Traffic Accident Reconstruction and Authenticity Analysis

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Abstract – Traffic accident reconstruction is helpful to know the course that the traffic accident occurs, know the damage and deformation mechanism; it is also helpful to analyze the accident authenticity, determine accident responsibility and evaluate the actual economic losses. We adopt vehicle damage analysis, kinematics analysis, energy analysis and simulation analysis to reconstruct and analyze the actual case of insurance companies in this paper. It has identified some feigned cases and redeemed certain pecuniary losses for insurance companies.

Keywords: traffic accident, accident reconstruction.

1 Introduction

The number of road traffic accidents that the nation-wide traffic management department accepted was 667,570 in 2003. With the rapid development of Chinese economy, automobile quantity goes up promptly, so the traffic safety situation will be sterner. On the other hand, because of domestic unperfect legal system and the burgeoning but unperfect insurance system of motor vehicles, some illegal members forge traffic accident spots or enlarge accident vehicle loss in order to get illegal indemnity from insurance companies. According to the conservative estimation of domestic insurance companies, about 20% of vehicle indemnities are fraudulent recently. From 2000 to 2003 years, the loss of vehicle indemnity in China approximated 1,300 million Yuan, more than 150 thousand Yuan in average every day.

Therefore developing traffic accident reconstruction and its authenticity analysis are significant meaningful, under the stern traffic safety situation and serious motor vehicle insurance cheat environment. There are four accident reconstruction methods mentioned in this paper as following: vehicle damage analysis, kinematics analysis, energy analysis and emulation analysis which includes finite element analysis and multi-body analysis.

2 Vehicle Damage Analysis

The vehicle damage analysis based on the investigation of the traffic accident spot and the condition of the accident vehicle damage and the description of the parties and so on, is used to identify the collision types, such as frontal impact, side impact, rear impact, vehicle-guardrail impact, vehicle-column impact, rollover and so on, find the first collision point and then make sure the relative motion of the vehicles in the course of collision and corresponding strained and damage points.

The method is used to analyze the damaged positions comparing with the vehicle metrics parameters, judge whether the damaged positions is anastomotic in height and whether it could caused damage to the vehicle, guard bar or column. And according to the collision type and the direction of motion, the force direction or deformation direction or scratch direction of the damaged positions can be determined, and whether the performance measures of drivers were logical or not. Additionally attachment on the vehicle body such as paint, something that fall down on the ground from vehicles and airbags are also important in damage analysis.

Figure 1 shows the damage picture of rear collision between two cars. The car b) had been bumped against under the static condition. There was only one obvious injury on the left of the bumper in picture a) (see mark 1). The height approximated 420mm. The height of the damage of the vehicle tail in picture b) approximated 700mm (see mark 2). Two places differed highly wide and the damage could not be corresponding. Therefore the damage of the accident was incredible.

a) b)

Figure 1 Damages of the accident car.

3 Kinematics Analysis

According to the points of contact and force, the path of motion and the vehicle velocity before impact and so on, kinematics analysis is used to make sure the motion conditions of vehicle after impact, including the velocity, the direction of motion, the direction of rotation, the path of motion and so on. And then, the credibility of damage vehicles is analyzed compared with the actual path of motion and the damage and deformation situation of the vehicles after impact. The velocity before and after impact are usually offered by involved parties, or obtained by the energy analysis according to the brake distance and the vehicle deformation. And the momentum conservation law is also very effective to achieve the velocity before and after impact.

The driver turned steering wheel towards right urgently in order to avoid colliding with the motorcycle which burst in from the road side, so the car collided against the guard bar on the road side (according to the description of the driver). The car stopped beside the guard bar in the opposite of crossing road after impact (see Figure 3).

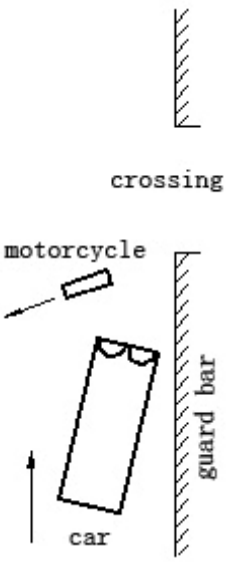


Figure 2 Accident sketch

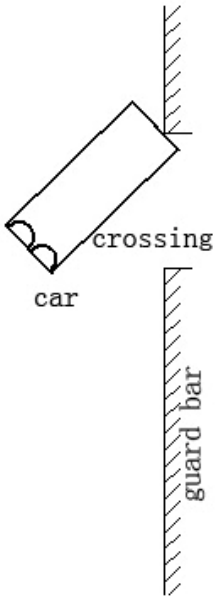


Figure 3 Stopped location of the car

Figure 4 Accident spot

Figure 5 Head damage

And Figure 5 shows the frontal damage of the car.

The velocity of the car was about 150km/h when the accident happened according to the description of the driver. Because of the different angles between the velocity direction and the guard bar, it might rotate in the clockwise direction or the counterclockwise direction after the collision.

When the angle between the car velocity direction and the guard bar is small, the force exerting on the car produces the moment which makes the car rotates counterclockwisely around its centroidal (see Figure 6). Because of inertia, the car will go forward continuously along the original speed direction while rotating. In other words, the side of the car body approaches to the guard bar when the it slides forward to the guard bar. Then the head separates from the guard bar because of rotation, and gradually away from it. And the tail may collide with the guard bar again so that the tail may be damaged and the right side may be scratched seriously (if the guard bar is long enough). In this case, the right side of the front bumper and the side body must be scratched by the guard bar; as a result, a trace will be left obviously.

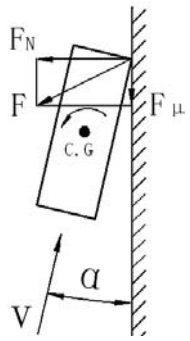


Figure 6 Force analysis of the car if the angle of α is smaller.

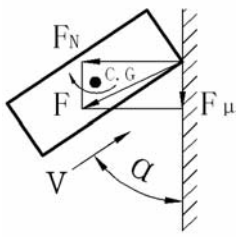


Figure 7 Force analysis of the car if the angle of α is bigger.

When the angle between the car velocity direction and the guard bar is large, the force exerting on the car produces the moment which makes it rotates clockwisely around its centroidal (see Figure 7). Because of inertia, the car will go forward continuously along the original speed direction while rotating. In other words, in a very short time in collision, the head of the car approaches to the guard bar when it slides forward and rotates clockwisely. Then the head separates from the guard bar because of moving and rotation, and gradually away from it. In this case, the front guard must be scratched by the guard bar; as a result, the damage will be seriously.

In a word, if the description of the driver is true, the front bumper must have been damaged seriously. But there is no obvious injury, deformation or scratched trace on the front bumper and the side body (see Figure 5). So we can conclude that the damage of the accident is not true.

4 Energy Analysis

Energy analysis based on the energy conservation law is used to analyze the mutual transformation among the kinetic energy, potential energy, deformation energy and thermal

a） **b）**

Figure 8 Impairment photographs

energy between tires and ground. According to the corresponding known conditions, some

parameters such as the velocity or the brake distance can be obtained. Also, whether the energy is conservation or not can be judged.

Car b) was impacted by car a) face to face when the car a) was overtaking a truck and crossing the middle line (see Fig.9). Damage condition was shown in Figure 8. According to the description of the parties, the velocities of the car a) and car b) were shown as following individually:

$$v_a = 70km/h = 19.444m/s \qquad v_b = 85km/h = 23.611m/s$$

The total mass:

$$m_a = 1405kg\ ,\quad m_b = 1120kg$$

So, the total kinetic energy of car a) and car b):

$$\begin{aligned} E_k &= \frac{1}{2}\times m_a \times v_a^2 + \frac{1}{2}\times m_b \times v_b^2 \\ &= \frac{1}{2}\times 1405 \times 19.444^2 + \frac{1}{2}\times 1120 \times 23.611^2 \\ &= 577782J \end{aligned}$$

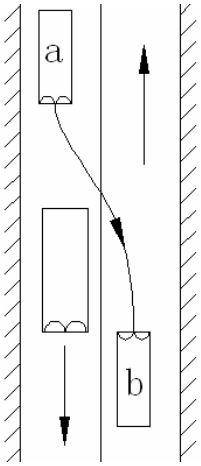


Figure 9

Accident sketch

The brake distance of each vehicle would not exceed 10m conservative estimated, because the accident of frontal impact occurred when the car a) was overtaking the truck and the braking measurement had been carried out subconsciously. When

$$\varphi = 0.7,\quad g = 9.8m/s^2$$

the brake energy:

$$E_f = m_a g\varphi S + m_b g\varphi S = 1405\times 9.8\times 0.7\times 10 + 1120\times 9.8\times 0.7\times 10 = 173215J$$

The deformation parameters of the car a):

Deflection: about 0.2m; deformation width: about 1.6m

The deformation parameters of the car b):

Deflection: about 0.1m; deformation width: about 1.6m

Average stiffness coefficient:

$$C_A = 101121N/m$$
$$C_B = 2056626N/m^2$$

So the energy of deformation:

$$E_{da} = \int_0^D (C_A + C_B x)Bdx = \int_0^{0.2} (101121 + 2056626x)\times 1.6dx = 98171J$$

$$E_{db} = \int_0^D (C_A + C_B x)Bdx = \int_0^{0.1} (101121 + 2056626x)\times 1.6dx = 32632J$$

So

$$E_d = E_{da} + E_{db} = 98171 + 32632 = 130803J$$

Thus

$$E_f + E_d = 173215 + 130803 = 304018J << E_k = 577782J$$

So the energy was not conservation. And the description of the parties was incredible.

5 Emulation Analysis

Along with the fast development of computer software and hardware, the computer emulation accident reconstruction based on the actual parameters has become possible and got continuous optimization. Emulation analyses can simulate the reality on computer, reconstruct the entire course that accident occurs, know the damage and deformed mechanism and evaluate the loss of the accident. At the same time, emulation analysis can save the economize expense. In this paper, the emulation analysis is based on the software of LS - DYNA and MADYMO. These methods first need to get collision velocity and collision position, brake condition and driver respond as well as the original dates such as environmental parameters, in order to analyze and calculate. Then analyze the authenticity of accident damage by comparing the result with the vehicle damage.

5.1 Finite element analysis

This method based on finite element analysis software LS - DYNA and it calculates the collision result on the foundation of the definition contact.

This method can calculate the damage and deformation condition of every time in any position of the vehicle accurately in collision, and can show every detail of results livelily (see Figure 9). But the vehicle model is the finite element model, which model has complex and many units, and need longer time to be calculated. Therefore this method is used to calculate the vehicle deformation in collision in a shorter time and it is not proper for emulating the entire course of the impact. And it is not used to calculate the path of motion in impact.

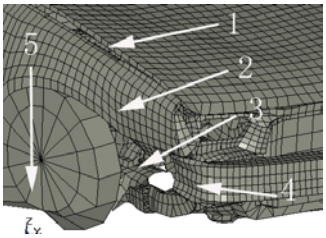
The finite element analysis is used to emulate the case which is mentioned in part 3. Three emulations of different angles 10°, 30°, 60°, are calculated in the same velocity, which approximate 150 km/h. Figure 10 shows the results individually.

The injury of the head is as following when the impact angle is 10°.

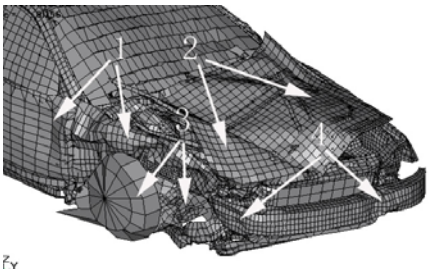
1. light deformation of the engine cover
2. hollow of the right-front fender with serious scratch
3. deformation of the right-front suspension system
4. deformation of the right side of the bumper
5. scratch of the right-front wheel

The injury of the head is as following when the impact angle is 30°.

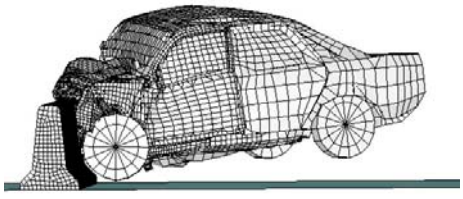
1. serious deformation of the right-front fender
2. serious deformation of the engine cover
3. deformation of the right-front suspension system and scratch of the right-front wheel
4. deformation of the right side of the bumper with scratch



a) 10°



b) 30°



c) 60°

Figure 10 Results of the finite element emulation

The injury of the head is as following when the impact angle is 60°:

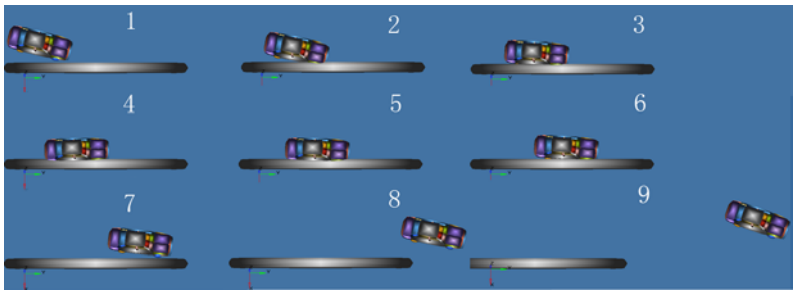
serious deformation of the entire head

From the analysis above, compared with the damage in figure 5, the damage of the accident can be judged to be untruthful.

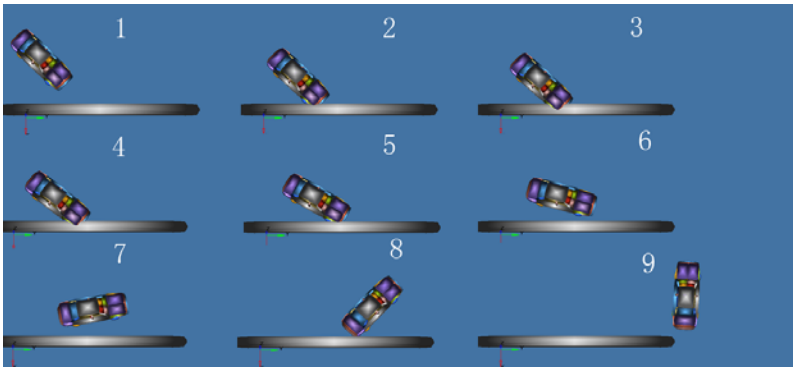
5.2 Multi-body Analysis

This method based on the rigid-body kinetics principle, by the software MADYMO, can be used to analyze the vehicle impact accident.

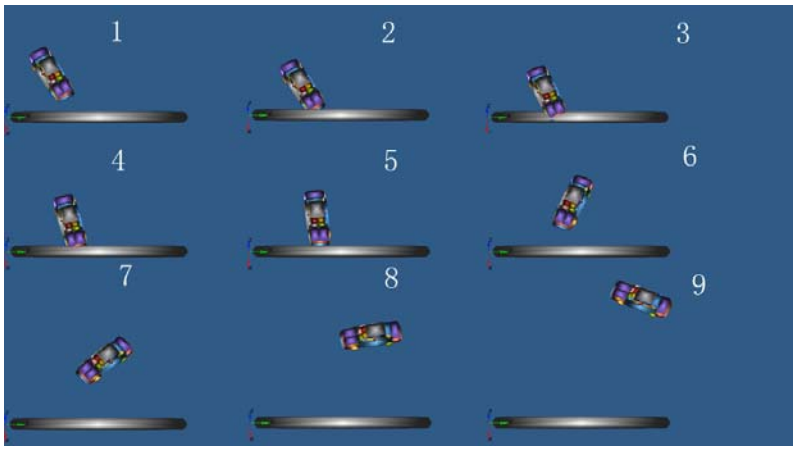
Different from the finite element method, multi-body vehicle model is used in this method. Because of the fewer quantity of rigid body, the smaller computation and the higher computing speed, the entire course of the vehicle impact can be emulated and the path of motion of vehicles



a) 20°



b) 45°



c) 60°

Figure 11 Results of the multi-body emulation

can also be achieved. At the same time, the intrusion distance of vehicles in the accident can be obtained by this method. Because of the limitation of the rigid-body model, this method can not show visualized the deformed conditions of some specific positions of vehicles in the course of the collision, and the vehicle deformation.(see Figure 11).

The multi-body analysis is used to emulate the case which is mentioned above. Figure 11 shows the results which are calculated under the same velocity of 150km/h and in different impact angles as following: 20°, 45°, 60°.

The emulation results show that the right side of the front bumper and the right body of the car have been scratched in the angle of 20°; the right side of the front bumper , the engine cover , the right-front fender and the right body of the car all have been scratched in the angle of 45°; the entire head of the car is damaged seriously in the angle of 60 °.

So compared with the damage in figure 5, the damage of the accident can be judged to be untruthful.

6 Conclusions

The methods of accident reconstruction mentioned in this paper can be used to carry out traffic accident reconstruction as well as analyze the authenticity of impairment of accident vehicles. All the methods have been applied to analyze the authenticity of impairment of motor vehicle accident in insurance and checking the damage level. Because of the particularity of insurance, it is difficult for the working people to get to the spot in time and obtain detailed information on-the-spot. So the information used in the accident reconstruction usually is the pictures of the damaged vehicles and spot photos shot by traffic police, and it is necessary to achieve accurate information from pictures by the image processing techniques. Thus it adds difficulty for more accurate analysis. Therefore it is necessary to develop the precision of calculated results, but it is already adequate for analyzing the authenticity of impairment of motor vehicle accident in insurance.

In order to reduce the fraud rate of motor vehicle insurance, system management need to be strengthened and legal system need to be improved. Then problems can be solved thoroughly.

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