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Research on the Crash Test's Safety in NCAP of Electrical Vehicle

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Abstract: With the development of electrical vehicle, the technique of electrical vehicle's passive safety is very worth researching. As the highest level of safety performance evaluation procedures, electric vehicles are tested in the NCAP. An important characteristic of electrical vehicle is that there is high voltage of power cycle. This paper's key-point is the safety of electrical vehicle in crash test compared with gasoline vehicle. First, the crash standard of electrical vehicle is analyzed. Then the crash test's process is researched. With the data of test, the difference between electrical vehicle and gasoline vehicle is analyzed. The key we have to pay attention is suggested in our regulation. The matters needing attention in the crash test are suggested too.

Keywords: electrical vehicle, electrical safety, NCAP regulations

1 Introduction

The crash test of electric vehicle is different from the gasoline vehicles, because of involving various types of power battery, if the battery package is damaged by the impact, there may be an explosion, fire, leakage or any other related issues. At the same time, in the body weight and body structure, there are some differences between electric car and the ordinary car, the crash test results will be different also.

The crash test of EV, especially for the electrical vehicle's structure feature, should meet the requirement of standards *The protection for occupants in front impact for passenger car*, *The protection for occupants in side impact for passenger car, The protection in rear impact for passenger car*, and other relative rules and regulations as well. National Highway Traffic Safety Administration (NHTSA) FMVSS 305, GB/T 31498-2015, and Economic Commission for European(ECE) R100, R94 and 95 are the main regulations and standards of electrical vehicle. By comparing the different electric vehicle crash test standards, how to meet the standard requirements in the electrolyte leakage and battery location are basically the same: after the impact test, the power battery electrolyte leakage (30 minutes 5L and not into the crew cabin); Significant displacement of power battery is not allowed (such as not into the crew cabin, not thrown from the body, etc.).

In the aspect of electric shock protection, it is necessary to measure the insulation resistance before and after the collision test. It mainly includes low voltage, low energy, physical protection and insulation resistance.

(A)The voltage of the high-voltage bus Vb, V1 and V2 is equal to or less than 30 VAC or 60 VDC

(B)The low-energy energy of the high-voltage bus is less than 2.0 joules when measured.

(C)Human protection against direct contact with high-voltage parts, should provide IPXXB level protection

(D)Insulation resistance minimum 100Ω/ V in DC bus, minimum 500Ω/ V in AC bus

2 Analysis of NCAP rules on Electric Vehicles

The different NCAP has been clearly doing tests of electric vehicles as shown in figure 1, which should face more stringent star rating evaluation test than the national standard, whether it is more serious side moving barrier, or a higher collision speed, the electric vehicle test should meet a higher requirement.

Euro NCAP tests require to measure the voltage of battery during the entire experiment. For low voltage and low energy, the on-board recording instrument must be used in a limited time. IPXXB testing is not allowed, and at least an insulation resistance test is required. In order to determine whether the automatic disconnection device is working properly, an LED indicator can be installed externally to indicate the switching status of the automatic disconnection device, and the equipment manufacturer shall provide LED lamp installation instructions.

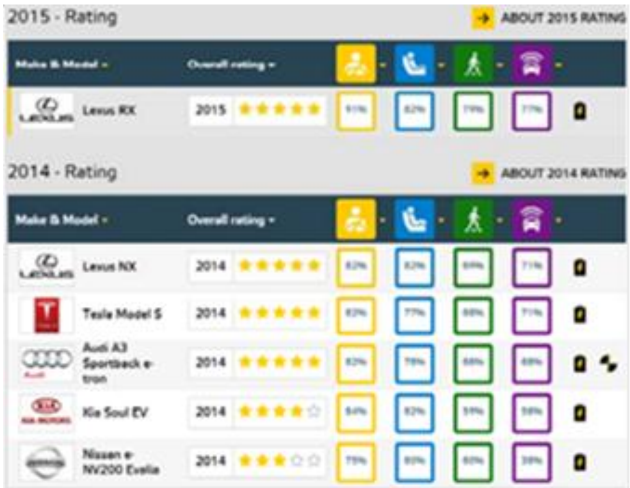

Fig.1 Assessment of EV in NCAP

The US-NCAP measure the insulation resistance after the frontal collision, side impact and side pole collision test. The electrolyte leakage and battery position were observed, and then the static reverse test was continued (90degree/time). The insulation resistance, electrolyte leakage and Position, this three indicators were observed also.Japan NCAP operation flow basic reference ECE R94.

An important difference between NCAP and the regulatory system is that NCAP has a complex scoring system based on different probability of accident occurrence and probability of personal injury index. Electric car accident statistics samples are less, can not form a certain probability. Electrical safety of the human body injury index can not be quantified gradient, only safe and unsafe. The safety evaluation of electric vehicles is basically based on the relevant laws and regulations of the country.

It is worth mentioning that, for short-circuit and overcurrent disconnection device requirements, although the national regulations are not explicitly mentioned, but for the collision accident to prevent the occupant electric shock is a very effective way.

3 Analysis of C-NCAP rules on Electric Vehicles

C-NCAP electric vehicle evaluation will be in full accordance with the traditional car 18 version of the collision test procedures, in the existing frontal collision, side impact, 40% frontal impact test, after which there are additional safety tests, do compliance determination as shown in figure 2. According to the current GB/T 314998-2015 electric vehicle safety requirements after the collision, the difference between NCAP and the GB/T 314998-2015: an increase of 40% collision and the electrical safety evaluation, minimum speed of 100% Frontal collision is 48km/h, while the minimum C-NCAP collision speed is 50km/h; side impact test increased dummy, increased vehicle test weight. As shown in figure 3, for the electrical shock evaluation option increases insulation resistance measurement as the required option, the other three options can choose one.

Relative to the traditional gasoline vehicles, whether electric vehicles in the process of collision is safe or not, except for dummy damage indicators and body structure, the importance of electrical safety problems is self-evident. According to regulatory requirements, mainly from the following four aspects:

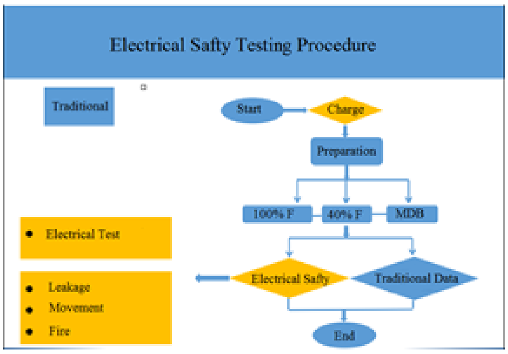

Fig.2 Electrical safety testing procedures

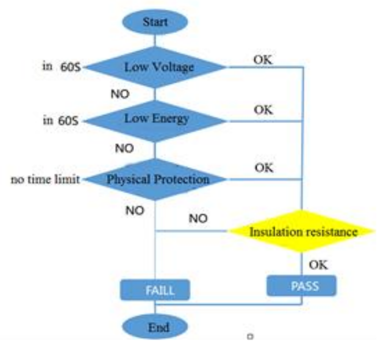

Fig.3 Electrical safety testing options

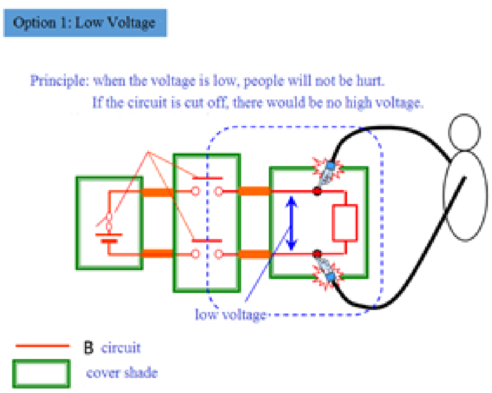

Fig.4 Principle of low Voltage

3.1 Low voltage

Voltage of the high-voltage bus is less than or equal to 30V in AC part and in DC part less than or equal to 60V. At present, more than 70% of the electric vehicle battery management system has collision power protection, mainly through the acquisition of collision signals to achieve function. It is possible to effectively reduce the possibility of electrical safety problems such as a short circuit overcurrent or a low insulation resistance after a collision test. The electrical vehicle battery management system receives the collision signal, then cut off the high-voltage lines, in seconds to make the circuit voltage be a low voltage, to ensure the electrical safety of the vehicle.

3.2 Low energy

Because the impact test is destructive, the site of electric vehicle will certainly be damaged, resulting in high-voltage lines may be exposed or even short-circuit. Electrical safety problems can occur when people touch the vehicle body. To make the total energy is less than 2.0 joules, the battery management system will cut off the high voltage circuit immediately after the collision. The load circuit of the front end of the vehicle can be designed to reduce the power consumption and ensure the residual energy will not produce electrical safety problem. Electric vehicles without a crash protection function can be dangerous due to exposure of electrical parts to personnel.

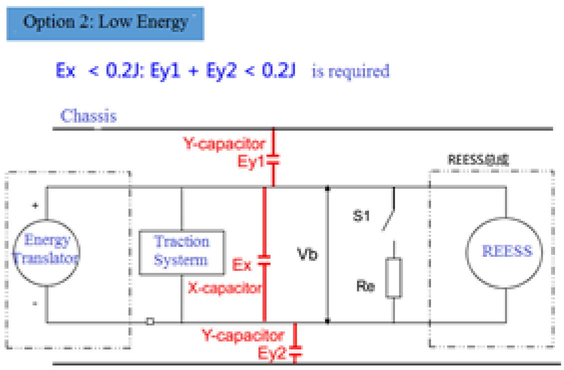

Fig.5 Principle of low Energy

3.3 IPXXD and IPXXD

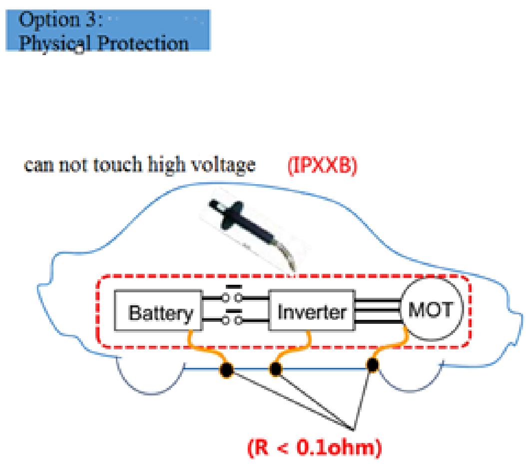

Fig.6 Principle of physical Protection

The instruments used to test the direct contact have two grades, which are slender, rod-like IPXXD grades, and an IPXXB rating that looks like a finger. The IPXXD class is used to detect the passenger compartment or cargo area where the human body may come into direct contact with the vehicle. The slender instrument simulates small objects such as hairpins to poke into smaller holes, Body status; the IPXXB rating, it is a thick finger shape, check the region outside passenger compartment and cargo area to determine whether it meet the requirement.

As the crash test is a destructive test, many parts even high-voltage circuits and components can be damaged in the collision, whether the crew or outside rescuers are likely to touch the high-voltage and be dangerous, it is difficult to achieve 100% electrical safety only by insulation protection.

3.4 Insulation resistance

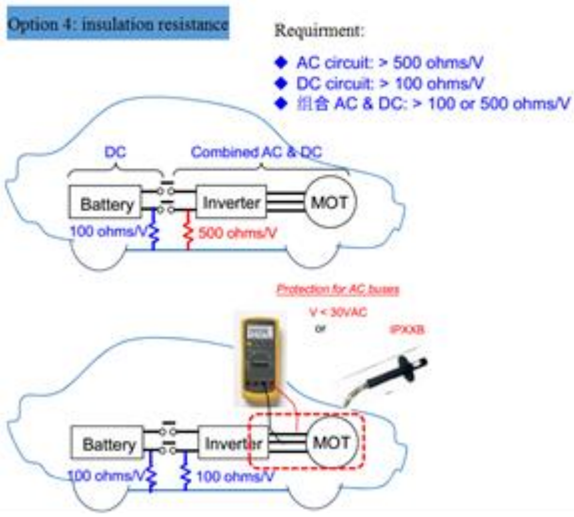

Fig.7 Principle of insulation resistance

After the collision test, the electric vehicle is likely to appear low insulation resistance due to the damage of the high voltage line. The regulations require that the part of the DC is greater than 100Ω/V and the AC part is greater than 500Ω/V. So the battery management system is very necessary to do insulation testing. In the event of insulation resistance is too low, it should promptly cut off the power, and give a warning. The following picture shows the detection of insulation resistance after the collision test.

4 Verification and Analysis of Electric Vehicle's Impact Test

4.1 Real-time monitoring of electrical safety testing methods

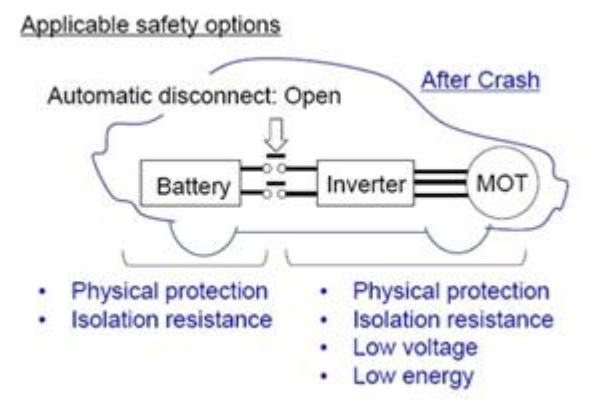

Fig.8 Procedure of electrical testing

In order to evaluate the safety of electric vehicles, according to the structural characteristics of electric vehicles, real-time monitoring the high-pressure circuit is a necessary means, as shown in Figure 8, electric vehicles can be divided into battery pack, electrical appliances and charging Line three parts. The battery pack is a high-voltage live parts, electrical appliances when non-charged may contain capacitors for charging and discharging components, the charging circuit need high-voltage protection as the important loop. For the electrical safety of the battery pack, we can do physical protection and insulation resistance measurement, and electrical parts such as electrical wiring, in addition to the above two methods, we can also do low voltage and low energy measurements.

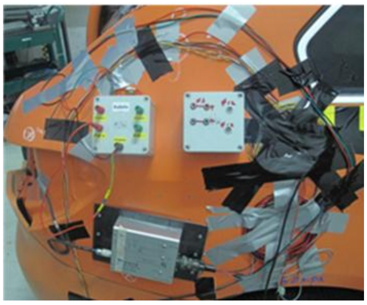

Figure 9. Real time monitoring test method

Figure10. Real time monitoring test window

At present, doing the inspection of electric vehicle safety in crash test remains with eyes and temperature gun as external monitoring technology, not only the safety of testing personnel is difficult to guarantee that the experimental data can not be real-time monitoring and recording. Through the research of electric vehicle collision technology, the new experimental method and equipment can be connected and communicated with the onboard ECU and the battery management system BMS through the CAN bus. The testing personnel can transmit through the wireless network during the collision, obtain the vehicle battery management system information remotely, Real-time monitoring of battery temperature, voltage and other information can represent the safety of vehicles, if the state is normal, the information stored for easy analysis after the test; if not, immediately enter the emergency procedures, may discharge, or cut off power, in a timely manner to avoid test equipment and Personnel risk.

In order to carry out the above measurement, as shown in Fig. 9, including an insulation resistance measuring cell, a battery state monitoring box, an active discharge detection cassette. The results are shown in Figures 10 and 11. Figure 10 is the real-time data sent by the battery management system, including battery voltage, energy, temperature and insulation resistance during the electric vehicle collision, which is of great practical significance for monitoring the safety of battery pack. The figure 11 shows the real-time acquisition through the CAN communication collision, the electric vehicle battery management system receives the collision signal, then cut off the body high-voltage lines, in a second AC circuit voltage from 300V to 60V below to ensure that the safety of body.

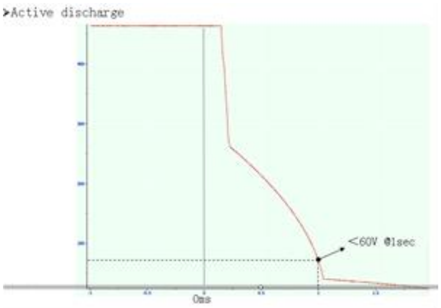

Fig.11 Real-time monitoring testing result

4.2 Analysis of relative motion between battery pack and vehicle body

Because of the quality of battery pack, in order to avoid moving and throwing or other hazards in the process of collision, the pack needs to to be firmly connected. In order to judge whether it is safe, usually with the method of the relative acceleration and relative displacement analysis.

Early in the development of electric vehicles, due to lack of experience in the collision test process the relative movement between the battery pack and the body will occur, usually manifested as the relative acceleration and relative displacement. With the further study, there is no such problem, as shown in Figure 12 , in a section of the front and rear of battery pack and the B-pillar of body settle the acceleration sensors, from the collision curves can see there is no obvious difference between the curves, whether the trend or size are basically the same, so we can think that there is no relative movement and displacement between the battery pack with the body in the collision process , battery pack is tightened rigidly with the body.

For more safety, we can use other method and design in the collision process, to make the acceleration of the battery pack less than the body's. As shown in Figure13, so that the battery pack received a smaller impact.

Table 1. Testing Data in frontal Crash

TEST / DATA	Position	T0727DZ	T0729DZ	T0730DZ	T0731DZ	T0733DZ	T0732DZ
Head HPC⩽1000	Driver	693	1101	645	582	769	671
	Passenger	445	570	771	324	600	452
Dis Chest ThPC⩽75mm	Driver	43.23	25.87	37.15	55.59	40.71	26.64
	Passenger	28.37	27.42	25.7	49.15	52.31	42.19
Femur FPC⩽10kN	Left	12.41	1.119	5.35	3.986	4.031	2.44
	Right	5.85	2.215	3.32	2.796	1.453	2.01

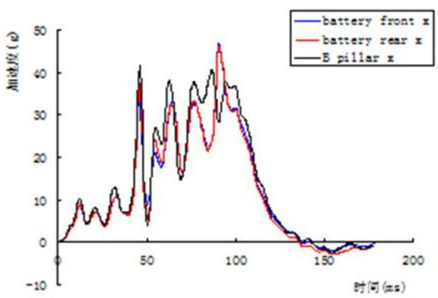

Figure 12. Relative accelaration

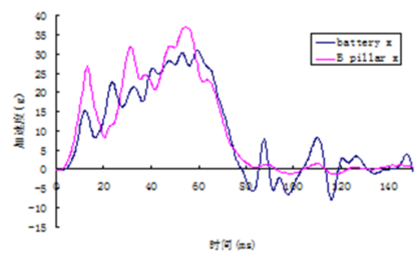

Figure13. Relative accelaration

4.3 Analysis of test data

Because of the cost of electric vehicles, they generally have a shorter and lighter body, a larger battery weight, lack of security configuration. Therefore, relative to the traditional gasoline vehicles, collision safety issues of electrical vehicle will be more prominent, mainly reflected in the body structure is not reasonable, the battery security considerations, security configuration and other issues are not enough. The excel shows test results of six different electric vehicles in frontal impact with the national standard, in the case of non-rectification without a product fully qualified. Key issues include:

(A)Dummy data

The problem is mainly concentrated in the head data and leg data, due to cost considerations, low airbag installation rate, coupled with a small driving space and deformation of the body and the seat belts' pre-tension and limited force function work bad. And even seats' slide and the seat belt fixed points' failure and other issues occurred during the collision, resulting in dummy head and leg data exceed the national standard as shown in table 1.

(B) Body structure

The body is short, and the space layout is not reasonable enough, resulting in energy-absorbing area is missing and the deformation zone is too large in the collision, the compression of occupants' safety space, or even the door can not open, the staff can not escape and rescue;

(C) Electrical safety issues

Mainly reflected in the battery's location and settle is not reasonable enough. In the collision process it may lead to deformation of the battery parts, cause the movement or even be thrown into the crew cabin or out of the car. High-voltage circuit design can not take full account of the collision's damage lead to low insulation resistance and risk of electrification.

5 Conclusion

In this paper, the collision safety of electrical vehicle is researched. First, the electric vehicle crash test standards are analyzed, then analyse the electric vehicle crash test method, and the test data, the important issue need to pay attention to. At the same time we can draw the following conclusions:

5.1 Electrical Safety

Power battery should be cut off in the case of severe collision; load circuit after the power battery's cut off should be able to discharge energy quickly; high voltage circuit's layout should be considered in the early stage of vehicle's development, especially we should consider when the power does not cut off how to ensure line conditions not be damaged; battery's space layout and protection design (such as tray).

5.2 Structural arrangement

Power battery pack should be settled at the non-deformation and non-energy absorption area as much as possible to avoid the battery extrusion deformation in the collision; power battery pack should be connected with the vehicle body stably; cells should be fixed independently and in stable structure; high-voltage wire should be located in the non-deformation of the body structure as far as possible, while improving the high-voltage line's insulation protection;

5.3 Influence of the impact's form

The battery pack is less affected in the frontal impact, because the battery's deformation is less. but still some tests were failed for the movement. In the side impact test and pole side impact, the battery pack will be seriously affected by the deformation of the vehicle for the space is not enough between pack and vehicle body.

And the rear impact test should be pay attention to for many electrical components are settled in the rear part. In rollover test you can cut off the high-voltage output when you see the danger with sensors.

References

[1] General Administration of Quality Supervision, Inspection and Quarantine，GB/T 19751-2005（in Chinese），Hybrid electric vehicles safety specification，Peking: China Regulation，2005.

[2] General Administration of Quality Supervision, Inspection and Quarantine，GB/T 31498-2015（in Chinese），Electric vehicle—Safety specifications，GB/T 31498-2015（in Chinese），Peking: China Regulation，2001.

[3] General Administration of Quality Supervision, Inspection and Quarantine，GB11551-2003（in Chinese）, The protection of the occupants in the event of a frontal collision for passenger car, Peking: China Regulation，2003.

[4] General Administration of Quality Supervision, Inspection and Quarantine，GB20071-2006（in Chinese），The protection of the occupants in the event of a lateral collision， Peking: China Regulation，2006.

[5] General Administration of Quality Supervision, Inspection and Quarantine，GB20072-2006（in Chinese）, The requirement of a fuel system safety in the event of rear-end collision for passenger car，Peking: China Regulation，2006.

[6] NHTSA，FMVSS305-2010, Electric Powered Vehicles, Electrolyte Spillage and Electrical Shock

[7] ECE，R94-2011，The protection of the occupants in the event of a frontal collision

[8] ECE，R95-2011，The protection of the occupants in the event of a lateral collision

[9] ECE，R100-2011，Specific requirement for the construction and functional safety

[10] EuroNCAP，TB011-2010，Testing of Electric Vehicle