Developing "Fun to Ride" factors that attract motorcycle riders on an emotional level

The chassis as well as engine performance needs to be improved in order to enhance "Fun to Ride" factors that appeal to the rider. In particular, a pleasing engine sound, excellent riding comfort and greater handling stability are "Fun to Ride" factors that determine the value of a motorcycle as a product. As such, they are essential in maximizing the brand appeal of a model targeting customers in advanced countries. In this paper, we report the technologies involved in creating these "Fun to Ride" factors.

Preface

We aim to develop attractive motorcycles that are "Fun to Ride" for riders to the maximum degree possible. Some factors that make a motorcycle "Fun to Ride" are a pleasing engine sound, excellent riding comfort, and greater handling stability. These are described below.

① Pleasing engine sound:
Technology to scientifically evaluate and control the impression of the engine sound to make it pleasing

② Excellent riding comfort:
Technology for whole-body vibration analysis to control and present the vibration from the engine, which significantly influences riding comfort

③ Greater handling stability:
Technology for measurement of dynamic deformation of motorcycle bodies and for creating functional design to efficiently enhance the rider's feeling of control

1 Pleasing engine sound

While observing each country's noise regulations, we are developing technology to create pleasing engine sounds. The powerful sound of a sport bike creates a feeling of acceleration, and the comfortable sound and pulsating harmonic vibrations of a cruiser give it appeal (Fig. 1). To create sounds that appeal to riders on an emotional level, we have been developing technology for sensory evaluation to grasp rider psychology objectively, and technology to control sound to meet the targets obtained from sensory evaluation. These technologies have been applied to the development of the Z1000[1] to achieve an excellent feeling of acceleration through intake howl.

(a) Sport bike

(b) Cruiser

Fig. 1 Category of motorcycles

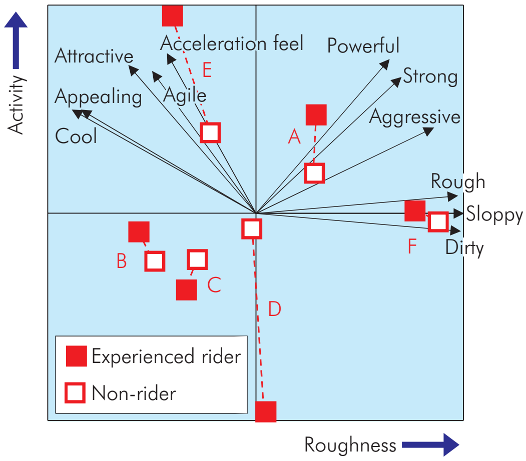

Fig. 2 Impression of engine sounds of six different models (A-F)

(1) Sensory evaluation technology

To improve marketability, customers' psychology must be interpreted and reflected in design, but challenges arise from the difficulty of quantifying people's feelings about things. However, we developed a motorcycle sound evaluation method based on the SD (semantic differential) method to scientifically capture emotional impressions[2)].

Figure 2 represents an example of evaluating engine sound impressions for six sport bike models (A through F). The sound impressions are plotted on a 2D plane so that one can see their relations. One notices that there are some differences in the way people interpret the sounds, such as depending on whether they have experience riding motorcycles. By examining the relationships between these impressions and the corresponding acoustic characteristics, we are clarifying the directions in which sound should be taken in development of future models.

(2) Sound control technology[3)]

To create the sounds targeted, we are utilizing acoustic analysis of intake and exhaust systems from the early stages of development, as well as factor tests with existing models, etc. We pick out methods that will help us achieve our target acoustic characteristics, such as using resonance from the air cleaner box or adjusting the muffling characteristics of the exhaust muffler. Also, we predict the pressure pulsation in the engine using non-stationary one-dimensional computational fluid dynamics (CFD) analysis to balance intake and exhaust sounds and power characteristics. An example of calculation of exhaust pressure pulsation is shown in Fig. 3.

While such a process is used to construct a prototype model, in the end, it is still necessary to refine it using people's ears. We do all of this so that customers can enjoy a polished sound finely tuned by the hands of the engineers.

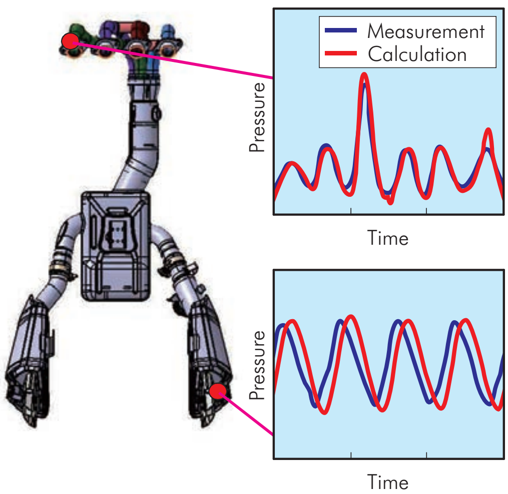

Fig. 3 Calculated pressure pulsation in exhaust system

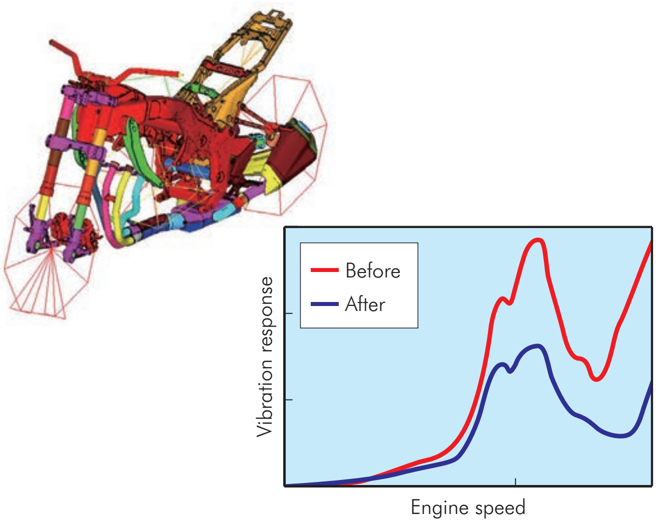

Fig. 4 Example of application of the whole-body motorcycle vibration analysis system (sport type)

2 Excellent riding comfort

(1) Motorcycle body vibration

Vibration is an important factor affecting the riding comfort of a motorcycle, but is not as simple as limiting vibration as much as possible. Sometimes bringing vibration to the forefront is just what is needed to improve riding comfort.

For example, on a sport bike, the rider's whole body is used, feeling the motorcycle body and the road conditions, to enjoy a sporty ride. The rider will feel uncomfortable if the body vibration is too strong. Vibration must be limited on such models. On the other hand, on a cruiser, a unique kind of vibration is favored which allows the rider to feel the pulsation of the engine and the strength of the machine. In such a case, vibration makes the ride more fun.

Thus, motorcycle vibration, from a riding comfort standpoint, must be separated into vibration that should be limited and vibration that is desired, according to the product category.

(2) Technology for improving riding comfort

Our motorcycles have started to apply a whole-body motorcycle vibration analysis system to predict the vibration of the whole body from the early stages of development. With this analysis system, we model the whole motorcycle body using the finite element method (FEM), consider the vibratory force from the engine, and evaluate vibration values at various points on the body.

An example of application to a sport bike is shown in Fig. 4. In this category, it is desired to limit unpleasant vibration, so we make design changes to the main frame and rear frame structures, reduce vibration at our points of concern, and improve riding comfort.

We apply the same kind of analysis to cruisers. In this category, it is required to play up vibration, so, unlike with the sport bike, we work on the structure at various points of the body in order to achieve certain vibration values.

These technologies have been applied to the development of the sport-type Ninja 250/300[4], helping to improve riding comfort by reducing vibration.

3 Handling and stability

(1) Technology for measuring dynamic deformation of motorcycle bodies[5]

To create the rider's feeling of control, it is important to use riding tests, a base of development, to quantitatively grasp body behavior, which is closely connected to the rider's feeling of control. "Body behavior" refers to the way the motorcycle body responds to rider handling, the way vibration and acceleration communicate the riding conditions to the rider, etc. A major factor in body behavior is elastic deformation of the body, always changing from moment to moment. One method to measure deformation is to use a relatively large measurement apparatus to directly measure the relative displacement between two points. However, since a motorcycle has a light body weight, such measuring equipment will have a relatively large impact, changing the motorcycle's motion performance. Therefore, instead of measuring displacement directly, we have developed technology to

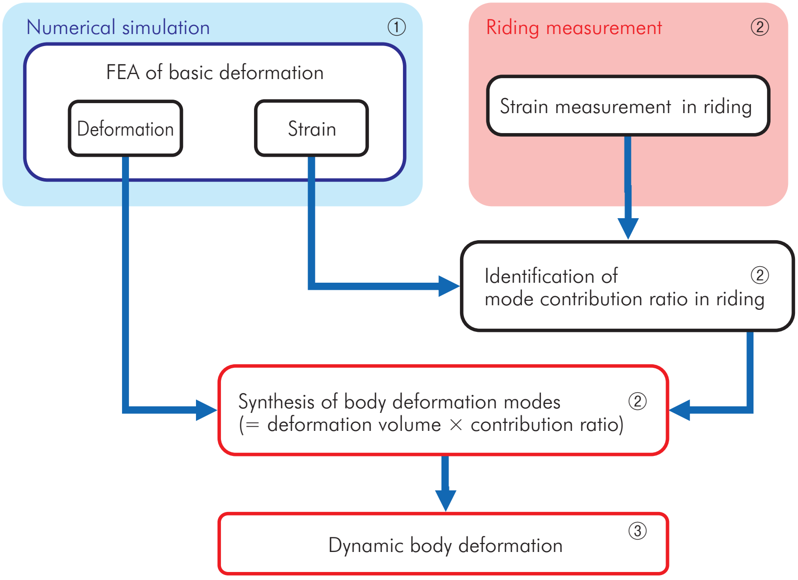

Fig.5 System flow for measuring dynamic deformation of motorcycle bodies

appropriately combine the numerical simulation and the measurement of strains without measuring the displacement directly.

The system flow developed is shown in Fig. 5, and an outline is shown in Fig. 6. Our idea was that the constantly changing dynamic deformation of a motorcycle body could be expressed by superimposing the individual deformations (basic deformation modes) for the dominant individual forces acting on the body. First, ① a detailed numerical simulation is used to calculate deformation volumes for each basic deformation mode of the body and the strain corresponding to each. Next, ② the strain in actual riding is measured, and the strains in the basic deformation modes are compared in order to superimpose the deformation in each mode and its contribution ratio. Finally, ③ the dynamic body deformation at a given time during riding is calculated.

As shown in Fig. 7, the dominant forces deforming the body are the load input from the tires (suspension) and the chain tension which transmits the engine's drive to the tires.

To precisely calculate the dynamic deformation of a motorcycle body, it is necessary to calculate the contribution ratios* of the basic dynamic deformation modes (hereafter "mode contribution ratios") from actual measured data. So we calculated the mode contribution ratios from strain, which can be measured with high precision using little space. Since measurement location has great effect on the precision of the body deformation measurement system. Therefore, the positions of strain gauges are selected from the following viewpoints.

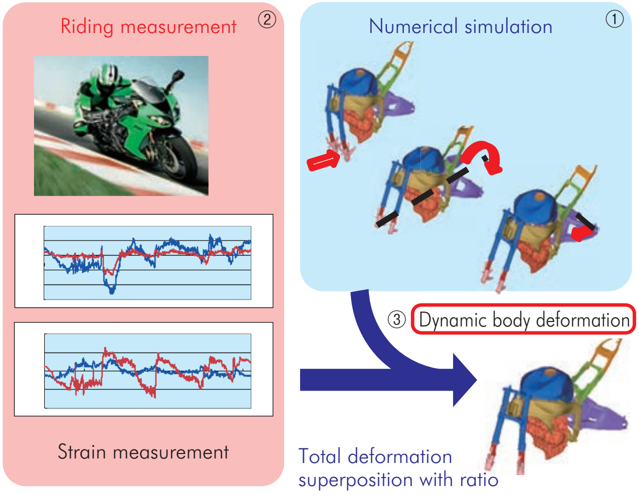

Fig. 6 Outline for measuring dynamic deformation of motorcycle bodies

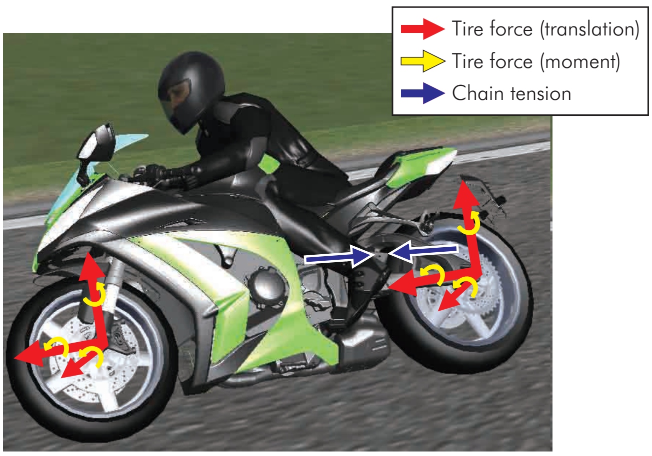

Fig. 7 Load acting on a motorcycle

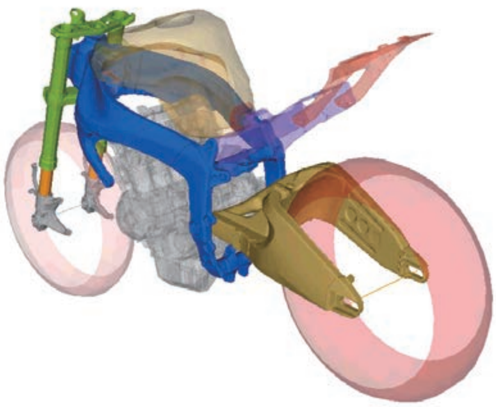

Fig. 8 Dynamic deformation of a motorcycle body

① Positions where strain due to individual forces is easily identified
② Positions where temperature does not influence strain
③ Positions where the change of strain is small (not sudden)

Calculation results for dynamic deformation of a motorcycle body are shown in Fig. 8. Thus, we are now able to visualize dynamic deformation of a motorcycle body based on measurement data in actual riding and to evaluate it quantitatively.

*Mode contribution ratio: The ratio expressing the magnitude of basic deformation.

(2) Technology for creating functional design

In the design of motorcycle parts, there are many factors that must be evaluated, such as weight, stiffness, strength (stress), vibration, and design. Previously, we have refined parts using repeat tests by experiment based on past experience. However, in recent years, there is a demand for better analytic technology to allow for better industrial design in the concept stage.

Therefore, using motorcycle wheels as an example, we developed technology for structural optimization analysis to calculate the lightest shape which would fulfill characteristics including stiffness, strength (stress), and vibration. An overview is shown in Fig. 9.

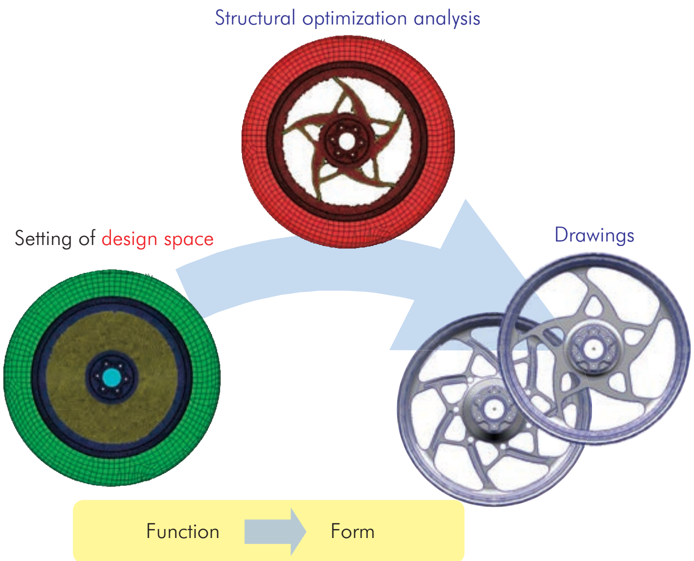

Fig. 9 Overview of technology for creating functional design

Setting the design space in which parts can be placed, and then specifying required performance values, such as stiffness, strength (stress), and vibration, we find the lightest placement of parts. The results of this structural optimization analysis are used as a base for drawings by a designer. This makes it possible for us to achieve functional design (design grounded in function) that is polished from an engineering standpoint without having to go back.

The wheels produced using this technology have been received well among riders in riding tests. Becoming able to grasp quantitatively the performance demanded in wheels has helped us greatly to make our products "Fun to Ride" for riders.

Concluding remarks

This paper has introduced our efforts to address major factors in motorcycle development that make a motorcycle "Fun to Ride," namely a pleasing engine sound, excellent riding comfort, and improvement of handling and stability. We intend to continue improving the technology involved and to develop motorcycles with greater product value.

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