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INTERACTION OF CYCLISTS AND CARS DURING SIDE COLLISION – HEAD INJURIES AND CONFRONTATION WITH PEDESTRIAN THROW FORMULAS – MULTIBODY SIMULATION

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SUMMARY

Although the issue of the injury of a cyclist in car collision is in slight shade compared to the pedestrian issues, we cannot completely ignore it. There is an increasing need of attention paid to the bike safety with the growing popularity of motor less single-track vehicles. This study finds out whether it is appropriate to analyze cyclist accidents by using the relations describing the pedestrian throw and using the simulation software models the side-impact collision caused by car. This paper also describes how influential are the forms of the front parts of normal cars and the position of cyclist on three types of bicycles. Initial mechanical and kinematic conditions that affect Head Injury Criterion (HIC) after a car hits a cyclist were determined using simulation software MADYMO. The analysis of formulas which estimate the car speed before the impact contributes mainly in the field of judicial connoisseurship and investigating of car accidents.

INTRODUCTION

This study is focused on the most common type of collision and offers insights into the biomechanics of cyclist's head injury without the use of bicycle helmet. In relation to HIC, three different shapes of the front part of the car and three basic cyclist´s positions were compared. There were 77 cyclists killed on the Czech roads, including 2 children under the age of 14 years. Another 431 cyclists were seriously injured and 2516 slightly injured. The seriousness of accidents (deaths per 1 000 accidents) caused by cyclists in 2008 was 19.6, second highest after motorcycle riders. Out of the total number of 77 cyclists killed in an accident 68 cyclists wore the helmet, i.e. 88.3%. In case of severe injuries 348 cyclists didn't were the helmet (80.7%) and in case of slight injuries 2041 cyclist didn't were the helmet (81.1%). The 60-90% of fatal cyclist injuries were due to head injury [3]. The usual question during the reconstruction of pedestrian accidents is how fast the car was driving when it hit the pedestrian. Groups of investigators determinate relations specially appointed to estimate the impact velocity of vehicles. It is based on the throw distance measured directly on the spot. Such question arises also in accidents of cyclists. Can some of the patterns be use also when cyclists are concerned?

METHODS

For this simulation was chosen a validated model of the human body of 50th‰ of standing pedestrian "h_ped50el". Many attempts have been made to validate pedestrian models in MADYMO by reconstructing the real collisions. The pedestrian model as the cyclist has been validated for lateral impacts up to 40 km/h [5]. Pedestrian model was used as well for bicycle impacts [8]. Multibody modelling of cyclist impacts using MADYMO showed good ability of the model to reproduce cadaver kinematics for a 50 km/h side impact [11]. The model is mounted on bicycle models with a geometry corresponding to a normal mountain bike, road bike and trekking bike. We used the type of vehicle SEDAN with a conventional bow shaped. With this type of vehicle for assessing the influence of the length of the hood we will consider three lengths of hood. In addition, vehicle type SUV with a higher nose and a higher located impact edge and MPV vehicle type, with low-placed impact edge and a shorter hood. The car crashed into the left side of the cyclist. Initial vehicle speed was 35 km/h, 40 km/h and 65 km/h and in all the cases the slowdown of the car was 8.0 m/s/s. To assess the severity of head injury was used HIC.

RESULTS AND DISCUSSION

The values of HIC36 in the contact phase for three different types of cars are summarized in Table 1, for tree length of the front hood in Table 2 and for tree cyclist´s position in Table 3.

Table 1: Average HIC 36 for vehicle type
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HIC36	35 km/h	40 km/h	65 km/h
SEDAN	60	135	927
SUV	216	412	2353
MPV	100	211	1515

Table 2: Average HIC36 for mountain bike and various hood lengths.

HIC36	**35 km/h**	**40 km/h**	**65 km/h**
SEDAN	104	192	731
hood longer 0.2m	172	286	960
hood longer 0.2m	366	515	2235

Table 3: Average HIC36 for each position.

HIC36	**35 km/h**	**40 km/h**	**65 km/h**
Mountain bike	119	180	1345
Road bike	24	46	1009
Trekking bike	234	532	2441

To analyze the cyclist accident using the relations relevant for pedestrian throw, the car speed just before the impact was 40 km/h. The throw distance for each type of car and the position of the cyclist are in the Table 4. The speed determined by using the Schmidt et al. [10] relation differs on average by 3.3 km/h and approaches the most of all non-interval methods the speed of 40 km/h, while the smallest deviations are observed by SUV and MPV. The speed according to Collins, et al. [2] differs on average by 6.3 km/h, according to Limpert [6] by 8 km/h and according to Fugger, et al. [4] by 10.5 km/h. If the interval method [12] was used then the calculated speed was correspondent with SUV and MPV. The values calculated according to Searle, et al. [9] were slightly below the real speed, mainly with SUV and MPV.

CONCLUSIONS

In accordance with the results of the previous study [1] an influence of design of the front vehicle part is evident. The impact velocity and impact angle of the head are very important parameters for the cyclist's head injury [7]. We have demonstrated that the severity of head injury increases with the speed of the car in the moment of the impact. For the higher-positioned center of gravity of a cyclist (trekking bike) the HIC36 is higher than for lower position (road bike). For SUV-type vehicles the HIC36 is higher than for the SEDAN type and the SEDAN type with a longer front hood will cause more severe head injuries than a SEDAN with a shorter front hood.

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Table 4: Calculation of the car speed just before the collision.

Type of car	Type of bike (position of cyclist)	Throw distance (m)	Schmidt, et al. (1971) (impact speed / deviation)		Collins, et al. (1979) (impact speed / deviation)		Limpert (1999) (impact speed / deviation)		Fugger, et al. (2000) (impact speed / deviation)		Searle, et al. (1983) - min max (km/h)		Wood (1997) - min max (km/h)	
SEDAN	Mountain	6,91	34	15%	30	25%	29	28%	27	33%	28	34	25	36
	Road	6,45	33	18%	29	28%	27	32%	26	35%	27	33	24	35
	Touring	7,25	35	13%	31	22%	30	26%	28	31%	29	35	26	37
SUV	Mountain	9,79	40	0%	39	3%	37	8%	33	17%	34	41	27	43
	Road	8,41	38	6%	35	13%	33	17%	30	24%	31	38	25	40
	Touring	8,45	38	6%	35	13%	33	17%	30	24%	31	38	25	40
MPV	Mountain	8,84	38	4%	36	10%	34	14%	31	22%	32	39	29	41
	Road	7,92	36	9%	33	17%	32	21%	29	27%	30	36	27	40
	Touring	8,51	38	6%	35	12%	33	17%	31	24%	32	38	28	40