ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

Structural Deformation of Sandwich Composite Heliostats

Sulaiman Fadlallah[1], Timothy Anderson[1] and Roy Nates[1]

[1] Department of Mechanical Engineering, Auckland University of Technology, Auckland, New Zealand

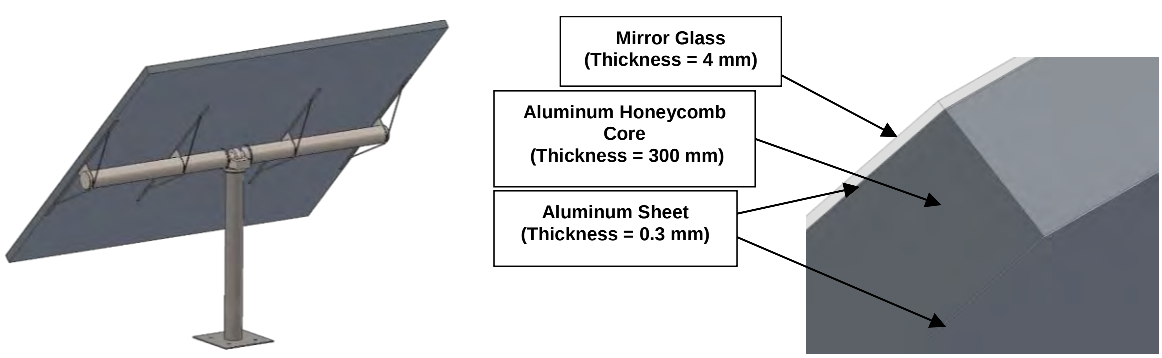
1. Introduction

One of the challenges to the widespread implementation of central tower concentrating solar power (CSP) systems is their cost. Heliostats contribute almost 50% to the plant's cost and are the most significant cost element of central tower CSP systems (Kolb et al., 2007). For both large and small-sized heliostats, the drive element holds the most influence on the production cost of heliostats (Kolb et al., 2011). Concentrating on large-sized heliostats, they require a high-torque drive, due in part to the heavy mirror support structure that is generally designed from steel. A promising opportunity arises for reducing the cost of heliostats by reducing the mirror support structure's total weight. Given the fact that sandwich composites have been widely employed over the past decades due to their lightweight and high flexural stiffness (Heimbs et al., 2008; Ayub et al., 2011); this work focuses on investigating the suitability of composite materials for developing a heliostat mirror.

2. Method

For this work, it was assumed that the heliostat would consist of a 148 m^2 rectangular sandwich composite plate mounted and supported by four steel attachments (Figure 1a). The heliostat's sandwich composite structure (Figure 1b) was assumed to consist of a 300 mm thick aluminium honeycomb core sandwiched between two thin aluminium skins with a thickness of 0.3 mm and a 4 mm thick glass mirror mounted on top of the sandwich composite. The honeycomb cores mechanical properties were calculated from the equations provided by Nast (1997).

To understand the characteristics of the sandwich composite, fluid-structure interaction (FSI) simulations were performed to investigate the structural behaviour of the heliostat's composite structure under wind-loaded conditions for multiple tilt angles.



(a) Full-scale **(b) Sandwich composite structure**

Figure 1. Composite material-based heliostat structure

3. Results

Figure 2 demonstrates the displacement distributions of the heliostat surface for different tilt angles at wind speed of 20 m/s. In all of the cases studied, the largest resultant displacement is of 19.6 mm taking place at tilt angle of 30°. According to Kolb et al. (2007) the maximum allowable deflection for a typical heliostat is 3.6 mRad, meaning that for the heliostat's chord length of 11.84 m, the maximum allowable deflection is approximately 21.3 mm. On this basis, the deformation of the structure from the simulation suggests that it is within the allowable threshold, and may be suitable for use as a heliostat.

Under the same worst case scenario, the highly stressed regions are located at the lower aluminium sheet of the sandwich panel, primarily at its junction with the supporting steel attachments. The calculated maximum von Mises equivalent stress is 122 MPa, which is well below the aluminum's yield strength (280 MPa). This indicates the given heliostat's composite structure is unlikely to experience material failure and is expected to maintain a very high optical performance when subjected to a wind of 20 m/s and below.

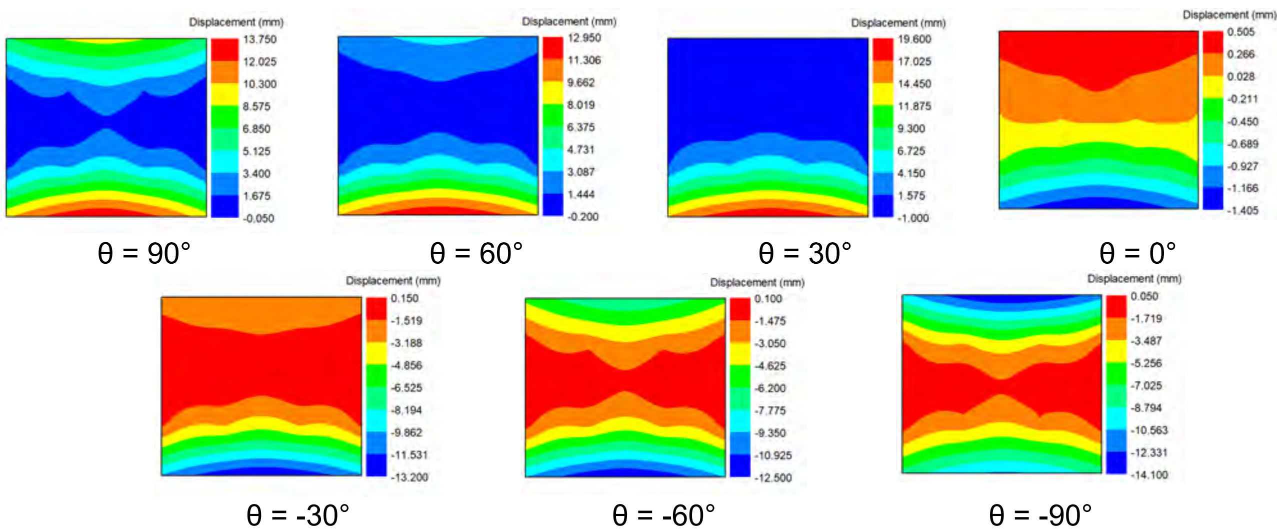


Figure 2. Displacement distribution of the heliostat surface at wind speed of 20 m/s for different tilt angles.

References

Kolb, G., Jones, S., Donnelly, M., Gorman, D., Thomas, R., Davenport, R. and Lumia, R, 2007, 'Heliostat cost reduction study', Sandia National Laboratories, Albuquerque, New Mexico, Report number SAND2007-3293.

Kolb, G.J., Ho, C.H., Mancini, T.R. and Gary, J.A, 2011, 'Power tower technology roadmap and cost reduction plan', Sandia National Laboratories, Albuquerque, New Mexico, Report No. SAND2011-2419.

Heimbs, S., Vogt, D., Hartnack, R., Schlattmann, J. and Maier, M, 2008, 'Numerical simulation of aircraft interior components under crash loads', *International Journal of Crashworthiness*, 13(5), p511-521.

Ayub, M.Y., Ahmer, Z., Khan, S.R. and Shah, M.A, 2011, 'Mechanical behavior characterization of aluminum based honey comb structure by optimized modeling and numerical simulations', *Journal of Space Technology*, 1(1), p26-33.

Nast, E, 1997, 'On Honeycomb-Type Core Moduli', *Presented at the Collection of Technical Papers-AIAA/ASME/ASCE/AHS/ ASC Structures, Structural Dynamics and Materials Conference*, 2, p1035-1044.