Research on Vehicle Accident Simulation Based on Multi-source Information Combined

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Keywords: Accident multi-source information, Modeling, Simulation and reconstruction, Collision kinematics, Occupant injury.

Abstract. The real vehicle accident case is selected, and accident multi-source data such as vehicle damage deformation, vehicle final position, scene ground traces, scattered objects, occupant injury and so on are combined in the paper. The vehicle model and road environment model are built on the basis of PC-Crash software. In order to reproduce real accident, the vehicle collision dynamics and kinematics parameters are analyzed by vehicle dynamics simulation, moreover, occupant collision injury and its cause involving vehicle accident are analyzed through human trauma assessment software. The methodology based on multi-source accident information combined in this paper is applied on real accident and validated the practicality and effectiveness on simulation and reconstruction, which is of great value in research on vehicle accident.

Introduction

In the 1960s, foreign research began in the field of road traffic accident reproduction analysis, and various simulation softwares are built in order to reproduce traffic accident. PC-Crash is the most widely used in the world, and has become necessary accident simulation and reconstruction software for a number of vehicle safety and traffic accident research institutions. At present, the domestic research on traffic accident is still in the initial stage. PC-Crash and Trauma Evaluation software are applied to research on real vehicle accident involving kinematics simulation and occupant injury assessment and its cause analysis in this paper.

Accident Multi-source Information

Accident Overview

At the crossroads, the left front side of the Wuling Hongguang minivans (referred to as Wuling minivans) traveling from east to west collided with the right front of the Chang’an Benben small car (referred to as Chang’an car) traveling from south to north, after the collision Wuling minivans left side rollover after clockwise rotation, Chang’an car continue to travel west to stop. The driver was not injured, the rear two passengers were injured in Wuling minivans, the occupant in Chang’an car was not injured.

Accident Scene Ground Traces

On the accident scene road surface, there are tire traces, coolant and glass fragments, plastic parts, debris and other scattered objects for Wuling minivans, and left tires trace for Chang’an car.
Figure 1. Accident scene traces.

**Vehicle Damage Situation**

(1) Wuling minivans damage situation
   Front bumper deformation, Left headlights broken, Left front fender deformation damage, Hood bending deformation, Front windshield broken.

(2) Chang’an car damage situation
   Right front wheel deformation, Right front fender deformation, Right front door and threshold beam deformation, Right A-column deformation.

**Vehicle Collision Configuration**

In order to determine the two vehicles collision configuration, the traces of the vehicle damaged are analyzed.

The width of damaged area from left headlamps to middle of radiator in Wuling minivans is about 82 cm, the width of damaged area from right front wheel to right front door in Chang’an car is about 83 cm. The traces for two damaged areas can basically correspond, the two vehicles collision configuration can be determined according to above two damaged areas.

![Wuling minivans and Chang’an car](image)

Figure 2. Vehicle collision configuration.

**Vehicle Speed**

The accident scene survey data can show that movement distance \( (S_1) \) of Wuling minivans after collision is about 14 m, while the rotation angle \( (\alpha_i) \) is about 200°. So Wuling minivans post collision velocity can be calculated.

\[
v_{1i} = \sqrt{254\varphi_2 s_i + 254 \frac{\alpha_i}{360} \pi \varphi_2 d_i} \approx 35.5 km/h
\]

(1)
After collision, the length of tire footprint ($S_2$) for Chang'an car is about 30.5m, and the rotation angle ($\alpha$) is about 83°. So Chang'an car post collision velocity can be calculated.

$$v_{21} = \sqrt{254\varphi_1 x_2 + 254 \frac{\alpha}{360} \pi \varphi_2 d_2} \approx 33km/h$$

Vehicles collision configuration is shown below through CAD software assist analysis.

The two vehicle collision velocity can be determined according to momentum conservation of two vehicles in the moment of collision, Wuling minivans collision velocity is about 45km/h and Chang’an car collision velocity is about 39km/h.

$$m_1v_1 + m_2v_2 \sin \beta_1 = m_1v_{11} \cos \beta_2 + m_2v_{21} \sin \beta_3.$$  \hspace{1cm} (3)

$$m_2v_2 \cos \beta_1 = m_1v_{11} \sin \beta_2 + m_2v_{21} \cos \beta_3.$$ \hspace{1cm} (4)

In the formula:

$\varphi_1$, longitudinal adhesion coefficient of vehicle tires, $\varphi_1 = 0.1$; $\varphi_2$, transverse adhesion coefficient of vehicle tires, $\varphi_2 = 0.75$; $d_1$, Wuling minivans wheelbase, $d_1 = 2.675m$; $d_2$, Chang’an car wheelbase, $d_2 = 2.345m$; $m_1$, total quality of Wuling minivans, $m_1 \approx 1490kg$; $m_2$, total quality of Chang’an car, $m_2 \approx 970kg$; $\beta_1$, angle between direction of Chang’an car collision speed and east-west road center line, $\beta_1 \approx 15^\circ$; $\beta_2$, angle between direction of Wuling minivans post collision velocity and north-south road center line, $\beta_2 \approx 24^\circ$; $\beta_3$, angle between direction of Chang’an car post collision velocity and east-west road center line, $\beta_3 \approx 62^\circ$.

Occupant Injury Information

There are shoulder soft tissue contusion, acromioclavicular joint effusion, multiple rib fractures, traumatic wet lungs, traumatic headache, head skin wiping contusion and multiple soft tissue contusion for left side occupant injury in Wuling minivans rear seat. For right side occupant injury in Wuling minivans rear seat involving multiple rib fractures, traumatic wet lungs, sternum fracture, cervical fracture, left acetabulum fracture and left proximal femoral fracture.

Simulation Analyses

Vehicle Model

The appropriate vehicle model are selected according to the accident vehicle information, and vehicle parameters including vehicle size, wheelbase, center of gravity height, load and tire parameters and so on are input.
Road Environment Model
The accident scene CAD map is directly imported for the plane road environment, moreover accident collision point, vehicle final position, vehicle tire traces or vehicle trajectory and accident track evidence are marked in the CAD map.

Collision Sequence Settings
Collision sequence setting of the two vehicles including speed, braking and steering conditions are determined according to accident vehicle collision configuration, impact speed, contact location and movement process and other information.

Vehicle Kinematics Analysis
By repeatedly adjusting the vehicle steering, braking, contact surface, contact point, collision angle and speed and other collision parameters, until the simulating results are mostly matched with that of real accident investigation. Thus collision dynamics parameters such as collision angle, collision speed and EES can be obtained as shown below.

![Figure 4. Vehicle collision configuration.](image1)
![Figure 5. Vehicle collision process.](image2)

<table>
<thead>
<tr>
<th>Collision dynamics parameters</th>
<th>car</th>
<th>Wuling minivans</th>
<th>Chang’an car</th>
</tr>
</thead>
<tbody>
<tr>
<td>t[s]</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Pre-impact speed[Km/h]</td>
<td>47.00</td>
<td>43.00</td>
<td></td>
</tr>
<tr>
<td>Velocity after impact[Km/h]</td>
<td>39.16</td>
<td>41.53</td>
<td></td>
</tr>
<tr>
<td>Speed change rate dv[Km/h]</td>
<td>12.77</td>
<td>18.72</td>
<td></td>
</tr>
<tr>
<td>EES[Km/h]</td>
<td>12.81</td>
<td>22.94</td>
<td></td>
</tr>
<tr>
<td>Collision direction[deg]</td>
<td>-134.42</td>
<td>45.08</td>
<td>107.19</td>
</tr>
</tbody>
</table>

Occupational Injury and Cause Analysis
(1) Occupant injury assessment

Table 2. Injury assessment results.

<table>
<thead>
<tr>
<th>Name</th>
<th>-/-</th>
<th>Gender</th>
<th>Male/Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>68/70</td>
<td>Occupant position</td>
<td>Rear left/Rear right</td>
</tr>
<tr>
<td>AISM head</td>
<td>1/0</td>
<td>AISM neck</td>
<td>3/3</td>
</tr>
<tr>
<td>AISM spine</td>
<td>0/2</td>
<td>AISM upper limb</td>
<td>0/0</td>
</tr>
<tr>
<td>AISM face</td>
<td>0/0</td>
<td>AISM Lower limbs</td>
<td>0/3</td>
</tr>
<tr>
<td>AISM neck</td>
<td>0/3</td>
<td>AISM Body surface / other</td>
<td>0/0</td>
</tr>
<tr>
<td>AISM chest</td>
<td>0/0</td>
<td>AISM abdomen</td>
<td>3/3</td>
</tr>
<tr>
<td>AISM abdomen</td>
<td>0/0</td>
<td>AISM</td>
<td></td>
</tr>
</tbody>
</table>
(2) Occupant injury cause analysis

According to vehicle collision kinematics simulation and vehicle damaged investigation, the occupant injury cause and vehicle collision part are analyzed.

In the accident, the cause of left side occupant injury involving head, chest and shoulder in Wuling minivans rear seat is that the left side occupant collides with the left rear door; moreover the right side occupant without seat belt moves to the left and collides with left side occupant in the course of Wuling minivans left side rollover, chest injury assessment grade is for AISM 3. The cause of right side occupant injury in Wuling minivans rear seat is that right side occupant without seat belt collided with the seat armrest and left side occupant, chest and lower limbs injuries assessment grade are for AISM 3, spine injury grade AISM 2.

Conclusion

In this paper, PC-Crash and human trauma assessment software are used to conduct vehicle accident process simulation and occupant injury and its cause analysis through multi-source data combined of real vehicle accident. Moreover, real accident case has shown that this methodology has good accuracy and practical value in the field of vehicle accident simulation and vehicle safety analysis.

Acknowledgment

This project is supported by Outstanding Middle and Young Scientists Research Award Fund of Shandong Province (BS2011SF014), Science and Technology Project of Higher School of Shandong Province (J11LG17), Natural Science Foundation of Shandong Province (ZR2010EL023) and National Automobile Accident In-depth Investigation System. This project would not have been possibly accomplished without these funds support.

References

