Study on Side Collision of Battery Boxes Based on HyperWorks

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Abstract. To effectively improve the safety of battery boxes in side collision of electric vehicles, two measures are proposed: Firstly spread the boss evenly around the battery box. Secondly the upper and lower parts of the battery box are matched with the convex heads and groove structure. The finite element models of the battery boxes before and after the optimization, the vehicle and the movable barrier are established in this paper. According to the collision regulations, the side collision simulation of the vehicle body is carried out. The changes of the stress, deformation and lateral acceleration of the battery boxes are analyzed. The effectiveness of the measures is verified. The extrusion models of the battery boxes are established. The deformation and the changes of the internal energy of the battery boxes are analyzed. The effectiveness of the measures is verified again.

1. Introduction

When an electric vehicle has a side impact, the battery box is subjected to a large extrusion stress which may cause irreversible damage to the battery box. Therefore, domestic and foreign scholars are constantly strengthening the safety research of battery boxes in recent years. By establishing the finite element models of the battery pack, Fengchong L has studied the collision methods suitable for the collision performance of the battery pack of electric vehicles [1]. According to the analysis of the simulation results, it is found that the structure of the battery pack has great potential dangers. Istiyanto has established the finite element models for front, side and rear collisions of the battery rack. According to the simulation results, the design of the structure optimization is carried out to improve the performance of the battery rack. Kukreja A has performed the analysis of the vehicle crash on several battery pack configurations [2]. A multifunctional battery system is compared with a battery pack that uses a battery alone. The results show that using multifunctional battery systems can improve the safety of battery system in collision. These studies provide good experience for the collision research of battery boxes. In order to improve the performance against collision and reduce the deformation in the process of side collision, the optimization study of the battery box is carried out in this paper. Firstly, the models of the battery box before and after optimization are established based on CATIA. Secondly, the finite element models of the battery box, the vehicle and MDB are established. Then, the collision models are established and calculated to compare the simulation results to meet the requirements. Finally, the...
extrusion model is established to further verify its safety. The deformation and energy change of the battery box are analyzed.

2. The model establishment and simulation analysis of battery boxes before and after optimization

2.1 The establishment of 3D models
The models before and after optimization are shown in figure 1. The optimization of the structure is divided into two main parts: Firstly there are many convex platforms on the lower box of the battery box. Small holes in the convex platforms facilitate the installation and position of the battery box. There are stiffeners under the convex platform which can withstand certain stress and absorb energy when it is deformed. Secondly the connection of the lower body and the upper body is no longer only connected by bolts. The lower body also has the convex structure which is matched with the groove part of the upper box. When the collision occurs, the structure is also more secure. It is not easy to separate the upper and lower cover and hurt people by splashing electrolyte.

![Figure 1. The 3D models before and after optimization](image)

2.2 The establishment of finite element models
The upper and lower boxes of the battery box are meshed by shell cells. The size of the unit is 5mm. The proportion of triangular elements in the model is less than 1% which meets the requirements. The material of the upper and lower boxes of the battery box is Q235, and the MAT24 in LS-DYNA is selected [3]. The finite element models of two battery boxes are shown in figure 2.

![Figure 2. The finite element models before and after optimization](image)

In the assembly of electric vehicles, movable barriers and battery boxes, the battery box is arranged as a whole which is installed under the driver's seat and connected with the chassis of the vehicle by a rigid unit. In this paper, the contact between the components on the electric vehicle and itself, the contact between the movable barrier and itself are single-sided automatic contact [4]. The dynamic and static friction coefficients are set to 0.1. The gravity acceleration of the simulation environment is set as 9.81. The initial speed of the movable barrier is 50km/h, the simulation time is set to 120ms, the hourglass coefficient is 0.05, and the minimum time step is $9.57 \times 10^{-7}$ s.
2.3 The simulation analysis of side impact

Before optimization, the energy at the initial moment of the side collision system is the energy when the movable barrier hits at 50km/h, and the size is \(1.37 \times 10^5\) J. Within 0-60ms, the kinetic energy of the system decreases rapidly while the internal energy increases rapidly. In this process, the kinetic energy of the movable barrier is gradually transformed into the internal energy of the system. At the end of the collision, the hourglass energy is 887J which accounts for 0.63% of the total energy of the system, less than 5%. The results show that the model is credible. After optimization, the kinetic energy of the side impact system decreases rapidly and the internal energy increases rapidly in 0-60ms. The hourglass energy at the end of the collision is 874J, accounting for 0.62% of the total energy of the system. The results show that the model is credible.

After the side impact of electric vehicle, the battery box will produce large stress, deformation and lateral acceleration [5]. Figure 3 shows the stress cloud diagrams of side collision before and after optimization of the battery boxes. Before optimization, the stress distribution on the surface is very irregular. The maximum stress is concentrated on the side of the battery box affected by the impact. The side far away from the collision also has a large stress concentration distribution. After optimization, the stress distribution of the battery box is regular. The maximum stress is concentrated on the protective measures. It is not subjected to great stress. The results show that the optimized measures can effectively reduce the stress of the battery box.
(b) The optimized

Figure 3. The stress clouds before and after optimization

Figure 4 shows the deformation diagrams of side collision before and after optimization of battery boxes. Before optimization, the maximum deformation of the battery box is 10.7mm. The side near the collision area produces a great deal of deformation. The battery box is severely damaged. But the maximum deformation of the optimized battery box is 8.5mm. The maximum deformation occurs in the optimization measures of the battery box. The rest of the area directly impacted is only slightly deformed. According to the analysis of deformation results, the damage caused by collision can be effectively prevented by reasonable arrangement of battery cells and electrical components. The results show that the optimized measures can effectively reduce the deformation of the battery box.
Part of the kinetic energy of the movable barrier during the side impact is converted to the kinetic energy of the battery box [6]. The safety of the battery box can also be obtained by analyzing the acceleration of the battery box during the collision [7]. Figure 5 shows the acceleration curve of the battery box in the Y direction in side impact before and after optimization. The acceleration curves of the battery box in the Y direction are basically the same. The time nodes of acceleration change are similar. The maximum acceleration occurs around 40ms, with a size of 39.35g. The optimization measures do not significantly change the acceleration of the battery box in the direction of impact. But they are also able to reduce it by about 4.1 percent. The results show that the optimization measures have a slight effect on the acceleration of the battery box in the direction of collision, but the effect is not obvious.
3. The establishment of extrusion model and analysis of simulation results

3.1 The establishment of extrusion models

In order to further verify the effectiveness of the optimization measures, the rigid column is used to conduct extrusion experiments on the battery boxes before and after the optimization. The contacts between the battery box and the ground, the wall and the rigid column are all automatic contact. The dynamic and static contact coefficients are 0.1. Set the displacement of the rigid column in the Y direction as 200mm within 50ms. Slowly squeeze the rigid column towards the battery box. The hourglass coefficients are set to 0.1.

The hourglass energy of the models should be within 5%. Figure 6 shows the energy curves of the simulation models before and after optimization. The total energy of the system increases continuously before optimization, and the increase of internal energy accounts for most of it. The kinetic energy is going to be close to zero the whole time. The hourglass energy ends up being 3548J. The total energy of the system is 80132J. Hourglass energy accounts for 4.4%, less than 5%. The model is trusted. The energy curve of the optimized model is basically the same as that before optimization. The final hourglass energy is 3628J and the total energy of the system is 80158J. Hourglass energy is 4.5%, less than 5%. The model is also trusted.
3.2 The deformation and energy analysis of battery boxes

Figure 7 shows the deformation of the battery boxes within 50ms before and after optimization. The battery box before optimization has obvious deformation at 20ms. The optimized battery box is not deformed until the protection measures on both sides failed completely in 20ms~30ms. The optimized measures effectively delay the deformation of the body. At 50ms, the middle part of the battery box before optimization is seriously deformed and almost fractures. After optimization, the deformation in the middle of the battery box is small, and the coordination between the upper and lower parts is still good. The results show that the middle of the battery box is easy to be deformed when it is squeezed. Optimized measures can effectively reduce this deformation. The effectiveness of the optimized measures is verified by comparing the deformation process of the battery boxes.
Figure 7. The deformation of the battery boxes in 50ms before and after optimization.

As the rigid column gradually squeezes towards the battery box, the internal energy of the upper and lower parts of the battery box increases. The safety of the battery box can also be verified by analyzing the changes of the internal energy. Figure 8 shows the comparison of internal energy of upper and lower boxes before and after optimization. The internal energy of the battery box before optimization rises very fast. However, the internal energy of the optimized battery box increases slowly within 25ms before extrusion. After 25ms, the optimization measures failed, and the internal energy of the box increased at a faster rate. The results show that the optimization measures are effective.

Figure 8. The comparison of internal energy of upper and lower parts of battery boxes before and after optimization.
4. Conclusion
Firstly this paper proposes two optimization measures for the battery boxes to improve the safety performance in the process of side impact. Secondly in this paper, the finite element method is used to establish the models before and after optimization, the vehicle model for analysis of side impact and the mobile barrier model. The stress, deformation and lateral acceleration are analyzed through the simulation calculation. And the effectiveness of the optimization measures is verified. Finally the extrusion models of the battery boxes before and after optimization are established in this paper. Through the extrusion simulation, the deformation and energy changes of the battery boxes are analyzed. The results verify the effectiveness of the optimized measures again.

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