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Study to the simulation for pedestrian-vehicle collision accident of the second crushing by PC-CRASH

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Abstract. In the pedestrian-vehicle accident, vehicle may make the second crushing for people after collision. Among the fatal accidents caused by this, there is necessary connection between the movement trail of vehicle and the position of pedestrian, therefore, this text compares with their position relationship through simulating the site of accident by PC-CRASH and the simulation between vehicle parameters and the position of pedestrian, analyzing the injury of each part in pedestrian and the condition of AIS. Analyze the whole process of second crushing and analyze accident cause to put forward scientific, effective solutions.

1. Introduction

At present, in the various accidents which cause the death of people, the accidents caused by motor vehicle continuously increase every year. The most fatal type is caused by second crushing of vehicle in pedestrian-vehicle collision accidents. Second crushing is that driver of motor vehicle re-crush suffer through backing the car or turning direction after colliding suffer to make him injured but not dead. This is the malignant activity to make suffer dead. Therefore, enhance the study to the simulation of pedestrian-vehicle collision accidents is good for just identification of accident liability. Now, the most mature technique to study simulation of pedestrian-vehicle collision accidents is to use PC-CRASH to simulate traffic accident, and it can judge the responsible party of accident through the data of simulation. In 2009, Hua Xiaomin put forward a type of research method to analyze the result error for simulation of pedestrian-vehicle collision accidents by PC-Crash, and this method introduces the relevant solutions. In 2014, Wang Chen made study to simulation of car-guard bar accident by PC-CRASH, which rebuilds field model of accident and specifically analyzes the preventive plan and the damage of driver caused in the process of collision. [1] However, China has no relevant experimental case before, so they have great research significance..

2. Introduction of PC-CRASH

In 1999, Austrian Doctor Hermann Steffan developed a type of new software based on the model Kudlich-Sliba, namely PC-CRASH, which is the basic software to study the simulation reappearance of traffic accident, and also the learning model for other relevant software. PC-CRASH, the typical software used for accident simulation through momentum and impulse momentum method, has very strong practicability. Later, in order to verify the applied accuracy of PC-CRASH in reality, Cliff and relevant people use the software data of JARI and RICSAC to make check analysis for this system, and the conclusion is that this software can automatically analyze result for reference of analyst. What is more, it can make the digital simulation and calculation for motor vehicle---motor vehicle, motor

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vehicle---fixture, motor vehicle---pedestrian, motor vehicle---cylinder, turnover and other types of accident, and make complete three-dimensional animation display. [2] That means the final result output from analog computation can display through functional images.

3. The Establishment Of Second Crushing Accident Model

In the morning of Oct. 17th, 2013, at the gate of Wuhan Municipal Government, an accident happened that when one cyclist (female, 23 years old) crossed the road,. he was collided by the vehicle behind and then re-crushed by the vehicle finally leading to the cyclist gets damage of AIS51.30 grade. The vehicle in accident is Audi A4 produced in 2000, after accident, its front bumper is damaged, as shown in figure 1. Before accident, the distance between the cyclist and accident site is 1.8m, and the distance between after and before the collision is 22.2m. At that time, the weather is fine, view is wide, road surface is straight, broad and dry, and the rate-limiting of the road is 60 km/h. According to the description of parties, there is no braking before re-crushing, and the running speed of vehicle is about 56 km/h. [3]

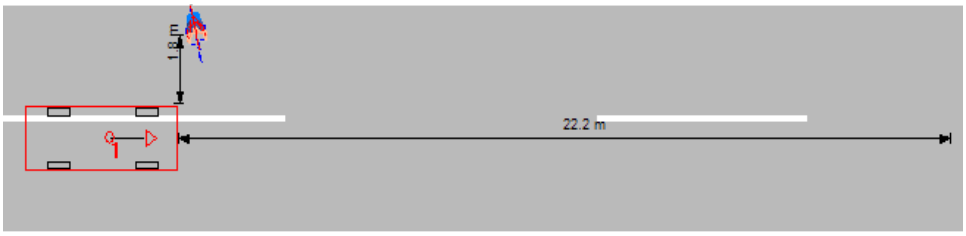

Figure 1. Schematic diagram for the site of accident

As shown in figures 2 and 3, generally, we can directly search vehicle information in the database of PC-CRASH, and also can set it through manual operation in relatively fuzzy parameters. In order to accurately obtain simulation data, we should maximum avoid generating information with large error when establish accident model [4]. We can obtain the specific parameters through using PC-RECT. As for cyclist model, we can replace it with using rigid-body model provided by inner software, and before replacement, we should input relevant height, weight, cycling vehicle length, weight and other detailed information. In the process of case simulation, the input information sees figure 1.

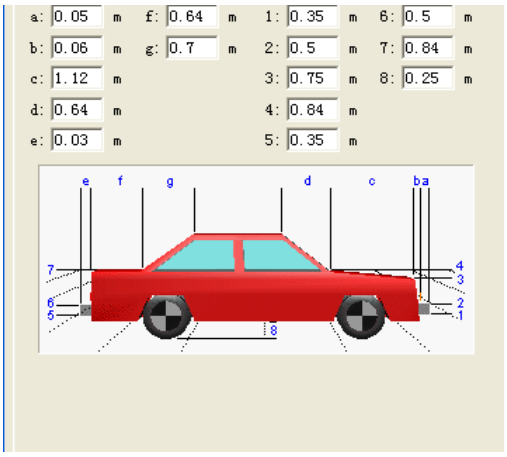

Figure 2. Contour parameter of vehicle in accident

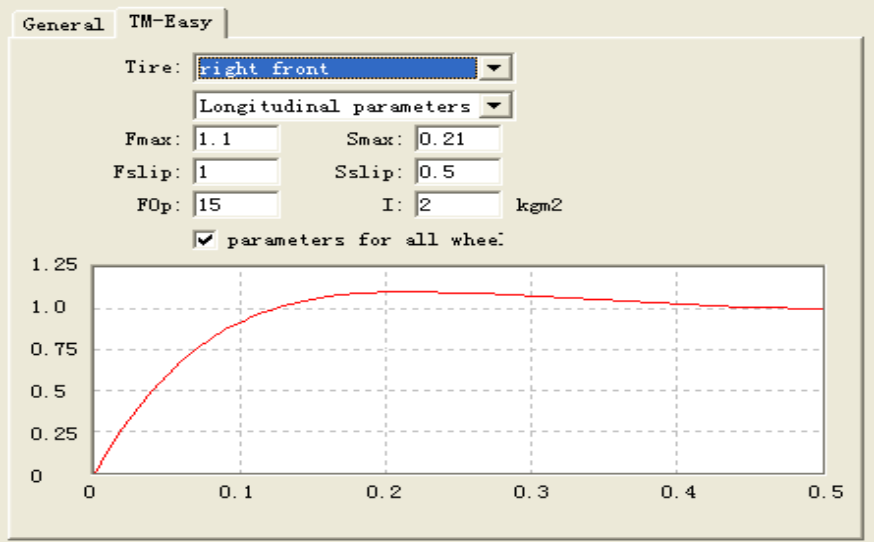

Figure 3. Tire longitudinal parameters

Table 1. Cyclist's Paraneter

Driver		Bike	
Height	Weight	Riding vehicle length	Weight
166cm	55kg	173cm	14kg

4. Simulated Test Of Second Crushing Accident

After the completion of parameter input and information input, it can begin to simulate second crushing accident. If it has inconsistent phenomenon with actual accident, belongs to normal range. Due to the site of accident has so many sundry factors, it needs fine adjustment through manual operation, that is, continuously adjust the angle of vehicle and cyclist in accident. In view of it is not very accurate for the bear load of vehicle and loaded speed of cyclist. Therefore, it needs to make proper adjustment for the motion parameter and outer contour parameter of vehicle and cyclist. Only up to the simulative parameters is consistent with the accident parameters, can adjustment stop. After the repeated fine adjustment, it finds that when speed of motor vehicle is 54km/h, coordinative time of braking system is 0.23s, friction coefficient between vehicle and road surface is 0.84, riding speed is 15km/h, friction coefficient between cycling and motor is 0.4, and friction coefficient between cyclist and road surface is 0.7, the simulation result is consistent with the information provided by accident.

Figure 4 shows simulation accident in the 0.13s, namely the first crushing; meanwhile, it provides the picture of relevant position relationship between cyclist and vehicle. From the figure, we can see that during the first crushing, the body of cyclist and the left tire of vehicle contact firstly, and then the first crushing happens. In this process, the cyclist also gets the certain damages from the crushing and scraping of bike.

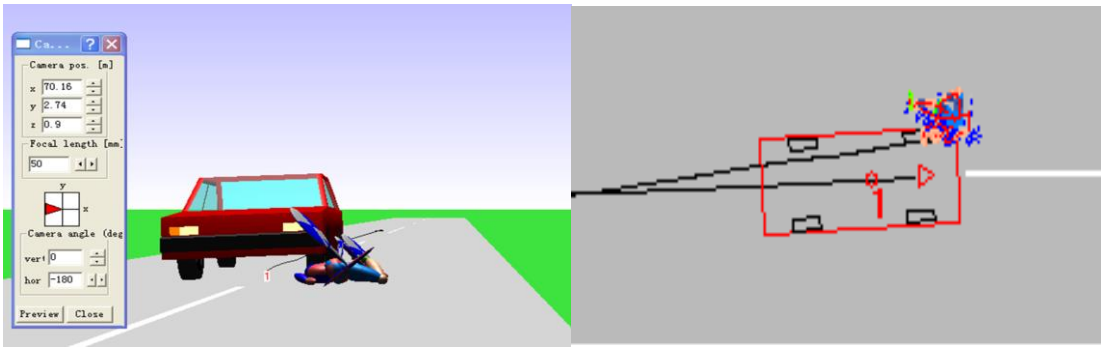

Figure 4. The information about participant's position happened in the first crushing in stimulation (the left side is three-dimensional view, the right side is two-dimensional view)

Form figure 5, we can see that after the first crushing, vehicle begins to reduce its speed, but at the same time, cyclist is relatively still, so at the moment of reducing speed, cyclist moves to the back of the vehicle. We also can see that after the 0.27s of collision, cyclist's foot begin to contact to the left rear wheel of vehicle, namely, the second crushing begins to happen.

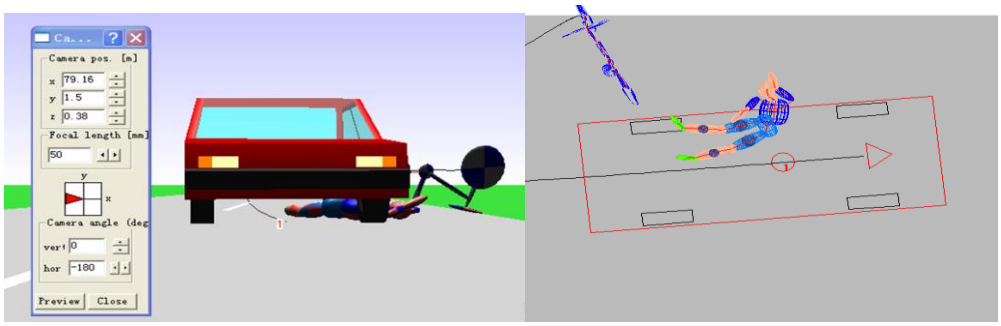

Figure 5. The relative position and location plan (0.27S) of accidental participant after the crushing first time

From figure 6, we can see that the second crushing is occurring, and the damaged part is cyclist's main body, which accords with the damage in actual accident. After the end of accident in 0.44s, the human body has crushing damages with total value of 1237.65N in the whole process, the accelerated speed of human body reaches to 47.7 m/s2, and the accelerated speed of main body of cyclist reaches to 143.3m/s2 .

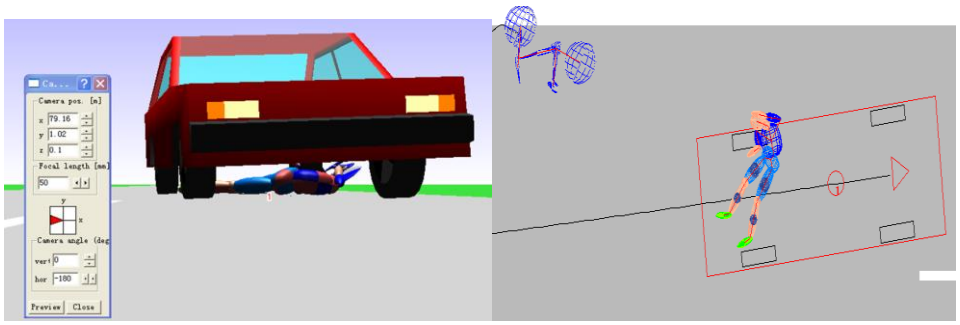

Figure 6. The information about participant's position happened in the second crushing in stimulation (the left side is three-dimensional view, the right side is two-dimensional view)

Figure 7 shows the maximum impact force for the head of cyclist in the whole accident, which means the cyclist's body injury mainly comes from the squeezing between tire and ground.

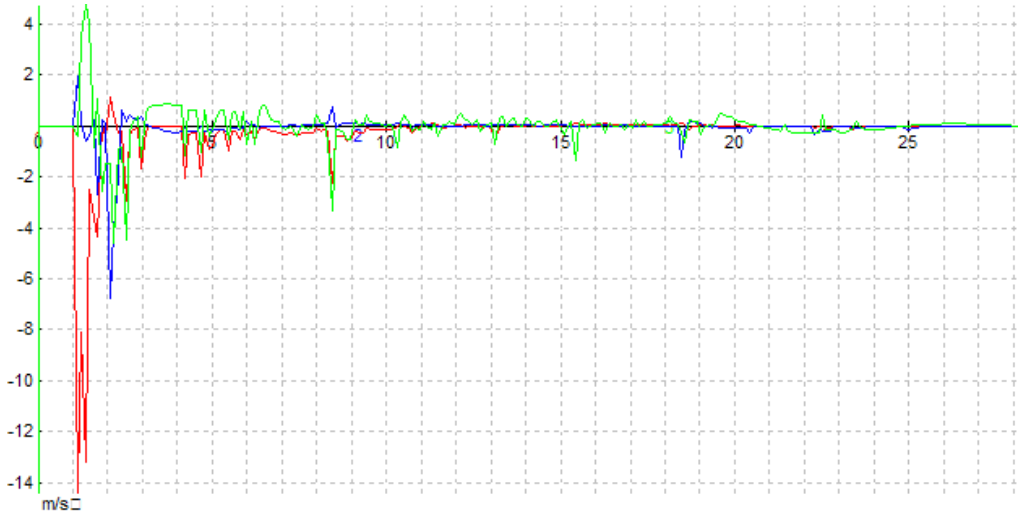

Figure 7. Graph about body affected by shearing force

5. Analysis to Simulation Data of Accident

After the accident simulation of second crushing, we can acquire the stress relations between cyclist and tire, as shown in figure 8.

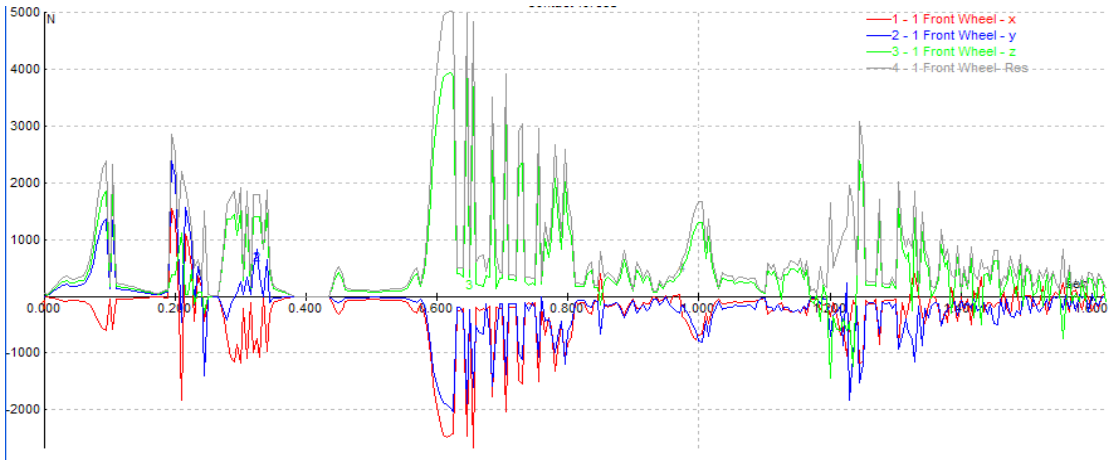

Figure 8. The schematic map about contact load between body and tire

In the first crushing, the shear force between road surface and tire for cyclist's body is less than the second crushing, and the maximum peak happens in the first half of second crushing. According to the data, we can speculate that when the second crushing begins, the speed of vehicle reduces, so the contact area between tires and cyclist increase, and during the simulation, the second crushing time is also more than the first time. Therefore, the fatal damage of cyclist happens in the first half of second crushing.

In the medical report, AIS grade damage of cyclist reaches to 51.30 in this case. According to the explanation of simulation data and mechanical model of TRL impactor, the stress in the first half of first crushing has already caused fatal damage for cyclist, so the fatal damage will not happen in the second crushing.

The result indicates that the damage is chest compression. From figure 9, we can see that the vertical stress time of left rear wheel in the second crushing is longer than the first time, but the instant rising speed rate of vertical stress in first time is larger than the second time, and appears explosive growth, so the damage for human body in short time can cause fatal damage.

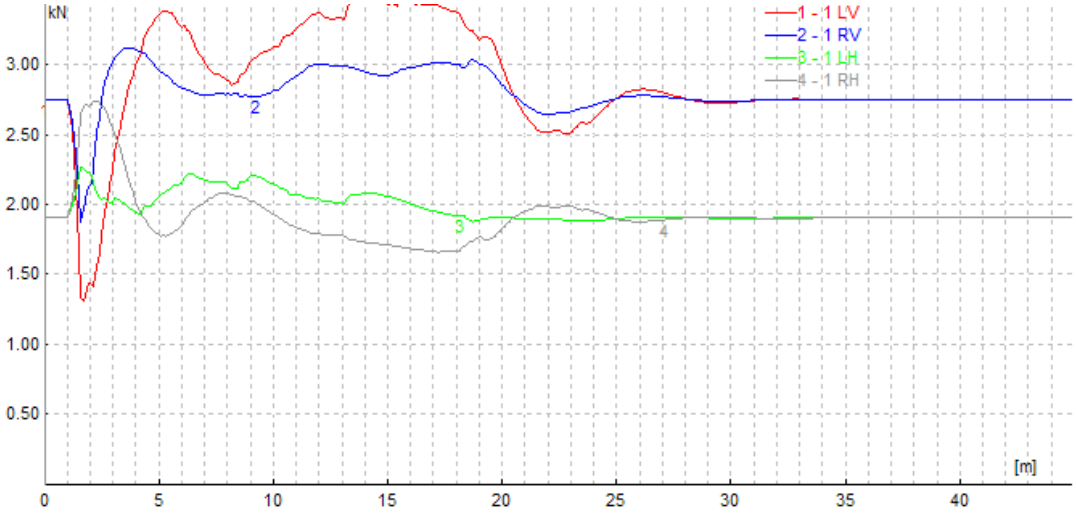

Figure 9. The graph about vertical stress of vehicle wheel

From the rising speed ratio of vertical stress, we can identify that the major fatal injury of cyclist in the second crushing is still generated from the first crushing, and the secondary fatal injury happens in the second crushing. Therefore, from the theoretical analysis, increasing the prevention for process of the second crushing plays very important role. However, if we want to fundamentally solve the fatal damage, should begin from preventing crushing. Form figure 10, we can see that if the cyclist gets the collision in this way, the head will have main injury, and the lower limbs will have secondary damage. So wearing helmet can avoid fatal injury.

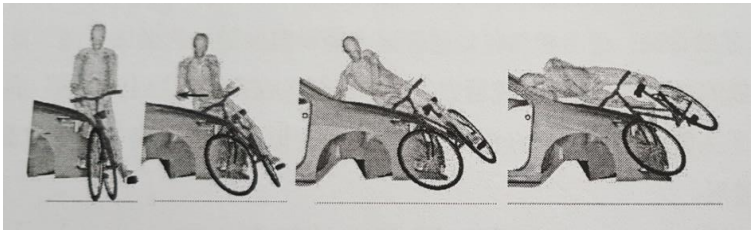

Figure 10. The schematic diagram of contact collision between simulative cyclist and vehicle

6. Summary and prospect

This text uses PC-CRASH to simulate the typical accident of second crushing. It use lots of data to restore the process of accident, then analyze the lethality of accident through simulation data, finally obtain the conclusion that if it can avoid crushing, may prevent the fatal injury. Therefore, during the later prevention and control of accident, we can prevent the crushing through designing the front parts of vehicle. This study simulates the typical accident and provides prevention of accident with effective evidences and reference information.

7. References

[1] Xiaolong. Li and Jieyuan. Liu,“PC - CRASH simulation system in the traffic accident treatment courses teaching the application,” Journal of course education research, vol. 34, Dec. 2014, pp. 205-206.

[2] Li. Shi, “Car collision theory elaboration and collision accident reappearance,”China mechanical, vol. 34, Mar. 2014, pp. 120-121.

[3] Qingbin. Deng, “Based on the energy absorption analysis of vehicle collision simulation and representation research,”Harbin industrial university, vol. 22, Mar. 2010, pp. 22-28.

[4] Cai. Siming., “Motor vehicles and non-motor vehicles and pedestrians traffic accident both sides of no-fault liability is briefly divided into,”Journal of shenyang university, vol. 23, Apr. 2011, pp. 22-24, doi: 10.3969/j.issn.1008-9225.2011.03.007.

[5] Tiefang. Zou, Zhi Yu and Ming Cai,"Based on Pc - people - car collision accident Crash software simulation research," Chinese journal of safety science, vol. 20, Jul. 2010, pp. 156-149, doi: 10.3969/j.issn.1003-3033.2010.02.009.