

Study on Analysis of Input Loads to Motorcycle Frames in Rough Road Running

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ABSTRACT

In this study, we developed a simulation method for rough road running condition to reproduce the behaviors of a vehicle body and to precisely estimate the input loads to the frame.

We designed the simulation method focusing on a front fork model and a rider model optimized for this type of analysis. In the suspension model development, we conducted detailed measurement of the suspension characteristics on a test bench. Based on the yielded results, the friction force, as well as the spring reaction force and the damping force, was reproduced in the suspension model. The friction of the suspension varies depending on the magnitude of the reaction force associated with bending and this effect was also implemented in the model.

Regarding the rider model, the actual behavior of a rider was investigated through the recorded motion video data and used to define the necessary degrees of freedom. Based on this investigation, the degree of freedom of three, i.e. vertical, longitudinal and forward leaning motions, was adopted to the rider model. In addition, the model was designed assuming that the rider is connected to the vehicle body at the points of the handle bar, the foot pegs and the seat through springs and dampers.

Using the multi-body dynamics model composed of the aforementioned model elements, the input load to the frame was accurately estimated within an error of 10% to the actual measurement result.

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INTRODUCTION

A frame body is a core part of a motorcycle that sustains the forces from road via front and rear suspensions as well as holding heavy objects such as the engine. It is therefore important to finish the base design in the early stage of product development.

In the actual process, we firstly tried to estimate the load input to the frame under severe conditions. Rough road running is one of the most severe conditions. If we could estimate this input to the frame, it would be possible to design a frame appropriately in the early stage of development.

In the field of automobile body development, the development methodology trend is moving toward prototype-less development. One of the examples of such techniques is an estimation method that provides input loads to axles when running on rough roads. In this study example, they conducted that analysis using a full vehicle simulation with multi body

dynamics but without actual running tests [1]. Another example is a technique that allows simulation of the dynamic responses of heavy objects and/or estimation of accumulated fatigue using a full vehicle model. In this example, the vehicle body was treated as a flexible-body [2, 3, 4]. Meanwhile, in motorcycle fields, there have been only a few studies on estimations of input loads and behaviors when a vehicle is running on rough roads. These few cases include a reproduction technique on bench test for rough road running [5] and a development of technique that substitutes bench tests with a CAE simulation [6, 7].

When it is compared to automobiles, in motorcycles, the ratio of a rider mass is significantly large to the whole mass of a vehicle. Therefore, a rider mass largely affects the input loads to the vehicle body. Another characteristic inherent to motorcycles is an adoption of telescopic type front forks suspension system. The suspension of this type has not only

the function of shock absorber but also the function of structural support. Accordingly, the suspension bears a bending load when a load input is applied from the road surface. The suspension movement is affected by the variation of friction generated by this bending load.

In a motorcycle, the inertia moment of vehicle body is small and the wheel base is short. Therefore its pitching motion is highly susceptible to influences from unevenness of the road. This factor should be taken into account when a simulation model of a motorcycle is designed. We considered a simulation model applicable to a rough road running could be established for motorcycles as well if we took those factors mentioned above into account.

In this study, we set our objective as establishing a simulation technology that can estimate the input loads while rough road running. For establishing that simulation model, we focused on the modeling of the front fork and the rider. In the modeling, the results of phenomenal analyses, which are collected through actual vehicle running and the tests on a bench, are used.

MEASUREMENTS FROM ACTUAL RUNNING

Measurements were taken from actual running to clarify the influence of the input loads from the road surface to the frame and to analyze the behaviors of the motorcycle and the rider when running on rough roads.

Test Motorcycle and Test Conditions

A "family-type" motorcycle equipped with a 110 cm³ engine was selected as the test motorcycle. Table 1 shows the major specifications of the test motorcycle. The appearance of the test motorcycle and the location of various sensors necessary for measurements are shown in Fig.1. At the front, the longitudinal bending load and the stroke of the front fork are measured. The longitudinal bending load of the front fork is acquired by pre-calibrating the inner pipe strain measured directly below the triple clamp. The stroke length is measured by a displacement sensor directly attached to the front fork. At the rear, the input loads to the frame and the suspension stroke are measured. The input load to the frame is obtained by pre-calibrating the strain measured near the rear suspension mounting point. Also, to measure changes in the motorcycle pitching motion, a gyro sensor is attached to the swing-arm pivot. Moreover, to monitor the behavior of the motorcycle and the rider, a high-speed camera was set beside the test course to take pictures during the tests. To monitor where on the course the test motorcycle traveled, movies were taken by a compact video camera with a focus on the contact points of the front and rear tires. For the running tests, a 21-meter-long rough road course was used, split into Course A and Course B. Course A and Course B have road surfaces with a maximum gap of 40 mm and 70 mm respectively. To clarify where on the

test course the test motorcycle should travel, two white lines, 200 mm apart, were drawn on the course. The test speed was 40 km/h when taking the measurements.

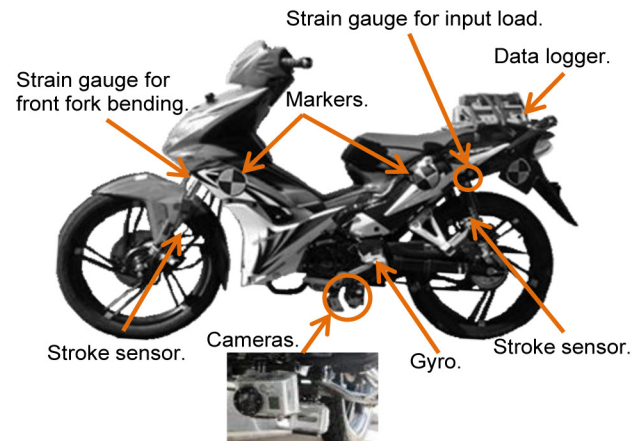


Figure 1. Test motorcycle and location of installed sensors.

Table 1. Test motorcycle specifications

Wheelbase		1219.6 mm
Weight		97.6kg (inc. sensor)
Engine displacement		110 cm³
Suspension	Front	Telescopic
	Rear	Conventional
Suspension travel	Front	90 mm
	Rear	75 mm
Tire size	Front	MC2.5-17
	Rear	MC2.75-17
Rider mass		72.2 kg

Actual Running Test Data

Fig. 2 shows typical data taken from the actual running tests. Fig. 2-1 shows time history waveforms of the front and rear suspension strokes. Fig. 2-2 shows time history waveforms of the longitudinal bending load on the front fork and the input load on the rear suspension. The maximum load on the rear suspension is seen in Course B. Fig. 2-3 shows time history waveforms of the pitch rate. It can be understood that the pitching motions change more extensively in Course B than in Course A.

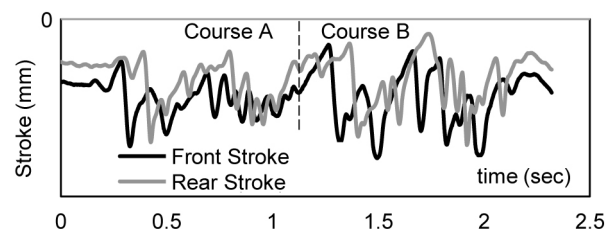


Figure 2-1. Result of suspension stroke measurement from rough road test ride

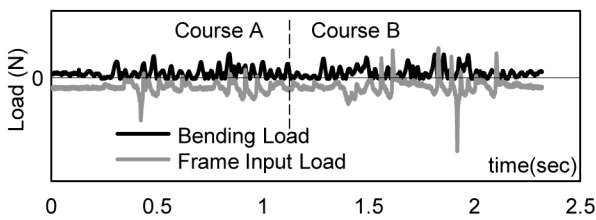


Figure 2-2. Result of front fork bending load and frame input load measurement from rough road test ride

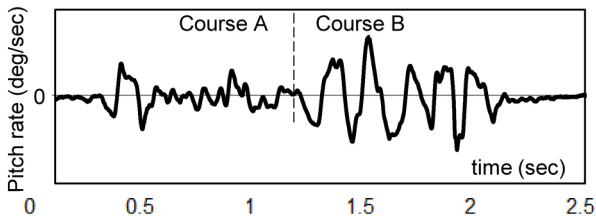


Figure 2-3. Result of test motorcycle pitch rate measurement from rough road test ride

SIMULATION MODEL

Fig. 3 shows the simulation model we used in this study. The model is composed of a flexible body and rigid parts. We used a multi-body dynamics model having degrees of freedom for rotation in the steering stem and the swing-arm pivot, and a degree of freedom in the sliding direction of the front fork. The details of each part are explained in the following section.

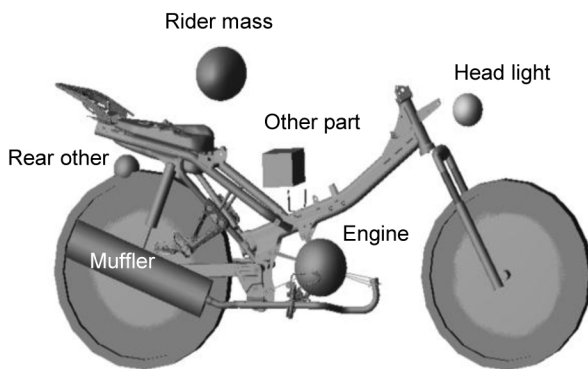


Figure 3. Simulation model

Vehicle Body Model

The frame model and the swing-arm model are deemed as a flexible body. Regarding the parts with large mass such as the engine, muffler, headlight, etc., each part is laid independently at the location of their centers of gravity [8]. Those parts were fastened via springs and dampers to their fixing structures.

Having a degree of freedom for rotation, the front fork is connected to the head pipe via the triple clamp.

Suspension Model

The suspension functions to absorb impact energy from the road surface when running and to control the vehicle posture. For modeling these, it is necessary to simulate the reaction

force of the suspension stroke, the bending motions occurring from the input of longitudinal force, and the friction, which varies depending on the bending force [9]. The telescopic type front fork used in this project is shown in Fig. 4. Fig. 5 shows the suspension model we developed in this project. The slider, which is an unsprung weight, and the fork pipe, which is a sprung weight, are represented as two rigid elements, and the bending stiffness in the longitudinal direction is represented by a spring element.

Points A, B, C and D represent the upper end of the fork pipe, the bottom end of the fork pipe, the slide bush at the upper end of the slider, and the front wheel axle, respectively. Point C' is on the fork pipe, having a degree of freedom in the sliding direction of the fork pipe. Point B' is on the slider, having a degree of freedom in the sliding direction of the slider. Also, the distance AB' is fixed to always maintain the distance AB. C is connected to C' with a degree of freedom for rotation in three directions. The spring K_{bend} , which represents the longitudinal bending stiffness, is set between Point B and Point B'. The spring reaction force (i), the damping force (ii) and the reaction force from friction (iii) of the front fork are set by the elements attached between Points A and D.

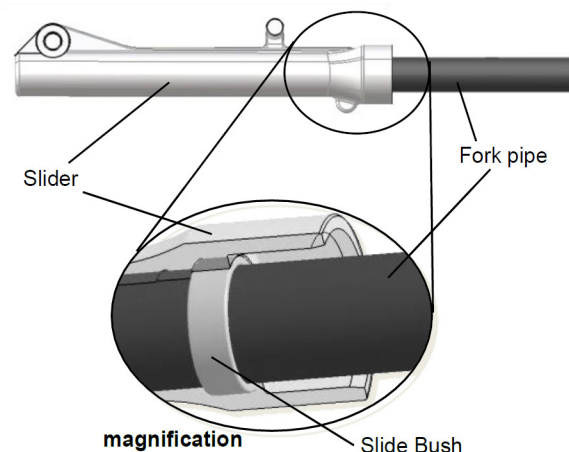


Figure 4. Telescopic front fork

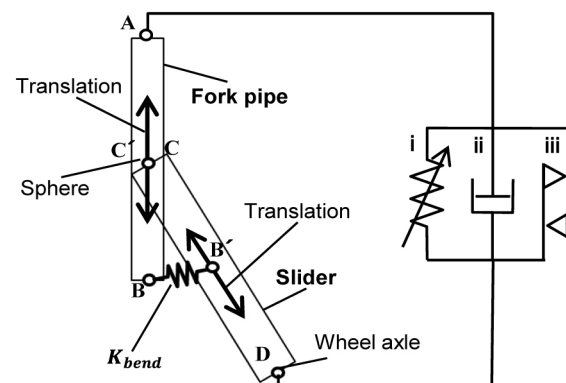


Figure 5. Front fork model including bending mechanism