SIMULATION OF CAR-PEDESTRIAN ACCIDENT FOR EVALUATE CAR STRUCTURE

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ABSTRACT

A new computer system and human body model to simulate the pedestrian road accidents involving vehicles were developed for evaluating vehicle structure and pedestrian injury. The aim of the simulation system is to predict the dynamic behavior of pedestrians and influence of car shape and structure on the pedestrian injury. To evaluate actual vehicle shapes and structures, this system carries simulations into an FEM environment. And new types of human body models were developed for the simulation. The character of human body model is to have a self-scaling modeling program for any pedestrian weight and height and particular joint characteristics obtained by the PMHS test. This paper describes the content of the simulation system and presents some results from the simulations.

INTRODUCTION

Pedestrians account for approximately one-third of those killed by traffic accident in Japan. There has been a desperate call for more effective structures of automobiles to reduce traffic accident casualties drastically. In recent years, responding to those demands, Honda proposed the ASV concept. And EURO-NCAP pedestrian tests are held using EEVC impactor method. To further enhance this safety improvement trend, it has been considered necessary to establish a simulation system for evaluate car structure and for analyze the phenomenon of car pedestrian accidents is desired.

The authors successfully developed one simulation system to reveal pedestrian body behavior. The major feature of the technique is having an analytical dummy of which behavior corresponds to the pedestrian PMHS test data. And it moves in the environment of FEM. This technique can evaluate the vehicle structure and identify phenomenon in car-pedestrian accident.

The new simulation system made it possible to comparatively study the influence of automotive body configuration on pedestrians, which could not otherwise be performed by impactor tests. This paper describes system description and examples of calculations conducted with mass production vehicles.

Simulation System

1. Analytical Dummy Model

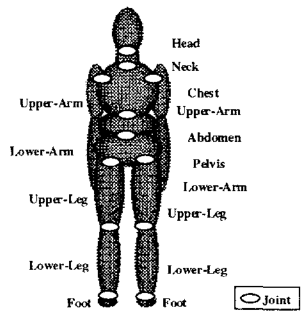

Figure 1. Ellipsoid Dummy

The dummy model described in this paper has 15 ellipsoids segments for each human body. And each geometric shape, center of gravity, inertia moment are created automatically by the program adjusting weight and height of every physiques. Physical properties of joint that connect adjacent segments were assumed to be common for every physique.

The geometrical properties, center of gravity, inertia moments were based on the measurement results of 32 body measurements used by the GEBOD.

This program was capable of creating various dummy models which differ in terms of height, weight, sex, and age (Figure 2.). Also standing initial positions and postures remain variable. It is necessary to determine new joint character in the process of corresponding with PMHS test data.

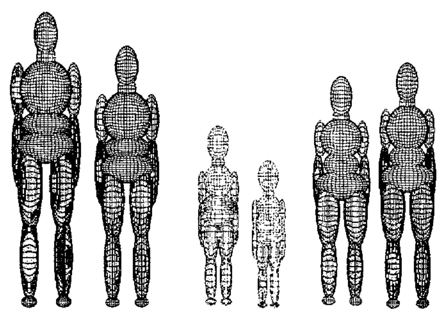

Figure 2. Child, Female, Male dummies

2. Vehicle Model

Two different vehicle models were available in this system. One was conventional ellipsoids and plane model (Figure 3.).

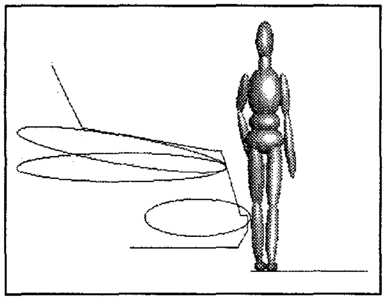

Figure 3. Ellipsoids and plane model

It defined contact forces with pedestrian body in terms of variable representing the amount of pedestrian invasion into vehicle body. This type of model was used to check the correlation with experimental PMHS test data. Another one was FEM model that represented the actual front-end structure of a vehicle (Figure 4.).

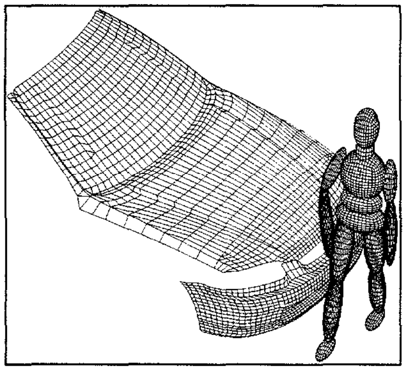

Figure 4. Finite element model

The FEM model enabled us to evaluate body structure using this simulation system.

Joint Character

1. PMHS Test Data

The correlation between simulation results and PMHS test data was studied, especially on joint character. The pedestrian test data used as a reference was that reported by Ishikawa et al(1). The summary of experimental condition was listed in table 1. The simulation were performed based on the conditions listed prior to comparing with experimental results.

Table 1. PMHS test cases

Case	Sex	Hight (m)	Weight (Kg)	Velocity (Km/h)
T2	Male	1.67	56	25
T6	Male	1.78	65	32
T9	Male	1.75	68	39

2. Simulation Model

The vehicle model used was simplified as shown in Figure 3. The bumper, hood edge, hood are modeled by ellipsoids and front windshield modeled by a plane.

All the components of the vehicle modeled as solid bodies featuring rigidity in terms of variable representing the amount of pedestrian invasion into vehicle body. And coefficient of friction between pedestrian and vehicle body was 0.25 and that between pedestrian and road surface was 0.67.

Each joint character could be determined by comparing the results of the PMHS tests and simulations. Those were described by comparison between that of Hybrid Ⅱ dummy which is widely used for frontal crash tests.

When compared with Hybrid Ⅱ properties, the one determined featured a Neck bending rigidity of approximately 25% and a Torso bending rigidity of approximately 50%. The lateral bending characteristics of Hip joint is free until it reached to 30 degree. And lateral bending of Knee is 200Nm at bending angle 15° Lateral bending of Ankle is 120Nm at bending angle 30°. The bending rigidity for the Shoulder and Elbow joints remained minimal. And Ishikawa (1) describes stretch behavior of human body. Then elongation type of spine model was produced and was included in the options. The elongation properties were identified by experimental result of several cases that achieved by varying vehicle velocity.

3. Simulation results

Figure 5. shows behavior of human model after crash at experimental condition T6 test for example of calculation.

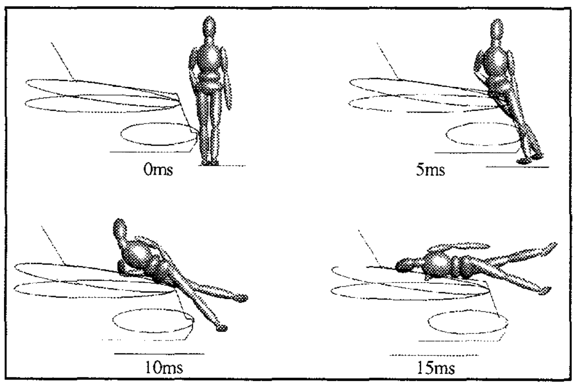

Figure 5. Simulation example

And Figure 6. explains trajectories of each pedestrian parts. Figure 7. shows Head velocities at different velocity conditions of T2, T6, T9.

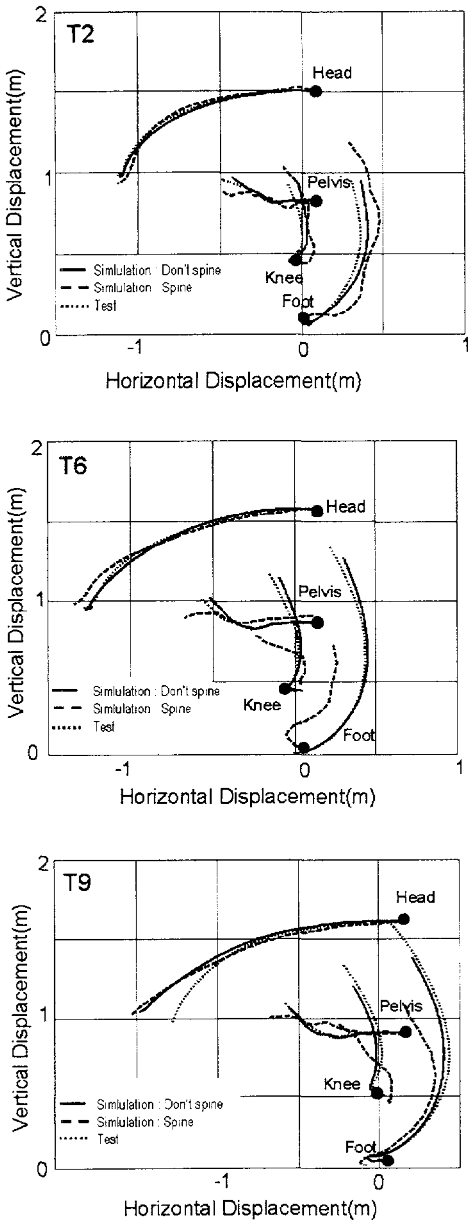

Figure 6. Trajectories of body segments (Fixed car body coordinate)

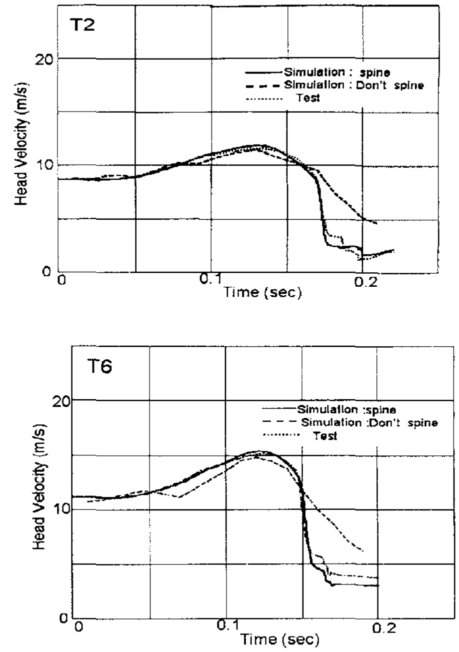

Figure 7. Head resultant velocity

In Figure 6. and 7., dotted lines represent the experimental results, whereas the solid lines shows simulation. Two combinations of the lines represent results that does not considering spine elongation. In Figure 6., each trajectory represent those of the Head, Pelvis, Knee, Foot in relation to vehicle coordinate.

Looking at trajectory of pedestrian after crash, in the case of T2 that has low velocity, simulation result shows good corresponding with experimental result. Oppositely in the case of T9 that has high velocity condition, ultimate difference reached approximately 220mm in Head trajectory.

Then considering the elongation of spine joint, adding the elongation properties correspond with test, we obtained the nearly trajectory of head at case T9.

And foot behavior shows difference between simulation and test in case T6. The reason for the difference in the leg trajectories under T6 condition was attributable to the fact that the simulation did not deal with a leg bone fracture which had occurred in the experiment.

In Figure 7., head velocity at low velocity condition shows better corresponding than that of high velocity cases. As same as trajectory of body parts, it shows consideration of spine elongation supply better corresponding for test result of T9.

Analytical Results with Mass Production Vehicles

1. Analysis with FEM Vehicle Model

As the examples of car-pedestrian crash simulation, examination was made to show the influence of configuration at mass product vehicles. Figure 8. and Figure 9. depict cross section of mass production models used in the simulation.

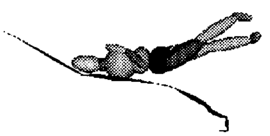

Figure 8. Vehicle A

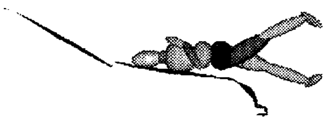

Figure 9. Vehicle B

There had been no significant differences in the striking potential between vehicles A and B in the impactor test similar to the EEVC.

At first he FEM models of car A and car B were made. And the analytical dummy models, described in the earlier sections, were set at between 140-160cm in height, which represent the majority of casualties in road traffic accident in Japan.

Calculation was executed using the dummy and FEM car model in environment of PAM-CRASH.

2. Difference of Head Trajectory

Firstly the comparison of head trajectory between car A and car B was investigated from results of accident simulation.

The analysis showed that there were differences in contact points and angles, though no significant difference was found with the head velocity at the moment of contact.

Showed by Figure 10., the head trajectory of Vehicle B finished relatively forward of area when compared with that observed with Vehicle A. Additionally, the contact angle was larger in case of Vehicle A. At the other hand velocity of head is almost same.

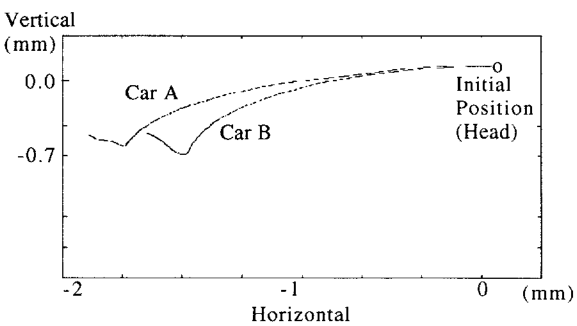

Figure 10. Head Trajectories

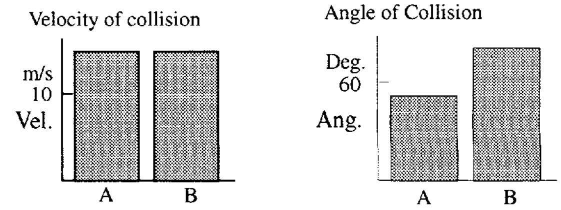

Fig 11. Head Velocities and Angles

This is presumed to be caused by the influence of the front-end design difference, which resulted in the differences in dummy behavior.

In the impactor test currently being carried out, the crash velocity and angle of the impactor to the vehicle are defined as constant.

3. Difference of Chest Trajectory

Secondly, the comparison of chest trajectory was investigated. As shown in Figure 12., the chest trajectory of the pedestrian with a height between 150-160cm tended to come into contact with the hood area above the cylinder head. Then it is possible that chest injury becomes different between Vehicle A and B.

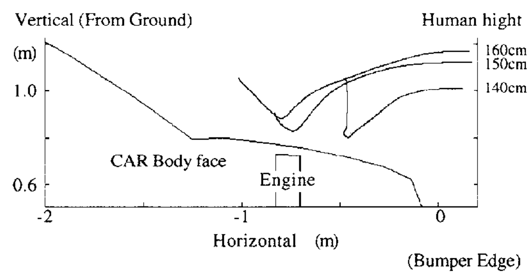

Figure 12. Chest trajectories

The difference of pedestrian behavior between car A and car B can be estimated by followings. One is difference of head angles when head contacts the car, and another is difference of contact position of chest that caused by frontal shapes of cars.

As a result, the simulation system was proved to be somewhat effective in revealing the difference in pedestrian body behavior due to the difference in front-end configuration, which had not been identified by the impactor test.

Conclusion

About the pedestrian behavior in the accident, described ellipsoidal simulation dummy could correspond to several experimental results. Also, the FEM analysis method which is basis for analytical evaluation of the vehicle body configuration and structure was established.

For future studies, the amount of data would be increased as much as possible in order to further improve the joint and elongation characteristics. And it is considered necessary to develop dummy model that can calculate injury seriousness, to predict injury of pedestrian. Then the measure for this problem, the dummy model build by FEM element is now considered (Figure 13.).

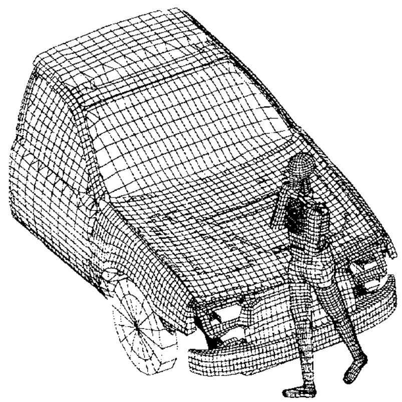

Figure 13. Finite Element Dummy

It can be made automatically for each height and weight. Basic model should be a EuroSID model with the 15 joints from the neck down to the hip. Upper leg, hip, chest, head, and arms are modeled using the FEM mesh. Injury analysis will be conducted with the model.

6. Acknowledgment

Finally, the authors would like to extend their gratitude to Dr. Hirotoshi Ishikawa of the Japan Automobile Research Institute (JARI) for valuable advice in developing the simulation system.