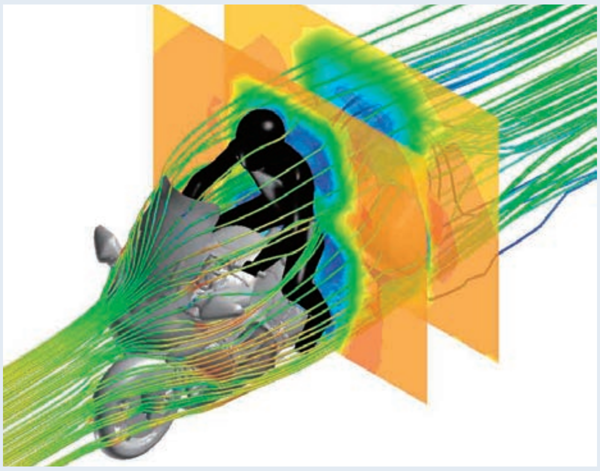
Engineering riding comfort and aerodynamic and cooling performance in the sketching stage



In the development of a motorcycle, design is as important an element as performance. Therefore, a technology for achieving the optimal balance between design and performance during the sketching stage is vital. This paper will examine development evaluation methods for the chassis during the sketching stage aimed at improving aerodynamic and cooling performance as well as riding comfort.

Preface

In the development of a motorcycle chassis, to improve marketability, design is as important an element for development as performance improvements such as in riding performance and comfort. Many sketches are drawn in the earliest stages of development, and, from these, a design that realizes the product concept is set. To improve acceleration performance and fuel efficiency, it is particularly important to reduce aerodynamic drag (CD value) at high speeds[1]. However, this is greatly affected by the shape of the design of the cowling that shields the chassis.

For touring products used for long-distance rides, improved wind protection and improved comfort through reduction in sensory temperature in the summer can both contribute to the enjoyment of riding. The shape of the wind shield is important to improve the rider's wind

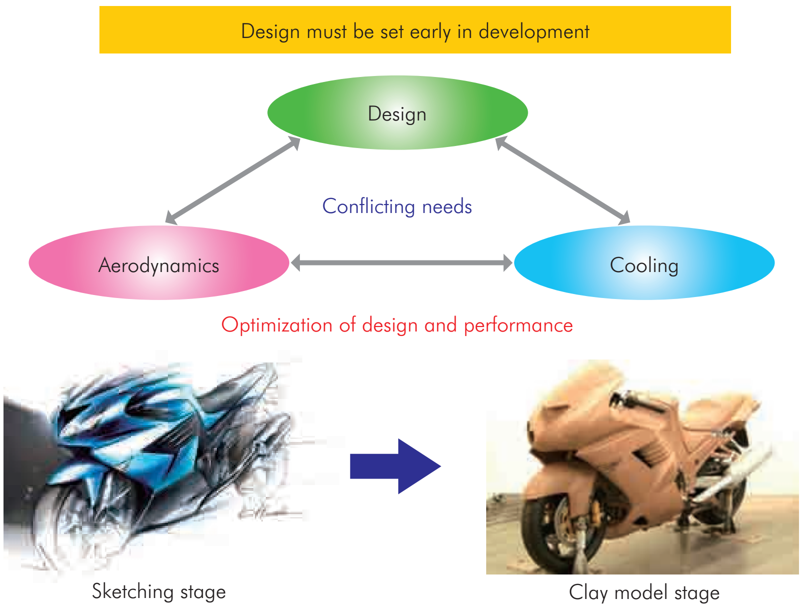


Fig. 1 Optimal balance in the sketching stage

protection, and the shape of the side is important to reduce the sensory (subjective evaluation of) temperature. Also, to improve engine performance, it is necessary to cool the engine cleverly by leading wind efficiently across the radiator. For this purpose, the shape of the cowling covering the engine must be optimized. Thus, the form of a motorcycle chassis is closely related to its function in aerodynamics, wind protection, sensory temperature, and engine cooling.

However, the design of the chassis shape is set at the very start of the development process, at the stage of sketches and clay models (clay mockups) reflecting the sketches. Changes after that are severely limited in scope due to the demands of form and function. Therefore, development in performance, including aerodynamics and cooling, must enter at the sketching stage, considering many specifications through simulation, so that the design can be optimized accordingly (Fig. 1).

This paper will examine efforts in motorcycle chassis development during the sketching stage aimed at improving aerodynamic and cooling performance as well as riding comfort. It will also examine the use of more efficient and quick models.

1 Application to development of touring models

Our 1400GTR tourer offers pleasant riding through its improved performance in wind protection, important for long-distance touring, and comfort, reducing sensory temperature in the summer. Since it places an engine with a car-level displacement of 1,400 cm^3 in a narrow engine compartment, the challenge is how to cool the engine efficiently. Wind protection, thermal comfort, and engine cooling are all closely related to design-based shape decisions, such as for the cowling. Therefore, in the earliest stages of development, the sketching and clay mockup stages, we apply total-vehicle computational fluid dynamics (CFD) analysis (reproducing entire components) and wind tunnel tests.

In particular, since wind tunnel tests are a vital stage for optimizing design while improving aerodynamic performance, in 2009, we installed an actual vehicle wind tunnel facility dedicated to motorcycles, one of the very few in the world, to improve design and aerodynamic performance[2].

The 2008 model of the 1400GTR is compared to the improved 2010 model in Fig. 2. One will notice that the cowl side shape has been changed to make the design more functional.

(1) Improvement in engine cooling

For our first development target, we aimed to improve engine cooling, which plays a major role in improving the performance of the motorcycle. To cool the engine, wind must be guided efficiently across the radiator. An obvious step might be to widen the opening of the front of the radiator, but, in fact, to increase the air passing the radiator, the space at the back is more critical than the area where the air enters at the front. The space at the back is closely related to the shape of the side cowl. To come up with a shape that would uphold the design in the sketching stage while improving cooling performance, we predicted cooling performance using total-vehicle CFD analysis, modeling the chassis including all parts in the engine compartment.

The old method was to first make a prototype in the design stage and then experiment to check its cooling performance. However, in the development of the

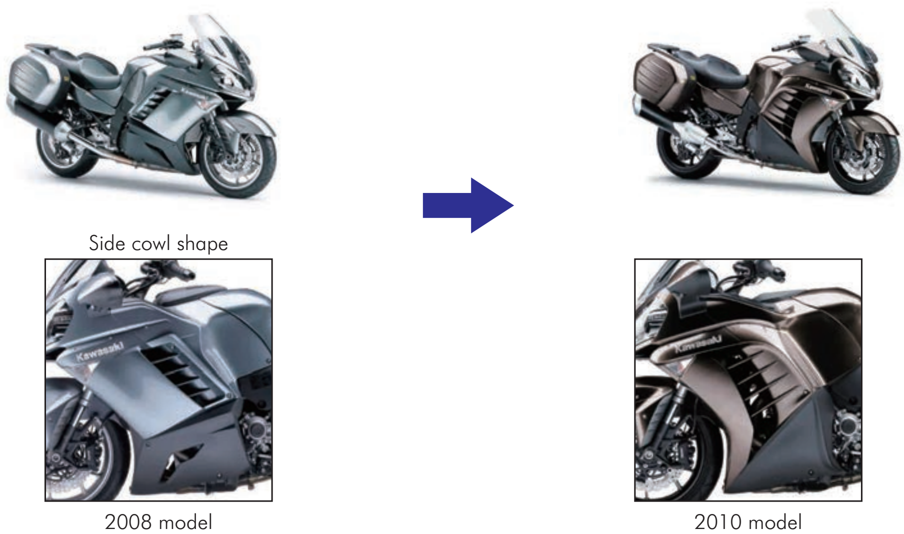


Fig. 2 Design change of 1400GTR

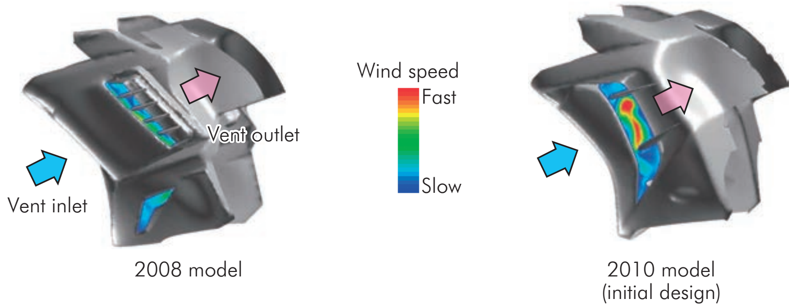


Fig. 3 Engine cooling prediction during the sketching stage

1400GTR, we analyzed the sketch shape based on a 3D CAD-generated design model.

The flow of cooling wind from the side cowl during idling, as implemented at the start of development, is shown in Fig. 3. One will see that, in the 2008 model, the blue area indicating slow wind speed is prominent, but in the 2010 model, there is a larger red area indicating fast wind speed. This demonstrates that the cooling wind is passing the radiator more efficiently. Comparing the initial design for the 2010 model (Fig. 3) with what went into production (Fig. 2), the number of ribs increased from two to four, but the shape of the side cowl is the same as in the initial design. We succeeded in starting development with a cowl shape that fulfills both design and cooling performance.

(2) Reduction of temperature on the rider's legs

Through the efforts described in section (1) above, we achieved our aim of improving engine cooling performance, but as the heat flow improved, there came the new issue of the possibility of the hot air from the side cowl hitting the rider's legs. Therefore, we used total-vehicle CFD analysis to look at how to reduce the temperature at the rider's legs. The flow of hot air onto the rider and the analysis results for the rider's temperature are shown in Fig. 4. With the 2008 model, there was somewhat of a tendency for hot air to hit the rider's legs, but we tweaked the cowl shape to deflect the hot air outward and reduce the temperature of the rider's legs.

(3) Reduction of pressure on the rider

Improving wind protection requires windshield work, but what is demanded is a design that does not make the windshield larger and yet offers excellent wind protection. A comparison of flow lines on the helmet is shown in Fig. 5 (b). With the 2010 model, the flow lines flow smoothly over the helmet, reducing the high-pressure zone of the 2008 model. It can be seen that there is less pressure on the shoulders as well, enhancing the rider's comfort (Fig. 5 (c)).

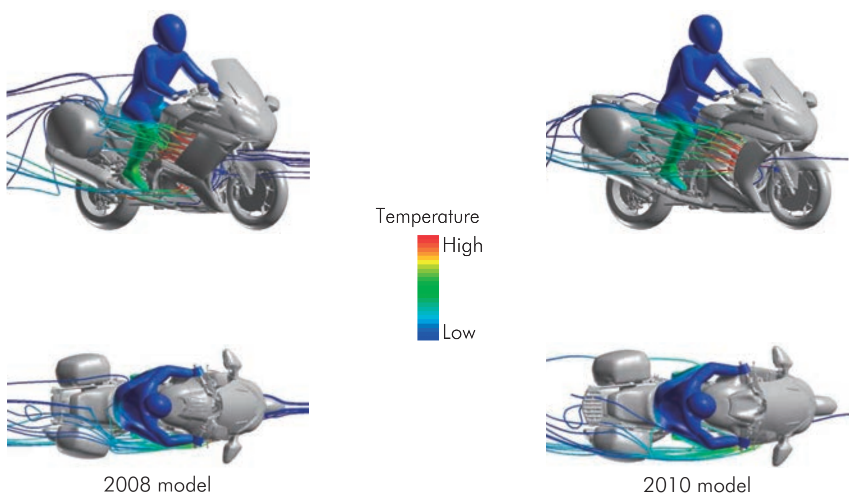
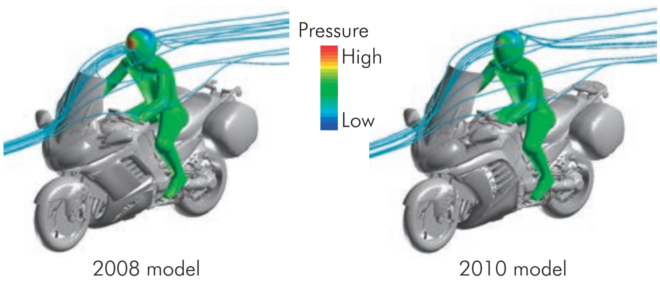
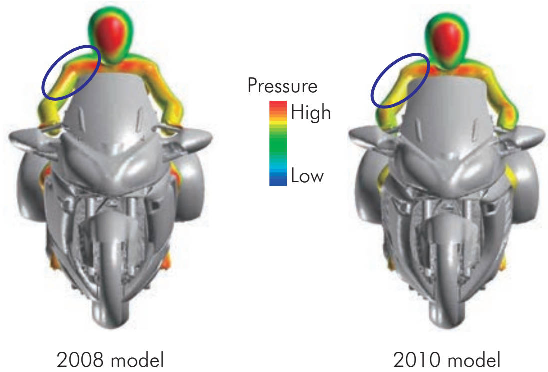


Fig. 4 Evaluation of the riders' thermal comfort

(a) Cowl shape



(b) Wind pressure on helmet



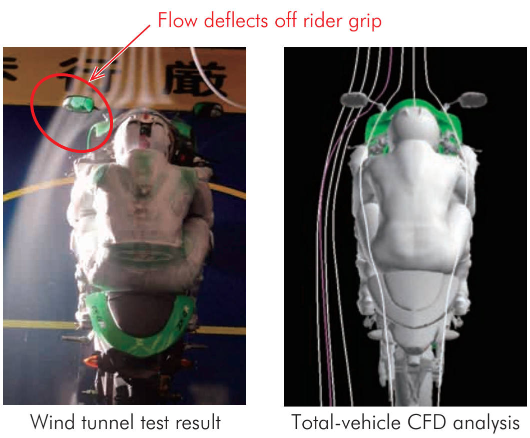
(c) Wind pressure on shoulders

Fig. 5 Wind protection evaluation of 1400GTR

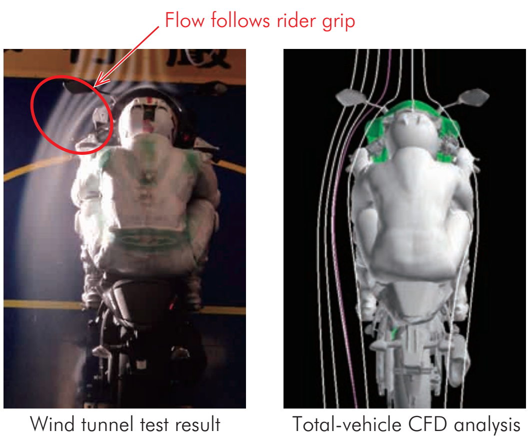
2 Advancement of wind tunnel aerodynamics and cooling prediction methods

For total-vehicle CFD analysis, we obtained validation data in our wind tunnel, and we have improved our analysis model. Smoke tests in the wind tunnel facility are compared with flow line maps from total-vehicle CFD analysis in Fig. 6. The test vehicles are the 2005 and 2009 models of the 600 cm^3 supersport ZX-6R. In the 2005 model, the upper region of the cowl is relatively large, with the intent of deflecting wind with the grip. The 2009 model has a more compact design. Wind tunnel tests made the flow visible using multiple streams of smoke from comb-shaped nozzles. It can be seen that the wind deflection pattern around the grip differs between the two models, and this is represented likewise in CFD analysis.

To evaluate engine cooling performance, it is not possible to directly measure water temperature using clay models (mockups), but considering optimization with design, it would be best if it could be predicted and validated in wind tunnel testing. Therefore, we are developing technology for aerodynamic optimization by placing many small anemometers to measure the amount of wind passing the radiator, which affects the liquid temperature, while measuring the six aerodynamic components using a balance.



(a) ZX-6R (2005 model)



(b) ZX-6R (2009 model)

Fig. 6 Aerodynamic test in a wind tunnel facility

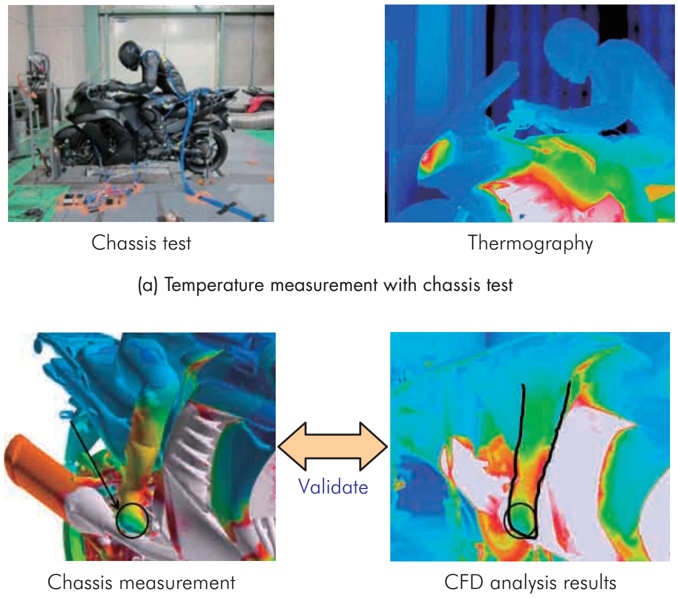


Fig. 7 Hot air test and advanced analysis model

3 Improvement of hot air evaluation prediction methods

To reduce sensory temperature in the summer, we use chassis tests in the prototype stage, in which an actual engine can be run, and we measure the temperature of the rider simulating actual riding. However, since hot air cannot be seen, it is difficult to measure its paths, and we end up relying on trial and error in tests for development. To deal with hot air, it is necessary to evaluate thermal comfort with total-vehicle CFD analysis early in development. It is important to predict precisely not only the wind flow, but also the temperature distribution. To measure temperature all over the rider's body in a chassis test, we made a hot air evaluation dummy with its surface painted black for a radiation factor of 1, and we measured temperatures using thermocouples and thermography (Fig. 7 (a)). A comparison of thermographic measurement of the rider's leg in chassis tests with analysis results is shown in Fig. 7 (b). The temperature distribution around

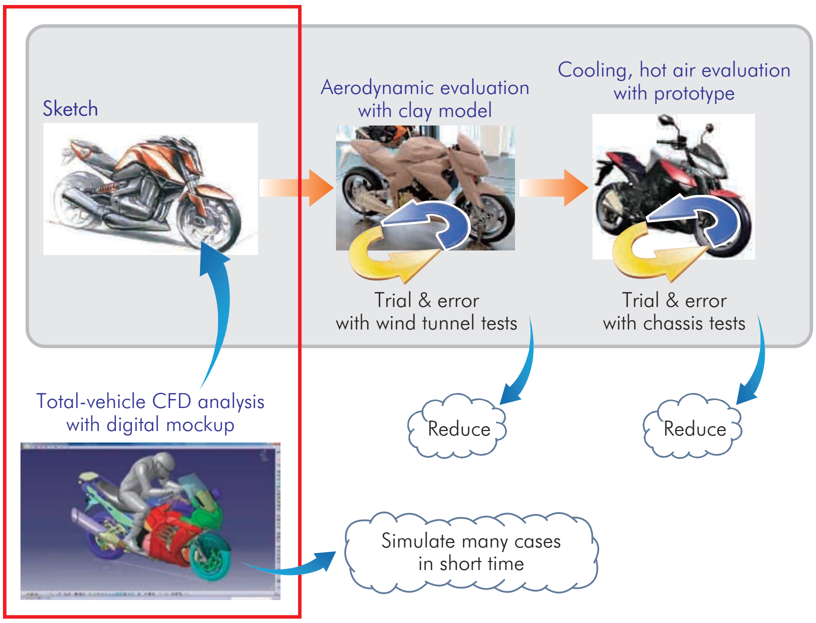


Fig. 8 Application of total-vehicle CFD analysis in the sketching stage

the rider's leg is successfully reproduced. We were able to make this analysis relatively precise in regard to temperature prediction by modeling not only heat transfer from convection, but also the impact of radiation from hot parts such as the exhaust pipe.

4 Automation of total-vehicle CFD analysis in the sketching stage

By improving total-vehicle CFD analysis as described above, we were able to predict in advance the aerodynamics, cooling, and hot air in the design process of an actual vehicle. Now, to make design even more efficient, we are working on automating total-vehicle CFD analysis in the sketching stage (Fig. 8). A key point for automation is to make it possible to use data for CFD analysis without manipulating the original 3D model. The original 3D model includes information unnecessary to CFD analysis, such as on gaps and overlaps between parts and the internal structure of parts. Such information only gets in the way of creating grid data for CFD analysis. Previously, such editing was done by hand, but now we can make full use of wrapping technology to eliminate editing work and automate grid generation. Using such automation technology for total-vehicle CFD analysis, we can now generate models for CFD analysis to make analysis much more efficient, compare and consider many cases in a short time, and optimize design, aerodynamics, and cooling performance in the sketching stage.

Concluding remarks

We have developed technology to optimize the balance of design, aerodynamics, and cooling performance in the sketching stage. We used validation to improve and to systematize this technology for application to design in the sketching stage. It is expected to become only more important in the future, improving motorcycles' performance in aspects such as engine cooling, as well as their comfort and marketability. We look forward to applying this technology to the development of more new models, advancing development towards a higher-level balance of design and marketability, and continuing to improve the technology itself.

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