Optimizing aerodynamic design through testing with a wind tunnel facility

A critical aspect of designing a motorcycle is to create a design that optimizes aerodynamic performance during the initial stages of development. For this purpose, a wind tunnel is an indispensable facility. Through tests conducted with a wind tunnel, engineers search for a design that optimizes the aerodynamic performance of a motorcycle.

This paper provides an overview of Kawasaki's wind tunnel testing facility that was established in 2009.

Preface

In developing a new motorcycle model, wind tunnel testing is a critical stage for optimizing aerodynamic performance and design. For this reason, in 2009, Kawasaki established an actual vehicle wind tunnel facility dedicated to motorcycles to further improve design and aerodynamic performance.

1 Wind tunnel testing facility

(1) Main facility

The specifications of the wind tunnel facility are shown in Table 1, and a general overview is shown in Fig. 1. This facility was designed and made by Kawasaki. It is a circuit with overall dimensions of length 68 m, width 29 m, and height 10 m, and it has a semi-open test section.

① The contraction ratio of before and after the nozzle, very important to airflow performance, is 1:7, securing uniform airflow.

② The standard dimensions of the outlet are width 3 m and height 2.5 m, with a maximum wind speed of 180 km/h, which can be increased further to 205 km/h by installing a nozzle onto the outlet.

③ The test section includes a boundary layer absorber and a six-component balance, and, on its turntable, measurement can be performed adjusted for motorcycle wheel bases from 1,160 to 1,960 mm.

Table 1 Specifications of the wind tunnel

Model	Semi-open circuit
Maximum wind speed (km/h)	180 (to 205)
Overall dimension (m) L × W × H	68 × 29 × 10
Test section length (m)	8
Outlet dimension (m) W × H	3 × 2.5
Contraction ratio	7
Blower	Diameter: 4.5 m; motor: 500 kW
Main equipment	Six-component balance, boundary layer absorber, traversing device

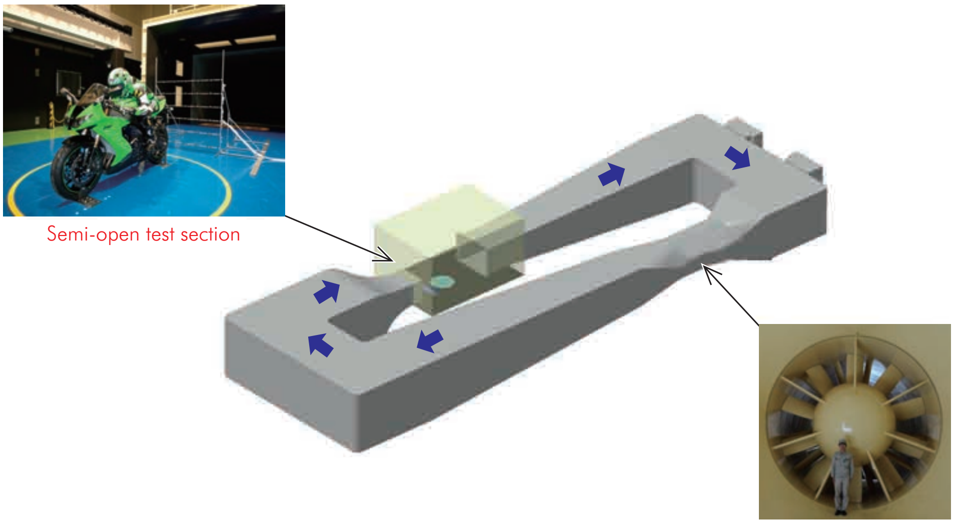


Fig.1 Overview of the wind tunnel

④ The test section has a length of 8 m, allowing slipstream measurement with two vehicles aligned in front and back, critical to aerodynamic performance when a racing vehicle is overtaking another.

⑤ Multi-Use Light Equipment (MULE) type vehicles can be evaluated for wind resistance by applying winds of 180 km/h on the turntable.

⑥ The traversing device withstands wind speeds of up to 108 km/h and supports 3D measurement using instruments such as the hot-wire anemometer and the pitot tube. Also, a smoke generator can be equipped for visualization using smoke blown from a selected position.

(2) Wind tunnel performance

The airflow performance of the facility is shown in Table 2. The tunnel outlet has wind speed fluctuations of within ±0.67%, and the turbulence intensity stays within 0.25%, assuring satisfactory precision. The boundary layer properties are shown in Fig. 2. To simulate actual motorcycle riding, the flow near the ground must be close to the main flow. A boundary layer absorber is used to reduce the thickness of the boundary layer at the center of the turntable from 180 mm to around 30 mm, making the effectiveness of the boundary layer absorber evident.

Table 2 Airflow performance

Item	Performance
Wind speed distribution	Within ±0.67%: tunnel outlet
Turbulence intensity	≤ 0.25%: tunnel outlet
Boundary layer thickness	31.3 mm: turntable center

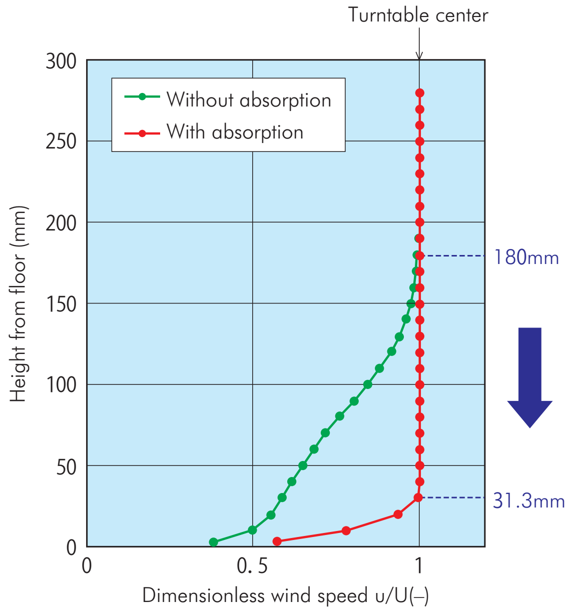


Fig.2 Effect of boundary layer absorber on boundary layer properties

2 Wind tunnel measurement

(1) Motorcycle measurement method and wind tunnel dummy rider development

Motorcycles differ from automobiles in that wind hits the rider directly, making the rider an aerodynamic part extremely consequential to aerodynamic performance. Therefore, we have an actual human rider get on a motorcycle for wind tunnel testing as we make measurements at a wind speed of 180 km/h.

However, with the long duration of the wind speed and pressure distribution measurements using the traversing device, it is difficult for a rider to hold a fixed position. With laser measurement, safety prohibits measurement with a rider on the vehicle. Therefore, we have developed a wind tunnel dummy rider and are deploying it for measurements that are difficult with an actual rider (Fig. 3).

(2) Visual measurement

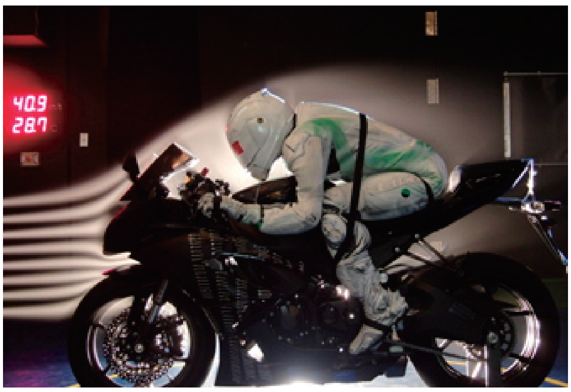
We use multiple streams of smoke from comb-shaped nozzles to visualize the flow around the motorcycle. Using the traversing device, smoke can be blown at a selected position from comb-shaped nozzles installed horizontally or vertically. The results of measurement visualizing flow onto the helmet and onto the front radiator are shown in Fig. 3.

(3) Wind speed and pressure measurement

Wind speed can be measured with pitot tubes and with small hot-wire anemometers. The hot-wire anemometer has a probe as small as a matchstick and is capable of measurement at multiple points. Attaching probes to multiple points on the radiator allows simultaneous measurement of six aerodynamic components and wind speed through the radiator, which is useful for optimizing the wind tunnel aerodynamics and engine cooling.

Pressure is measured using a multi-point electronic scanner gauge, capable of detailed measurement of the motorcycle body, the rider, and the space around the vehicle.

(a) Flow onto helmet



(b) Flow onto radiator

Fig. 3 Visualization measurement using comb-shaped nozzles
(measurement taken with a dummy rider)

3 Use as a general-purpose wind tunnel

This facility was made mainly for motorcycle measurements, but it is semi-open and is useful as a general-purpose wind tunnel, with its ability for detailed measurement with a multi-point pressure gauge and anemometers attached to the traversing device, etc. In fact, we have already adopted a system so that all of Kawasaki can utilize it to address aerodynamic issues. It has proven useful for aerodynamic performance testing of watercraft, for example (Fig. 4).

Concluding remarks

To improve product marketability, motorcycle development will increasingly demand rider comfort, etc., such as through wind protection. We hope to use this wind tunnel testing facility to send into the world products with new added value.

Reference

1) K. Sakagawa, E. Ihara, Y. Ustumi, T. Haraguchi, M. Morikawa, Y. Horinouchi: “Engineering riding comfort and aerodynamic and cooling performance in the sketching stage,” Kawasaki Technical Review No. 174, pp. 51-56 (2014)

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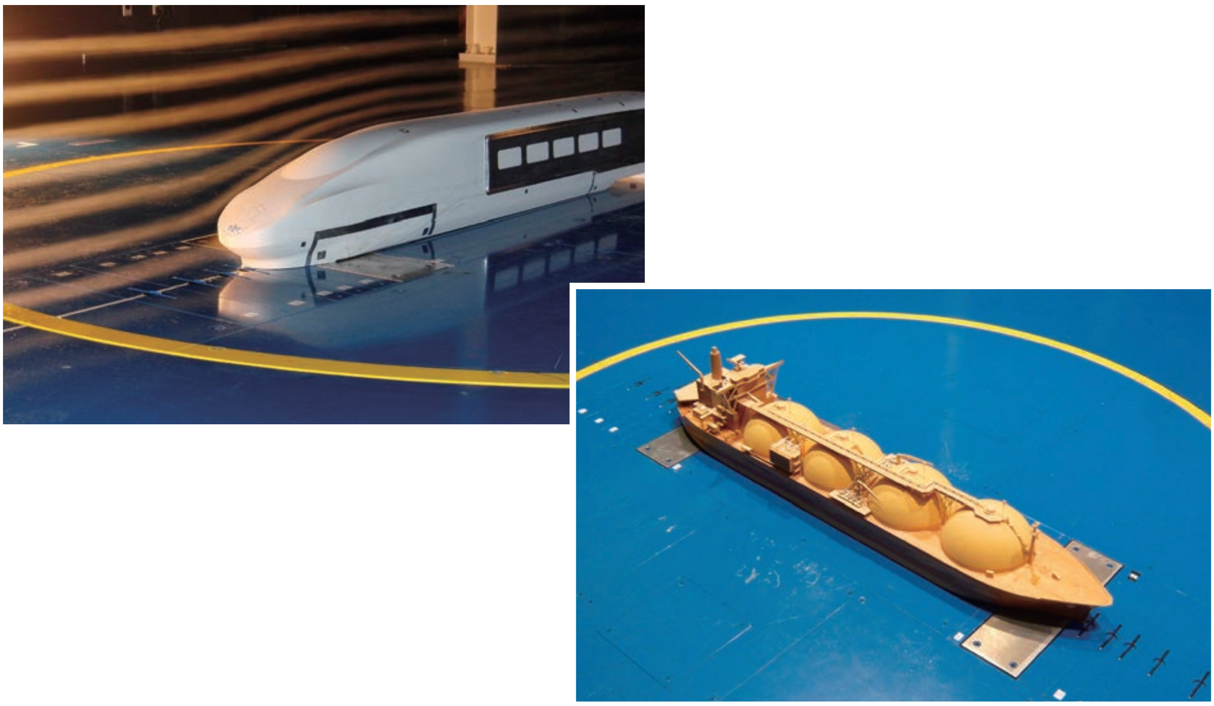

Fig.4 Aerodynamic performance testing