflatable elements to generate the precise reflector surface. After the rigidization has finished, the internal pressure is removed. Fig.1 shows the function model of the modularized inflatable structure and an example of application to 10mϕ space VLBI antenna.

3 INFLATABLE ELEMENT

Inflatable elements supported by deployable truss structure approximate to an ideal parabolic surface.

1)Shapes: Elements of circle,ellipse,square,and hexagonal configurations are considered.Of these configurations hexagon is evaluated to be the best,considering arrangement,compatibility with paraboloid and back-up truss etc.

2)Types : Inflatable elements are classified into three membrane types,which are described as follows.

Flat type : The element is constructed of two plane membranes
Gore type : The element is constructed of many plane gores and entire

element has three dimensional shape

3-Dim type : The element is made of two 3-dimensionally curved membranes Manufacturing becomes more difficult in the order of flat,gore and 3-Dim type.On the other hand stress and strain levels during pressurization are small in this order. Comparison of the types is shown in table 1.

3) Rigidization of membrane : Membrane material of the inflatable element should rigidize in space. Unless the rigidizing material is used for inflatable elements,the internal pressure should be maintained to control the surface accuracy throughout the mission phase, and the gas losses caused by leaks through seals or holes made by micrometeoroid penetration etc. would be great. For the rigidizing material a lamina composed of fiber-reinforced(Kevlar, or Graphite) thermo-curing prepreg and gas barrier film is planed to be used.

4 BACK-UP TRUSS

Square and hexagonal shapes are compared and evaluated. Based on compatibility with inflatable elements etc, hexagonal truss is selected. Fig.2 shows square and hexagonal truss concept.

5 TESTS

Measurements of deformed membrane, rigidization test of membrane, and function test of one-cell truss models were carried out.

1) Measurement of deformed membrane

Configurations of the test membrane models are circle, ellipse and hexagon, based on the projection of 90cm ϕ circle and hexagon upon the 5m focal length paraboloid. The membrane is 100 μ PET film. Internal pressure is applied to the film. Deflection of the membranes were measured with optical displacement sensor or theodolite system. An example of view of the measurement is shown in Fig.3. An example of measured deflection is shown in Fig.4. Fig.5 shows the measured rms errors of each element. From this figure it is seen that rms error of the order of 0.3mm is attained when the boundary of the membrane fits to BFP(Best Fit Parabola).

2) Rigidization Test of Membrane

Rigidization test was carried out using 40cmϕ ~90cmϕ membrane models. The membrane is a lamina composed of GFRP prepreg as rigidizing material and thin gas barrier film. Cure runs were made in an oven chamber. During the process differential pressure was being applied to the membrane models. After the rigidization of the membrane the pressure was removed and the deflection was measured. Fig.6 shows an example of test model in an oven chamber. Fig.7 shows an example of measured deflection and corresponding BFP. Surface rms errors of these models are of the order of 0.3mm, which are considered to be sufficiently small.

3) Functional Test of One-cell Truss Models

Two kinds of hexagonal one cell truss models(A and B) were fabricated and tested. Fig.8 shows test model A with an inflatable element model attached. The size of the element is about 1m ϕ. Deployment and folding of the model was smooth. No interference between the model and the inflatable element was found. Fig.9 shows model B in stowed and deployed configurations. This model has a synchronizer at each joint. Deployment and folding of the model is also smooth.

6 CONCLUSIONS

Concept of modularized inflatable antenna structure employing inflatable elements and back-up truss , and the relevant test results are presented and discussed. With these studies and test results, it has been cleared that the concept of modularized inflatable structure has potential for high precision antenna missions. Further investigations for rigidized materials, fabrication and test on seven cells truss model, detail study of membrane surface accuracy control, etc. are planed.

REFERENCES

1) G.G.Reibaldi&M.C.Bernasconi,"Quasat Program:The ESA Reflector",IAF-85-400, 36th Cong. Internatl.Astronautical Fed.,Stockholm,Oct.1985
2) M.Natori,H.Furuya,S.Kato,Y.Takeshita,&Y.Sakai,"A Reflector Concept Using Inflatable elements",16th Internatl.Symp.Space Technology and Science(ISTS) Sapporo, May 1988,pp459~467
3) S.Kato,Y.Takeshita,Y.Sakai,O.Muragishi,Y.Shibayama,&M.Natori,"Concept of Inflatable Elements Supported by Truss Structure for Reflector Applications" ,IAF-88-274,36th Cong. Internatl.Astronautical Fed.,Bangalore,Oct.1988

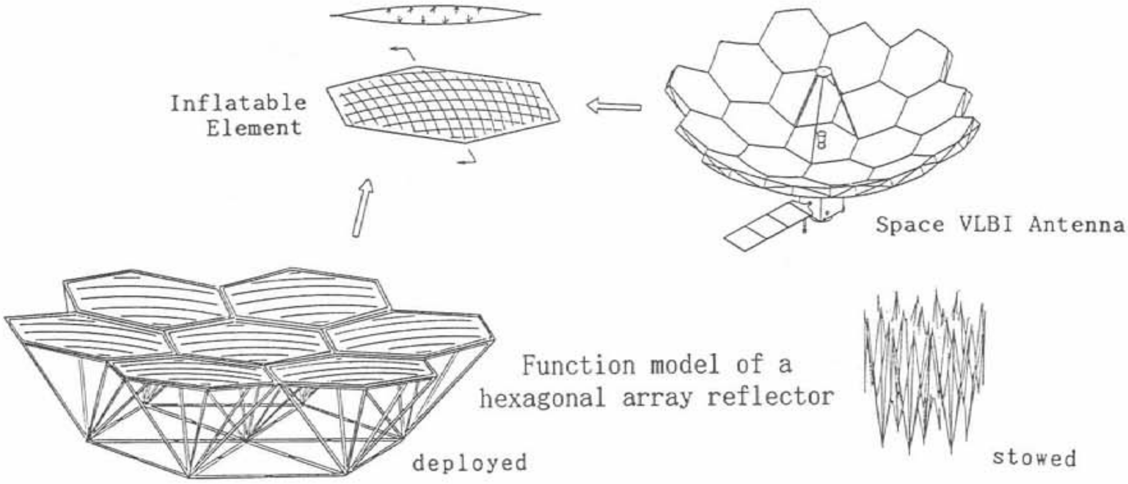
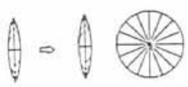


Fig.1 Function model and application to space VLBI antenna

Table 1 Types of Element

Type	shape	Manufacturing	Stress level	Strain level	Surface accuracy
Flat		Easy	Large	Large	Good for shallow dish
Gore		Middle	Small	Small	Good for deep dish
3-Dim		Difficult	Small	Small	Good for deep dish

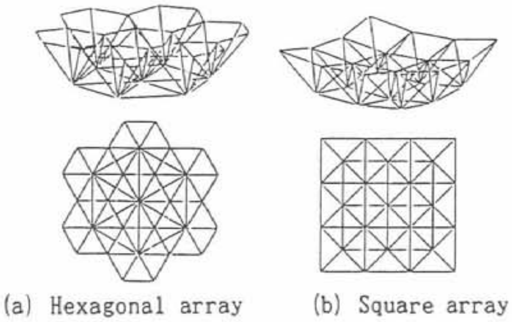


Fig.2 Back-up truss structure concept

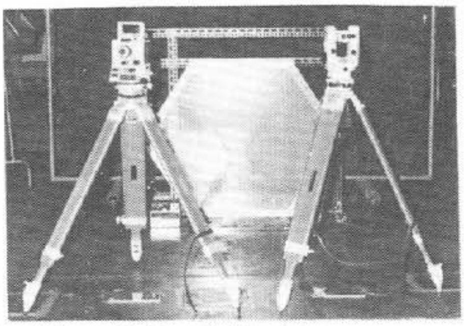


Fig.3 View of the deflection measurement using theodolite system(example)

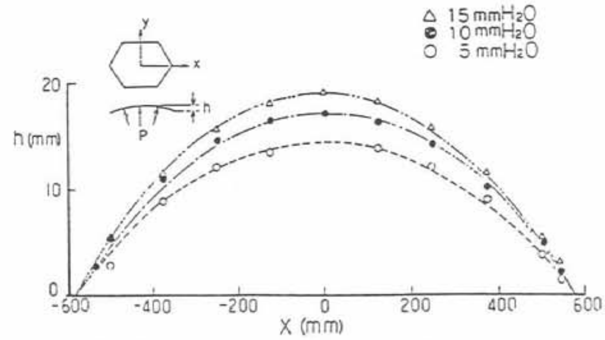


Fig. 4 Deflection of a hexagonal membrane subjected to internal pressure (curved boundary)

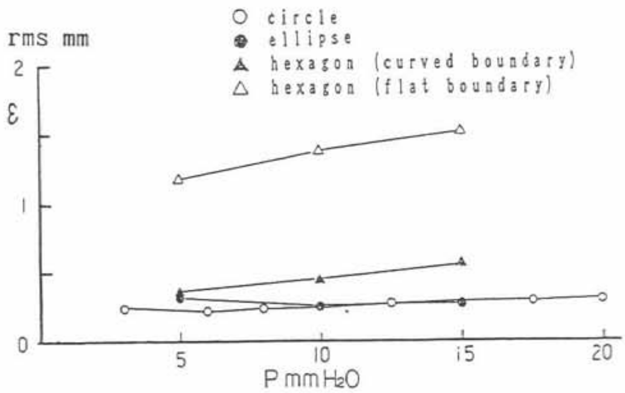


Fig. 5 RMS errors of inflatable elements

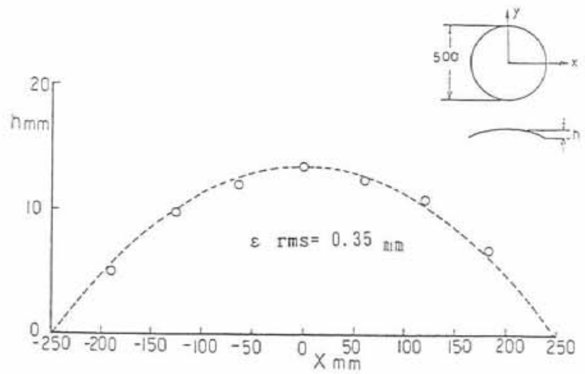


Fig. 7 Deflection of a rigidized test model

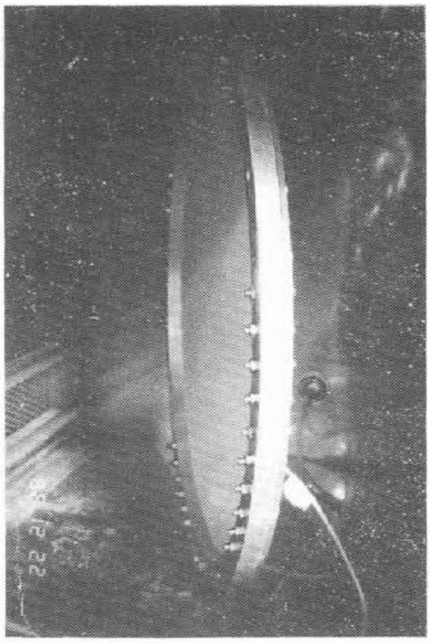
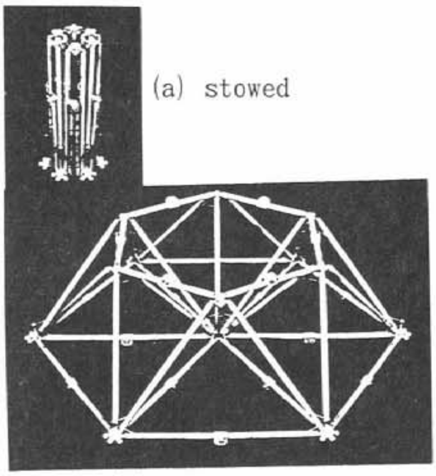


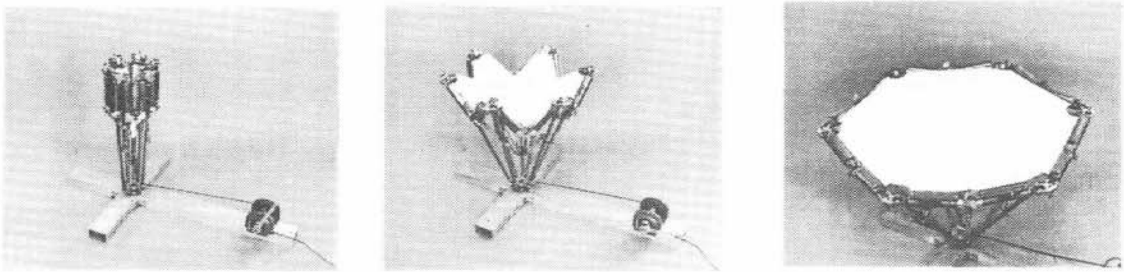
Fig. 6 Rigidization test model in an oven chamber (90cm φ circular element)



(a) stowed

(b) deployed

Fig. 9 Hexagonal one cell truss model B



(a) stowed (b) half deployed (c) deployed

Fig. 8 One cell truss model A with an inflatable element attached