Journal of International Scientific Publications:
Materials, Methods & Technologies, Volume 7, Part 2
ISSN 1313-2539, Published at: http://www.scientific-publications.net

FREQUENCY ANALYSIS OF A REFLECTOR THAT IS FOLDABLE AS COMPACT AND CAN BE OPENED AUTOMATICALLY

Abdurrahman KARABULUT[1] Lütfiye DAHİL[2]

[1]Afyon Kocatepe University, Faculty of Technology, MechanicalEngineering

[2]Istanbul Arel University, Department of Mechanical an Metal Technologies,

e-mail: lutfiyedahil@arel.edu.tr, kbulut@aku.edu.tr ,

Abstract

In this study, design and product of ¼ scaled mode of a composite reflector, which can be used on small satellites that have 6 m diameter in full-scale version and is thought to be worked in Ku frequency band range, has been practiced. Its reflector has been incited in different frequencies by using shaker. Resonance frequencies have been measured in 4 end points of reflector and in center. By connecting the reflector vertically and with elastic materials, mode shape has been determined by acceleration receivers from its 20 points.6 modes have been obtained between 2,8-15,80 Hz. Finite elements method is in accord with frequency values that have been found experimentally.It has been observed that excitations from the middle point of reflector surge to all surfaces. It has been seen that frequency values in the end points of reflector are less than those in the middle point.

Key words: *Foldable Composite Reflector, Finite Elements Method, Frequency Response.*

1. INTRODUCTION

There are many folding structure's practices in both space and earth. The simplest example is umbrellas which we use it in the earth. Another example is folding roof in the sport centers. The history of folding structures in the space has started with the first satellite "Sputnik" which was launched by The Soviet Union in 1957. In the beginning, researches had mounted the erectable structures in space conditions with helping astronauts and robots because there are limited volume and difficulties in spacecrafts. But these structures' mounting in space condition is both costly and hazardous and so researches of soft and flexible structures which are possible for remote control have gathered speed.

The biggest advantage of the folding structures is low, mass and packing volume (Tibert - Pellegrino 2002). Signal losses in terms of Electronic performance and center or side connection in terms of satellite connection are another criteria to consider (Baier & Datashvilli, 2005). Pre strain and thermo-elastic analysis had been made by forming finite element model of reflector model and reflector's mode had been determined. (Datashvilli 2010). For this reason form memory composite materials create grand potential for space structures with their low mass, rigidity, stability and packaging features (Scarborough and Cadogan, 2010). Deformations after folding have determined as things to consider in these structures' design which are made by composite materials (Soykasap, 2008). Antenna reflector which provides spacecraft's communication folds with its energy. It is made by soft and high strenght composite materials. Cellular metallic materials, mechanical damping depends on structural factors and test conditions (Dahil, Başpınar & Karabulut, 2011).

In this study, the manufacturing of the folding reflector with composite materials have practiced. Its surface flatness has researched. Its natural frequencies have obtained with experimental and finite element methods. Some modes have been found in resonance frequency with finite element. Frequency values have been found and finite elements and values have been compared. Special software for experimental study has been used.

2. REFLECTOR DESIGN AND ITS PRODUCTION

Manufacturing in 1/4 scale have performed with using special mold. Scale model diameter is D=1.5 m, offset amount is 0,075 m, flap width is 0,0625 m. Layer state is similar with full-scale optimum model and four different beddings have been provided. As you see in Figure1, there are eight carbon layers which are 0.11 mm for remaining body (red) in D_3 $[0/45/0/45]_s$, five carbon layers(yellow) from D_2 to D_3 $[0/45_3/0]$; three carbon layers (green) from D_1 to D_2, [0/45/0]. Outer reflective surface(turquois) consists of two [0/45] layers. Flap [0/45/0] consists of three layers. ¼ scale reflector in the mold is shown in Figure 2.

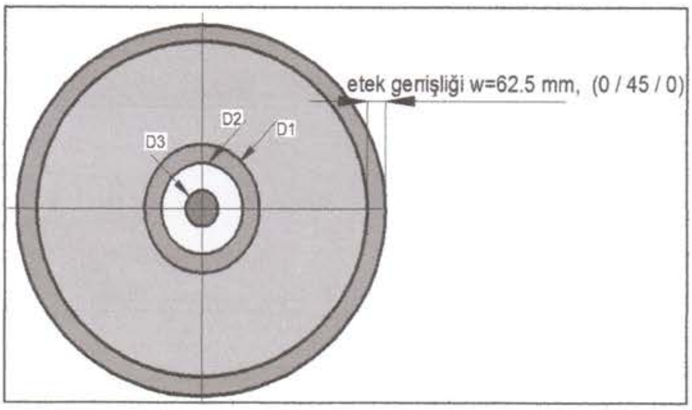


Figure 1. Schematic view of ¼ scale model

Figure2. ¼ scale reflector

2.1. Material Specifications of Offset Reflector

Scale reflector model have been manufactured with three bedded (0/45/0) carbon fiber materials. Thickness on the reflector has measured as average 0.4 mm. It is not possible to measure elactic specifications with this value because surface has resine and this resine has not homogenous spread. Efective thickness has proposed in some studies by emphasizing this. Each layer thickness of T300B, 94 g/m2 fabrics is 0.11 mm that it is obtained with material data. Three bedded composite reflector thickness has taken as tref=0.33 mm for this.

Scale reflector mass has measured as 1770 g with precision dynamometer. You can find the reflector intensity with following equations:

$$\rho_{ref} = \frac{m_{ref}}{A_{ref} \times t_{ref}} = \frac{1.770}{3.7212 \times 0.00033} = 1441\,\text{kg/m}^3 \quad \text{..................} \quad (1)$$

In here, A_{ref} is reflector surface. In- plane specifications of scale reflector must be known in the modelling. Effective specifications of composite is obtained by using material specifications of resine-impregnated fiber. $\rho_f = 1750$ kg/m^3 *and* $\rho_m = 1150\ kg/m^3$ values have selected from the material information data.

$$\begin{aligned} V_f + V_m &= 1 \\ \rho_{ref} &= V_f \rho_f + (1 - V_f)\rho_m \end{aligned} \quad \text{..} (2)$$

In here, fiber volume rate is $V_f = 0.485$. $E_1 = 230$ GPa, $E_2 = 14$ GPa, $G_{12} = 9$ GPa, $v_{12} = 0.2$ are taken for T300B fibers. (Soykasap, 2008). E=3.4 GPa is taken for L160 epoxy matrix. Slip modulus and Poisson rate are accepted as G_{12}=1.4 GPa, $v_{12} = 0.35$. considering these material specification;

$$E_1^y = V_f E_{1f} + E_m(1 - V_f) \quad \text{..} (3)$$

Mixing ratio formula cannot give good results for cross direction while it estimates the model on long direction. For this reason, Halpin–Tsai equations have been used for both cross direction and slip modulus. According to this;

$$E_2^y = \frac{(1 + \xi\eta V_y)E_m}{1 - \eta V_f} \quad \text{..} (4)$$

Burada, $\eta = \dfrac{E_{2f}/E_m - 1}{E_{2f}/E_m - \xi}$ ve E_{2f} is elastic module on cross direction of fiber. ζ is a kind of measure of fiber supplement and it depends on fiber geometry, how to package and how to store; ζ=2 is proposed for circular fibers. Shear modulus is obtained.

$$G_{12}^y = G_m \frac{(G_{12f} + G_m) + V_f(G_{12f} - G_m)}{(G_{12f} + G_m) - V_f(G_{12f} - G_m)} \quad \text{..} (5)$$

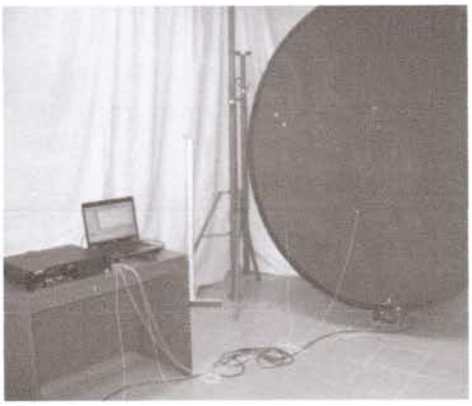
In here, G_m is shear modulus of matrix and G_{12f} is slip modulus of fiber. $v^y_{12} = V_f v_{21f} + v_m(1 - V_f)$, the Poisson rate of resine-impregnated fiber can be measured with Poisson rates of fiber and matrix and volume rate of fiber. Effective specifications of composite is obtained by using material specifications of resine-impregnated fiber.

ISSN 1313-2539, Published at: http://www.scientific-publications.net

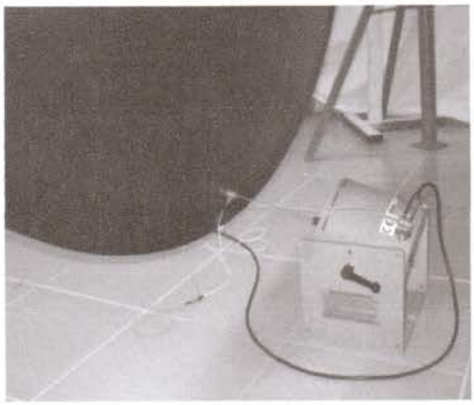
$$E_1 = E_2 = \frac{1}{2}\frac{E_1^y\left[\left(E_1^y\right)^2 + 2E_1^y E_2^y + \left(E_2^y\right)^2 - 4\left(v_{12}^y\right)^2\left(E_2^y\right)^2\right]}{\left(E_1^y - \left(v_{12}^y\right)^2 E_2^y\right)\left(E_1^y + E_2^y\right)} \quad \text{.............................(6)}$$

2.2. Modal Test Analysis

Elements of test ring consist of modal system vibrator, analyser, accelerometers, force meter, amplifier, computer and software. One of accelerometers has been placed in the point of provoking of the vibrator and other accelerometer has been placed in reflector center and the last one has been placed in endpoint which is parallel with the center. Accelerometers' states have been changed. Especially acceleometer in endpoint has been turned around the reflector with 30°. Impulse method has been used for measures. The vibrator in this method provokes the reflector at regular intervals. It is known that the vibrator gives more healthy results with hammer. Each accelerometer is connected with teflon cable to analyser. Analyser is connected with USB socket to the computer. BNC connection has been used for cable connections. Testing apparatus has been shown in Figure3. Cable losses have been reduced with this connection. Reflector has been hanged with elastic yarns from two points. Displacement range for system has been scaled with amplifier. Reflector has changed with mode in resonance frequency value. Reflector vibration frequency and vibrator frequency have same value in every resonance frequency value. When vibrator frequency increases reflector areas which vibrates get off the resonance. Finally the obtained results are shown in Graphic 4. Frequency values in three different accelerometers are shown in the Graphic.

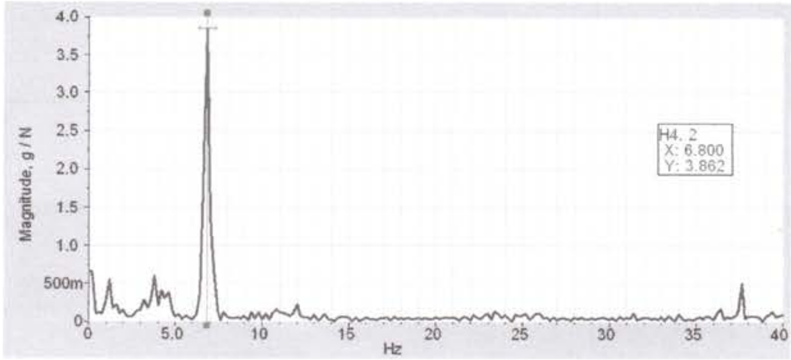


a) The front surface of the reflector

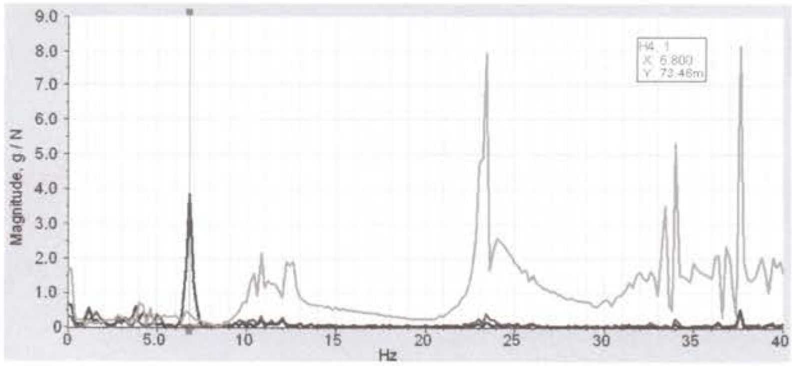


b) Back surface of reflector

Figure 3. Modal test apparatus and vibrator connection to reflector



a) Acceleration curve center of reflector



b) The bend of three accelerations on reflector

Figure 4. Resonance frequencies

Three accelerometers' bends are different from each other. Green bend belongs to acceleration which is connected to reflector's endpoint. Frequency value of bends is resonance frequency. Material changes in these values. The first six modes value have been measured. Head of reflector has came in resonance before 5Hz. Midpoint of the object has came in resonance after sides. Modal analysis results of ABAQUS finite element programme and modelled reflector have been compared. The obtained mode values with finite elements method are bigger than the obtained mode value with experimental studies. While the difference in 1. Mode value is 16%, this value is 6-10% in other values. The influence of gravity of these differences has stemed from limiting conditions and materials specifications. The modal is shown with test results in Table 1.

Table 1. The obtained frequency values for six modes of reflectors.

Mod Shapes	FEM Frequency (Hz)	EXPERİMENT Frequency (Hz)
1	3,39	2,80
2	3,75	-
3	11,18	7,90
4	11,26	-
5	22,42	15,50
6	22,60	15,80

Six modes values are obtained in vibration analysis by using Lanscoz solution method in free limiting conditions. Finally there is certain convergency between finite element method and experimental study for every mode value. Difference for every mode is 18-28%. Frequency differences after two different measures have stemed from influence of gravity, material and measure failures. Frequencies in 2 and 4. Modes have not been obtained based on materials with experimental method.

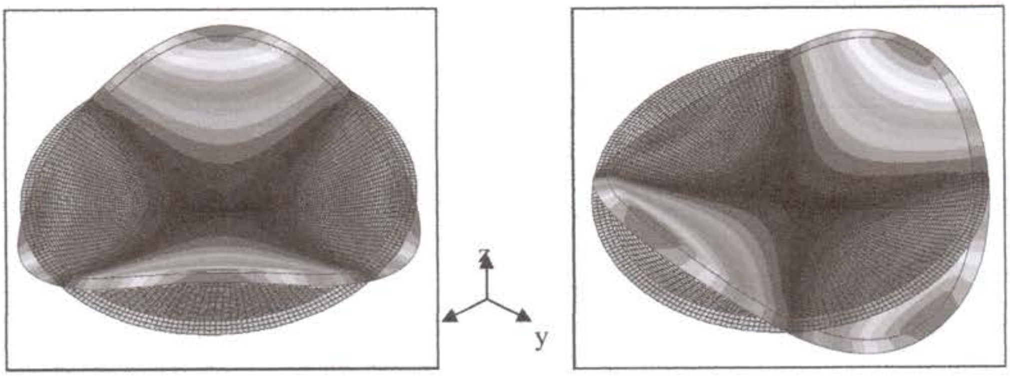
The obtained modes with finite element methods of 1/4 scale reflector are shown in Figure 5. The modes of reflector seems like stipule. While the phase difference between these stipules in 1. and 2. modes is 90°, the phase difference between 3. and 4. modes is 60°. There is a situation which stems from weakness in the flap in 5. and 6. modes.

Mode shapes obtained from finite element analysis by considering 1/4 scale reflector determined 1. mode shape. Modal testing software system was used to this to determine as experimental. reflector has been driven harmonic motion. The reflector enters in resonance with this motion and atrial like the obtained mode with finite element method is observed. As you see in Figure 6, to see this stipule, pictures have taken from reflector by using 125 photo/sn shoot fast. The action in stipule has seen very clearly. While A point goes back, B point goes forward.

Composite reflector design and analysis have been realised by using Ku frequency band in this study. The production of ¼ scale reflector has been decided after the determination of optimum model. The new mold has been produced in line with the obtained data from the manufacturing and tests of first scale reflector. Relevancy of structure has been determined by using different tests for optimum offset reflector.

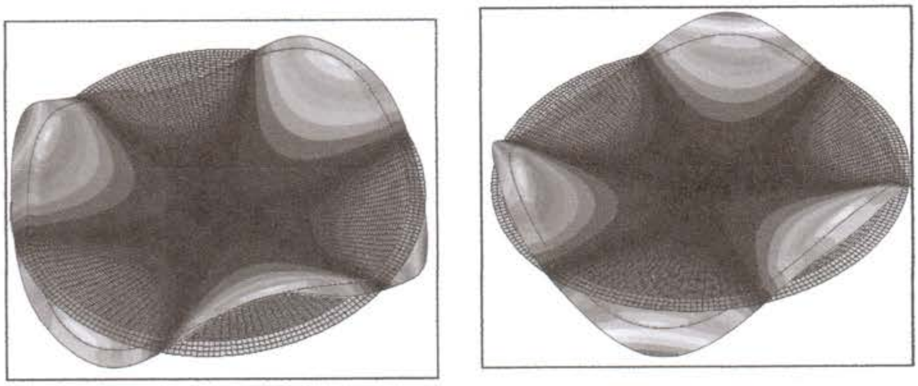
If the study branchs, these sections are examination of preliminary design, production of scale models, test analysis and examination of full-scaled optimum reflector.

1. Offset reflector model with flap is more advantage than the other reflectors in terms of mass and natural frequency. This relevancy is valid in both folding test and analyse. Focus point and RMS error are not same value in surface relevancy on this reflector. Reason of this is accepted as influence of gravity and the mold error.



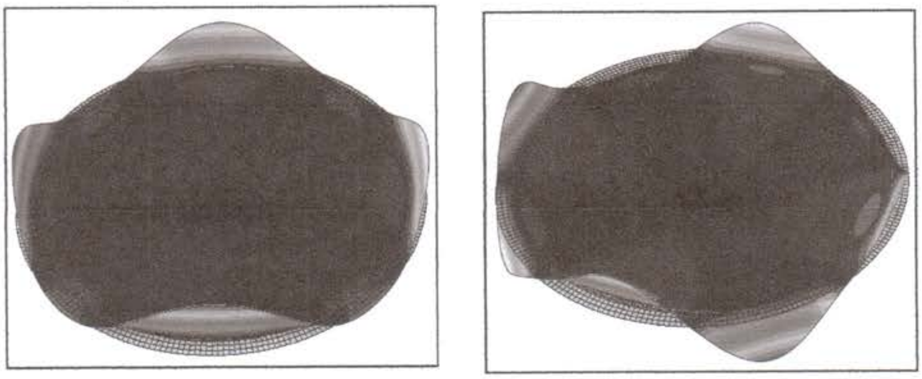
a) **1. Mod**

b) **2. Mod**



c) **3. Mod**

d) **4. Mod**



e) **5. Mod**

f) **6. Mod**

Figure 5. Fourth scale mode shapes of the reflector was obtained by FEM

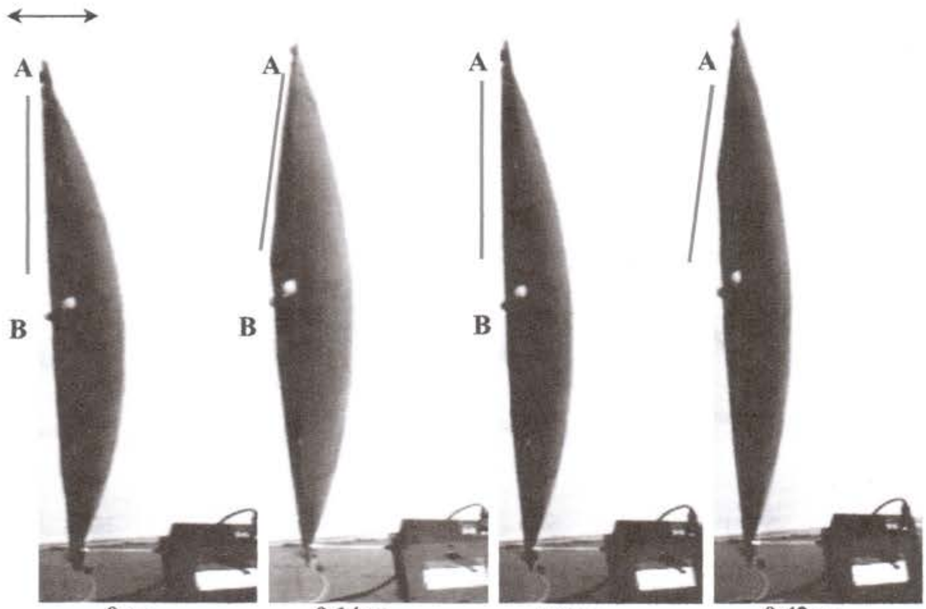


Figure 6. Reflector Determination of status of the 1. mode with high speed camera

2. Optimization operation has been realised on full-scaled offset reflector. The relevancy of optimum model has been tested by different analysis. Layer's angle is important for optimum reflector. Especially layers determined as 450 has positive effect on flap. Rising of flap width rises natural frequency value as well.

3. The surface of full-scaled reflector with flap is not optimum in terms of mass and rigidity. Frequency value changes based on reflector center. So, central power supply is important for this. While central power supply and mass are rised , frequency value rises as 100%.

4. Modal is useful for optimum reflector in terms of bended tests. Mode 1 state of reflector has been determined by using finite element method and camera. The obtained analyse and test frequency values are relevancy in optimum ¼ scale reflector.

5. both endpoint and center of reflector come in resonance in different frequency. The endpoint range is more closer than the other's range.

REFERENCES

1. Tibert, AG & Pellegrino, S 2002, 'Deployable Tensegrity Reflectors for Small Satellites', *Journal of Spacecraft and Rockets*, vol. 39, no.5, pp.

2. Baier, H & Datashvili, L 2005, Technical Assessment of High Accuracy Large Space Borne Reflector Antenna, Final Technical Report, Institute of lightweight Structures Aerospace Department Technical University of Munich.

3. Datashvili, L, Baier, H, Schimitschek, J, Lang, M & Huber, M 2007, 'High Precision Large Deployable Space Reflector Based on Pillow-Effect-Free Technology', paper presented to the 48th. AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Honolulu, Hawaii.

4. Scarborough, SE & Cadogan, D.P 2006, 'Applications of Inflatable Rigidizable Structures', SAMPE, Long Beach.

5.Soykasap, Ö 2008, 'Polymer matrix composites textured thermo - mechanical behavior', Afyon Kocatepe University, Supporting: TÜBİTAK, Project No: 106M005

6. Dahil, L, Başpınar, S & Karabulut, A 2011, 'Damping Effect Of Porous Materials', *AKU Science Magazine,* vol. 11, no.1, pp.1-7