Wind loads on heliostats in operating position

Jeremy Shiyao Yu, Farzin Ghanadi, Matthew Emes, Maziar Arjomandi, Richard Kelso
Centre of Energy. The University of Adelaide, South Australia, Australia

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During operation, heliostats act as bluff bodies submersed in the atmospheric boundary layer (ABL) flow, where velocity gradients and high turbulence intensities are characteristic of the conditions [1]. These parameters have significant effects on the static and dynamic loads on heliostats which affect their structural integrity and performance [2, 3]. Knowledge of how heliostats are affected by the ABL would allow designs to be more optimized for specific sites and therefore reduce overall costs.

Objectives

- Investigate the static loads on heliostats under high turbulence intensities at different operating angles
- Investigate the effects on loads for tandem heliostats at various angles,
- Determine the dynamic response of a single heliostat,
- Investigate methods for load reduction such as flow control techniques.

Methods

- Single square facet dimension of 800mm×800mm heliostat at various operating angles in a closed loop wind tunnel with 3m×3m test section.
- The heliostat pylon will also have an adjustable pylon in order to experiment at different heights within the boundary layer.
- The velocity of the tests was set to a constant 9.8m/s which represented a Reynolds number of 510,000, with a 200mm boundary layer thickness at the test location and an approximate turbulence intensity of 2%.

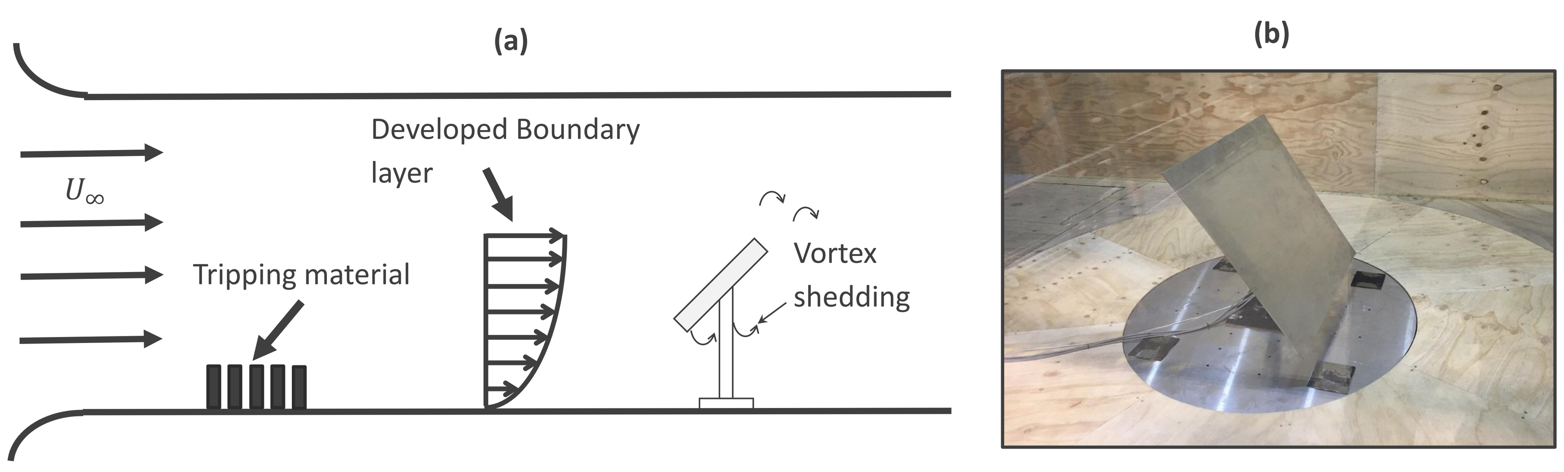

Figure 1: (a) Schematic of wind tunnel experiment, (b) heliostat rig setup

- The heliostat facet has a hollowed out compartment in order to house the electronics required for pressure sensors.
- Pressure taps are placed over the facet in order to measure the pressure distribution along the facet at different orientations.

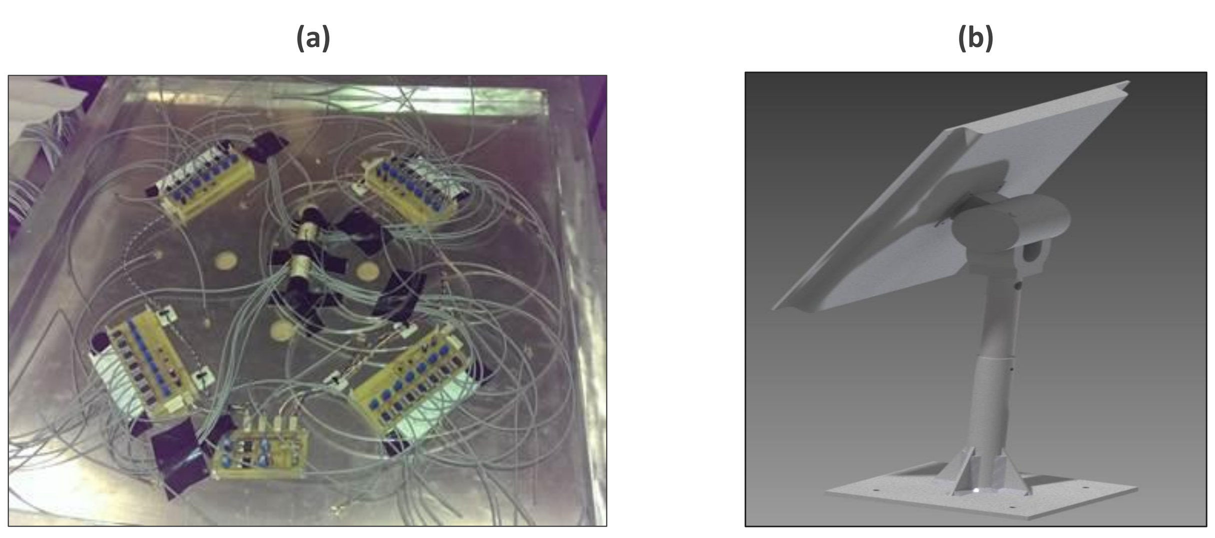

Figure 2: (a) High frequency differential pressure sensors, (b) adjustable pylon design

- Load cell platform has been designed and manufactured which allows azimuthal rotations to the heliostat.
- Four three-axis load cells implemented at the four corners of the platform allow all three components of force and moments to be measured.

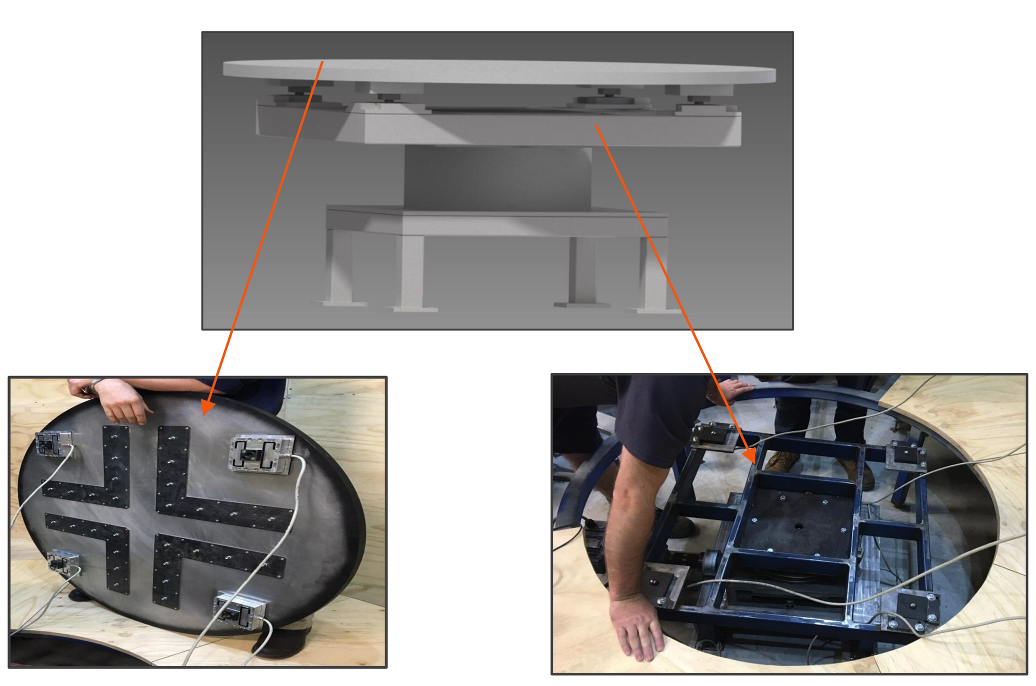

Figure 3: Turntable rig and supporting frame for the heliostat at the Thebarton campus wind tunnel

- Quantitative numerical analysis of the three-dimensional flow using Embedded Large Eddy Simulation (ELES) has also been conducted to provide a detailed analysis of the forces acting on the heliostat at different orientations.
- The flow was simulated within a channel such that the inlet boundary condition was defined by a power law velocity profile with a roughness exponent of 0.14 and turbulence intensity of 18%. This results in a fully developed atmospheric turbulent boundary layer in the vicinity of the heliostats.
- Fine hexahedral mesh containing 5 to 8 million cells has been used throughout the domain to fit the geometry and support a high amount of skewness and stretching without affecting the results.

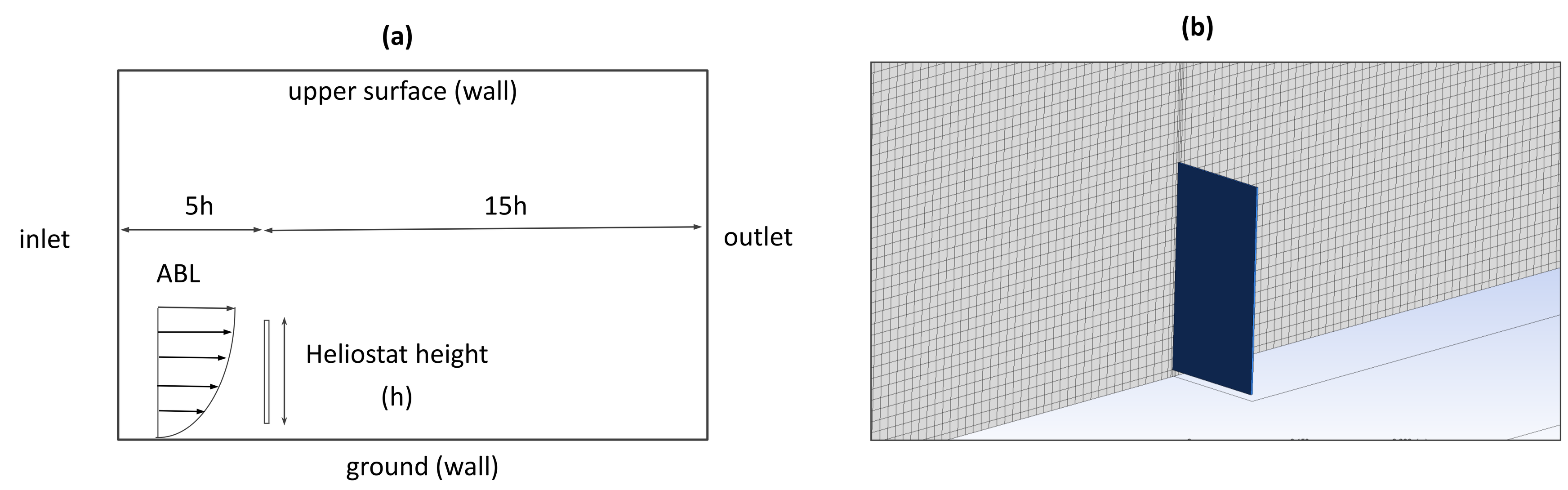

Figure 4: (a) Boundary conditions of the numerical domain for a 30cm × 30cm normal heliostat with thickness of 3mm, (b) structured fine mesh around the heliostat.

Results

- The effect of a sharp increase in load at the 30 degree elevation is reduced with increasing azimuthal angle from 0 degrees.
- The loads experienced by the heliostat when facing away from the flow at 135 and 180 degree azimuthal angles are also lower than their counterparts at 0 and 45 degrees, showing that the support pylon has a very noticeable influence on loads.

Table 1: Drag coefficients for elevation and azimuthal rotations

Azimuthal Angle (deg)	Elevation Angle (deg)				
	15	30	45	60	90
0	0.15	0.76	0.95	1.16	1.32
30	0.11	0.58	0.83	0.96	1.10
45	0.09	0.38	0.71	0.81	0.86
60	0.05	0.19	0.39	0.58	0.58
90*	0	0	0	0	0
135	0.07	0.32	0.48	0.71	0.75
180	0.19	0.60	0.88	1.15	1.30

- There is a significant increase in peak drag coefficient under high turbulence intensities (≥12%)

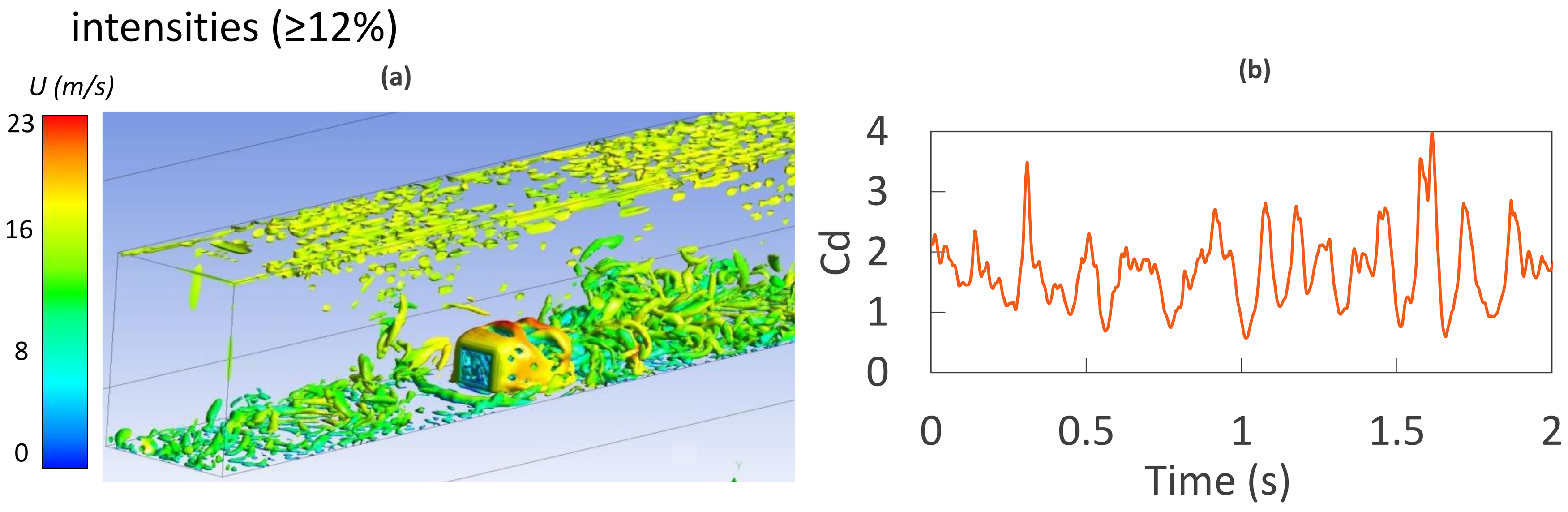

Figure 5: (a) Vortical flow structure surrounding heliostat in the normal position. (b) Drag coefficient of a single heliostat within ABL when flow speed and turbulence intensity are 15m/s and 18% respectively.

Future work

- High turbulence generation in wind tunnel
- Tandem heliostat measurements at various angles
- Numerical analysis of flow characteristics behind heliostat facets under various flow conditions

AUTHOR CONTACT
Jeremy Shiyao Yu
e jeremy.yu@adelaide.edu.au
w www.astri.org.au

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