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Study on side collision reconstruction using database based on deformed shape information †

Jeonghyun Sohn[1], Seokcheon Park[1], Jaewook Lee[2] and Wansuk Yoo[2,*]

[1]*Department of Mechanical Engineering, Pukyong National University, 608-739, Busan, Korea*
[2]*Department of Mechanical Engineering, Pusan National University, 609-735, Busan, Korea*

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Abstract

A side collision reconstruction algorithm using a database based on the deformed shape information from experiments is suggested. A deformation index related to the deformed shape is developed to set the database for the side collision reconstruction algorithm. Two small-sized model cars are developed to carry out the side collision test. Several side collision tests according to velocities and collision angles are performed for establishing side collision database. A high speed camera with 1000fps is used to capture the motion of the car. Side collision reconstruction algorithm is developed and applied to find the collision conditions before the accident occurred. Several collision cases are tested to validate the database and the algorithm. A database from computer simulation is verified with experiments. According to comparing errors between simulation and experiment, it is satisfied within 6.6%.

Keywords: Accident reconstruction; Collision test; Model cars; Side collision simulation

1. Introduction

The meaning of a collision reconstruction is to identify the cause of an accident and to reconstruct the conditions before a collision by using all the information after a collision. Reconstruction of a car collision accidents deals with the analysis of the cause of the accidents and collision behavior by using the available information from vehicle accident circumstances. In many researches, the collision reconstruction is based on the principle of the impulse-momentum, a restitution coefficient, and an impulse ratio at the impact center [1-3]. Strother measured the stiffness and developed a method for calculating the deformation energy according to velocities from the experiments [4]. Ueyama studied the determination of collision configurations from vehicle deformation patterns [5]. In past researches, the finite element models for accident reconstruction were well developed but not verified with experiments because of costs and time. But an experiment which uses model cars can be an alternative.

In this study, a side collision reconstruction algorithm using a database based on the deformed shape information from experiments of model cars is suggested. A deformation and angle index related to the deformed shape are developed to set the database for the side collision reconstruction algorithm. Two small-sized RC cars are developed for the side collision test. Several side collision tests according to velocities and collision angles are conducted to establish the side collision database. A high speed camera with 1000fps is used to capture the motion of the car and a sensor (LVDT) is used to measure the deformation of the car after the collision.

From the tests, all the information related to the deformation is used to build the database. Moreover, collision database information in the side of cars is

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*Corresponding author. Tel.: +82 51 510 1457, Fax.: +82 51 581 8514
E-mail address: wsyoo@pusan.ac.kr

used for giving a basis for scientific and practical reasons in a reconstruction of the car accident. A side collision reconstruction algorithm is developed and applied to find the collision conditions before the accident occurs. Several collision cases are tested to validate the presented database and algorithm.

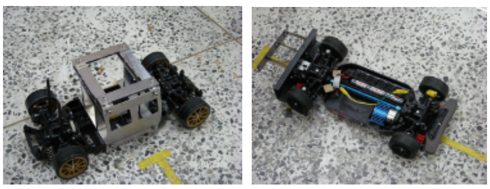
2. Experiments of side collision

2.1 Experimental setup

Model cars as shown in Fig. 1 are made for the side collision test. The suspension and frame of the model cars are made at 10% size of a racing car. But, the weights and stiffness are not considered. The collided car is 2,000g and the colliding car is 1410g. Two small-sized RC (Remote Control) cars have the following dimensions: wheelbase 198mm, length 365mm, and width 183mm.

The side door of a colliding car has a round shape and the bumper of the colliding car has the 4 support beam. As shown in Fig. 1, the side door of the collided car is bolted to the frame. The door and bumper parts for test cars are designed by using CATIA. The material for door and bumper is selected as SS41. Computer simulation was carried out by using LS-Dyna 3D. First, a pre-analysis was done to set the thickness of material and curvature radius of the door which can represent the deformation of a real accident car well enough. But, it is impossible to find the deformation of the real car according to the velocities and collision angles. So, in this research, to have similar results with the full car simulation as shown in the reference [4], the thickness and radius are set to 0.8mm and 106mm, respectively. The numbers and dimensions of the support beam are set to show the bump deformation well according to the collision angle.

The deformation quantities of the side door are measured by using LVDT for calculating the deformation and angle index. The deformation of each test piece is measured before and after the collision. Tests with 3 different velocities, 18, 22, 26km/h, and 3 different collision angles, 60, 70, 90 degrees are performed.



(a) Collided car (b) Colliding car

Fig. 1. Model cars used in tests.

2.2 Deformation index

Fig. 2 shows the deformed shape according to collision velocities and angles. Tests were performed for 9 cases. The side door is divided into 12 sections with 10mm in horizontal direction and 7 sections with 8mm in vertical direction, respectively. The deformation index is calculated by using Eq. (1).

$$I_d = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M} x_{ij}^2}{T} \quad (1)$$

where T (=84) is total number of nodes, and N (=7), M (=12) means the number of nodes in vertical and horizontal direction, respectively. The value of x_{ij} means the deformation value at position (i,j). The index means the mean square of deformations.

2.3 Angle index

The right half side of the door is mainly deformed; therefore, the right half side of door is considered for calculating the angle index. The angle index from side door deformation can be calculated by Eq. (2). At Eq. (2), denominator, 60, means the horizontal length of right half side. The deformation of the bump support beam is considered for calculating the angle index as shown in Eq. (3)

$$\alpha = \sum_{i=1}^{7} \frac{x_{i12} - x_{i6}}{60} \quad (2)$$

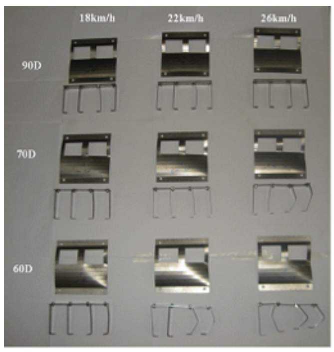


Fig. 2. Deformed shape according to collision velocity and angle.

$$\beta = \sum_{i=1}^{6} \theta_i \tag{3}$$

Finally, the angle index is defined as Eq. (4)

$$I_a = \alpha + \beta \tag{4}$$

3. Database construction using simulation

It is difficult to build a database for all the cases though experiments. Therefore, a database from the computer simulation was established. LS-Dyna 3D program for computer simulation was employed and HyperMesh was used for finite element modeling of the model cars. The number of nodes, solid elements, and shell elements is 32189, 24804, and 4391, respectively. Piecewise linear plasticity is applied to the door and bumper. The other parts are considered as elasticity property. Figs. 3 and 4 show the comparisons of collision velocities in case of 22km/h, 60deg, and 26km/h, 90deg, respectively. As shown in Figs. 3 and 4, the results of simulation show a good agreement with those of experiment. However, when the car collides with 18km/h at 90 degrees, there are relatively big errors compared to others. Because when the car collides at 90 degrees, the rollover motion of the collided car is larger than in the simulation. The differences are due to that. And the deformation and angle index have the tendency according to the velocities and impact angles. So, the presented database using the two indices can be used in reconstruction of the conditions before the impact.

4. Reconstruction examples

4.1 Reconstruction algorithm

The reconstruction algorithm for the side collision accident is as follows:

1) The deformation after the collision with the arbitrary speed and angle is measured.
2) The deformation index and the angle index are calculated from the measured information.
3) Angle index at the first velocity (18km/h) and the last velocity (26km/h) of database recalculated from the interpolation by using the calculated angle index at step 2.
4) Deformation indices at the first velocity (18 km/h) and the last velocity (26km/h) of the database are calculated.

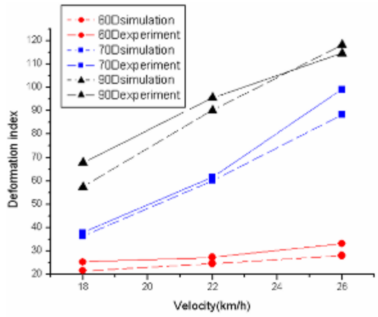


Fig. 3. Comparison of the deformation index.

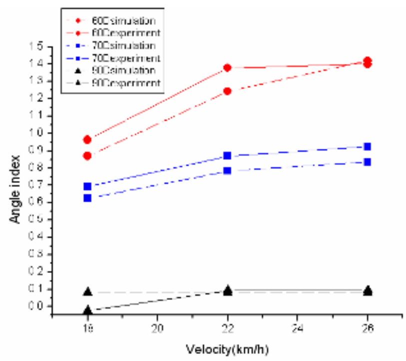


Fig. 4. Comparison of the angle index.

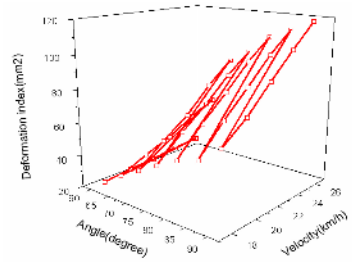
5) Gradient of deformation index is calculated by using deformation indices calculated at step 4.
6) By comparing the deformation index at step 4 with the gradient of deformation index, the collision velocity is calculated.
7) Gradient of angle index is calculated by using angle indices calculated at step 3.
8) By comparing the angle index at step 3 with the gradient of angle index, the collision angle is calculated.

4.2 Reconstruction examples

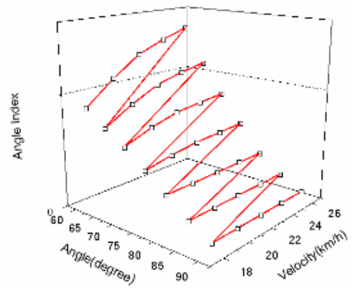
Fig. 5 shows the resultant deformation and angle index according to various impact velocities and angles. To show the fidelity of this paper, two reconstruction examples are suggested. In case 1, deformation and angle index calculated from deformation information are 86.0 and 0.34, respectively. In case 2, deformation and angle index are 54.5 and 1.13, respectively. As shown in Table 1, case 1 shows more errors compared to case 2. The velocity and angle are algorithmically affected by the gradient of the deformation index at the first step. Moreover, since there are no experimental data between 70 and 90 degrees,

Table 1. Comparison of results of accident reconstructions using simulations.

DB	Velocity (km/h)	18, 20, 22, 24, 26	
	Angle (deg)	60, 65, 70, 75, 80, 85, 90	
Case1 (20km/h, 80°)	Prediction	22.89km/h	80 °
	Error	14.45%	0%
Case2 (24km/h, 65°)	Prediction	25.6km/h	64.4 °
	Error	6.6%	0.86%



(a) Deformation index



(b) Angle index

Fig. 5. Resultant deformation and angle index according to various impact velocities and angles.

the gap between 70 and 90 degrees is bigger than that between 60 and 70 degrees. Therefore, the error of case 1 shows larger than the other.

5. Conclusions

Two different cases with arbitrary velocities and angles were tested for verifying the reconstruction algorithm. The following conclusions are drawn from the verification.

1) The velocity prediction error shows 14.45 and 6.6%. And the angle prediction error shows 2.90 and 0.43%.
2) The suggested algorithm is reliable because the errors are relatively small.
3) When the number of tests increases, the errors may be smaller.
4) According to the comparison of simulations with experiments, the errors are relatively small. Therefore, simulations can be used in many other accident cases instead of experiments.

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Dr. Jeong-Hyun Sohn received his B.S. degree from Pusan National University (1995), M.S. from PNU (1999), and Ph.D. from PNU (2002). He is currently an associate professor in the department of Mechanical Engineering at Pukyong National University in Busan, Korea. He is currently serving as a board member of dynamics and control division, KSME. His major area is vehicle dynamics and flexible multibody dynamics.

Dr. Wan-Suk Yoo received his B.S. degree from Seoul National University (1976), M.S. from KAIST (1978) and Ph.D. from University of Iowa(1985). He is professor at Pusan National University, and currently serving as a vice president in KSME. His major area is vehicle dynamics and flexible multibody dynamics.