Research on the neck protective effect with airbag

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Abstract. The neck injury is usually ignored by researchers and regulations, but in fact the human neck injury is very serious and the rate of being disabled in the traffic accidents is very high. This paper focuses its study on the influence of different parts of the dummy loaded after the initiation of the airbag on the dummy's neck so as to protect the occupants better by changing the design of the airbag. Hybrid III dummy is used to evaluate the response of the occupant in the collision. Recently people are interested in the neck's response to airbag during the process of its loading. The biological force reaction of Hybrid III dummy's neck is based on inertia during the collision, when the dummy is constrained by the safety belt or the seat back. When the Hybrid III dummy is designed, the response caused by the airbag is not considered. This paper evaluates the effect of airbag loading on 5% female Hybrid III dummy. With experimental methods, this paper studies the different effects of different contacting parts when the initiation of the airbag loads on the dummy, focusing on the effect of 5% female Hybrid III dummy. It also illustrates some results that are changed by the experiment about the head / neck design of the 5% female hybrid III dummy preventing the airbag from trapping in.

Introduction

A car can be a security problem. With more and more people own their own cars, road traffic accidents have increased year by year and have become a major problem worldwide. According to incomplete statistics, since the car came into existence, the number of deaths from road traffic accidents in the world has reached about 36,000,000, more than the number of deaths in the Second World War, which has caused great financial loss. Take America as an example, in 1994 the number of deaths caused by traffic accidents amounted to 43,536, accounting for about half of the total number of deaths caused by the accident. The traffic accidents in China basically tend to be shock upward with the car increasing year by year. In recent years, with more people own cars, road accidents increase year by year.

Because the road environment and the technical conditions are different, traffic accidents show different morphological features. Automobile safety has become one of the factors that hinder China's transportation industry and the further development of the automobile industry. Nowadays, when automobile industry in the world continues to develop and grow, especially with the continuous promotion of the expressway, it has been recognized that due to the effect of drivers, road environment, climate, the technical conditions and other unexpected factors, it is impossible to avoid traffic accidents completely. How to ensure the safety of passengers to the limits in accidents, reduce the injury caused by accidents and improve vehicle safety has important practical significance. Security has become one of the three major development directions of modern automotive

technology, which will gradually replace quality and price and become the prior factor in the competition of automobile market.

The risk of serious injury caused by accidents is minimized by the airbag, especially for short women and young children; at the same time, through the introduction of advanced technology, the airbag can provide better protection for all the passengers in the vehicle when vehicle accident happens.

The airbag is effective to reduce casualties in frontal collision. From 1986 to March 1st, 2000, the airbag had saved about 5,303 passengers (4496 pilots (85%)) in former row and 807 passengers (15%)). Adolescent and adult passengers can move the seat back to the limit position and fasten the safety belt to avoid harm caused by the airbag. Even in vehicle with airbags, children should also sit in the back seat, because it is the safest place.

What needs to be mentioned is that on the actual road, the types of vehicle collision accidents are varied. The common forms of the collision are the frontal collision, angled collision, side collision, rear-end collision and rollover, but statistics research on a large number of car accidents in foreign countries shows that in all these incidents, the vehicle frontal collision accounts for more than 50%, and most of the passengers are injured or killed in such accidents. In addition, the proportion of the number of the injured is greatly related to the collision velocity. Therefore, from the perspective of protecting most of passengers in the vehicle, the collision type should be paid the most attention and research on the frontal collision of the high-speed vehicle should be carried out.

The research content and status quo of vehicle occupant restraint system

Vehicle occupant restraint system is one of the main research contents in automotive passive safety field. Occupant restraint system is mainly composed of a seat belt, airbag, seat, dashboard, steering system and other subsystems, mainly focusing on the mechanical characteristics of the belt and the airbag in order to obtain the optimal performance constraints, making the body avoid colliding for the second time with the internal subassemblies. In recent years, many scholars have found that simply optimizing characteristic of the seat belt or the airbag system can only improve the performance of occupant restraint system in a certain extent, but if from the definition of system, the coordination of mechanical safety belts, airbags and seat can greatly improve occupant restraint system.

The car seat belt is one of the important facilities of occupant protection restraint system, which plays an important role in reducing the degree of occupant injury. As the first line of defense to protect the occupant in the restraint system, the safety belt is the most important. The principle of safety belt for occupant protection is that when the collision occurs, the safety belt will "bound" the passenger in the seat, enabling passenger's head and chest not to go forward or hit the steering wheel, dashboard and the windshield, so that the passenger can be prevented from the danger of a second collision and meanwhile will not be thrown away from the seat.

SRS (Supplement Restraint System) airbag system was invented by American engineer Jorn Hertrick in 1953. The function is: when the car suffers a collision and the speed sharply changes, the airbag will expand rapidly and bear and buffer the inertial force generated by the driver’s or passenger’s head and upper body, thereby reducing the damage degree to the human body.

The amount of the chest compression defines the maximum amount of compression of the trunk and ribs, which indicates the situation of chest fracture. The important organs of the chest, including heart, main artery and lung, are composed of soft tissue. The previous studies show that the soft

tissue injury is caused by the rate sensitive deformation in the chest. In the case of high-speed collision speed and small amount of chest deformation, sometimes it can cause harm to lung and heart, which shares the same principle as the bullet hits the bulletproof vest or softball directly hits the chest. Some collisions sometimes are fatal, even without any visible chest hurt.

$$vc = \max\left(\frac{dD(t)}{dt} \cdot \frac{D(t)}{sz}\right)$$

In the formula, D (t) - deformation; Sz - specified dimensions, the initial thickness of the chest in the frontal collision and half the width of the chest in the side collision.

Full damage evaluation

HIC, chest 3MS criteria, chest compression and thigh bone axial stress tolerance are to evaluate the design of occupant restraint system at a certain level. In order to evaluate the overall performance of the restraint system, there should be a full damage criterion including a single damage parameter. Based on this consideration, in 1990 the United States General Company Viano and Arepally introduced weighted factor and use the weighted method to integrate various damage indexes, thus obtaining a regularized damage evaluation value WIC. In FMVSS208, WIC is defined as follows:

$$WIC = 0.6\left(\frac{HIC_{36}}{1000}\right) + 0.35\left(\frac{C_{3MS}}{60} + \frac{C_{cowp}}{0.0762}\right) / 2.0 + 0.05\left(F_{kk}^{ty} + F_{re}^{rwe}\right) / 20.0$$

The research method of vehicle occupant restraint system

Because consumers concern more and more about the safety of the car, and various countries also put forward higher requirements in the laws and regulations on vehicle safety, people begin to pay attention to the research work on the inverse problem of occupant restraint system. Two ways of studying occupant restraint system are in test and simulation. In addition, due to the continuous development and improvement of the core theory of new technology in other related fields, especially the rapid development of large electronic computers, continuous improvement of calculation method, and more thorough research on various material mechanisms, the simulation of complex structure becomes possible. Therefore, the research method of the constraint system is based on computer simulation, and then using fewer experiments to verify the results.

With the development of computer technology, software of automobile collision is becoming more and more mature. In vehicle collision simulation, the following two categories of computer software are widely used.

One, finite element software for structure crash simulation, including DYNA3D (LS-DYNA3D and OASYS-DYNA3D), ESI/PAM-CRASH and MSC/DYTRAN, whose core is based on DYNA theory of public version developed by the America Lawrence Livermore National Laboratory in the1970s, and has very strong function in analysis and research of the three-dimensional dynamic structural deformation is. In China, PAM-CRASH and LS-DYNA3D are often applied.

The other one is Crash Victim Simulation (CVS) Software. The widely used CVS software is CAL3D and MADYMO based on the multi-rigid body theory. PAM-SAFE software of France's ESI is a computer simulation system for 3D collision simulation based on explicit finite element algorithm, which can simulate very accurately the large displacement, large rotation, large strain, contact impact and other problems, especially in the study of passive safety field. The interaction between the rigid body and finite element is illustrated with two methods. One is the support,

indicating the rigid connection between the node and the rigid; another is the contact, indicating the interaction between the forces of the rigid body and the node. In order to reduce the time of CPU, we can use different explicit integral methods and regard the finite element calculation as the subroutine of the multi rigid body calculation.

The theoretical basis of vehicle collision simulation

Study on the occupant collision began in the 70's. Currently, the more mature or widely used research method is the multi-body dynamics method. The method is represented by MADYMO software researched and developed by Holland National Academy of Sciences (TNO). Based on occupant characteristics, riding environment, restraint system and the collision state, it establishes a hinged multi-body system model, as is shown in Fig. 1, to conduct the calculation and analysis of the motion and dynamic response of the victims in the collision.

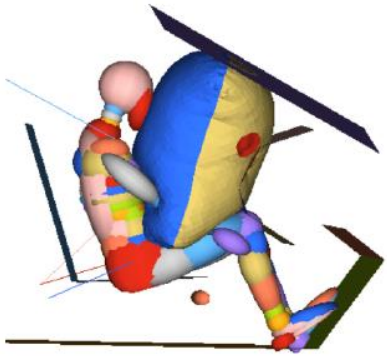

Fig. 1 occupant multi-body dynamics analysis model

Multi-body dynamics method uses the rigid bodies to represent the floor, dashboard, seats, steering system and dummy, the interaction of each rigid body is defined by the contact and the force is calculated according to the penetration volume and contact characteristics. The input of the multi-body system model is the impact acceleration curve borne by the vehicle while the output results are the force that each part of the dummy tolerates, deceleration curve and damage index etc. Because the multi-body dynamics method uses the rigid bodies to represent the objects of analysis and force bearing, it cannot be directly used to calculate and analyze the impact deformation of car body structure, but to evaluate the occupant’s response in the specific state of the collision. Therefore, in the design and research of safety in the vehicle collision, the multi-body dynamics method is limited to occupant collision research.

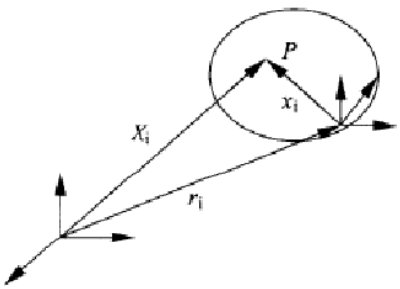

Fig. 2 the multi-body coordinate system

The research on the effect of the airbag on neck

In the design of Hybrid III dummy, the response caused by the airbag is not considered. The design of the Hybrid III dummy's neck mainly emphasizes the proper bending and extension, and mechanical performance requirements of the neck is to establish the association between the occipital condyle (bone) torque and the rotation of head relative to body. The neck deformation is because the head produces motion relative to the body. When the body is constraint by the safety belt or the seat backrest, airbag's loading on the human body is different from that on the safety belt or the seat back, because there are a lot of loading paths of the airbag on the head. In the process of airbag loading, in the test dummy's neck shows different reactions while in the process of the safety belt or the seat back loading on the neck, it only experiences the first bending mode. During the airbag loading, the neck experiences the second bending mode. 5% female Hybrid III dummy is often used to evaluate the response of the small passenger on airbag. This paper analyzes the response of the 5% female Hybrid III dummy's neck due to the airbag loading. That depends on how the airbag and human interact. Three ways of interaction of airbags and neck are researched and observed. First, the airbag directly acts on the head; second, in the process of initiation the airbag traps in the dummy's chin; third, the air bag is trapped in the head behind the chin. This paper also illustrates some results that are changed by the experiment about the head / neck design of the 5% female hybrid III dummy preventing the airbag from trapping in.

A series of static airbag detonation experiments are used to direct and study 5% female Hybrid III dummy's head / neck region. Fig. 3 is the typical test equipment. The dummy is positioned, tilted to the dashboard, in the passenger seat on the full front. Selection in the static environment is to obtain simplicity of the initial permutation of the dummy, relative to the airbag module.

Fig. 3 the typical experimental device

This device is man-made, which may not occur in the vehicle collision. For the description of the possible different interaction methods between airbag and neck in the dynamic impact test, it is a useful test condition. The main focus of this study is to test in the correct position, for example, in a vehicle crash with dummy seated or sliding test. Select the dummy position to strengthen the possibility of the airbag trapping into the neck - chin cavity. A standard 5% female Hybrid III dummy with TMJ head skin and SAE neck protection is used in a basic test.

The three the airbag-dummy interactions are as follows.

1. The neck load is mainly caused by the front airbag loading to the head.
2. The neck load is mainly caused by the air bag traps to the chin.
3. The neck load is mainly caused by the airbag traps behind the chin.

In all three kinds of interactions, the airbag almost contacts the head at the same time (15ms in airbag ignition). When the airbag is filled and film tension is generated, load is produced. In the contact, the head and chest begin to accelerate and the neck force immediately becomes strong.

Conclusion

This paper mainly analyzes the limited response of hybrid III on the dummy's neck to the airbag loading. It only records the occupant in the correct position and the results may not apply to the passenger near the airbag, such as the passenger who is not in the correct position. Research focuses on airbag loading area in very special and artificial conditions. The results need a lot of research before being promoted. However, the results show that the design of hybrid III dummy needs to be changed to describe correctly the response of human beings to the airbag loading.

A series of tests recorded in this article show that the response of the dummy's neck depends on the interaction mode of the air bag and the dummy's head. The airbag doesn't trap in the chin area or below the chin but in the chin and the cavity of the neck, and the head is pushed forward, which causes neck to bend. If the airbag is caught in the chin area, the head is pulled towards the neck front and upper and the neck extends and forms an angle. If the airbag is caught below the jaw and in the cavity of the neck and head, the head is pulled forward and upward again, and the neck extends and forms a higher angle.

In the experiment described in the article, during the initiation of the airbag, dummy's neck suffers the second bending constraint mode. Currently, the available biological force of bending and extending neck response materials of the hybrid III dummy's neck cannot be applied to the test of the neck responding to the airbag. During the airbag loading, the neck biological force data of the neck response should be recorded to evaluate correctly the potential harm to passengers. In addition, the biological force data is needed to improve the mechanical characteristics of the human jaw / neck area. So it is with the dummy. The characteristics of interaction can be described more accurately and designed.

Through the above experiments, the following conclusions can be drawn: when the airbag explodes and contacts with different parts of the dummy, it has fewer effects on the head, the chest or the thigh but a great impact on the neck. The mode of the airbag directly contacting with the head of the dummy does minimal harm to the neck. If it contacts with the chin, then the harm will be relatively serious; if it directly occurs between the jaw and neck, then the harm will be extremely serious. Therefore, in the process of designing the airbag, a series of parameters need to be adjusted to control the direction and posture when it opens so as to guarantee that the airbag acts on the head of the dummy when it is exploded.

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