Reconstruction of a real world complex vehicle-pedestrian accident

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Abstract: Pedestrian accidents are normally regarded as single vehicle-pedestrian collision as it is the most common type of pedestrian accident. However, complex pedestrian accident is often seen in inner city or living area, e.g. accidents involve more than one pedestrian. In such accidents, apart from the vehicle itself, there are many injury sources such as vehicle run-over, human interaction and ground impact, associated injury are often to be classified in the fatal/serious category. This study shows the basic characteristics and complexity of a real world multi-pedestrian accident using the Madymo reconstruction method
Keywords: Pedestrian accident, Madymo Reconstruction

1 Introduction

The reported fatal accident involving a Nissan Micra and three pedestrian. Among the pedestrian, two were children, another was an adult woman with 7 month pregnancy. The accident occurred while the three pedestrian was walking over a pedestrian crossing. As the result of the collision, one child pedestrian was killed another child received injured, the adult woman pedestrian was also killed. However, because the woman pedestrian was run over by the vehicle and dragged for a considerable distance, it was hard to determine if she was killed from the primary impact with the windscreen. Therefore, Madymo software package is used as a reconstruction tool, this paper discusses the possibility of fatal injury received by the children and woman after the initial impact.

2 Madymo Model

2.1 Vehicle Model

The mass of the vehicle model is set to be 900kg. This is taking consideration of the vehicle kerb weight of 820 kg, obtained from PC-Crash V5.1 Vehicle Database(PC-Crash and Database 1998), plus approximate driver weight and fuel onboard. The vehicle geometry data is obtained from the PC-Crash V5.1 Vehicle Database, some physical geometry measurement on similar vehicle model was also carried out. The vehicle stiffness data was obtained from EuroNCAP test result.(EuroNCAP and programme) 2004)

2.2 Pedestrian Model

Because it is a time consuming process to created model matching the victims' anthropometric value, scaled model based on existing TNO model is used. The TNO pedestrian model is considered as well-validated and industrial recognized model. The child pedestrian model is 139cm in statures and 37 kg in weight. The adult female pedestrian model is 165cm in statures, and 70 kg in weight, this is taken into consideration that she was pregnant at the time of accident.

3 Accident Reconstruction

3.1 Initial Condition –Vehicle

Due to the complex nature and unknown factors in this accident, the reconstruction can only give a rough guideline to the real event. In the reconstruction, Initial Vehicle Velocity is 11 m/s .This value is assumed based on the estimation made by police using the skid mark test suggests an impact speed between 23-27 mph,.Vehicle Deceleration is 7 m/s^2**,** The vehicle front wheels were locked period to the initial impact, this suggested a full braking effect as described in police report.

3.2 Initial Condition-Pedestrian

According the witness statement and police report, the victims were crossing the road over a

pedestrian crossing, from nearside toward offside. Woman 1 was in the middle, with Child 1 on her right and Child 2 on her left. Observing the contact marks found on the vehicle, the described possible vehicle and pedestrian position period to the impact is shown in Figure 1.

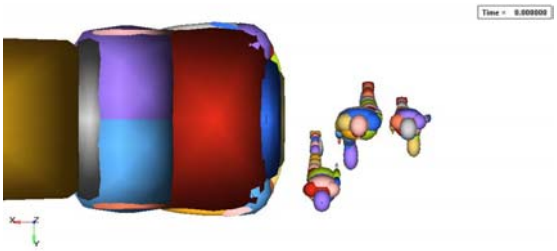


Figure 1

3.3 Simulation Result vs Real Event

As shown in the Figure 2, for the Child 1 pedestrian model, the contact point obtained from the simulation matches the damage found on the vehicle. At the first stage of the impact, his right leg made contact with the number plate first then hit by the bonnet leading edge, his left leg made contact with the offside corner of the bumper, his pelvis made the contact with the offside headlight. After the impact with the vehicle front, his body rotated and his head then hit the offside bottom corner on the windscreen, this can be found in Figure 3. The body contact with vehicle and associated injury can be found in Table 1. Due to his height and position, his body was hit by the relative stiffer part in the vehicle front; his head impact location was also on of the most stiff parts on the windscreen. As Table 2 shows, he received the highest HIC value and highest TTI value.

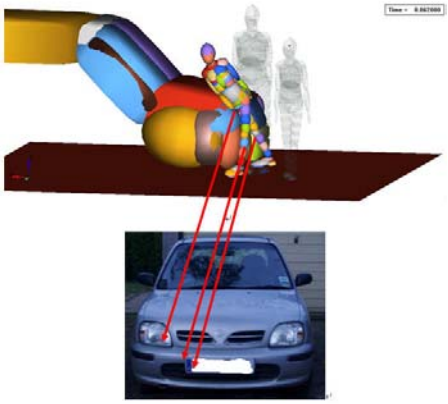
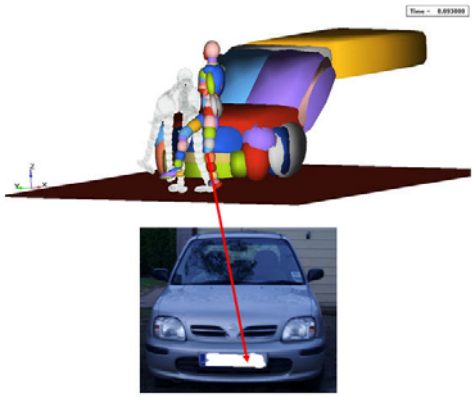


Figure 2

Figure 3



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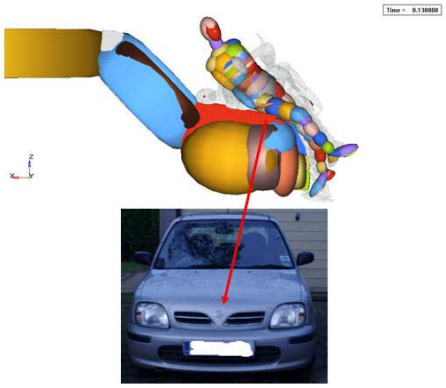

Figure 5

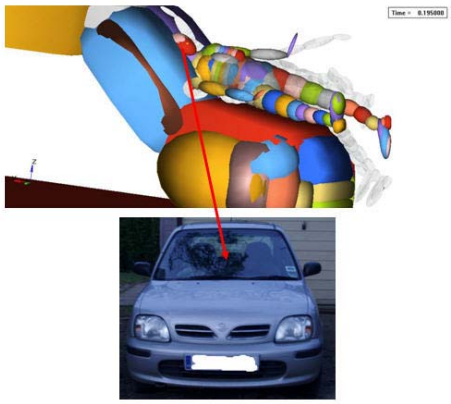

Figure 6

Table 1.Simulation Contact vs Autopsy Injury

Simulation Contact	**Vehicle Damage Location**	**Injury Associated (From Autopsy)(Acland 2006)**	**Note**
Child 1 Left Upper Leg /Pelvis	Offside Headlight	There was also a further brushing measuring 12 by 6 cm to the anterior let knee with no evidence of fracture	
Child 1 Left Lower Leg	Offside Bumper Corner		
Child 1 Right Upper Leg	BLE	There were deep blue bruises, measuring 20 by 10 cm to the lateral right upper thigh and also lateral mid leg and lower leg	
Child 1 Right Lower Leg	Number Plate-Bottom right		
Child 1 Head	Windscreen Offside Bottom	There were abrasions across the forehead extending down over the bridge of the nose and the right side of the face. There was Bruising around the right eye. There were irregular lacerations, measuring 6cm long across the upper left forehead and a similar irregular laceration measuring 4cm along the upper right forehead.	
Child 1 Pelvis	Bonnet Leading Edge	There were further linear abrasions down vertically across the abdomen	
Woman 1 Body	Bonnet Leading Edge /Bonnet	There was an extensive abrasion down the central back on the shoulder blades down to the buttocks	Partial caused by initial impact
Woman 1 left lower leg	Number plate-Bottom left	There was a laceration measuring 10cm long below the left knee	
Woman 1 right lower leg		There was an open fracture of the right lower tibia and fibula	Maybe caused by run-over
Woman 1 head	Windscreen Centre	On the right parietal region was an 8cm diameter area of eroded scalp down through the right parietal skull, exposing the brain	Partial caused by initial impact

It is likely the Woman 1 was also in walking position period to the impact. As shown in the Figure 4, her right leg hit by the Child 1's foot or other body part, her left lower leg made contact with the vehicle bumper, and possibly causing the damage to the number plate. After the impact with the bumper, there is a WRAP effect, her pelvis and back made full contact with the bonnet, causing the massive dent on the bonnet before hitting the windscreen, there are shown in the Figure 5 and 6. According to the simulation, the woman only received modest head injury and thorax injury, this can be found in the Table 2. The maximum force acted on her pelvis during the initial impact was 231.52N.

Table 2 Initial Impact Result

	HIC (Head Injury Criterion)	TTI (Thoracic Trauma Index)	Probability of Skull Fracture (based on HIC)
Child 1	6245.1	27.692	98.204%
Woman 1	378.18	14.762	11.769%
Child 2	29.704	24.837	0.003%

Due to the complexity of the accident, it is hard to make comments on the Child 2's impact with the vehicle. However, from their initial position, it is very likely the Woman 1 was positioned between Child 2 and the vehicle, therefore, Child 2 only received modest injury.

The probability of fatal brain injury is calculation using the following equation from NHTSA(NHTSA 1998), this equation is:

$$p(fracture) = N\left[\frac{\ln(HIC) - \mu}{\sigma}\right]$$

Where N() is the cumulative normal distribution, μ=6.96352 and σ=0.84664.

3.4 Extended Simulation and varies factors

An extended simulation last for 1.5 seconds. As in the Figure 7, it actually shows the two children was thrown to the air, this also matches the witness statement. Due to her weight, the woman was not thrown to the air, but she was sliding over the bonnet, this could also cause some dents over the bonnet.

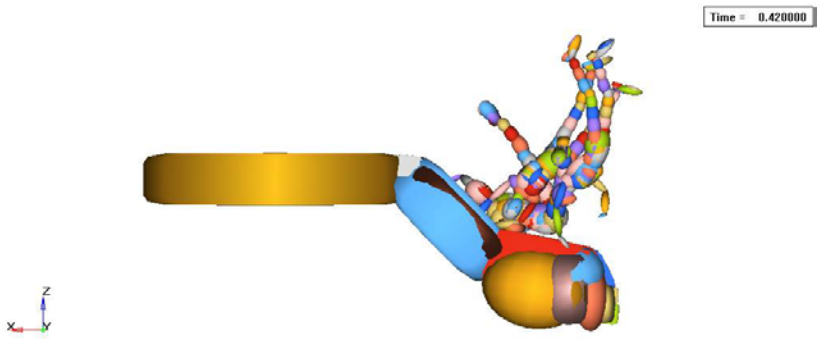

Figure 7

Figure 8 shows the final resting position of 3 pedestrian. It shows the Child 2 and Woman 1 was landed in the front of the vehicle. From the tyre skid marks, the vehicle did not come to full stop after hitting the pedestrian, the change in deceleration rate can result to slight different pedestrian kinematics; therefore, the final resting position in the figure 8 might also be changed. Initial pedestrian position and even a slight movement of arm can also lead to big difference in final resting position.

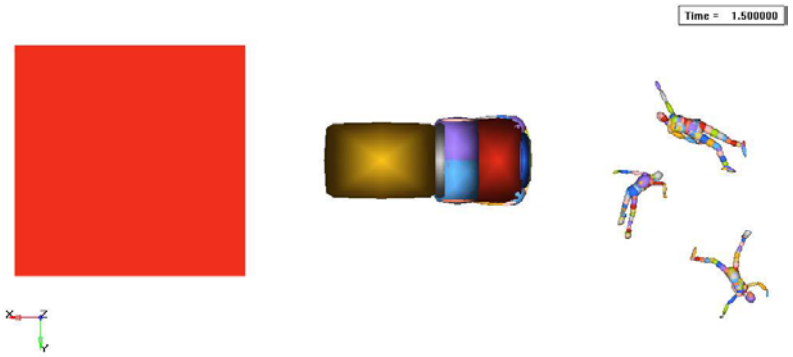

Figure 8

4 Conclusion

The Child 1 received fatal injures following the initial impact. This is mainly due to the vehicle design and unfortunate impact location, as the bottom corner of windscreen is much stiffer than the middle section of windscreen. Such impact results a very high HIC value, based on the HIC value, the probability of receiving skull fracture is 98%. The Expanded Prasad/Mertz Curve (NHTSA 1995)showed in Figure 9 also suggested the initial impact results a fatal injury. It is also notable that the Child 1's kinematics movement also contributed to the pedestrian death, as his movement was limited by the pedestrians next to him, so the overall deceleration is greater.

The WOMAN 1 received relatively low level of injury from the initial impact with vehicle, as show in the pervious table. Although the interaction with the Child 1 also changed the kinematics of the female pedestrian, it is almost certain that those injures are not life-threaten. This is due to relatively low impact speed and head striking point is in the relatively softer region of the windscreen. The simulation shows the initial impact only produced a very low HIC value which only result 11.7% chance to receive a skull fracture. Therefore, it is suggested that the female pedestrian might have killed as result of run-over and internal organ trauma.

The Child 2 only received modest injury, because it was likely that the WOMAN 1 was between him and the vehicle.

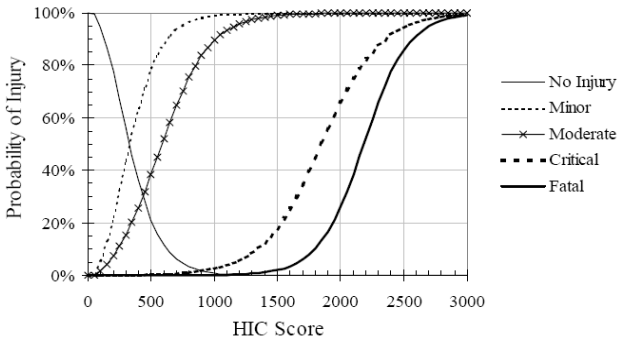

Figure 9 Probability of Specific Head Injury Level for a Given HIC Score

Reference

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