Wind Engineering Joint Usage/Research Center
FY2018 Research Result Report

Research Field: Wind Hazard Mitigation/Wind Resistant design
Research Year: FY2018
Research Number: 183001
Research Theme: Wind loads on panels of solar wing under boundary layer flows

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Budget [FY2018]: 200,000Yen

*There is no limitation of the number of pages of this report.
*Figures can be included to the report and they can also be colored.
*Submitted reports will be uploaded to the JURC Homepage.

1. Research Aim

The heavy dependence on fossil fuels has severe consequences on the global warming and put the balance of the natural environment in danger. This trend has led to growing research and development of clean alternative energy sources to meet energy needs and to reduce fossil fuel consumption. Solar, wind and biomass are generally well known as representative clean energy sources, especially the solar energy.

Most solar power systems are mounted on the ground, but these systems require huge areas of land, an alternative solar power systems called solar wing systems or tracking photovoltaic systems are being developed. Solar wing system consists of solar panels, cables, columns and foundation. Using solar wing systems have lots of advantages, they are, double use of land, low maintenance cost and optimal energy yield etc.

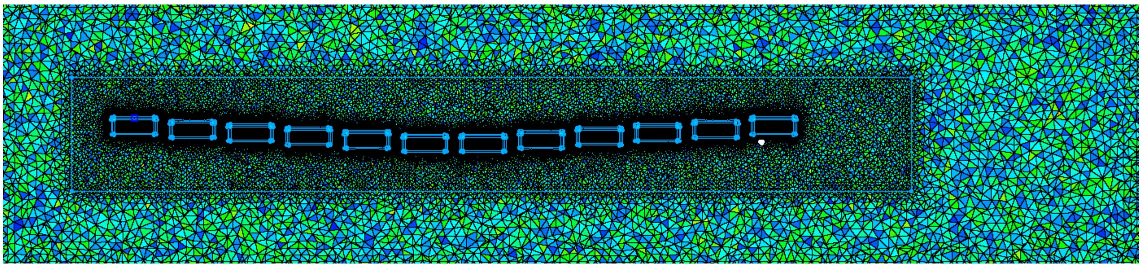
However, such cable-based solar wing systems are exactly sensitive to wind. Wind-induced vibration characteristics of solar wing structure are affected by parameters related to the shape of panels. The responses of solar wing structure with various panel shapes at the action of wind have been sufficiently studied by Kim and Tamura (2017), based on aero-elastic wind tunnel tests of solar wing system under the low-turbulence and gird-generated flows. Furthermore, the wind pressure distributions and areas-averaged net pressure on the panels of solar wings system under boundary layer flows are needed for structure design and stability check, but these investigations are far from sufficient. There should be much more researches, including wind tunnel test and/or full scale measurements.

2. Research Method

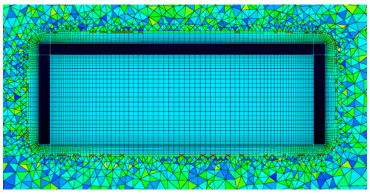
To design reasonable wind tunnel tests of solar wings system, several simulation laws between the prototype systems and the scale models should be satisfied. There are: geometric scale, velocity scale and time scale. Considering the existing researches, in the tests, the length scale of 1/13 and, the velocity scale of 1/3.7 will be used. By using instantaneous pressure system and a hot wire to measure the wind pressure on the surface of the solar panels and wind velocity around the system. Meanwhile, from the time history of the wind pressure of each point, the mean, fluctuating and extreme pressure coefficients can be achieved to describe the wind pressure characteristic. Power spectrum can be used to judge the frequency.

3. Research Result

Wind tunnel tests were scheduled, but because of small amount of budget, LES numerical simulation was conducted using OPENFOAM. Figure 1 show the mesh system used in the numerical simulation. Around the panels, structural mesh was used, and structural meshes are changed to unstructural meshes. And Table 1 shows the numerical conditions. y+ is lower than 8, and mesh extension ratio was strictly limited to be less than 1.2. Total number of mesh is 15,500,000 and 10^{-6} was used as an convergence criteria.



(a) overview



(b) meshes around the panel

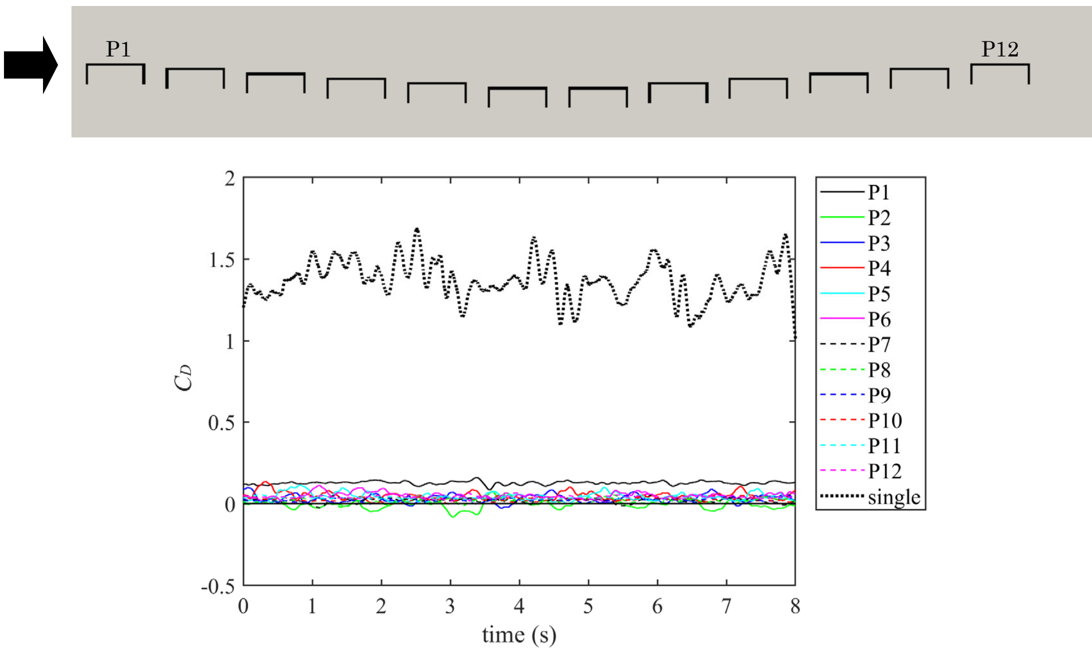
Figure 1. Mesh system.

Table 1. Numerical conditions.

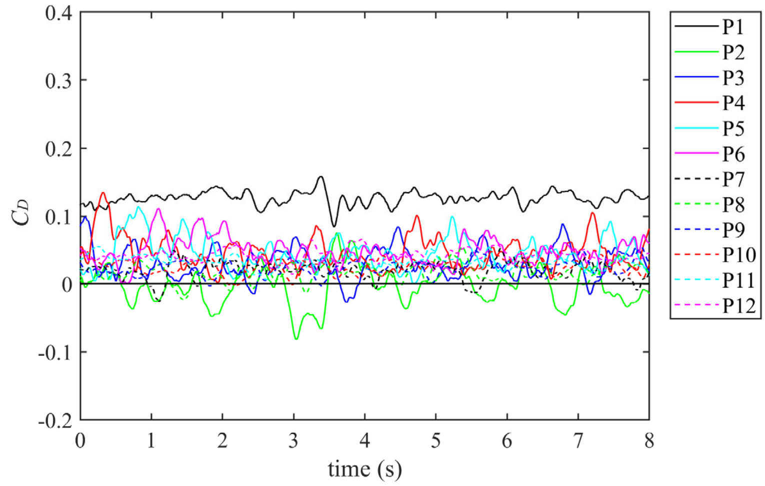
Turbulence model	LES Smagorinsky model
Range of y^+	$y^+ < 8$
Mesh expansion ratio	less than 1.2
Calculation domain size ($X \times Z \times Y$)	1,970×456×100
Mesh number	About 15,500,000
Outlet boundary condition	Zero gradient
Outside boundary condition	Symmetry
End time	10s
Time interval	0.001s
Pressure-velocity coupling	PIMPLE
Time discretization	backward

Gradient discretization		Gauss linear
Spatial discretization	velocity	Bounded gauss linear upwind limited
	others	Bounded gauss limited linear
Convergence criteria		10^{-6}

The calculation was conducted for two cases: single panel case and 12 panel cases. The variation of drag force coefficients was shown in Figure 2. The dotted line indicates the drag force coefficient of single panel, showing much larger than that of 12 panel. Among 12 panels, the drag force coefficient shows larger values than others, showing small differences.



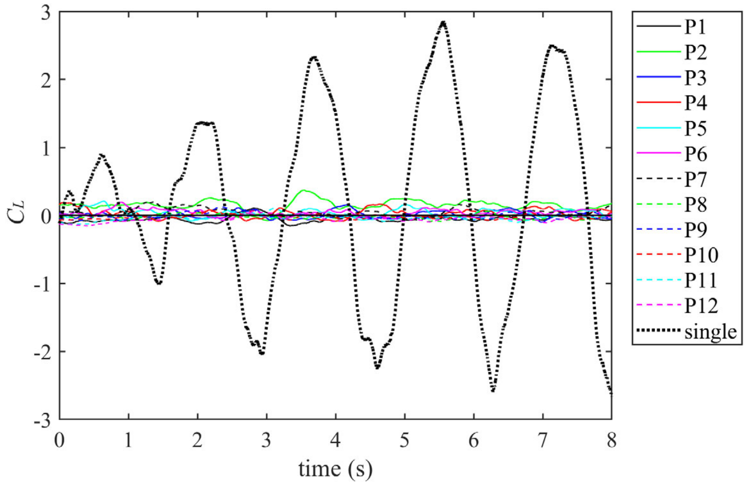
(a) single and 12 panels



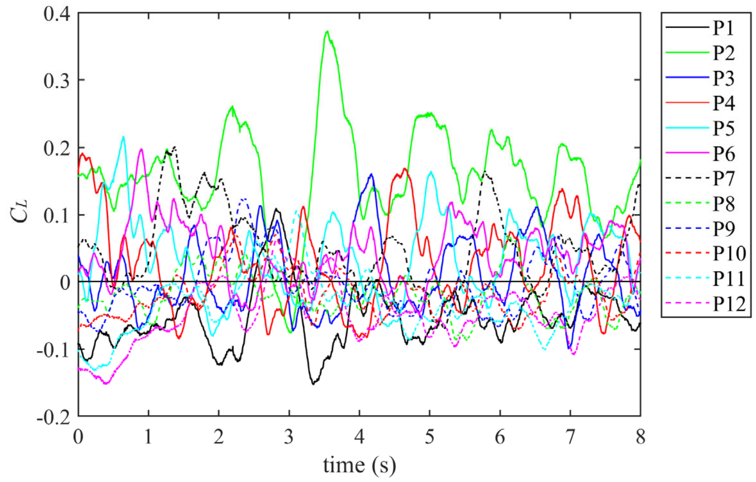
(b) close-up view of 12 panels

Figure 2. Drag force coefficients

For lift force coefficients shown in Figure 3, periodic variation was found for the single panel case, showing much larger values than those of 12 cases. The variation of life force coefficients of 12 panels are very random.



(a) single and 12 panels



(b) close-up view of 12 panels

Figure 3. Lift force coefficients

4. Published Paper etc.
[Underline the representative researcher and collaborate researchers]
[Published papers]
1.
2.

[Presentations at academic societies]
1. Yong Chul Kim, Yi-Chao. Li, 2018, Evaluation of flow field characteristics around solar wing system using CFD, The 7th International Symposium on Computational Wind Engineering 2018, ID4, Seoul, Korea.

[Published books]

1.
2.

[Other]
Intellectual property rights, Homepage etc.

5. Research Group
1. Representative Researcher
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2. Collaborate Researchers
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Y.C. Kim
Q.S. Yang
Y. Tamura

6. Abstract (half page)

Research Theme
Representative Researcher (Affiliation)