SIMULATION OF MOTORCYCLE-CAR COLLISION

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ABSTRACT

Numerical simulation of motorcycle-car collisions is one of the most effective tools in research on motorcycle passive safety, considering the diversity of collision configurations. In addition, due to the length of analysis time to be considered, the multi-body dynamics-based software "MADYMO" (MAthematical DYnamic MOdel) rather than FEM based software has been adopted as a basic simulation tool.

In this research, a scooter-type motorcycle model for collision simulation was developed. Detailed modeling steps of the motorcycle model were presented in 18th ESV [1]. This paper presents 1) a general description of a motorcycle, car and dummy model for collision simulation, and 2) comparisons between the FST (Full Scale Test) and a simulation in which these models are used. As for collision configurations of FST, several of seven basic impact configurations recommended in ISO13232 [2], which defines test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles, were selected. The corresponding simulations were then carried out. As a result of validating the model with FST data, the dummy kinematics and dummy signals (such as head acceleration) obtained in simulations show qualitatively good agreement with FST results.

INTRODUCTION

The aim of this simulation is to develop a tool to evaluate rider protective devices and therefore to reduce rider injuries when a motorcycle-car accident occurs. One feature of motorcycle-car accidents is their diversity of collision configurations. In ISO13232, 200 configurations are recommended to evaluate rider protective devices. Another feature of motorcycle-car collisions is that the rider is likely to experience secondary impact with the environment (such as the road) and therefore the analysis time to be considered is much longer than that in car-to-car collisions. Considering these specific features, multi-body dynamics-based software MADYMO was adopted as a basic simulation tool.

In this simulation, a scooter-type motorcycle model (a prototype test vehicle), a rider dummy model and a car model are used (see Figure 1). A part of this paper gives a general description of the motorcycle, the dummy and the car model. Using these models, several simulations of seven basic configurations recommended in ISO13232 were carried out. On the other hand, corresponding FSTs (Full Scale Tests) were also performed. In addition to the basic steps of modeling such as component tests and barrier tests, these FST data greatly contributed to refinement of the simulation model. As a result of the validation process, comparisons between simulations and FST results are also shown herein.

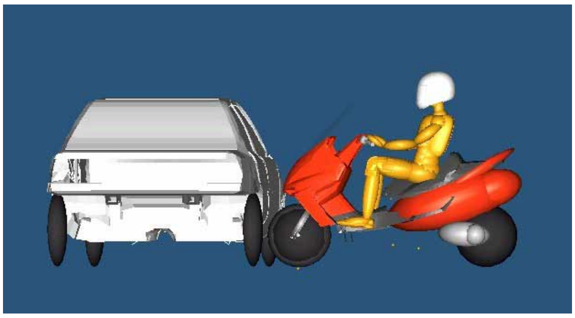


Figure 1. Full simulation model.

MOTORCYCLE MODEL

Our motorcycle model (see Figure 2), which is a rigid model, consists of 21 rigid bodies, 12 movable joints and many surfaces. In MADYMO [3], an ellipsoid, cylinder, plane and facet surface are used for the surface. The surface is attached to the rigid body to visualize the model or to calculate the contact force. A facet surface, which is an FEM mesh-like surface but not deformable, is used when more precise contact force is required.

Figure 2. Motorcycle model.

Detailed modeling steps of the motorcycle model were provided in the previous paper [1]. From that time on, several additional component tests were performed to determine the contact characteristics of the motorcycle in case of rear and side impact. Some small ellipsoids were replaced by the corresponding facet surfaces to avoid an irrational contact force caused by a certain algorithm to generate a contact force.

RIDER DUMMY MODEL

The Hybrid Ⅲ standing model (see Figure 3) in MADYMO database is used as a rider dummy model because it had been employed in the FST. This dummy model is a rigid model with 32 rigid bodies and 51 ellipsoids originally, but now some ellipsoids have been replaced by the facet surfaces for the same reason as in the case of the motorcycle model. In addition, the bending characteristics of the neck were adjusted by doing pendulum test simulations.

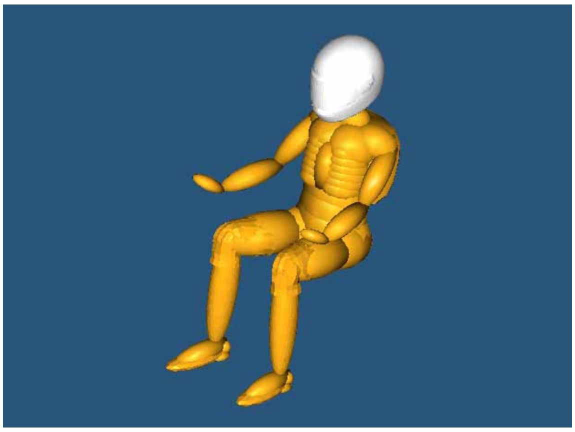


Figure 3. Rider dummy model.

A helmet model, which is also a rigid model and has a fine facet surface, was attached to the dummy model. The contact characteristics of the helmet model were determined using various conditions for the component test.

CAR MODEL

An existing FE (Finite Element) model was appropriated for a car model. This car model (see Figure 4) originally had approximately 47,000 nodes and 40,000 elements. After re-meshing for the purpose of reducing calculation time, it has approximately 27,000 nodes and 19,000 elements. The four tires are replaced by ellipsoids for the same reason.

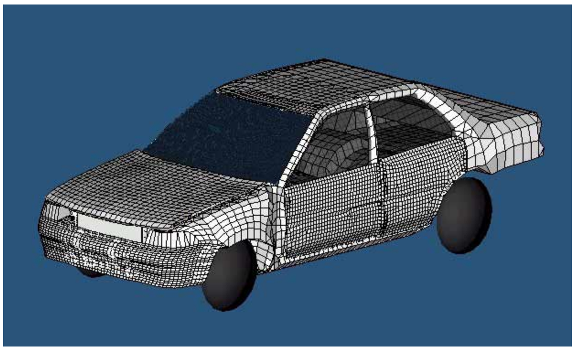


Figure 4. Car model.

ISO13232 SEVEN BASIC CONFIGURATIONS

As mentioned before, ISO13232 specifies seven basic impact configurations (Figure 5). The impact configuration code (such as “413-0/13.4” in Figure 5) comprises a series of three digits describing the car contact point, the motorcycle contact point and relative heading angle, respectively, followed by a hyphen (-), the car impact speed, and the motorcycle impact speed, respectively in m/s. Researchers are recommended to carry out these configurations of FST and validate their simulation model using these test data. We have already finished several FSTs and validated corresponding configurations of the simulation model. Hereafter these results are shown.

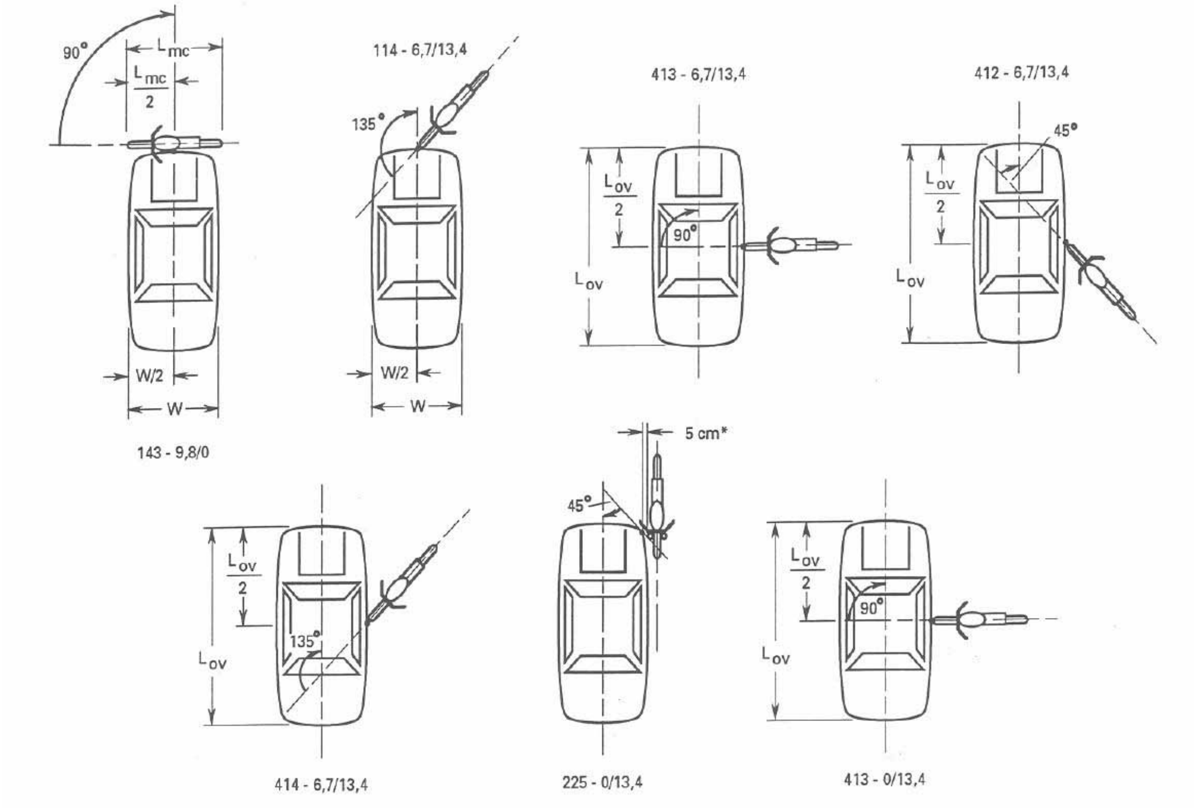
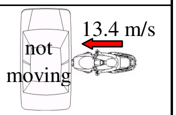
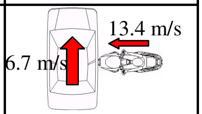
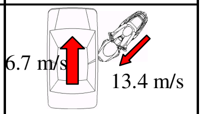
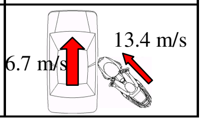


Figure 5. ISO13232 seven basic configurations.

FULL MODEL SIMULATION

Combining the motorcycle, the rider dummy and the car model, a full model simulation corresponding to each FST was carried out. At first, four basic configurations, in which the motorcycle collides with the side of the car, were selected. In each case, a validation process such as adjusting a contact force or a friction coefficient was performed. As a result of these detailed and cumulative efforts, our model proved to show good agreement in dummy's kinematics and head resultant acceleration data. In ISO13232, the maximum allowed tolerances between FST and simulation for the dummy's displacement and velocity about its head (helmet) and hip point, are specified. In addition, the correlation coefficient about the head maximum resultant linear acceleration should be calculated. Figures 6 to 9 show kinematic comparisons between FST and simulation from 0 ms (at which time the first motorcycle/car contact occurs) to 500 ms at time intervals of 100 ms. Table 1 lists what each figure shows. For example, Figure 6 shows a kinematic comparison in case of configuration code "413-0/13.4".

Table 1.
List of Figures.

Configuration code	Kinematic comparison	Head acceleration comparison	Configuration diagram
413-0/13.4	Figure 6	Figure 10	
413-6.7/13.4	Figure 7	Figure 11	
414-6.7/13.4	Figure 8	Figure 12	
412-6.7/13.4	Figure 9	Figure 13	

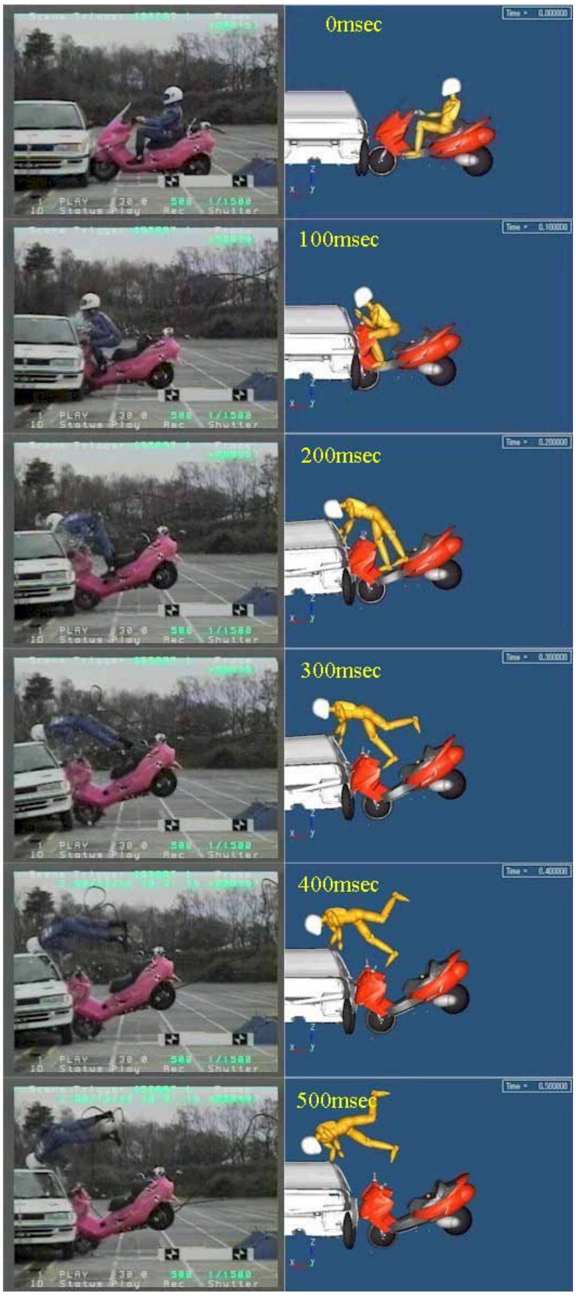


Figure 6. Kinematic comparison (413-0/13. 4).

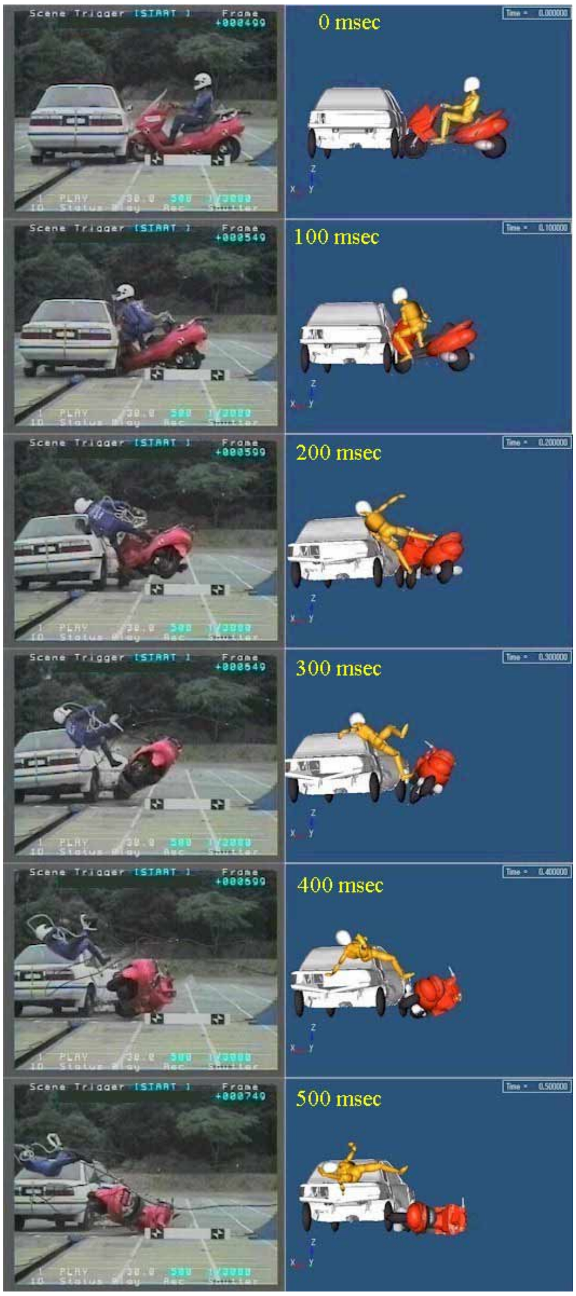


Figure 7. Kinematic comparison (413-6.7/13.4).

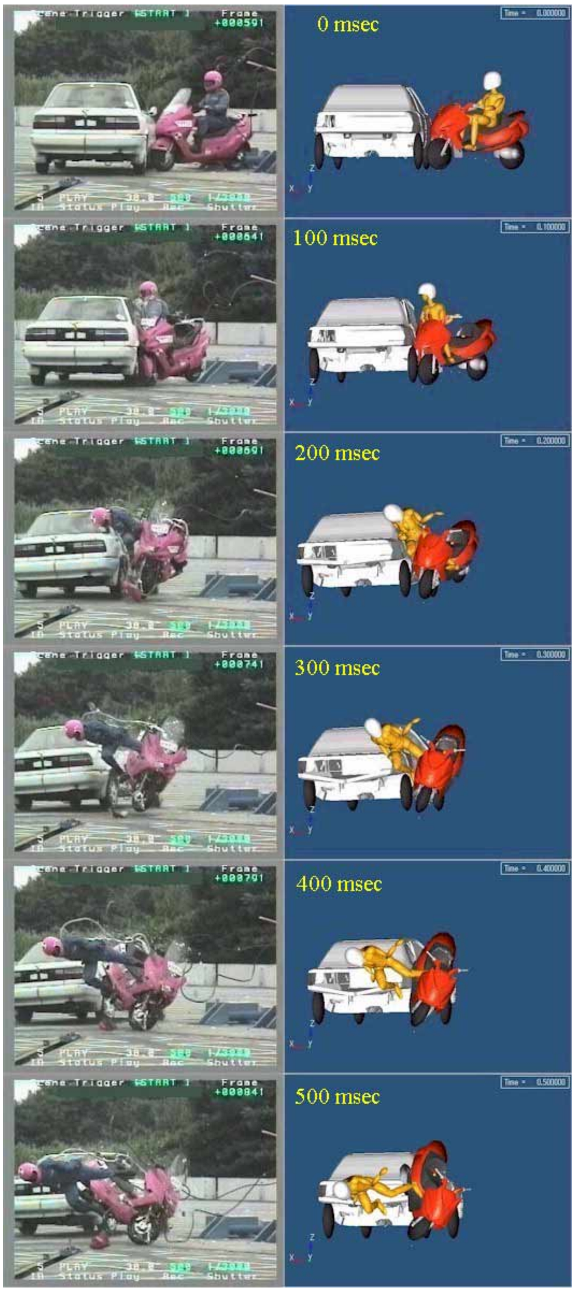


Figure 8. Kinematic comparison (414-6.7/13.4).

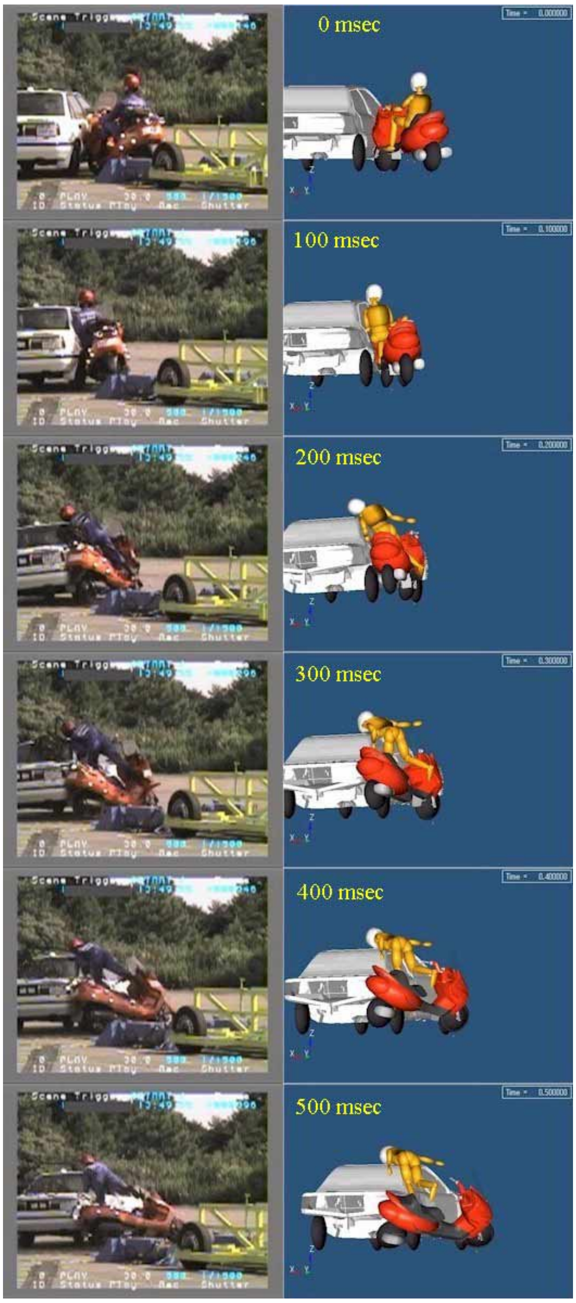


Figure 9. Kinematic comparison (412-6.7/13.4).

These figures show good kinematic agreement especially in the dummy's head and hip point position.

As listed in Table 1, Figures 10 to 13 compare the head resultant acceleration between FST and simulation. The blue lines indicate test data and light blue lines simulation results. And the same scale is adopted for all vertical axes.

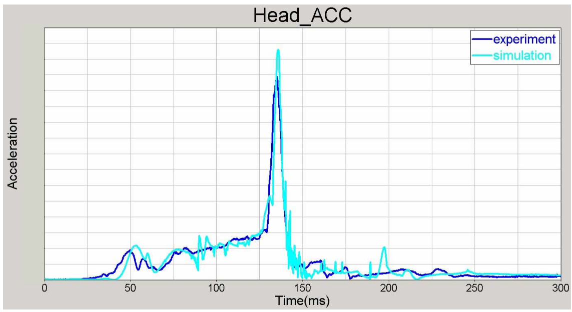


Figure 10. Head resultant ACC (413-0/13.4).

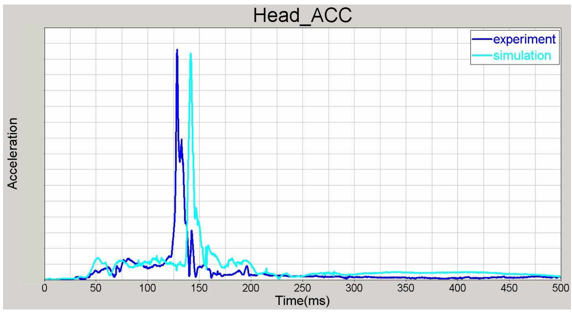


Figure 11. Head resultant ACC (413-6.7/13.4).

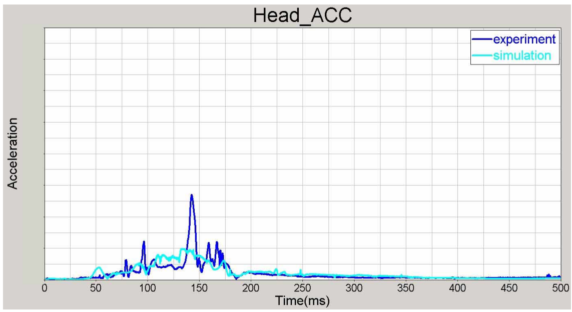


Figure 12. Head resultant ACC (414-6.7/13.4).

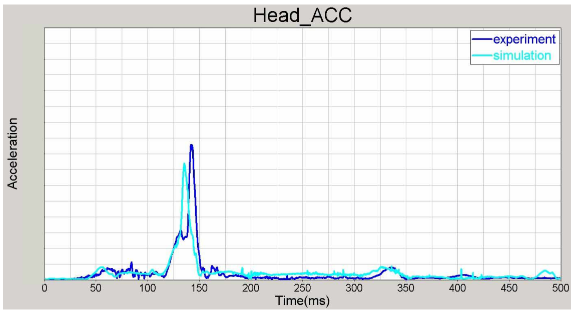


Figure 13. Head resultant ACC (412-6.7/13.4).

In these figures, fairly good agreement with the dummy's head resultant acceleration is observed. In case of 413-6.7/13.4 (Figure 11), the peak timing in simulation is slightly later than that in FST. And in case of 414-6.7/13.4 (Figure 12), the peak value of simulation is far below that of FST, though its absolute value is very small compared to other cases. In this case, the helmet of the rider dummy had a slight contact with a pillar of the car in FST, but no contact in simulation. The reason for the first difference is considered mainly that the contact between the motorcycle front cowl and the dummy's knee is not fully reproduced. In the second case, the contact between the car and the motorcycle front tire is considered to be the reason for the difference. Although there may be a more elaborate model, thus far, our model is considered to have sufficient accuracy to predict the dummy kinematics for practical use.

CONCLUSIONS

A scooter-type motorcycle model, as well as a rider dummy model, had been developed and some modifications were introduced. Using the motorcycle model, the dummy model and a car model, Full model motorcycle/car collision simulations were carried out. In several of the ISO13232 seven basic configurations, satisfying agreement in dummy kinematics and the dummy head acceleration was obtained. This means that an effective tool for evaluating rider protective devices is being developed. We will continue to validate three other cases and improve the model, and to utilize this simulation method to effectively evaluate and develop rider protective devices.

REFERENCES

(1) Deguchi M., Modeling of a motorcycle for collision simulation, 18th ESV Paper No.157-O, 2003.

(2) International Standard ISO 13232: 1996(E). Motorcycles – Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles, Parts 1 to 8, International Standards Organizations, Geneva, December 1996.

(3) MADYMO Theory Manual Version 6.2, TNO MADYMO BV, June 2004.