Study of damage of passenger with short stature during a frontal collision

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Abstract. Many scholars have found that just taking 50% mix type III of male dummies as the basis to optimize passenger restraint system parameters limits the performance of the passenger restraint system to some extent, and if 5% of mix type III of female dummies is add to 50% mix type III of male dummies to optimize passenger restraint system parameters, it can greatly improve passenger restraint system performance. By using collision protection standards, it can cover the study of passengers with various statures, improving safety protection that airbags can provide to maximum extent to passengers with various statures rather than to take some compromise approach, reducing the injury risk to those vulnerable passenger, namely lowering the injury of short stature passengers in frontal collision, study the injury of female dummies at driver's side in frontal collision, matching the optimal airbag, making the airbag provide maximum safety protection for passengers with various statures.

Introduction

With the continuous development and growth of world automobile industry today, especially with the continuous promotion of the highway, it is recognized that due to the driver itself, road conditions, weather, vehicle technical conditions and other unexpected factors, accidents can not be completely avoided, how to ensure passenger safety to maximum extent during collision, reduce injuries caused by the accident and improve vehicle safety has important practical significance. Safety has become one of the three major development directions of modern automobile technology, it will gradually replace quality and price to become prior factor in the automobile market competition.

Government management and user needs are two impetus to promote automobile industry technological progress and constantly improve automobile safety. Facing serious traffic accidents, many countries such as the United States, Japan and European Community countries have formulated strict safety regulations and standards. At the same time, foreign research on automobile collision safety also developed early in the 1960s and achieved rapid development. With the implementation of safety regulations and development of vehicle safety research, the traffic fatality rate is greatly reduced in many countries. In the US, the number of deaths per 100 million kilometers has reduced by a peak of 15.6 persons down to 3.5 persons in 1980, and then dropped to 1.8 persons, the effect is very significant.

Today, because of the development of electronic technology, automobile has begun fitted with ABS, airbags and a number of intelligent systems, the active safety and passive safety of automobile are greatly improved. In developed countries, although car ownership is increasing, car traffic accident deaths or mortality has a downward trend, indicating that advanced safety technology can save life.

Automobile safety has become one of the important factors restricting China's further development of transport and automobile industry, to carry out automobile safety study is necessary and urgent. In order to promote research work in this area, Society of Automotive Engineers of China set up (passive) Safety Technology Profession Committee in September, 1995. The establishment of this professional committee marks China's automobile passive safety research is gradually on the systematic and formalized development road. On October 28, 1999, the enactment of CMVDR 294 Design Rules on Frontal Collision Passenger Protection indicates that China's rules on collision are gradually in line with international practice. The risk of serious injury accident caused by airbag is reduced to minimum, especially for short stature women and young children; at the same time, through the introduction of advanced airbag technology, provide better protection for all the passengers inside the vehicle when frontal collision happens.

The highest test of not wearing a seatbelt rigid barrier collision test improved safety protection that airbags can provide to maximum extent to passengers with various statures rather than to take some compromise approach, reducing the injury risk to those vulnerable passenger, including children and diminutive woman near airbags, and passengers not in normal seat.

Vehicle frontal collision includes two collisions. The first collision is the vehicle crashed into another car or other object, such as a tree. The second collision was the collision of human body with vehicle interior ornaments. Frontal collision is the leading cause in vehicle injuries accident. More than two-thirds of the deceased was not wearing a seatbelt in a frontal collision accident. Among these not-wearing a seatbelt died people, young people aged 10-20 years accounted for nearly 40%. Study have shown that the proper use of thign/shoulder belts can make the risk of fatal injury of the front passenger decreased by 45%, to reduce the risk of intermediate injuries by 50%. For light truck passengers, seat belts make the risk of fatal injury decreased by 60%, to reduce the risk of intermediate injuries by 65%. Airbags is very effective for reducing frontal impact casualties. From 1986 to March 1, 2000, airbags have saved about 530 front passengers (4,496 drivers (85%) and 807 passengers seating beside drivers (15%)) of life. Adolescent and adult passengers can also move the seat back to the limit position and fasten the seatbelt to avoid damage by airbags. Even in the vehicles without airbags, children should sit in the back seat as far as possible, because there is the safest place.

Software

With the development of computer technology, automobile collision software is also more mature. There are mainly two categories which are widely used in automobile collision simulation as follows: one is finite element software of structure collision simulation, DYNA3D (LS-DYNA3D and OASYS-DYNA3D) is commonly used, the core of ESI/PAM-CRASH and MSC/DYTRAN both take DYNA public version theory developed in the 1970s by the US Lawrence Livermore national laboratory, it has very strong function in analysis and research of three-dimensional dynamic deformation. The other type is CVS-Crash Victim Simulation, the widely used CVS type software includes CAL3D and MADYMO based on multi-rigid-body theory. French ESI's PAM-SAFE software is the computer three-dimensional collision impact simulation system based on explicit finite element method, it can carry out very accurate simulation for issues like large displacement, large rotation, large strain and contact collision, especially in the field of passive safety field, the research is very successful.

Research on passenger collision began in the 1970s, at present, the more mature or widely used research method is multi-rigid-body dynamics method, which is represented by MADYMO software developed by the Netherlands National Academy of Sciences (abbreviated as ‘TNO’), it is based on passenger features, seating environment, restraint system and collision state, establishing multi-rigid-body system model joined by hinge, as shown in Fig .1, performing motion and dynamic response calculation and analysis of crash victims.

Figure. 1 Passenger multi-rigid-body dynamics analysis model 1

In Fig .1, passenger and seating environment system is composed of many rigid bodies, MADYMO uses D alembert_Lagrange's equation to describe calculation of dynamics of multi-rigid-body system, as shown in Fig .2, position, speed and acceleration of any point (shown as P) on rigid body are:

$$\vec{X}_i = \vec{r}_i + \vec{x}_i$$
$$\dot{\vec{X}}_i = \dot{\vec{r}}_j + \vec{\omega} \times \vec{x}_i$$
$$\ddot{\vec{X}}_j = \ddot{\vec{r}}_i + \dot{\vec{\omega}} \times \vec{x}_i + \vec{\omega}(\vec{\omega} \times \vec{x})$$

In the equation, ω is rotation angle speed of the rigid body to inertia coordinate system. The multi-rigid-body dynamics method uses rigid body to represent floor, dashboard, seats, steering system, dummies, etc., the interaction between various rigid bodies is defined by contact, size of acting force is according to breakthrough amount and contact characteristics. The input of multi-rigid-body system model is the impact acceleration curve that vehicle bears, the output result is the receiving force, deceleration history curve and injury index, etc. of each part of dummies. As multi-rigid-body dynamics method takes rigid bodies to represent analysis and force-receiving objects, therefore, it can not be directly used to calculate and analyse the collision deformation of the vehicle body structure, but can only be used to evaluate the response of passenger in specific collision status, etc, thus, in the design and research of vehicle collision safety, multi-rigid-body dynamics method is limited to passenger collision research.

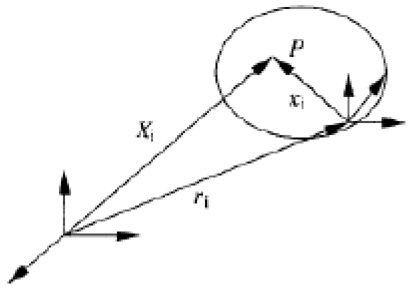

Figure. 2 Multi-rigid-body coordinate system

The simulation algorithm of airbag

Analog of airbag finite element model is divided into two steps: simulation of airbag fold and simulations of airbag unfolding.

Initial Metric Method is widely used for airbag fold. It selects a geometric body which can be folded, according to airbag model establishing requirements, it establishes finite element grid and takes it as a map grid. It establishes finite element grid according to the geometric shape of actual airbag as a reference grid. The number of units and nodes of reference grid should be equal with map grid, unit number, node number, unit shape and connection should be consistent with the map grid. Flatten and fold the map grid to establish airbag model. When doing simulation calculation, read map grid and reference grid at the initial time of calculation, calculate internal forces according to the shape difference of the same unit number in two grids. In subsequent calculations, take the map grid as airbag model and aerate and unfold it, with the internal forces calculated at the initial time, correct the shape of each unit in map grid so that the airbag eventually expanded into precise geometric shape.

Analog of airbag unfolding can generally be divided into two types: simulation for normal seated passenger airbag and simulation for leaving-seat passenger airbag. For normal seated passenger, it generally use uniform pressure model to simulate. It regards airbag as continuously expanding control volume, the inflow and outflow of gas is calculated by mass flow. In this model, gas mass flow leaking from airbag by airbag vents and other factors, there are two basic assumptions of the model: gas filled into airbag is ideal gas; pressure and temperature are equal everywhere inside airbag. It is closer to the actual situation only after the airbag is fully expanded. However, contact of leaving-seat passenger airbag with passenger will occur before the airbag is not fully expanded, some design parameters of airbag such as the jet direction of gas generator and airbag folding method, etc., will have huge influence on airbag unfolding, so the uniform pressure model can not be used. For analog of leaving-seat passenger airbag, different software has different ways. LS-DYNA uses ALE (Arbitrary Lagrangian-Eulerian) equation [29]. Lagrange's method in large deformation process, a large number of units will be distorted; although simple Euler method can avoid unit distortion, mass flow among units will disperse. ALE equation is a combination of the two methods, thereby controlling the translation, rotation and deformation, this method will save the overall energy of the system as possible. PAM-CRASH uses FPM (Finite Point Method) methods. FPM is a no-grid method based on Lagrange equation. It will first disperse based on conservation equation shape, a certain number of points represent compressible fluid, these points contain the following information: location, density, velocity and internal energy. These points will be automatically generated by software, the flow field gradient can be obtained by the interpolation of a series of points. MADYMO uses Euler equation to calculate the fluid, it will automatically generate Euler grid by airbag fiber grid; when the airbag is unfolded, Euler grid will automatically adjust size to ensure including airbag border. FCT (Flux Corrected Transport) method is one kind of finite difference method, in the past it was often used to solve this equation, the algorithm is suitable for compressible no-viscidity flow, in order to simplify the algorithm and to improve efficiency, in MADYMO, this algorithm is mainly used for gas generator modeling of airbag.

Establishment and verification of simulation model

Car cab model mainly includes windscreen, dash board, pedals, floor, seat (including the back) and the steering system, the structural arrangement is shown as in Fig .3-1. Vehicle body model uses the actual size of the original car. The coordinate origin point of vehicle body model is in the vicinity of the front axle, where is also as the origin point of the general arrangement. The X axis of coordinate system directs to the front, Y axis directs to the left, Z axis directs to the positive up. Oval-shaped ball is used for steering system and pedals for simulation, windshield, dash panel, floor, seat system use flat for simulation, each rigid body is set with a quality parameter for simulation of the whole vehicle quality. The vehicle body model is made up with multi-body system joined by hinge. Location and type of hinge determine that the vehicle body model can simulate what kind of deformation. Lock all the hinges in this model, namely the vehicle body model is not deformed in collision.

The goal of passenger restraint system optimization design is to find a design scheme which can provide the best protection for passenger from the vehicle's passive safety. This study is going to adopt the method of experimental design, to carry out analysis and research on the established passenger restraint system, to optimize the system design, to make the system parameters configured reasonably to achieve the best condition of protecting performance for passenger, to seek economical and feasible scheme.

Experimental design can be seen as a test process by design or through elaborately arranged, the aim is to make the test process scientific and orderly, so with less number of tests to obtain adequate and reliable information. The actual problem is complex, and factors influencing the test are often multifaceted. We should observe the impact of various factors on the test. In the multi-factor, multi-level test, if each level of each factor is mutually collocated to conduct a comprehensive test, the number of tests need to do is a lot. Doing so many tests needs to spend a lot of manpower, material resources, but also with a long time, it is obviously very difficult. Sometimes, due to excessive long time, conditions change, the test will fail. People found in long-term practice that to get ideal results, it does not need to conduct a comprehensive test, even the number of factors, the level is not too much, it need not to do a comprehensive test. Especially for those high cost of test, or destructive test, they do not need to do comprehensive test. We should under the premise of not affecting the test results, to minimize the number of tests. Orthogonal design is an effective method to solve this problem. The main tool of orthogonal design is orthogonal array, it is a better way to use orthogonal array to arrange test, which has been widely used in practice,

From simulation analysis we can know, oil film change in bonding process, joining of the three stages is affected by a number of impacts. Load, permeability of friction material, width and depth of groove on the friction piece surface have big impact on it, not only affects the ability to transmit torque, but the impact on bonding time is great.

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