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The Status Quo and Trends of Studies on Collision Safety of Eelectric Vehicles

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Abstract

The battery system of EV consists of decades and even hundreds of batteries through series connection or parallel connection, which causes the potential safety problems and injuries happening to passengers different from those of traditional vehicles. This paper will regard the collision safety of battery system of EV as the object of study and then summarize the status quo and future trends of studies on collision safety and conclude some strategies to improve the crashworthiness of EV.

Keywords: electeric vehicle, collision, computer simulation, power battery

1 Introduction

The vehicles are the most important public transportation means and devices that provide convenience for people and also cause the serious shortage of energy and problems of air pollution at the same time. So how to provide convenience for people without causing energy and environmental problems is becoming a new project that draws increasing attention. With the advantage of no-emission, it is one of the best choices of taking usage of new energy that the electric vehicles replace the traditional vehicles that can cause several serious energy and environmental problems. Especially in the 1990s, the electric vehicles have a great development owing to their own advantages and supports of many governments. Electric vehicle is a road vehicle which involves with electric propulsion. With this broad definition in mind, the electric vehicles contain the battery electric vehicle, the hybrid electric vehicle and the fuel cell electric vehicle.

This paper will only talk about the battery electric vehicles and call them EV for short. Though the electric vehicles have undergone a great development recently, the studies on safety and the corresponding special requirements of electric vehicles are very limited. And the studies on passive safety of electric vehicles is also very few compared with those on traditional vehicles though some studies on passive safety and crashworthiness of electric vehicles have been carried out. On the contrary the problems about passive safety of electric vehicles should be paid more attention to and the target-oriented studies should be executed.

2 The Methods to Study Collision of Vehicles

Now, the research methods of vehicle impact generally contain test method and computer simulation method[1]. The test method is the most basic and effective method for assessing the safety of vehicles and also can get the exactest result because it is most approximate to accident. But it also has some disadvantages such as complicated preparation, too much cost and great demand for equipment. And the computer simulation method firstly imports geometric model with the same size, shape and features as the real vehicle and generates nodes, elements and the grid model with the discrete element method and then puts the loads, constraints or boundary conditions on the finit element model and at last calculates and simulates the impact of vehicle. This paper only talks about the computer simulation method[2].

3 The Status Quo and Futere Trend of Studies on Collision Safety of Traditional Vehicles

There is a lot of work having been done about test and simulation of vehicle impact at abroad. In 1993, Pockett AK made a computer simulation of a car made in Korea and the finite element model is made up of solid elements, shell elements, beam elements and so on. And the material used in the finite element model was elastic plastic material and the problems about stress hardening, fracture and slip of contact surfaces owing to large deformation were also taken into consideration. With the help of all the measures above, the validity of the finite element model had a great improvement[3].

In 1998, the Ford Moter Company created a finite element model of a car. In the finite element model, every part of the geometric model was created without any simplification and all the geometric parameters and physical parameters in the model were the same as those of the real car. Thereby the accuracy of the model could be guaranteed. At the same time, every part of the geometric model of the car was meshed with fine grid cell in order to be able to be used in the simulations of frontal impact, side impact and rear impact. Though the model contained 125,000 solid elements and 88,000 shell elements, it could be achieved easily with the help of high-level hardwares and softwares of computer[4].

In 2000, Ge Ruhai, et al.., in Jiangsu University created the finite element model of frame and carried out the corresponding analog computation with the software ANSYS/LS-DYNA3D when they made some researches on the characteristic of offset frontal impact. In the model, the engine assembly, the axle assembly and so on were regarded as lumped mass and placed in the main sills. At last, the model included four kinds of elements and totaled to 1,942 elements and 2,124 nodes[5].

In 2001, with the help of the software PAM-CRASH, Wang Hongyan and Gao Weimin, in Tongji University created the finite element model of a car for frontal impact(Fig.1) and simulated the frontal impact of the body in white with an emphasis on the influences of the simulation of materials and welds, the simplification of mechanism, the setting of time step, the definitions of rigid and self contact and so on. It was illustrated that the error between computed value and test value was little through contrasting the computed value with test value and then modifying the finite element model[6] [7][8].

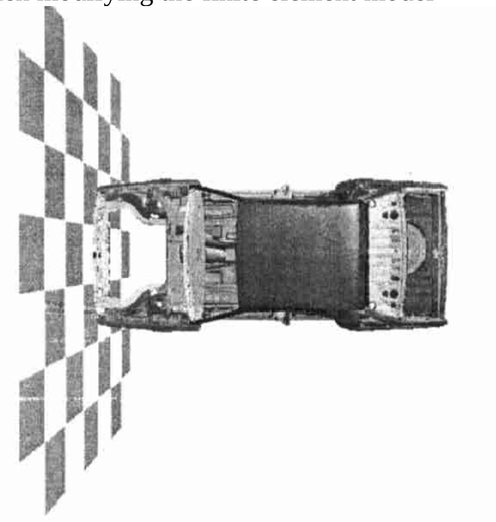

Fig.1 Finite element model of white-body of SAN TANA B2

In 2002, by the software LS-DYNA Zhang Zaofa, et al.., in Southeast University created the finite element models of the cab of a middle bus and the rigid wall. The finite elements models were made up of four kinds of elements such as Hughes—Liu, Shelll63, Beam161 and Mass166 and totaled to 4,948 nodes and 6172 elements and the rigid wall was definited as a infinite plane. The method that only some part of the middle bus was carried out analogue computer had such advantages as less time to be spent, less data to be computed, higher computing speed and more simplicity and feasibility while the disadvantages were that the result was not as good as that of complete vehicle due to the neglect of influences of each part[9].

In 2003, Wang Qingchun, etal.. , in Tsinghua University created the finite element model of white-body of a minibus(Fig.2) and studied the energy-absorbing characteristic of the body in white through a series of analogy calculation. In the finite element model, every part of the body in white was simulated with shell elements and the welds were simulated with the nodes definited directly. Thereby the finite element model totaled 163,458 elements and 174,205 nodes. In order to verify the correctness of the model, the frontal impact tests of the white-body were executed at various speed and the force-time curve and acceleration-time curve were gotten. At last through the analysis of and contrast between the computed value and the test value, the method to create and calculate the model was proved correct. Through a series of studies, the method to create good elements was introduced and tested and at last it was also proved that it was feasible to simplify and even delete the proper parts of body in white during the creation of finite element model[10][11].

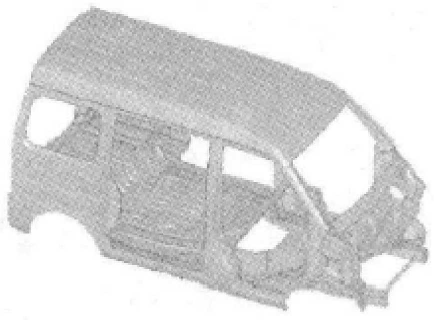

Fig.2 Finite element model of white-body

Nowadays the studies abroad include the study on crashworthiness of body, the study on collision biomechanics and the study on the developments of safe assembly of cab and passenger restraint systems[12]. And the concrete study contents are to change the structure and characteristic of the bumper, the engine hood and the front wing, to change the shape of frontal part of car. At present the studies at home on passive safety of vehicles mainly focus on the improvement of crashworthiness of some components of car, the accuracy of the finite element model and so on. At the same time, some Motor Corporations have also taken some measures to improve the safety of car in collision situation. There are some examples as following: Andy Clough with his co-worker, in the Corus Corporation have made a conceptual design of passenger safety with steel, aluminum, composite material and so on. Some famous Iron And Steel Companies are also developing the high-safety light steel material. The General Motors Corporation is taking the technology called laser welding to weld inner plate and front and rear sill so as to reduce the weight and the number of welding spot and the components of chassis are using the backward-hardening two-phase steel to improve stiffness and crashworthiness. And some american motor corporations are optimizing the structure match of frontal components of vehicle to improve the capacity of absorbing energy in collision situation[13].

4 The Status Quo of Studies on Collision Safety of Electric Vehicles

Nowadays there are a few studies on the influence of battery structure on crashworthiness of battery system at home and some papers only propose the advices about the methods to create model on the basis of computer simulation of classic structure of battery. Among the papers, most of them only introduce the present status and methods and only a few papers report the concrete data and the practical parameters. As for the studies on collision safety of EV, there are also some studies having been carried out and being paid high attention home and abroad. And some classic examples are as following:

In 996, Tae-Eun Chung, at Institute for Advanced Engineering designed aluminum space frame for Crashworthiness Improvement, becasuse aluminum has a good energy absorption property as well as contributed to weight reduction and recycling. The advantages of aluminum were utilized on electric vehicles that consist of aluminum space frames and other aluminum components. Occupant analyses were accomplished for the aluminum space frame vehicle and the results were verified by comparison with a real experiment which was a barrier test for frontal impact. With the model validated by test results, modifications were made to improve the crashworthiness and to minimize the injury of passenger by modifying the side members of the aluminum space frame. At last the results of experiment and simulation showed that the aluminum space frame could provide good crashworthiness in a frontal crash[14].

In 2008, the SAE compiled *Electric-Drive Battery Pack System: Functional Guidelines.* This SAE Information Report describes common practices for design of battery systems for vehicles that utilize a rechargeable battery to provide or recover all or some traction energy for an electric drive system. It covers termination, retention, venting system, thermal management, and other features. And this document does describe guidelines in proper packaging of the battery to meet the crash performance criteria detailed in SAE J1766[15].

In 2005, the SAE Fuel Cell Standards Committee compiled *Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing.* This SAE Recommended Practice is applicable to all Electric Vehicle and Hybrid Electric Vehicle battery designs, including those described in SAE J1797. The potentially harmful factors and materials addressed by this document include electrical isolation integrity, electrolyte spillage, and retention of the battery system. This document defined test methods and performance criteria which evaluated battery system spillage, battery retention, and electrical system isolation in Electric and Hybrid Electric Vehicles during specified crash tests[16].

In 2008, Jae Moon Lim, in KATRI explored issues related to the implementation of Federal Motor Vehicle Safety Standard (FMVSS) No. 305 in the Korean Motor Vehicle Safety Standard (KMVSS) No. 91. And two rear impact tests on generic hybrid electrical vehicles (HEVs) were performed. HEV batteries were mounted in the trunks of similar gasoline-powered vehicles. One vehicle were impacted by a barrier moving at the speed of 48 kph, while the other vehicle were impacted by a deformable barrier moving at the speed of 80 kph. Results of the tests were reported as accelerations of the battery and B-pillar and as deformations of overall vehicle, trunk, and occupant compartment. Finally, the results showed that the 80 kph impact condition were very severe and that crash protection for occupants were expected to be more challenging than for other crash scenarios[17].

There are also many examples such as Xie Qingxin, in Hunan University have studied the crashworthiness of the rhomboid vehicle's battery boxes(Fig.3) and then optimized its structure to improve the crashworthiness of battery boxes(Fig.4, Fig.5) with finite element method[18]. But they haven't studied the impact of each battery because of regarding the batteries as a rigid body.

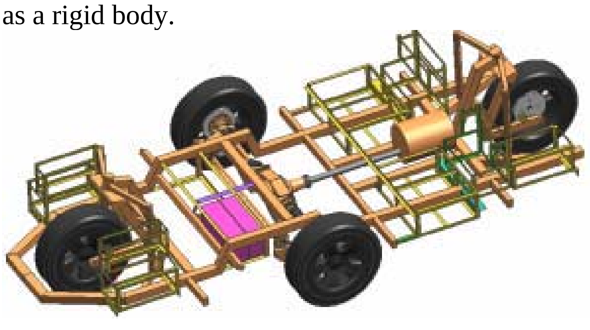

Fig.3 Structure of rhomboid electric vehicle

Fig.4 Deformation of frontal battery box

Fig.5 Improvement of frontal battery box

Yang Jian and Cao Libo, in Hunan University have made a analysis about the possible potential safety problems including the electric injury, the chemical injury, the burning injury etc and analyzed the corresponding reasons that cause these injuries. And then they did some tests(fig.6, fig.7) to study the safety performance of the battery system and its influence on the electric vehicles in the condition of simulating real car running by means of the equipments in the automotive laboratory of Hunan University[19].

Fig.6 Roll-over test of NI-MH battery

Fig.7 Vibration test of NI-MH battery

Sun Zhendong and Liu Guibing, in China Automotive Technology & Research Center have summarized and analyzed the corresponding domestic and foreign regulations and standards on electrical safety in full frontal crash tests for EV, put forward the test program and assessment procedure for frontal crash test of EV and then compared and analyzed the tests of the modified electric vehicle and the original base vehicle, which reveals the impact characteristics of EV in frontal crash and the remained problems in existing safety regulations and standards[20].

Yin Fanqi and Cai Mingyi, in Shanghai University have analyzed the time course of energy, deformation and acceleration during the frontal crash based on the simulation of electric vehicle frontal crash on rigid wall with 40km/h initial velocity and made some crashworthiness improvement designs such as energy absorb buffer, inductive structure, support circle beam and flange. With the new design(Fig.9), the result of frontal crash simulation of the improved vehicle has indicated that all main crashworthiness indexes had been improved evidently and the complete vehicle frontal crash passive safety ability of the electric motor vehicle had been improved[21].

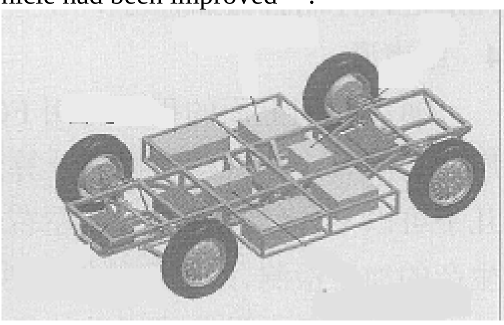

Fig.8 Structure of mini electric vehicle

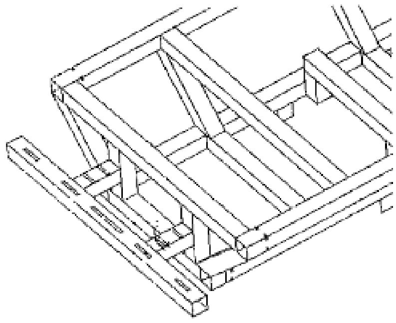

Fig.9 Improvement of frontal structure

5 Conclusions

Compared to traditional vehicles, electric vehicles differ from traditional vehicles at both energy storage pattern and driven pattern, which causes special safety problems. When electric vehicle have some accidents such as impact, the battery system may be involved in crash, short circuit, battery splitting and electricity leakage, explosion, burning etc[22]. At present, the studies on safety of battery system in collision situation mainly focus on the test program and assessment procedure for impact test of EV, potential safety problems of EV and corresponding strategies and how to improve the crashworthiness of electric vehicles through changing the structures of some related components while the studies on electrochemical reaction in collision situation are few. As for the issue how to improve the crashworthiness of electric vehicles, there are some strategies as following: 1. to fix the battery box in Non-collision zone; 2. to design the new structures of batteries so as to improve the crashworthiness of batteries; 3. to improve the performance of battery boxes to fasten batteries; 4. to design the new structures of battery boxes so as to improve the crashworthiness of battery boxes; 5. to lay the batteries a proper position in battery box so as to be free from strong impact etc.

The future trends of studies on collision-safety of electric vehicles are mainly as following: 1. to copy the methods applied to traditonal vehicles that it is to improve the collision-safety through improving the crashworthiness of some related components, using new materials to improve crashworthiness of EV and redesigning the structures of body and chassis of EV on the grounds of the characteristics and the special requirements of EV. In the studies of collision-safety of traditional vehicles, the level of vehiculary modeling influences the studies on collision-safety directly. The technology called hybrid modeling that is more approximate to practical situation is the future trend of technology of vehicular modeling. Optimizing numerical calculation to improve calculating speed of simulation is the key future trend of collision-simulation of vehicles. Developing new model of human body, developing new algorithm and studying the technology of degradation integral are becoming the topics of collision-simulation of vehicles; 2. to develop some active safety systems of battery system of EV such as overcurrent protection systems and high-voltage automatic shutdown systems. With the active safety systems, the battery system can switch off the circuit or disconnect the batteries once too high-current is generated in collision situation or impact happens; 3. to carry out the complete vehicle performance test of EV and the limiting safety performance test of battery such as battery puncture test, short-circuit explosion test, battery collision test, battery extrusion test, insulation test of EV in washing or rainy situation etc. And with the help of above tests we can analyze the safety of EV in depth; 4. It becomes a new issue how to test and assess the safety of EV when side impact or rear impact takes place. When the collision takes place, the batteries may leak out corrosive liquid, explode and burn. So it is necessary to develop better test program and assessment procedure for crash test of EV to ensure the safety of EV.

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