The Biennial International Conference on Experimental Solid Mechanics
(X-Mech 2016)
16-17 Feb., 2016, Tehran, Iran

IUST

Center of Excellence in Experimental Solid Mechanics and Dynamics,
School of Mechanical Engineering, Iran University of Science and Technology

Dynamic analysis of satellite sandwich panels: Experimental and Numerical approach

[1]Shahravy , M. [2,3*]Mokhtari, M.
[1]Associate Professor, Department of Aerospace Engineering, University of Malek-e-Ashtar, Lavizan, Tehran, Iran.
[2] PhD student, Department of Mechanical Engineering, University of Malek-e-Ashtar, Lavizan, Tehran, Iran.
[3] Senior Engineer, Shahid Ghandi Center of Research, Tehran, Iran.

*(m_mokhtari@mut.ac.ir)

Abstract- **The current investigation focuses on design, analysis and dynamic response of the sample of micro-satellite Aluminum panel structure. Aluminum face sheet sandwich panels have been manufactured and are studied. Modal tests have been performed with impact hammer equipment. Modal analysis have been done with 2D and 3D numerical models of sample satellite sandwich panel structure with commercial finite element (FE) code, ABAQUS 6.12.1. There is a good agreement between FE modeling and analytical stress results; also 6.73 % is the maximum discrepancy between numerical and experimental first 5th modal frequencies, also comparison between numerical predicted mode shapes and experimental ones implies a very good likeness.**

Keywords - Satellite Sandwich Panel, Dynamic Response, Preliminary design, Modal Test

I. INTRODUCTION

Satellites have gained considerable interest in the past decades as a result of applications in communication, remote sensing, and etc. The miniaturization of electronic components enabled to develop satellites of small size, with weight ranging from 10-100 kg. The benefits of developing a micro satellite leads to a shorter development time and much lower costs than that required for larger satellite, while achieving the same and high levels of performance and capability.

Complex environment and space mission constraints have pushed demands such as lighter weight structure, limitation of mass, low energy consumption, and reduced launch cost [1-3]. However, due to the flexible property of large sandwich panels, the deflection of the flexible panels has a significant influence on the dynamics performance and structural durability of satellites. Mainly, larger space structures are made with composite materials. Environmental conditions and various corrosion properties/condition affect the composites performances [4-6].

The current investigation focuses on design, analysis and dynamic response of the sample of micro-satellite Aluminum panel structure. Aluminum face sheet sandwich panels have been manufactured and are studied. Modal tests have been performed with impact hammer equipment. Modal analysis have been done with 2D and 3D numerical models of sample satellite sandwich panel structure with commercial finite element (FE) code, ABAQUS 6.12.1.

II. EXPERIMENTS & RESULTS

In preliminary design phase, dynamic loadings subjected to base of the satellite have been extracted with respect to natural frequency of pre-designed satellite and power spectral density (PSD) diagrams of selected launcher LM (Miles' equation), as shown in Table 1. Geometrical model of micro-satellite is shown in Fig. 1.

TABLE 1 LOAD CONDITION WITH RESPECT TO MILES' EQUATION AND LAUNCHER USER'S MANUAL

	Longitudinal	Lateral
Steady-State Acceleration	8.5g	1g
Sine-Vibration	1.875g	1.5g
Quasi-Static	**9g**	2.85g
Random Vibration	5.81g	5.81g

After extrication of exerted dynamic loads; the optimum ratio between the core thickness h_c (m) and face sheet thickness t_f (m), ($\frac{h_c}{t_f}$) has been optimized with respect to a minimum mass m_{total} (kg/m) of the sandwich construction against: maximum bending stiffness, strength, general buckling and faces dimpling.

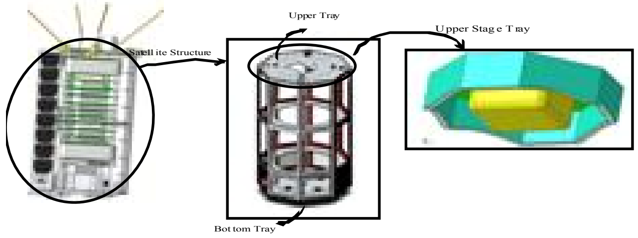

Fig. 1 Schematic sketch of model satellite geometry and its upper tray with attached equipment (about 350×350×700 mm)

At first in comparison reasons and primary calculation, two aerospace Aluminum grades, 7075 and 2618 (with average mechanical properties: $E_f = 71GPa, \nu_f = 0.28, \rho_f = 2850\frac{kg}{m^3}, \sigma_{ultimate} = 540MPa$) and T 300/Epoxy ($\rho_f = 1500\frac{kg}{m^3}$ [3]) were selected and compared to each other's. Also, Alominum core HC-1/8-5056-0.001 ($\rho_c = 72\frac{kg}{m^3}$ [5], $E_c = 1275MPa, G_L = 483MPa, G_W = 193MPa$) is selected as sandwich panel core.

As shown in Table 2, the maximum optimum core thickness vs. 0.6 mm face-sheet thickness is 9.366 mm. 10 mm core thickness has been selected to continue manufacturing and design process.

TABLE 2 OPTIMUM h_c IN TWO SUGGESTED t_f AGAINST THESE PARAMETERS: BENDING STIFFNESS, GENERAL BUCKLING, STRENGTH AND FACE DIMPLING

Materials		Al-7075		Al-2618		T300/914	
Opt. against [4]		h_c (mm)	t_f (mm)	h_c (mm)	t_f (mm)	h_c (mm)	t_f (mm)
Bending stiffness	[illegible]	3.122	0.2	3.088	0.2	16.5	0.2
		9.366	0.6	9.158	0.6	2	0.6
General buckling	[illegible]	2.522	0.2	2.788	0.2	16.06	0.2
		7.56	0.6	7.99	0.6	4.8	0.6
Strength	[illegible]	1.560	0.2	1.532	0.2	8.2	0.2
		4.68	0.6	4.596	0.6	2.5	0.6
Face dimpling	[illegible]	1.560	0.2	1.532	0.2	2.75	0.2
		4.68	0.6	4.596	0.6	0.83	0.6

Primary thickness study of the satellite sandwich panel core shows that the optimum thickness of the face sheets, against the mentioned parameters is 10 mm. Aluminum sandwich panel has been manufactured with aluminum 8000 series core and 5052 series face sheets. Schematic of sandwich panel is shown in Fig.2. Full free boundary condition sandwich panel has been tested with stand test of Fig.3. Comparison of experimental and numerical results is shown in Table 3. There is a good agreement between numerical and experimental natural modes (Table 3) and predicted mode shapes (Fig. 4).

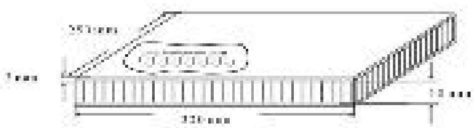

Fig. 2 Schematic of CFRP sandwich panel specimen geometry for free dynamic response test

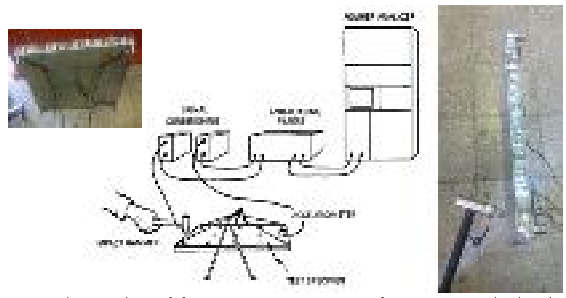

Fig. 3 Schematic of free response test of recommended Aluminum sandwich panel with impact hammer

TABLE 3 FIRST FIVE NON-ZERO NATURAL FREQUENCIES OF ALUMINUM SANDWICH PANEL STRUCTURE WITH FULL FREE BC'S: EXP. AND NUMERICAL

Experimental		Damping	Numerical	%discrepancy
Mode-1	646.12	0.31%	689.636	6.734972
2	1005.52	0.24%	902.853	-10.2103
3	1208.28	0.92%	1185.55	-1.88119
4	1251.96	0.53%	1244.88	-0.56551
5	1351.98	1.18%	1380.88	2.137606

Mode #1

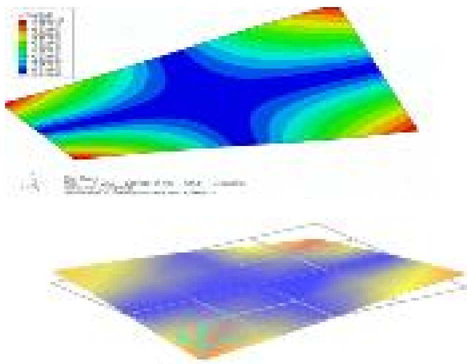

Fig. 4 Schematic sketch of model satellite geometry and its upper tray with attached equipment (about 350×350×700 mm)

III. CONCLUSION

The current investigation focuses on preliminary design, analysis and dynamic response of the micro-satellite with Al. panel structure. First non- zero natural frequency of mass-spring system (646 Hz) is much more than launcher limited longitudinal natural frequency (25 Hz), so structural stiffness in preliminary step could be acceptable.

REFERENCES

[1] F, Campbell, ASM- composite materials, ASM, 2010.

[2] F, Campbell, Manufacturing technology for Aerospace structural materials, Elsevier, 2006.

[3] EJ, Barbero, Introduction to Composite materials design, USA: Edwards Brothers, 1998.

[4] J. Wijker, Spacecraft Structures, Springer, 2008.

[5] Chunjin Yu, Jin Zhang, Wei Song, Kehong Yi, "Deformation and stress Analysis of FlappingWing Aerial Vehicles Based on Composites Model," Advanced Materials Research, Vols. 1006-1007, pp. 7-10, 2014.

[6] G. Naveen Kumar, G. Bharath Reddy, K. ChandraShekar, "Dynamic Response of NACA 0018 for Car Spoiler using CFRP Material," International Journal of Current Engineering and Technology , vol. 4, 2014.