Head impact conditions for two-wheelers in passenger car collisions – comparison of European and Chinese scenarios

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I. INTRODUCTION

According to the World Health Organization, in 2018 south-east Asia had the largest share of powered two-wheeler (PTW) fatalities (43%) worldwide [1]. To reduce the number of fatally injured two-wheelers, efforts are being made to adjust the passive safety tests for vulnerable road user safety [2], which to date have mainly targeted pedestrian protection. In previous studies, the difference between head impact conditions of pedestrians and bicyclists has been compared [3-4], with a focus on European accident scenarios. In this study, we investigated whether those findings could also be transferred to PTW accidents with a special focus on Chinese accident scenarios and population. The outcome of the analysis of PTW accident parameters and resulting head impact conditions is compared with a previous study focusing on bicyclists [4].

II. METHODS

Accident Analysis

Based on accident data from the China In-Depth Accident Study (CIDAS) [5], the most important accident parameters were analysed. After applying different filter criteria on the CIDAS database (among others: vehicle is a passenger car, VRU is a PTW, vehicle is moving forward, only first crash considered), a total of 2,758 accidents and 369 fully reconstructed accidents were available for analysis of PTW in passenger car collisions.

Impact Simulations

Head impact conditions – wrap around distance (WAD), relative head impact velocity, and relative head impact angle – were evaluated by impact simulations employing Human Body Models and different vehicle and PTW models. The THUMS v4 AM50 and a scaled THUMS v4 meeting the 50th percentile Chinese male (CM50) were used together with two different generic vehicle models (GVTR-Sedan, GVTR-SUV) representative of the current European fleet [4][6] and a generic PTW model [7]. For scaling the AM50 to meet the anthropometry of the 50th percentile Chinese male a uniform scaling factor (0.95%) in x, y and z was applied. Besides the generic vehicle and generic PTW model, three serial cars (Sedan1, Sedan2 and SUV1) and a serial PTW model were used for impact simulations. While the simulations with the GVTR were performed in LS-DYNA vR9.2, the simulations with the serial cars were executed with VPS v2017.07. The head impact conditions are evaluated as described in [4]. Unlike [4], the relative head velocity in x-direction was used for calculating the head impact angle. The parameters of the simulation matrix for the simulated PTW collisions are shown in Table I.

TABLE I
PARAMETERS OF SIMULATION MATRIX FOR PERPENDICULAR PTW COLLISIONS INVOLVING PASSENGER CARS

VRU	Anthropometry	Vehicle collision velocity [km/h]	PTW collision velocity [km/h]	Vehicle shape
PTW	AM50	30	0	Sedan
	CM50	35	15	SUV
		40	20	

III. INITIAL FINDINGS

Accident Analysis

The accident analysis showed that in 83% of the filtered CIDAS accident data the collision partner of the PTW was a Sedan or SUV. It was also shown that nearly half (47%) of involved PTW had a scooter-like shape (no backbone). Most of the passenger car-to-PTW accidents were perpendicular scenarios. Based on the analysis of a heatmap showing the most common combinations of impact velocities of PTW and vehicle, 30 km/h for the vehicle and 20 km/h for the PTW was identified as the most representative scenario. Based on the CIDAS data, the average weight of the male PTW drivers was 70 kg and the height 170 cm, which is close to the 50th percentile male anthropometry reported in [8]. Additional simulations with 35 km/h and 40 km/h vehicle collision velocities and 15 km/h PTW collision velocity were performed for comparisons with the cyclist simulations of [4].

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Impact Simulations

The results in terms of relative head impact velocity and WAD for the different impact simulations for bicyclists and PTW are shown in Fig. 1. For cyclists, mean relative head impact velocities for AM50 simulations of 45.7 km/h for all Sedans and 43.3 km/h for all SUVs were observed [4], which is higher than the head impact velocity of 16.7 km/h for all Sedans and of 32.4 km/h for all SUVs observed for the PTW drivers for the same impact configurations. For the PTW simulations, mean head impact velocities for AM50 of 27.2 km/h for all sedans and 33.1 km/h for all SUVs were observed. The impact velocities of the CM50 were very similar to the AM50 (27.1 km/h for Sedans and 33.9 km/h for SUVs). Regarding WADs, the span observed from the bicyclist simulations was 2014–2708 and 1531–2793 for the PTW simulations. The CM50 simulations showed slightly lower WAD than the simulations with the AM50 stature (maximum 2,433 compared to 2,793).

Boxplots of the relative head impact angle can be seen in Fig. 2. The mean relative head impact angle for AM50 cyclist simulations is 59° for Sedan and 53° for SUV. For PTW simulations, the mean relative head impact angle for AM50 is 37° for Sedan and 63° for SUV. The mean relative head impact angle for CM50 scooter simulations is 43° for Sedan and 55° for SUV. However, the scatter of the observed angles is generally very wide and therefore the reported differences are not significant.

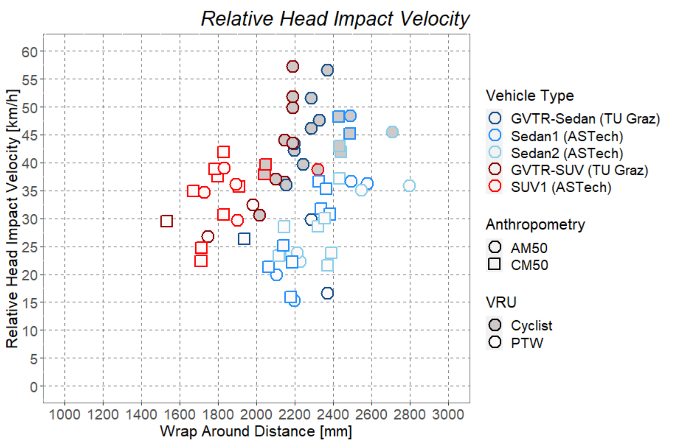

Fig. 1. Relative head impact velocity over WAD for different vehicle types, anthropometries and VRU types for perpendicular scenarios and 30 km/h, 35 km/h and 40 km/h vehicle collision velocities.

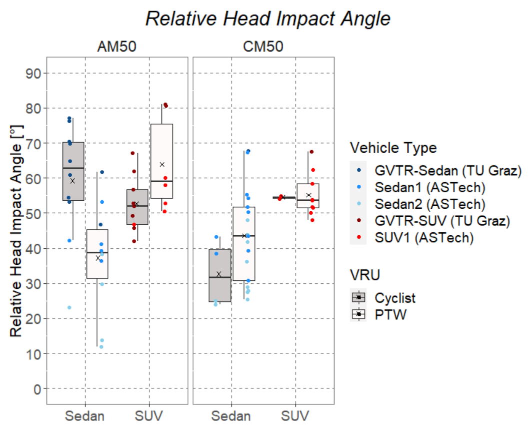

Fig. 2. Relative head impact angle for Sedan and SUV for perpendicular scenarios and 30 km/h, 35 km/h and 40 km/h vehicle collision velocities (mean values are marked with a cross).

IV. DISCUSSION

For PTW drivers, lower head impact velocities were observed compared to cyclists. PTW simulations show lower minimum WADs but nearly the same maximum WAD as cyclist simulations. The head impact angle seems to be very sensitive and a wide range of head impact angles can be observed for PTW and cyclists. The smaller stature of the CM50 model did mainly affect the WAD. It seems that headform impactor speed of 35 km/h, angle of 65° and WAD≤2500, as discussed currently for European regulations to cover cyclists as well, would also cover Chinese PTW accident scenarios. This study also shows that head impact conditions are very sensitive to the vehicle shape.

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VI. REFERENCES

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