FUNDAMENTAL STUDY OF LIGHT-WEIGHT COMPOSITE HONEYCOMB SANDWICH PANELS AS APPLIED ON RADIATORS FOR SPACE SOLAR POWER SYSTEM APPLICATION

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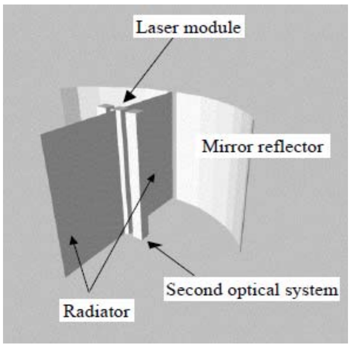
Summary Conceptual design studies result an extremely large scale radiator subsystem to reject the large quantity of waste energy during the power generation and conversion into microwaves or laser in the Space Solar Power Systems (SSPSs). In this study, performances between mechanical properties like dynamic rigidity and total weight of such radiator subsystems applied with the light-weight composite honeycomb sandwich panels were analytically evaluated through 3-demensional modeling approaches.

INTRODUCTION

Environmental issues like atmospheric pollution and energy depletion have emerged as serious problems for the whole globe earth recently. Solar energy utilization has been widely noticed as most effective way to solve those problems. Although the environmental impact of the solar power generation is minimal, on Earth the large effect of nights and weather on the power availability reduces the competitiveness of solar power as an alternative energy resource. The concept of generating solar power in space and transmitting the power to the ground was introduced by Dr. Peter Glaser in the late 1960s, and is now called the Space Solar Power Systems (SSPSs). Generally SSPSs consists of three parts: a large mirror to concentrate the sunlight rays; a large transmitter to convert the solar power into microwaves or laser to send power to Earth, and an extremely large radiator subsystem to reject the large quantity of waste energy during the power generation and conversion into microwaves or laser. In order to realize the SSPSs concept, a large number of studies have been conducted over the past three decades. Conceptual design studies are also actively done in Japan for both microwave- and laser-based SSPSs. Fig.1 shows a sample image of laser-based SSPSs with coupled radiator-mirror system which is composed of a sun-oriented parabolic mirror reflector, the planar radiator subsystem, and an array of laser devices (Laser Module) which is set up on the mirror's focal line. The parabolic mirror collects the sunlight and the Laser Module oscillates the solid laser by optical excitation of solar lay in space and send to Earth. The planar radiator subsystem is designed to provide the waste heat rejection during the energy transformation.



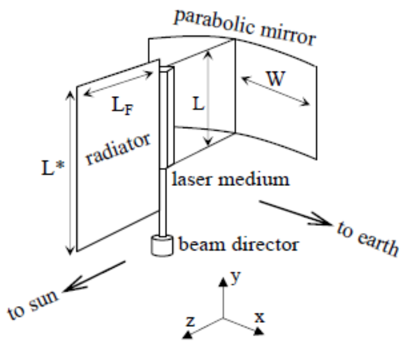


Fig.1 Conception of Laser-based Space Solar Power System (2004 JAXA Model)

SENSITIVITY ANALYSIS ON MASS PROPERTY OF HONEYCOMB SANDWICH PANELS

When honeycomb sandwich panels are applied to the radiator subsystem for SSPSs, the total mass of radiator subsystem can be approached by the radiator area and the specific mass property $\rho_R\,\delta$ (ρ_R the volume density kg/m^3 and δ the thickness of the honeycomb sandwich panel) [1] . The specific mass property of the honeycomb sandwich panel is interested here and can be calculated through the following equation [2]:

$$f = \rho_R \delta = 2\rho_f T_f + \frac{t(3d-4t)}{d(d-t)}\rho_c T_c \qquad (1)$$

with the design parameters like ρ_f the face material density (kg/m^3); T_f the face thickness (mm); ρ_c the honeycomb material density (kg/m^3); T_c the core thickness; d the sell size and t the foil thickness of honeycomb structure as shown in Fig.2.

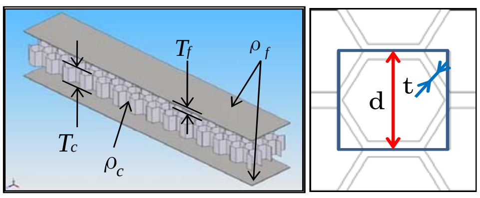


Fig.2 Design Parameters for Sensitivity Analysis

Based on equation (1), the sensitivity of foil thickness t and sell size d of the honeycomb structure to the specific mass property can be evaluated from the following equations. Table 1 shows the design parameter's values used in the sensitivity evaluation and the results are shown in Fig.3.

$$\frac{\partial f}{\partial t} = \frac{3d^3 - 8d^2 t + 4dt^2}{\{d(d-t)\}^2} \rho_c T_c \quad (2) \qquad \frac{\partial f}{\partial d} = \left| -\frac{3dt^2 - 8d^2 t + 4t^3}{\{d(d-t)\}^2} \rho_c T_c \right| \quad (3)$$

Table 1: The design parameters of foil thickness t and cell size d for sensitivity evaluation

Cell size d inch	d1 1/16	d2 1/8	d3 3/16	d4 1/4	d5 5/16	d6 3/8
Foil thickness t inch	t1 0.001	t2 0.002	t3 0.003	t4 0.004	t5 0.005	t6 0.006

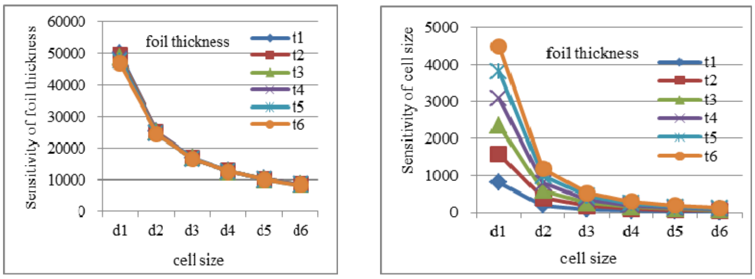


Fig.3 Sensitivity results for the specific mass property of Honeycomb sandwich panels

Comparing the above results of Fig.3, one can see that the sensitivity of foil thickness is 10 times larger than the sensitivity of the cell size under same design parameter values. That means the effect of the foil thickness of the honeycomb on the specific mass property of honeycomb sandwich panel is much more significant than the cell size. It concluded that setting small cell size and change the foil thickness to light weight and balance the mass property with mechanical strength/stiffness of the honeycomb sandwich panels should be very efficient as applied to the radiator subsystem of SSPSs.

3-DEMENSIONAL MODELING FOR DYNAMIC/STATIC COUPLING ANALYSIS OF SSPSs

Static mechanical problem, dynamic problem and thermal control problem etc. are very significant for the lower-weight flexible large space structure of radiator subsystem from the view point of realizing the whole practical SSPSs. Fig.4 shows the designed 3-demensional model of SSPSs with all of the construction sizes and shapes based on the image shown in Fig.1. The dynamic/static performance of SSPSs can be evaluated by applying the light-weight higher mechanical stiffness/strength honeycomb sandwich panels to the radiator subsystem with the design parameters examined by the above sensitivity analysis.

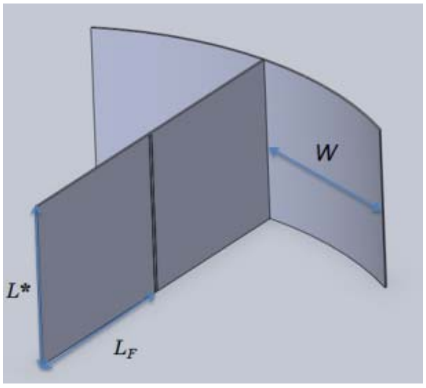


Fig.4 3D modeling of SSPSs including mirrors, radiators and laser module

CONCLUSIONS

The influence of structural design variables, such as cell size and foil thickness of honeycomb core, thickness and material density of different honeycomb cores and FRP laminate faces, on the mass density per unit area of honeycomb sandwich panels was checked out through the sensitivity analysis and resulted that the foil thickness of the honeycomb will most effective for the light weight approaches of radiator subsystem. The evaluations of dynamic/static performance for SSPSs through the coupling analysis are also carrying out.

REFERENCES

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[2] H. Iwasaki, F. Aoki, J. He, Sensitivity Analysis and Structural Optimization of the Honeycomb Sandwich Panels for Space Radiator Subsystem Application 9th World Congress on Structural and Multidisciplinary Optimization, CD-R 362-1, Shizuoka Japan, 2011