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Influence of Pedestrian Size and Vehicle Type on the Pedestrian Thoracic Dynamics Response and Injury

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Abstract. To investigate the influence of the pedestrian size and vehicle type 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. Our results show that the pedestrian dummy size had a significant influence on the thoracic maximum compression; the pedestrian dummy size had no significant influence on the peak value of thoracic linear velocity, peak value of thoracic linear acceleration, VC and thoracic 3ms acceleration. For 5% pedestrian dummy, the vehicle type had a significant influence on the thoracic maximum compression; the vehicle type had no significant influence on the peak value of thoracic linear velocity, peak value of thoracic linear acceleration, VC and thoracic 3ms acceleration. For 50% pedestrian dummy, the vehicle type had a significant influence on the peak value of thoracic linear velocity and thoracic maximum compression; the vehicle type had no significant influence on the peak value of thoracic linear acceleration, VC and thoracic 3ms acceleration. The conclusions of this study can be drawn: for collision situations of pedestrian thorax in contact with the hood and the lower part of front windshield, the vehicle type and pedestrian size might affect the thoracic dynamics; but they were not significant factors that affected the severity of pedestrian thoracic injury. This finding is of vital significance for the reconstruction of vehicle-pedestrian thorax collisions and the study on the thorax injuries.

1. Introduction

The vehicle-pedestrian impact is still hot topics of concern [1-3]. In the vehicle-to-pedestrian collisions, the pedestrian thorax will suffer from multiple injuries under different load condition, such as rib fractures and internal injuries with different distributions and severities. Researches both at home and abroad found that the vehicle type, collision speed, pedestrian gait, walking speed of pedestrian and pedestrian orientation would affect the pedestrian thoracic injuries [4-10]. The severity of pedestrian thoracic injury is likely to be concerned in the study of vehicle-pedestrian impact. However, for the studies on the reconstruction of collisions and the mechanism of pedestrian thoracic injuries, the dynamic response of pedestrian thorax should deserve more attention.

2. Materials and Methods

Two FE vehicle models and two MB pedestrian dummies were used to the coupling simulations (see Fig. 1). We simplified the FE vehicle models by deleting unimportant parts. And we used relative keywords and software to construct the coupling simulation models. 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. Parameter designs of the collisions were

shown as Table 1. Analysis of variance was used to analyze the data extracted, taking p values< 0.05 as significant.

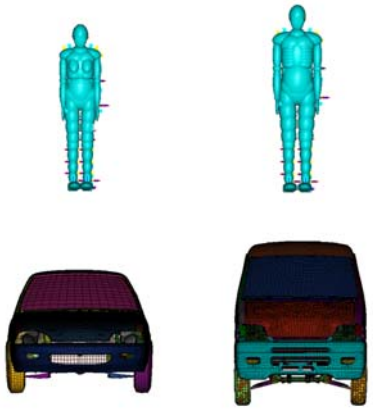

Fig. 1 FE vehicle models and MB pedestrian dummies

Table 1 Parameter designs of simulations

Numble	A_H	V_V	S_P	G_P	O_P
1	0	60	1	Parallel	Contact left side
2	15	30	3	Right ahead of left	Contact left side
3	0	30	2	Protect head	Contact right side
4	15	60	0	Left ahead of right	Contact right side
5	15	40	2	Parallel	Contact front
6	0	40	3	Left ahead of right	Contact back
7	-30	50	2	Left ahead of right	Contact left side
8	45	60	2	Right ahead of left	Contact back
9	45	50	3	Parallel	Contact right side
10	45	40	0	Protect head	Contact left side
11	45	30	1	Left ahead of right	Contact front
12	-30	40	1	Right ahead of left	Contact right side
13	15	50	1	Protect head	Contact back
14	0	50	0	Right ahead of left	Contact front
15	-30	60	3	Protect head	Contact front
16	-30	30	0	Parallel	Contact back

3. Results

3.1 Influence of Pedestrian Dummy Size on Thorax Dynamic Response and Injury

It was clear from Table 2 that, for both vehicle models, the pedestrian dummy size had a significant influence on the thoracic maximum compression (D); the pedestrian dummy size had no significant influence on the peak value of thoracic linear velocity (T_Vp), peak value of thoracic linear acceleration (T_Lacp), VC and thoracic 3ms acceleration (Con3msT).

Table 2 Means comparison of thorax dynamic response and injury with different pedestrian dummy size

	Car		*p*	Minivan		*p*
	5% dummy	50% dummy		5% dummy	50% dummy	
T_Vp	0.47+0.39	0.63+0.58	0.186	0.30+0.16	0.30+0.17	0.967
T_Lacp	1062+1301	1000+1171	0.445	942+1252	931+1341	0.332
D	0.14+0.00	0.17+0.01	0.000	0.13+0.00	0.16+0.00	0.000
VC	0.02+0.04	0.04+0.09	0.216	0.02+0.03	0.02+0.03	0.536
Con3msT	439+154	358+134	0.0563	366+136	341+145	0.540

3.2 Influence of Vehicle Type on Thorax Dynamic Response and Injury

It was clear from Table 3 that, for 5% pedestrian dummy, the vehicle type had a significant influence on the thoracic maximum compression; the vehicle type had no significant influence on the peak value of thoracic linear velocity, peak value of thoracic linear acceleration, VC and thoracic 3ms acceleration. For 50% pedestrian dummy, the vehicle type had a significant influence on the peak value of thoracic linear velocity and thoracic maximum compression; the vehicle type had no significant influence on the peak value of thoracic linear acceleration, VC and thoracic 3ms acceleration.

Table 3 Means comparison of thorax dynamic response and injury with different vehicle type

	5% dummy		*p*	50% dummy		*p*
	Car	Minivan		Car	Minivan	
T_Vp	0.47+0.39	0.30+0.16	0.094	0.63+0.58	0.30+0.17	0.010
T_Lacp	1062+1301	942+1252	0.789	1000+1171	931+1341	0.322
D	0.14+0.00	0.13+0.00	0.000	0.17+0.01	0.16+0.00	0.000
VC	0.02+0.04	0.02+0.03	0.386	0.04+0.09	0.02+0.03	0.160
Con3msT	439+154	366+136	0.089	358+134	341+145	0.685

4. Discussions

The vehicle type and the pedestrian size (height and weight) are common factors 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 factors.

According to our results above, for 5% pedestrian dummy, the vehicle type only had a significant influence on the thoracic maximum compression; and had not a significant influence on the VC and thoracic 3ms acceleration. For 50% pedestrian dummy, the vehicle type had a significant influence on the peak value of thoracic linear velocity and the thoracic maximum compression; and had not a significant influence on the VC and thoracic 3ms acceleration. Therefore, this study found that, as to the same pedestrian size (height and weight), the vehicle type was not a significant factor that affected the severity of pedestrian thoracic injury, which is inconsistent with some of the above studies. Our results suggest that the relationship between the pedestrian size (height and weight) and the dynamic response and injury (VC and thoracic 3ms acceleration) of pedestrian thorax is worthy of further exploration.

Liu [11] reported that there was a positive correlation between the thoracic 3ms acceleration and the collision velocity and pedestrian height, but there was a negative correlation between the thoracic 3ms acceleration and the pedestrian body weight. Li [12] reported that the pedestrian weight would have a slight impact on the severity of thoracic injuries. In our research, the influence of 5% and 50% pedestrian dummy on the thoracic dynamic response and injuries were found that, either sedan or minivan, the size of pedestrian dummy had a significant influence on the thoracic maximum compression, but have not a significant influence on the peak value of thoracic linear velocity, peak value of thoracic linear acceleration, VC and thoracic 3ms acceleration. Therefore, this study found that, as to the same vehicle type, the pedestrian size (height and weight) was not a significant factor that affected the severity of pedestrian thoracic injuries, which is inconsistent with some of the above studies. Based on the above findings, the influence of pedestrian size (height and weight) on the severity of pedestrian thoracic injury is worth exploring more deeply.

We should note that, according to results of this study, 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. The collision situations of pedestrian thorax in contact with hood side edges have not been fully taken into account. Therefore, it needs more attention in the future.

5. Conclusion

Our results demonstrated the significant relationship between the vehicle type, the pedestrian size and the dynamic response of pedestrian thorax. While the results in our study showed that, for

collision situations of pedestrian thorax in contact with the hood and the lower part of front windshield, the vehicle type and pedestrian size were not significant factors that affected the severity of pedestrian thoracic injury, which is worthy of further exploration.

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References

[1]. Wenjun Liu, Hui Zhao, Kui Li, et al. Study on pedestrian thorax injury in vehicle-to-pedestrian collisions using finite element analysis. Chinese Journal of Traumatology. Vol. 18 (2015) No. 2, p. 74-80.

[2]. Wenjun Liu, Sen Su, Jinlong Qiu, etal. Exploration of pedestrian head injuries—collision parameter relationships through a combination of retrospective analysis and finite element method. International Journal of Environmental Research & Public Health. Vol. 13(2016), p. 1250.

[3]. Wenjun Liu, Kui Li, Sen Su, etal. Car-pedestrian accident reconstruction based on finite element simulation and genetic neural network. Yiyong Shengwu Lixue/journal of Medical Biomechanics. Vol. 30 (2015), p. 125-130.

[4]. Kanayama Y, Akiyama A, Okamoto M, et al. Investigation of Injury Measures for the Thorax of a Pedestrian Dummy Based on Two-dimensional Evaluation of Chest Deflection Using Human and Pedestrian Dummy FE Models. Jsae Transactions. Vol. 42 (2011) No. 1, p. 823-828.

[5]. Cavanaugh J M, Yoganandan N. Thorax Injury Biomechanics. Accidental Injury. Springer New York, 2015, p. 331-372.

[6]. Yong Han, Shuozhen Fu, Zhiyong Yin, et al. A Study on Chest Soft Tissue Injury Risk in Vehicle to Pedestrian Collisions. Eighth International Conference on Measuring Technology and Mechatronics Automation. IEEE, 2016, p. 36-39.

[7]. Yong Han, Jikuang Yang. A study on the dynamic responses and injury mechanism of human chest in vehicle-pedestrian collisions. Qiche Gongcheng/automotive Engineering. Vol. 37 (2015) No. 5, p. 516-519 and 537.

[8]. Yang Jiang, Haibo Huang. A study on multiple factors effecting pedestrian injury in pedestrian-car collision accident. China Safety Science Journal. Vol. 27 (2017) No. 3, p. 95-99.

[9]. Yan Wang, Xiaoqing Xu, Bohan Liu, et al. A Study on the Coupling Influence of Impact Speed and Vehicle Type on the Movement and Injury of Pedestrian. Automotive Engineering. Vol. 3 (2015), p. 276-283.

[10]. Qi Chen, Daowen Zhang, Xin Wang. A study on movement form and injury of pedestrian in Minivan-pedestrian collision. China Safety Science Journal. Vol. 25 (2015) No. 9, p. 133-138.

[11]. Jing Liu, Zhongxiang Feng, Hanjian Chen. Simulation research on pedestrian injury severity in traffic accident of human-vehicle collisions. Road Traffic Technology: Application version. Vol. 11 (2012).

[12]. Dan Li: Pedestrian state analysis based on accident reconstruction in pedestrian-vehicle collision (Master, Xi Hua University, China 2016. p. 66).