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Analysis of Head Injury in Traffic Accidents Based on Human Body Biomechanics Model

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Abstract: In the process of reconstruction of traffic accident, it is very necessary to have a analysis of human body's biomechanics simulation. Starting from the traffic case, the injury caused by the airbag to the human head is discovered. Establish the finite element model of airbag and use the human head model established by team to have a simulation and analyze. The simulation results are basically consistent with the real head injury, and verified the speed of the car and the degree of head injury. The important role of the human body biomechanics research in traffic accident reconstruction and its application are expounded.

Keywords: Accident reconstruction; Head FEM; Airbag; Impact; Dynamic response

1 Introduction

In China, more than 100 thousands died in traffic accident every year, the number of injuries due to traffic accidents is more than 1 million[1]. Accident reconstruction is the process of reproduce the whole accident as much as possible, exploring the deep reasons and the truth of the accident. This is of great significance to the analysis of the accident.

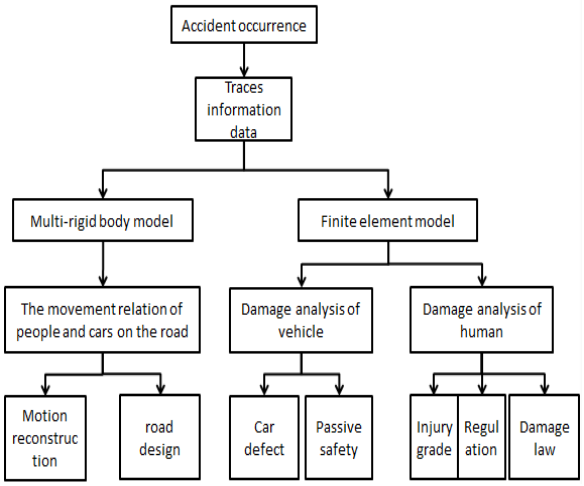


Figure 1. Accident analysis process

Accident reconstruction problem consists of the part of the car and the part of people. At the present stage, multi - rigid body model is often used to reconstruct the accident. For example, PC-crash is very widely used at home and abroad to reproduce the traffic accident, the validity of the car and the human body model has also been a certain degree of verification，the validity of multi - rigid model of the car and the human body has also been almost verified[2-3]. But only using the multi-rigid body model to reproduce the accident cannot explore the damage of human and car, and could not analyze the cause of injury and death accurately. This paper argues that in the process of reconstruction of traffic accident, that evaluating the damage of human body in the accident based on the finite element method could be more accurate to restore the entire accident, and it has important significance in the assessment of injury, the regulations of safety and exploration of the laws of human injury in the accident.

2 Accident profile

In the early morning of June 2016, in a motor vehicle lane, the left front of a car collided with the rear of the tricycle, then the front right side of the car collided with the roadside barrier, and the tricycle collided with the flower bed on road. The accident caused serious damage to the driver's head. Due to the driver's seat airbag deployed, the driver's head injury maybe related to the air bag. One person on the tricycle was died.

(a) Accident car (b) Tricycle in accident

Figure 2. Accident vehicle

As airbag deployment may cause damage to the driver's head，In this study, the finite element model of the airbag is established, and the protective effect of the airbag on the head is discussed based on the established finite element model of human head.

3 Accident reconstructions of air bag injury head

The Chinese 50th male adult head finite element model used in this study comes from Du Tianya[4-5] in research team. The model includes brain tissue, skull, skin, etc. The model mass is 4.52kg and is shown in figure 3.

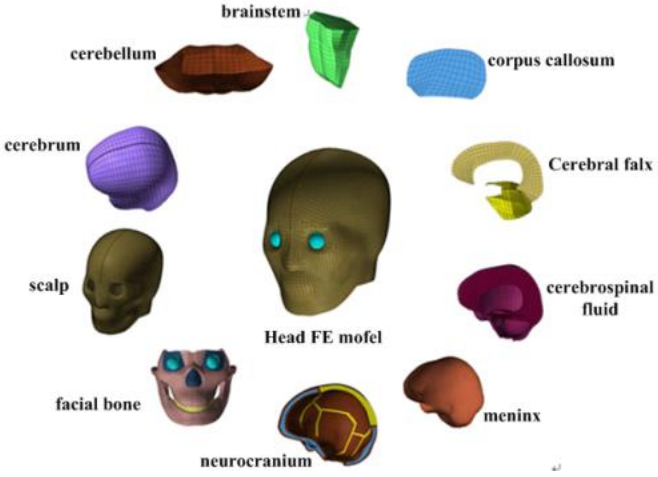
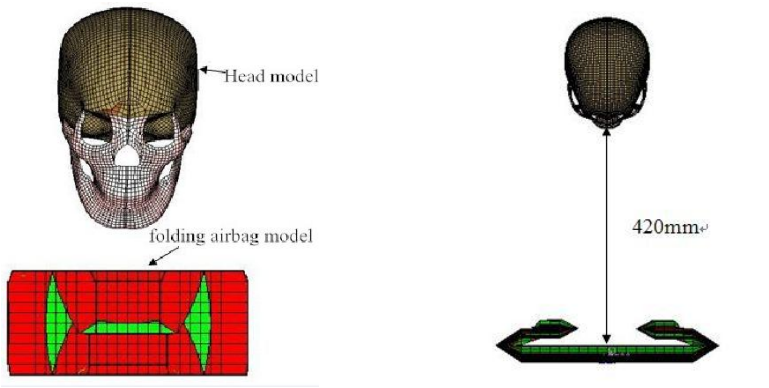


Figure 3. Head finite element model

The driver side airbag model proposed in this paper is composed of two blocks of wafer composition. First, the geometric model of the air bag is established, then the CAD model is divided into grid, and the corresponding material parameters are given to obtain the finite element model of the airbag fabric. As the airbag simulation model in this paper considers the impact of airbag deployment process on the simulation results, the finite element model of air bag is

needed to be folded. Choose a suitable gas pressure curve to determine the way of inflation of the airbag, and finally get the model of the air bag.

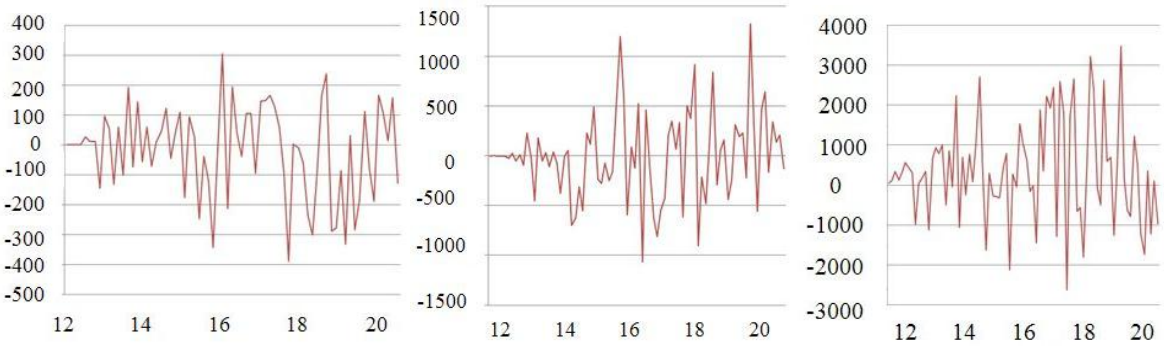
Simulation studies conducted by Zhang Xuerong[6] show that the ignition time of the pre-tightening safety belt is 12ms, which is completed in 24ms. This paper study the collision simulation of the head and airbag without wearing the seat belt, assume the head is to do uniform deceleration movement during 24ms after the car crash， then it has uniform motion until collide with the airbag. Corresponding car speed can be calculated according to the head speed in simulation process. Head and airbag models are shown in Figure 4(a). The distance between the head and the airbag is selected according to the accident car, which is 420mm.



(a)Head and airbag models (b) Distance between head and the airbag

Figure 4. Models and distance

In the process of simulation, the head is given a certain speed to have a collision with the airbag, and then corresponding car speed can be calculated according to the average deceleration of the vehicle during the collision process. According to the actual case, the biomechanical response of the head is simulated in the case of vehicle speed 36.4~50.8km/h. The centroid acceleration of the head are measured at intervals of 1.8km/h. The accelerations of the head under different vehicle speeds are shown partly in figure5.



(a) Head acceleration of 36.4 km/h (b) Head acceleration of 43.6km/h (c) Head acceleration of 50.8km/h

Figure 5. Accelerations of the head under different vehicle speeds

HIC (Head Injury Criterion) is the most commonly used head injury criterion, which is the world's general standard of the degree of the head injury [7], the formula is as follows:

$$HIC=\left[(t_2-t_1)\left(\frac{1}{t_2-t_1}\int_{t_1}^{t_2}a(t)dt\right)^{2.5}\right] \quad (1)$$

The integral variable a (t) in the formula is the rate of synthetic velocity change of the head in the process of being hit by the outside. The difference between the lower bound t1 and the upper bound T2 is the time interval when the head injury factor HIC reaches the maximum. Change the index of the head acceleration into the head injury criterion HIC as shown in figure 6.

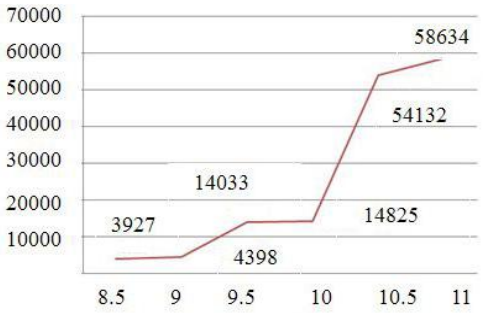
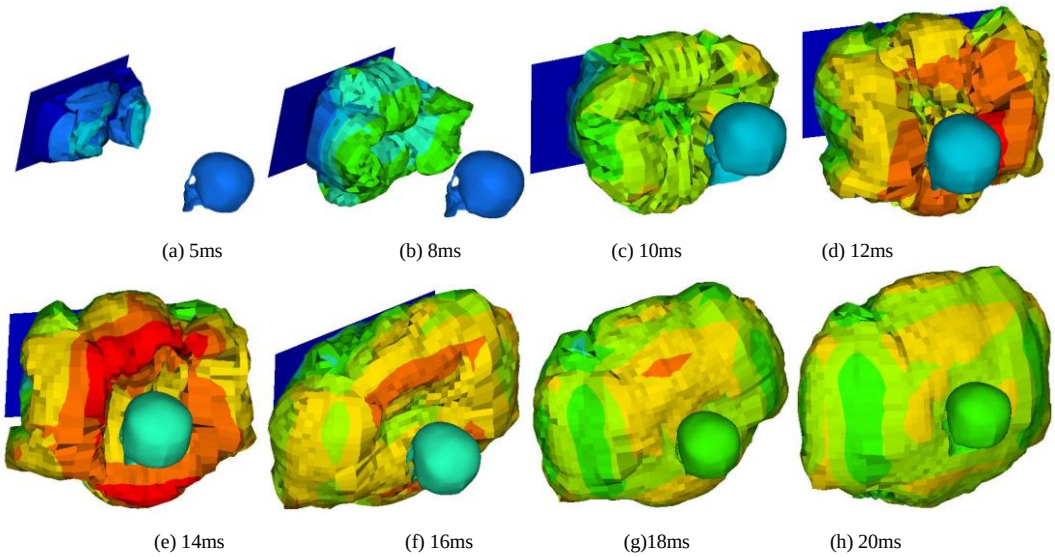


Figure 6. Head injury value (HIC)

Data analysis from Figure 6 show that the HIC value is proportional to the speed, with the increase of the vehicle speed, the HIC value is gradually increased. When the head speed reaches 8m/s, the HIC value is obviously increased for the first time, which is significantly more than the heavier damage limit specified by the simple damage rating, it shows that the head has been clearly hurt at this time. As the speed increases, the contact impact time between the head and the air bag becomes shorter and the air bag is too late to fully expanded, high - speed jet of gas in the air bag has hit the head which causing a damage. When the head speed reaches 8m/s, the HIC value greatly increased. At this time, the air bag is in the state of high-speed expansion which could cause serious damage to the head.

Figure 7 is the whole process of the simulation of the air bag and head crash when the vehicle speed is 50.8km/h. Figure 8 is the contact force curve between the head and the air bag. The contact force curve displays clearly that the air bag is in a rapid expansion stage at 12.5ms and hit the head. At this time, the contact force is the largest and easy to make the adult head fracture.



(a) 5ms (b) 8ms (c) 10ms (d) 12ms

(e) 14ms (f) 16ms (g)18ms (h) 20ms

Figure 7. Air bag and head impact process of 50.8km/h

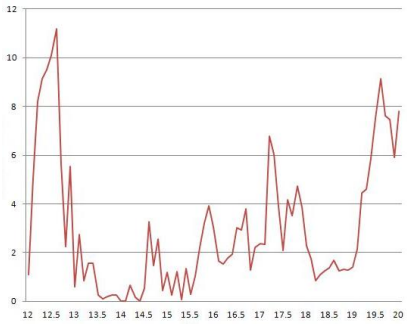
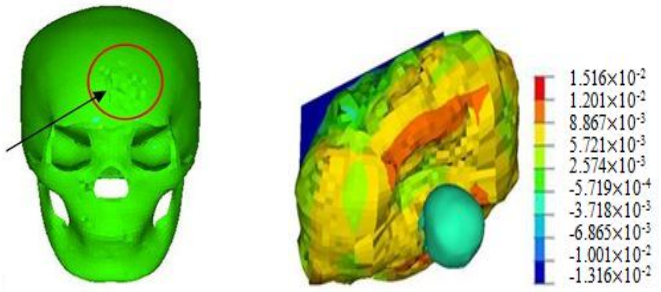


Figure 8. Contact force between head and air bag of 50.8km/h

Figure 9 is the simulation results of the collision between the head and the airbag when the vehicle speed is 50.8km/h. As it is showed in the figure that the frontal and facial parts deformation is obvious, noting here may have resulted inserious injury.



(a) Injury results (b) Injury time

Figure 9. Damage time and results of 50.8km/h

The result of simulation is consistent with the fact that the driver's head is badly injured in the accident. Due to the head injuries are consistent with the actual situation when the vehicle speed is 50.8km/h, accident speed has also been verified.

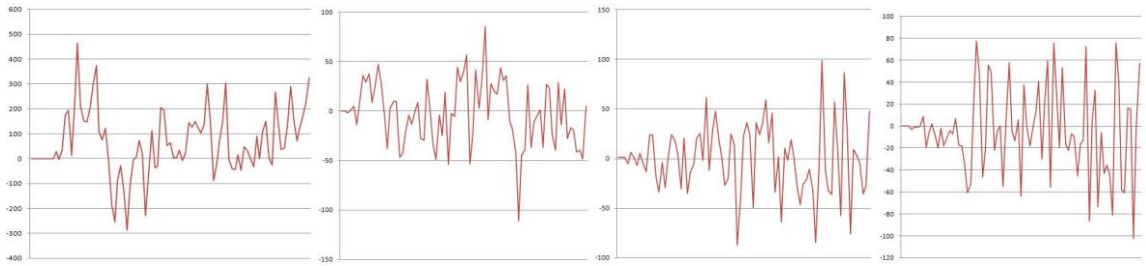


Figure 10. The stress changes of brain tissue of vehicle speed 50.8km/h (a) Contact force of dural and cerebrospinal (b) central unit stress(c) Cerebellum central unit stress (d) Brainstem center unit stress

Responses of brain tissue during the collision between air bag and head have been obtained. Because of the complex structure of the brain, a standard of evaluation of HIC value has not been established yet, and further research is needed to establish the standard of brain damage. After the standard has been specified, the damage assessment level of the driver's brain could be further analyzed.

4 Conclusions

(1) That study on accident reconstruction and make a detailed analysis of the damage based on body finite element model can help the police, doctors, accident researchers analyze the source of human body injury and what causes the human body injury.

(2) When the scene of the accident was destroyed, the impact factors of human casualties is difficult to analyze. Without carrying out the accident reconstruction based on the human body finite element, it is not easy to find the influence factors which are easy to be ignored.

(3) In terms of injury assessment of the accident, the use of human finite element analysis will make the classification more accurate and more scientific. Some accidents cause damage to the human body, but the appearance is not serious. The finite element analysis of the human body can clearly see the pressure wave and deformation of each part of the human body.

(4) When the information is incomplete or there are some contradictions, detailed scrutiny can be carried out based on finite element model of human body. It can make the accident reconstruction more detailed and accurate

(5) Through the damage analysis of the human body in the accident reconstruction, to find out the human damage law which can predict the damage of the human body in accident.

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