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Effect of Collision Parameters on the Pedestrian Thoracic Dynamics Response and Injury

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Abstract: To investigate the effect of collision parameters (impact area of hood, vehicle velocity, walking speed of pedestrian, pedestrian gait and pedestrian orientation) on the dynamics response and injury of pedestrian thorax by combining the merits of Finite Element (FE) method and analytical method of Multi-body (MB) system, the FE vehicle models and the MB pedestrian dummies were used to coupling simulations. The research shows that for collision situations of pedestrian thorax in contact with the hood and the lower part of the front windshield, the collision speed and pedestrian orientation were the two important parameters effecting the dynamic response and injury of pedestrian thorax. This result is of vital significance for the reconstruction of collisions and the mechanism of pedestrian thoracic injuries.

1. Introduction

Researches on vehicle-pedestrian impact reconstruction and pedestrian injury biomechanics are still hot topics of concern [1]. Although the most vulnerable part of pedestrians in a collision is the head, the thoracic injury is an important reason for their death and disability. Researches on thorax dynamic response and injury can not only provide an effective way for reducing pedestrian thorax injury risk, but also help guiding the clinical implementation of better diagnosis and treatment for traffic injuries of thorax. On the other hand, investigating the effect of collision parameters (impact area of hood, vehicle velocity, walking speed of pedestrian, pedestrian gait and pedestrian orientation) on the dynamics response and injury of pedestrian thorax is essential for the reconstruction of vehicle-pedestrian collisions and the mechanism of pedestrian thoracic injuries.

2. Materials and methods

Coupling simulation models included two vehicle models and two pedestrian models. The diagrams of the collisions between sedan and 5% pedestrian dummy, the collisions between sedan and 50% pedestrian dummy, the collisions between minivan and 5% pedestrian dummy and the collisions between minivan and 50% pedestrian dummy were shown in Fig. 1. Impact area of hood (A_H), vehicle velocity (V_V), walking speed of pedestrian (S_P), pedestrian gait (G_P) and pedestrian orientation (O_P) were chosen as the simulation parameters. And the parameters levels of simulations were shown in Table 1. Sixteen sets of data extracted from orthogonal experiments was analyzed by analysis of variance, and p values < 0.05 was taken as significant.

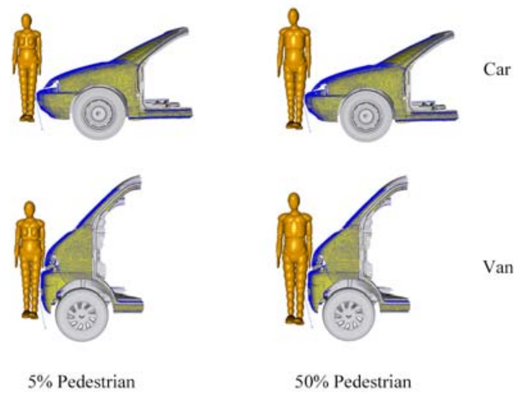

Fig. 1 Diagrams of coupling simulation models

Table 1. Parameter levels of simulations

Factors	A_H Impact area of hood (distance from center)/(cm)	V_V Vehicle velocity /(km • h^{-1})	S_P Walking speed of pedestrian /(m • s^{-1})	G_P Pedestrian gait	O_P Pedestrian orientation
Level 1	-30	30	0	Parallel	Contact back
Level 2	0	40	1	Right ahead of left	Contact right side
Level 3	15	50	2	Left ahead of right	Contact left side
Level 4	45	60	3	Protect head	Contact front

3. Results

3.1 Crash results of sedan-5% pedestrian dummy

It could be seen from Table 2 that the walking speed of pedestrian had a significant effect on the peak value of thoracic linear acceleration; the vehicle velocity and pedestrian orientation had a significant effect on the VC and thoracic 3ms acceleration; the impact area of hood had a significant effect on the thoracic 3ms acceleration.

Table 2. ANOVA tables for crash results of sedan-5% pedestrian dummy

	T_Vp	T_Lacp	D	VC	Con3msT
A_H	0.348	0.559	0.805	0.058	0.015
V_V	0.130	0.063	0.310	0.005	0.000
S_P	0.470	0.037	0.992	0.199	0.091
G_P	0.562	0.181	0.778	0.270	0.053
O_P	0.202	0.430	0.404	0.023	0.003

3.2 Crash results of sedan-50% pedestrian dummy

It could be seen from Table 3 that the pedestrian orientation had a significant effect on the peak value of thoracic linear velocity; the vehicle velocity and pedestrian orientation had a significant effect on the peak value of thoracic linear acceleration and VC; the vehicle velocity had a significant effect on the thoracic 3ms acceleration.

Table 3. ANOVA tables for crash results of sedan-50% pedestrian dummy

	T_Vp	T_Lacp	D	VC	Con3msT
A_H	0.431	0.230	0.416	0.155	0.214
V_V	0.377	0.021	0.377	0.013	0.001
S_P	0.428	0.220	0.579	0.164	0.718
G_P	0.508	0.054	0.527	0.091	0.627
O_P	0.046	0.007	0.180	0.002	0.062

3.3 Crash results of minivan-5% pedestrian dummy

It could be seen from Table 4 that the pedestrian orientation had a significant effect on the peak value of thorax linear acceleration; the vehicle velocity and pedestrian orientation had a significant effect on the VC and thoracic 3ms acceleration.

Table 4. ANOVA tables for crash results of minivan-5% pedestrian dummy

	T_Vp	T_Lacp	D	VC	Con3msT
A_H	0.072	0.343	0.108	0.148	0.669
V_V	0.159	0.100	0.640	0.014	0.002
S_P	0.448	0.186	0.921	0.162	0.589
G_P	0.159	0.203	0.667	0.160	0.470
O_P	0.002	0.086	0.158	0.000	0.014

3.4 Crash results of minivan-50% pedestrian dummy

It could be seen from Table 5 that the pedestrian orientation had a significant effect on the peak value of thorax linear velocity; the vehicle velocity and pedestrian orientation had a significant effect on the peak value of thoracic linear acceleration, VC and thoracic 3ms acceleration.

Table 5. ANOVA tables for crash results of minivan-50% pedestrian dummy

	T_Vp	T_Lacp	D	VC	Con3msT
A_H	0.280	0.026	0.814	0.132	0.534
V_V	0.190	0.006	0.555	0.016	0.000
S_P	0.744	0.051	0.670	0.240	0.554
G_P	0.840	0.065	0.707	0.370	0.097
O_P	0.003	0.000	0.145	0.000	0.014

4. Discussions

The thoracic linear velocity, linear velocity, maximum compression, VC and thoracic 3ms acceleration are the most common parameters used in the study on the dynamic response and injury of pedestrian thorax. Many researchers at home and abroad have made a body of researches and have gained great achievements based on these parameters. Watanabe [2] and Han [3] pointed out that the collision velocity was the most significant parameter effecting the severity of pedestrian thoracic injury. Han [3] also suggested that there was a significant correlation between thoracic injury and head injury. Watanabe [4] and Zou [5] reported that the collision speed and vehicle type have a greater impact on the pedestrian thoracic injury. Zou [5] also suggests that there was a higher correlation between the pedestrian thoracic injury and the head injury than lesions in the other body parts. More attention should be paid to the connection between the head and the thoracic injury of pedestrians. So that the injuries and traces of vehicle-pedestrian collisions can be better validated. Fu [6] reported that pedestrian thoracic injury would be effected by the geometrical structure of the front-end of minivan. Zhao [7] pointed out that there were significant differences in the dynamic response and the severity of pedestrian thoracic injury caused by van-pedestrian collisions and sedan-pedestrian collisions. Han [8] thought that the shape of vehicle front-end would affect the pedestrian thorax-vehicle contact time, synthesis collision velocity, synthesis collision angle and so on; characteristics of vehicle front end structure would affect the energy absorption of pedestrian thorax; the deform degree and the deformation pattern of pedestrian thorax would be effected by the local stiffness distribution of the vehicle's front-end (vehicle engine hood, front windshield and its lower crossbeam, etc.). The load, the deform degree and the deformation pattern of pedestrian thorax are the important factors effecting the severity of thoracic injury in the vehicle-pedestrian collisions. Liu [9] pointed out that the collision speed and pedestrian orientation in the car-pedestrian collisions would significantly affect the dynamic response and injury of pedestrian thorax.

This study was carried out by analyzing the collisions between sedan and 5% pedestrian dummy, the collisions between sedan and 50% pedestrian dummy, the collisions between minivan and 5% pedestrian dummy and the collisions between minivan and 50% pedestrian dummy. The results showed that the collision speed and pedestrian orientation were the two important parameters effecting the dynamic response of pedestrian thorax, and the they were the two important parameters effecting the severity of pedestrian thoracic injury (VC and thoracic 3ms acceleration) as well. This study confirmed the important role of collision speed and pedestrian orientation in vehicle-pedestrian impact on the dynamic response and the severity of injury of pedestrian thorax.

We should note that the conclusions of this research are primarily applicable to collision situations of pedestrian thorax in contact with the hood and the lower part of front windshield. Therefore, the other situations need more attention in the future.

5. Conclusion

This research demonstrated that, for collision situations of pedestrian thorax in contact with the hood and the lower part of front windshield, the collision speed and pedestrian orientation were the two important parameters effecting the dynamic response and injury (VC and thoracic 3ms acceleration) of pedestrian head.

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