Ⅳ-232 Effect of Tire Models on Estimating Model Parameters for Reconstructing Traffic Accidents

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1. Introduction

The main purpose of this study is to compare the effect of tire models on estimating unknown model parameters in reconstructing traffic accidents. For driving simulation in the pre-impact and post-impact phases, we introduced three tire models; Sakai's tire model, modified Sakai's tire model[1,2] and Gim's tire model[3]. And then, we combined them with the two-dimensional car-to-car impact model, which was first proposed by Ishikawa[4,5]. Assuming that we could determine the vehicle movement in the pre-impact phase preliminary based on the driver's witness, skid marks and accident site conditions, we defined the unknown parameters in those models; friction coefficient, steering angle, slip ratio of the front tires and slip ratio of the rear tires in the tire model, and normal and tangential restitution coefficients in the impact model. We estimated these unknown parameters so as to minimize the difference between the calculated and observed rest positions of vehicles. For this purpose, we employed Box's complex algorithm[6]. After the validity of Box's method in estimating the model parameters was examined using an artificial accident data, the model parameters of an actually observed traffic accident were estimated for three tire models.

2. Traffic Accident Reconstruction Model

(1) Tire models

A tire model is required for obtaining interaction friction forces between a tire and road surface. There are three main forces; the side force, the braking force or traction force, and self-aligning torque. We introduced three tire models; Sakai's tire model, modified Sakai's tire model[1,2] and Gim's tire model[3]. Under the assumptions that slip angle and slip ratio of tire are small and tread beam of tire is not bent in the lateral direction, Sakai proposed the tire model. To treat the problems in which slip ratio and slip angle are relatively large, Sakai modified the original model. In the new model, he considers the friction coefficient that depends on velocity, the contact pressure order with order of 4, and the bending and torsion of the tread in the lateral direction. Another tire model was proposed by Gim and Nikravesh. In this model not only slip angle and slip ratio but also camber angle was considered. However, the bending and torsion produced by side force were not considered. The forces between tire and road surface are non-linear function of combined slip ratio, slip angle, and camber angle.

(2) Impact model

In this model, there are three degrees of freedom for each vehicle; two translations and one rotation. The model is analyzed in a coordinate system in which the lateral and longitudinal axis's are normal and tangential to the impact center, respectively. In order to apply the model, six equations are necessary: four equations can be obtained from the conservation of linear and angular momentum. The last two equations are obtained from the constraint conditions at the impact center, in which the normal and the tangential restitution coefficients are defined.

3. Estimation of Model Parameters

We assumed that the movements in pre-impact phase were known in advance, based on the data collected from the accident site, driver's witness and damage profiles. In other words, we adopted that some model parameters in the both impact and post-impact were unknown.

(1) Model parameters

The unknown parameters from the impact model are :

e_n : Normal restitution coefficient.

e_t : Tangential restitution coefficient.

The unknown parameters from the tire model are :

u_i: Friction coefficient.

H_i = Steering angle.

$S.F_i$ = Slip ratio of front tire.

$S.R_i$ = Slip ratio of rear tire.

Where i denotes the striking or struck vehicle.

(2) Estimation of parameters

We estimated the unknown parameters using Box's algorithm. In this method, we estimated the parameters so as to minimize the difference between the calculated rest positions of the vehicles and the observed ones. Box's method[6] is a kind of sequential search technique for finding a minimum objective function while avoiding entrapment into the local minimum.

(3) Comparison of tire models in estimating model parameters by Box's complex algorithm

Data from an artificial traffic accident was introduced to compare the effect of tire models in estimating the model parameters by Box's method for reconstructing traffic accidents. We assumed that an accident, as shown in Fig. 1, occurred on a street. We specified the model parameters in advance. The initial, impact and rest positions are denoted by points 1, 2 and 3, respectively.

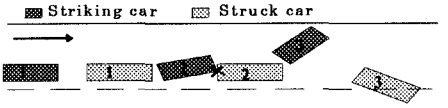

Fig. 1 Front to rear accident based on artificial data.

We calculated the rest position of each vehicle using the tire models combined with impact model, and then we compared the estimated parameters with the assumed ones using the tire models which are shown in Fig. 2. Using Gim's tire model and modified Sakai's tire model, the difference between them was sufficiently small. It was found that the differences between calculated rest positions of vehicles and assumed ones, Using Gim's tire model, are less than the others for each vehicle.

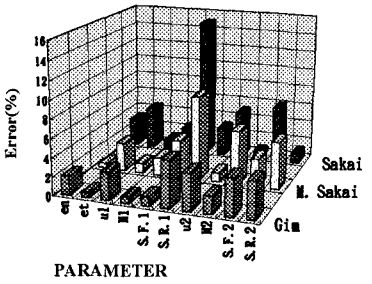

Fig. 2 Differences between assumed and estimated parameters.

4. Actual Traffic Accidents Data

A side impact accident occurred at an intersection as shown in Fig. 3. The driving simulation of the pre-impact phase was performed based on the data collected from the accident site. Table 1 presents the estimated parameters.

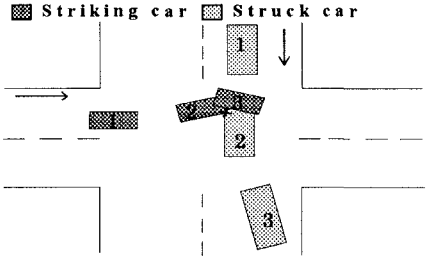

Fig. 3 Side impact accident based on observed data.

Table 1 Estimated parameters by Box's method, using Gim's tire model(2th row), modified Sakai's tire model (3th row) and Sakai's tire model(4th row)

e_n	e_t	u_1	H_1	$S.F_1$	$S.R_1$	u_2	H_2	$S.F_2$	$S.R_2$
-0.3	-0.9	0.25	-30°	0.7	0.8	0.3	-35°	0.6	0.6
-0.2	-0.8	0.45	-25°	0.55	0.55	0.6	-32°	0.5	0.7
-0.55	-0.64	0.48	2.86°	0.56	0.8	0.75	-31.5°	0.25	0.8

It is difficult to judge whether the parameters are reasonable or not. Maybe the parameters were much reasonable when Gim's tire model and modified Sakai's tire model were used. We have to investigate the validity of the ranges of constraints for all parameters, in combination with experimental data. This will help us to confine the ranges of the model parameters and to improve consequently the precision of estimation. The differences between the observed and the estimated rest positions are shown in Fig. 4 and 5. It should be noted that when the Gim's tire model and modified Sakai's tire model were used the differences were less than the other.

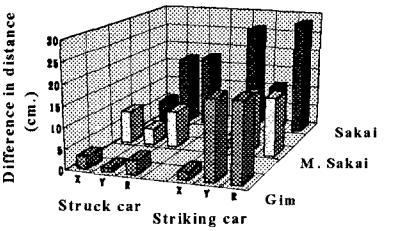

Fig. 4 Distance differences between observed rest positions and estimated ones.

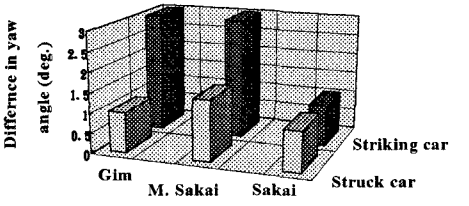

Fig. 5 Yaw angle differences between observed rest positions and estimated ones.

5. Conclusions

From this study the following conclusions can be drawn:

1) The impact model, combined with the driving simulation model including one of the Sakai's tire model, modified Sakai's tire model and Gim's tire model, was applicable for reconstructing traffic accidents.

2) Box's complex algorithm was effective in estimating the impact coefficients and the driving simulation parameters for reconstructing traffic accidents.

3) The driving simulation model including one of Gim's tire model or modified Sakai's tire model was much accurate in estimating model parameters by Box's complex algorithm.

References

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