

Development of Estimation for Strain in Damages of Motorcycle Engine Parts When Tipped Over from Stationary State

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ABSTRACT

In this research, a simulation method was developed in which it was able to estimate, in the early stage of design, the strains that potentially lead to damages to motorcycle engine parts when tipped over from a stationary state.

Splitting a series of phenomena from the start of tilting of motorcycle from the upright position up to the end of collision of engine parts after the contact on the ground to two groups by before and after the contact of engine parts on the ground, we applied the multi body dynamics analysis to the first group, and the elasto-plastic FEM analysis to the latter one. In the computer simulation of collision using the elasto-plastic FEM analysis, we minimized the FEM models from the entire motorcycle models and treated others as a solid model to shorten the computation period. It is also realized that the strains occurring in the engine parts can be simulated by considering only the mass of the parts which are rigidly mounted on the engine.

The developed simulation method allows remarkable reduction of analysis time while assuring a high accuracy, contributing the estimation of damages to engine parts in the early stage of design.

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INTRODUCTION

As the rider controls the motorcycle by actively shifting his or her body weight right or left, motorcycles excel in maneuverability and the riding itself is full of fun. However a user may tip over a motorcycle when it is stationary because of its structural characteristics. In such a case of tip over, the engine parts collide on the ground and suffer damages in some cases depending on the configuration of the engine. From the standpoint of user benefit, it is strongly required to minimize such damages.

The extent of damages to engine parts from a tip over of a stationary motorcycle used to be assessed using a prototype motorcycle. Accordingly, repetitive tests using a large number of prototypes were required until finalization of the design, causing an increase of development man hours, which hinders timely product development. To resolve these issues, it had been sought to allow validation in the design stage. However, to solve this issue, one of the challenges was to estimate the strains when damages occur in higher accuracy.

The subject to be assessed in this validation is the extent of strains on engine parts occurring from the collision against

the ground when a motorcycle tips over from stationary status.

Generally, the elasto-plastic FEM analysis is applied as the means for accurate estimation of such a phenomenon of collision^{(1),(2),(3)}. However, applying this FEM analysis method to the whole phenomena of the tip over requires a long computation time, and cannot serve as an efficient design aid on the presumption of repetitive redesigning.

In view of the above, we have set a goal of this theme at the development of an adequately-accurate simulation method that allows quick computation by combining the multi body dynamics (here after MBD) and the elasto-plastic FEM analysis to estimate strains to the engine parts from a tip over in the early stage of design.

CONSIDERATIONS OF SIMULATION PROCESS

To assess strength of engine parts of complex shapes, it is necessary to accurately calculate the stress and strain. It is therefore necessary to set the mesh size of analysis smaller than 1 mm. If such a fine mesh is applied to the entire

motorcycle, the modeling and computation would take too much time to be realistic. Although there is such an option to apply a fine mesh to some areas, as the actual time period subject to analysis is long, it requires many computation steps, not permitting reduction of computation time to the desired level. The authors of this paper consider that the analysis of tip over motions until just before collision of engine parts on the ground is for determination of contact position and load conditions at the time of collision, not requiring the elasto-plastic FEM analysis. Accordingly, the time reduction measure of computation was designed as shown in Fig. 1 and Table 1.

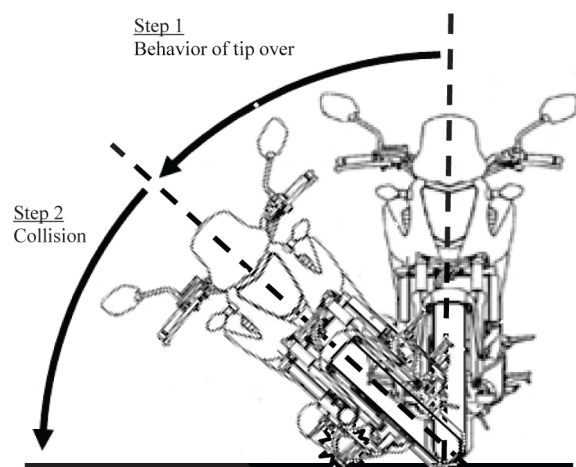


Fig. 1. Splitting of motions

Table 1. Considerations of simulation process

Phenomenon	Analysis method	Analysis model	
		Bodies for vehicles	Engine
From the tipping over till the collision of engine parts	Elasto-plastic FEM	FEM models	FEM models



Phenomenon		Analysis method	Analysis model	
			Bodies for vehicles	Engine
Step 1	Until just before the collision of engine parts on the ground	Multi body dynamics analysis	Rigid models	Rigid models
Step 2	After the collision of engine parts on the ground	Elasto-plastic FEM	Rigid models	FEM models

In Step 1, the behavior of tipping over was calculated using the MBD based on solid-modeling only for the phenomena until just before the collision. Following that, in Step 2, the collision was analyzed through the calculations using the elasto-plastic analysis based on the FEM model applied only for the engine parts. The MBD and the elasto-

plastic FEM were conducted by commercially available software with using standard functions^{(4), (5)}.

ANALYSIS OF TIP OVER MOTIONS

Influence Of Steering Angle

When simulating the tip over behavior in Step 1, it is necessary to conduct computation under the conditions that give maximum impact to the engine parts.

The motion of a tipping over of a motorcycle from stationary status can be translated as a rotational motion around the axis of line that passes through the contact points of the front and the rear tires to the ground. In addition, the energy given to the engine part through the collision impact can be translated as the impulse in dynamics, and that is proportional to the angular velocity as well, as the equation shown below. As a result, the condition that gives the larger angular velocity is considered to be the condition that gives the larger impact.

Impulse occurring when contacting the ground

$$\int_0^t F(t)dt = \frac{I\omega}{L}$$

where,

$F(t)$: Time history of the load applied from the ground at the contact point

t : Length of time through which the contact point sustains the load

I : Moment of inertia around the tire contact axis

ω : Angular velocity just before the collision

L : Length between the tire contact axis and the contact spot when tipped over

The cross sections of motorcycle tires have round shapes and the shapes are different between the front tire and the rear tire. Accordingly, the axis of rotation shifts during a motion of the tip over along with the movements of the tire-ground contact points associated with that motion.

At the same time, as the steering is turned to the direction of tip over due to the factors such as the position of center of gravity, the motorcycle makes rotating motions coupled with lateral motions. Taking such characteristics of motorcycles into considerations, the simulation conditions are selected after experimentally determining how the steering angle affects the angular velocity at the time of tip over.

Fig. 2 shows the motorcycle used for the tests and its specifications. The tests were conducted under the 6 steering positions; fixed at the center, fixed 15 degree to the right, fixed 15 degree to the left, fixed at fully turned to the left, fixed at fully turned to the right, and the center without fixing (free to turn). The motorcycle was allowed to tip over freely from the upright position to the right side.

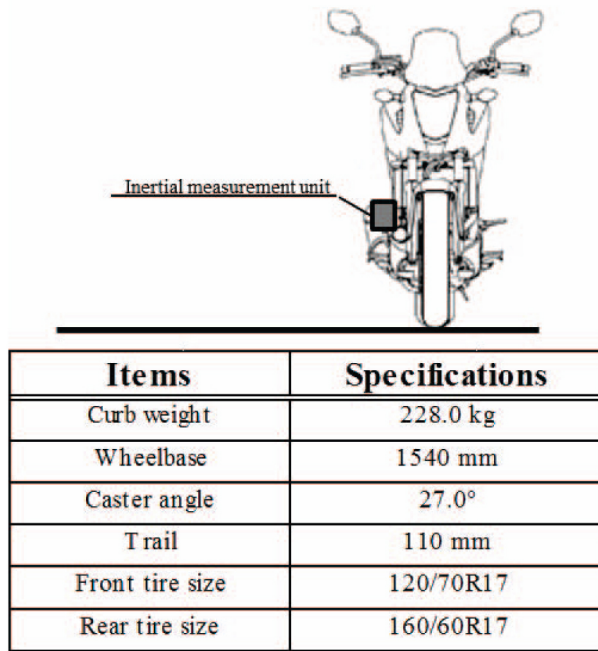
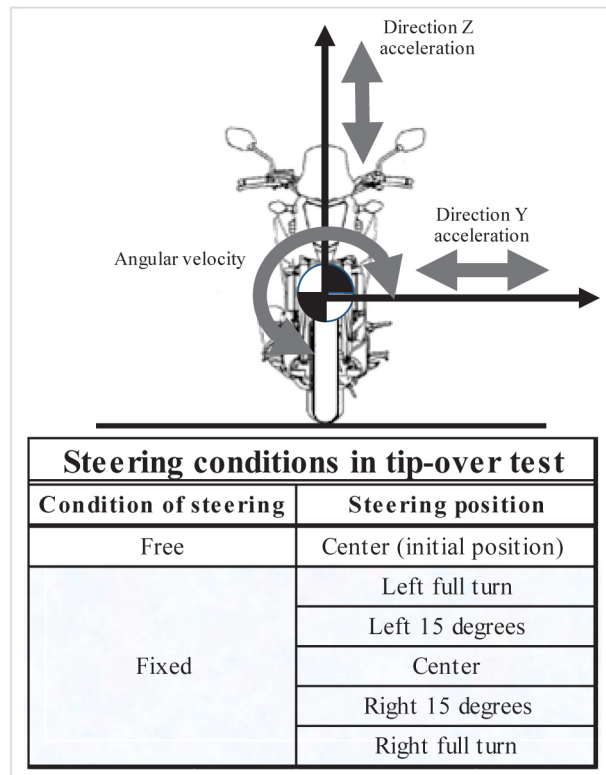


Fig. 2. Test motorcycle and specifications



In this picture, the direction of fall is referred to as right and the opposite as left

Fig. 3. Steering conditions in tip-over test

At that time, an inertia measuring unit is attached to a specific part of the engine to measure the angular velocity in

the tip over motions and the acceleration of impact at the time of contact on the ground in addition to the analyses on the motion pictures.

Fig. 3 shows measurement items and steering conditions in tip-over test.

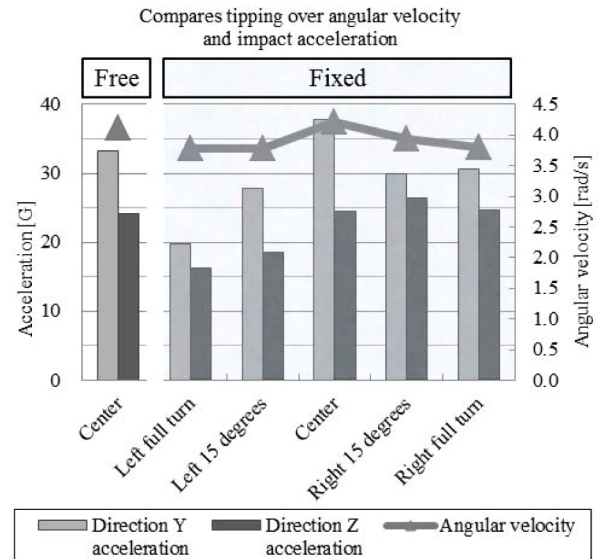


Fig. 4. Test results

Fig. 4 shows the test results. The angular velocity and the acceleration of impact were larger under the conditions where the steering was fixed at the center than under other steering conditions. It was understood that all the potential energy was converted to the rotational kinetic energy when the steering was fixed at the center. In the meantime, when the steering was turned, the energy was dispersed reducing the rotational kinetic energy with occurrence of the motions related to the rotation of the front wheel.

With those results mentioned above, we chose the center-fixed steering condition as the condition that was assumed to give the biggest impacts to the engine parts when a motorcycle tipped over from stationary status.

Thanks to this result, it was made possible to put steering motions out of consideration for the simulation conditions of tip over motions, allowing us to simplify the conditional parameters for calculation and the modeling.

Estimation Of Moment Of Inertia

The process of modeling for the simulation of motorcycle tip over motions involves the mass, the center of gravity and the moment of inertia of the motorcycle.

In the situation where the actual vehicle is available, it is possible to get the value of moment of inertia by measuring the vehicle. However, in the process of designing, it is a common practice to yield the moment of inertia of a motorcycle by arranging the parts modeled by 3D-CAD tools. Nevertheless, in the very early stage of the design, it is