

Aerodynamic Development of Solar Car Considering Actual Flow Characteristics

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General aerodynamic evaluation and development is carried out based on constant flow condition. On the contrary, real-world flow involves complex and unsteady wind conditions, including crosswinds and turbulence. The complex and unsteady wind conditions influence aerodynamic characteristics. Tokai University Solar Car Team participated in many international solar car challenges held all over the world and won many world titles. The Bridgestone World Solar Challenge (BWSC) is hailed as the pinnacle of international solar car challenges. The BWSC serves as a platform for teams from all over the world to demonstrate their latest technologies, and is a toughness race in which participants must traverse the Australian continent—a distance of approximately 3,000 km from Darwin to Adelaide—using only energy derived from the sun. Since the power output of the installed solar modules is extremely low—only about 1.5 kW even on a sunny day—it is crucial to reduce resistance such as aerodynamic drag to the absolute minimum in order to achieve high speeds and win the championship. Furthermore, since this challenge is held on public roads under real-world conditions, aerodynamic development that takes actual wind conditions into account is essential.

The objective of this study is to analyze actual wind conditions by examining wind direction and wind speed measured during the BWSC2025, evaluate the aerodynamic characteristics under those wind conditions, and thereby enable the aerodynamic development of solar car that take actual wind conditions into account. During the challenge, the lead car travels in front of the solar car, while the command car follows behind the solar car. According to the competition regulation, the command car is required to travel within 5 seconds behind the solar car, which corresponds to a following distance of approximately 25 meters. During the BWSC 2025, we installed measuring instruments on the command car to measure wind speed and wind direction. In order to avoid interference with the body of the command car, the measuring instruments were installed approximately 1.2 m above the roof, at a height of about 3 m above the ground. In this study, the measured data were analyzed using the following procedure to evaluate the natural wind conditions and assess the relative wind speed and direction during solar car cruising. ① Based on the wind speed and direction data measured during the BWSC 2025 event, sections where the vehicle was traveling at 70 km/h or less were excluded (including urban areas and other sections with frequent acceleration and deceleration, as well as sections where the vehicle made left or right turns at low speeds). ② Analyze natural wind conditions by removing the component attributable to vehicle speed from the measurement data. ③ Height correction of the natural wind condition (height of 3 m to the solar car's height of 1 m). ④ Calculate the relative wind speed and relative wind direction for a solar car assuming cruising conditions (speed: 90 km/h) ⑤ Clustering was performed using frequency-weighted k-means++ across all sections (the left and right sides were combined to account for the solar car's bilateral symmetry. The analysis was run with $k = 3, 5, 7$, and 10). ⑥ Determine the CFD inflow conditions based on the results in ⑤. The results for each of the above inflow conditions were weighted based on the frequency of each cluster and then summed to evaluate the aerodynamic characteristics under actual wind conditions. The results showed that, under conditions with no yaw angle, Type 1 had lower drag than Type 2; however, in an analysis that accounted for the frequency of wind direction and speed in natural winds, Type 2 was confirmed to have lower drag than Type 1. This quantitatively demonstrates that changes in yaw angle and flow velocity in real-world driving conditions influence the aerodynamic performance and actual fuel efficiency of solar cars. More detailed results and further discussion will be held in the presentation.

Table1 Comparison of Aerodynamic Drag between Two Solar Car Types

	Type 2 / Type 1	
	Yaw Angle = 0	Actual Flow Condition (Considering Actual Flow Data)
$C_D A$	1.0052	0.9910

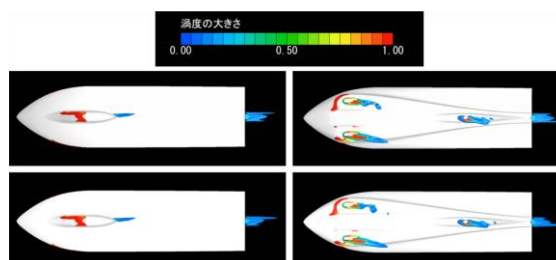


Fig.1 Comparison of Flow Patterns between Two Solar Car Types
(Iso-Surface: Turbulence Energy= $5\text{m}^2/\text{s}^2$, Contour: Vorticity,
Upper: Type 1, Lower: Type 2, Left: Upper Side, Right: Lower Side)