Original Research Article

Computer simulation analysis of heat dissipation performance of electric vehicle battery thermal management system

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Abstract: New energy vehicles can be seen everywhere around us, but the research on the thermal management and heat dissipation of the battery is not thorough enough. Under the guidance of the policies of the national government departments, the major domestic automobile manufacturers have developed new energy vehicles. With the development of Internet plus and new energy vehicle industry, many new automobile manufacturing forces have emerged in China. The development of new energy vehicles is the inevitable choice of low-carbon development and automobile industry development. As one of the industries guided by green and low-carbon policies in China, the development of new energy vehicles is the best way to show green development and the main breakthrough of economic development and industrial structure transformation.

Keywords: Electric vehicle, the battery, thermal management, the cooling system

1. Introduction

Battery electric vehicle range and safety are the key indicators to measure its market positioning. How far and how fast pure electric vehicles can run is closely related to the power battery heat dissipation management. The battery heat dissipation management is not only the evaluation of the car by users, but also the key factor of the market recognition of the enterprise. The safety of pure electric vehicles is directly related to the mechanical strength of the battery heat dissipation management. A pure electric vehicle with high safety must have the battery heat dissipation management with reasonable structure design and qualified strength[1].

2. Battery heat dissipation management structure design requirements

The structural design requirements of the battery heat dissipation management box must be analyzed based on its characteristics[2-4]. Although there are damping devices such as suspension to absorb shock, the vibration excitation generated by uneven road surface can still be transmitted to the battery heat dissipation management through the car body. Therefore, ensure that the bearing beam of the battery heat dissipation management box has sufficient strength and performance, and can bear the weight of battery heat dissipation management. At the same time, the box body has enough stiffness under the management of battery heat dissipation, and the module support is the part in direct contact with the lower box body. When subjected to sudden vibration, it has enough resilience to absorb vibration excitation from the road surface and avoid transmission to the module and the battery core. Thirdly, the upper cover of battery heat dissipation management is generally a thin-walled piece made of galvanized steel sheet like DC01 by stamping and welding[5].

The internal structure of cylindrical lithium battery is composed of positive plate diaphragm negative plate diaphragm superposition, rolled from one end to the other end as the pole core, and then filled with electrolytic medium and other processes to manufacture the single cell of battery heat dissipation management. The diaphragm is fragile and easily punctured by hard objects, resulting in a large amount of hydrogen and short circuit spark combustion explosion at the positive and negative poles. Therefore, the overall structure of the battery heat dissipation management must meet certain impact and extrusion resistance. In case of a collision, foreign bodies such as metal will not puncture the battery heat dissipation management and cause a short circuit. This requires that the container has enough stiffness to resist deformation and enough strength to resist damage[6-7].

3. Establishment of finite element model of battery heat dissipation management

FEM (Finite Element Method) is to transform practical engineering problems into mathematical models and solve problems into partial differential equations. In the process of modeling, the requirements of calculation accuracy and model size are mainly considered. In modeling, reasonable analysis items should be made according to the characteristics and requirements of actual problems. On the premise of satisfying the solution accuracy, the size of the calculation model should be reduced as far as possible, the calculation time should be reduced, the cost should be reduced, and the consumption of computer resources should be reduced[8].

The purpose of simulation analysis is to verify the virtual experiment and improve and revise the designed product. Therefore, if the calculation error is too large, the significance of simulation will be lost. The finite element simulation process is originally a very complicated calculation process, in which there are many sources of error. According to the analysis of Du Ping 'an from University of Electronic Science and Technology of China, the sources of error can be divided into calculation error and model error.

Smoke after completed the Surface, the model window is adjusted for 2 d, according to the topology model of freedom, according to the characteristics of the edge will be red red edge is first focus, and see that the free edges of shell element, not use the free Surface command completion: yellow is generally three or more of the side of the intersection of a Surface, for the side need to look at the entity model is the intersection of three parts, because in the process of Surface in the extraction of the software will connect it together by mistake; Then the green edge, the color instructions for there are two side of the intersection, if it is the rules of plane intersection, suggest to remove, usually by the quickedit toggle command will remove it, because this will affect the grid to make grid whole inclined towards a cause analysis in the process of the grid error: the blue side, this to hide for those who don't need to feature edge left after operation, grid generation, just skip it, only for view the outline of the role, we use the following formula for simulation calculation:

$$\iiint_V (\mathbf{\nabla} \cdot \mathbf{F}) \mathrm{d}V = \oiint_S \mathbf{F} \cdot \mathrm{d}\mathbf{S} \tag{1}$$

Then the processing of features needs to simplify the processing of the middle surface. First is the small hole. When its maximum size is smaller than the minimum size of the unit, use the Fller surf command under quick editing to fill it up, but the assembly hole must be retained. There are many small flanges or fillets in the bracket parts of the battery module. When the fillet radius is less than half of the minimum size of the cell, remove them. If there is a big impact on the stress, you can draw a layer of cells tilted 45° instead[9].

And then finally, symmetric processing. Generally, battery heat dissipation management is symmetrical. The battery heat dissipation management geometric model is separated from the middle to avoid repetitive work. After the grid is divided in the next chapter, the grid is completed by the mirror command, and the middle grid is connected with the front and rear grid nodes by the equivalence command (so that the two parts have the same degree of freedom). Then hide all geometric features to see if the free edges of all cells are correct.

4. Grid division standard for battery thermal management of electric vehicles

Element meshing is one of the key steps in finite element simulation analysis. It is a process of discretization of continuum, which will be represented by a block of cells. For a continuum, there are infinite degrees of freedom. Dividing it into a finite number of grid cells will transform the dimension of the problem into a finite number of degrees of freedom. "One dimension one equation" will eventually transform the practical problem into an equation problem. Therefore, the more dense the grid is, the more accurate the result will be theoretically. Meanwhile, the number of dividing units determines the number of nodes, and the node dimension determines the amount of calculation, as shown in **Figure 1** below:

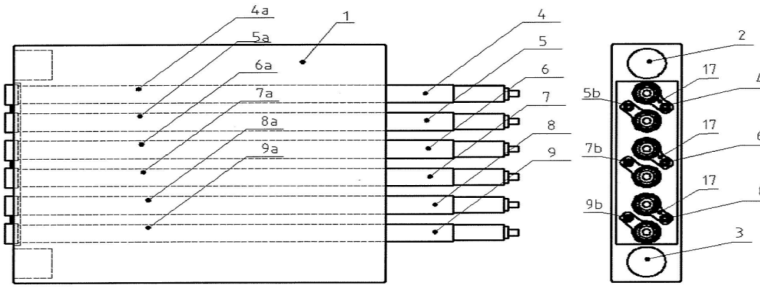

Figure 1. Computer simulation of a battery thermal management system.

(1) The first is the selection of grid type. From dimension can be divided into 1 d link unit (such as weld, solder joints, adhesive and beam element), 2 d shell element and 3 d entity unit: from points and sampling points for, can be divided into: linear unit at a time, the second unit, three with higher order, including high order unit can reduce the amount of calculation, through the integration of the cut, for example, a 2 d quadrilateral element of a four points points, there are four node has 9 points, and each side has three nodes. When the reduced integral is used, the edge elements are reduced to four but the sampling interpolation points are still 9, which ensures the accuracy and reduces the amount of addition. However, in nonlinear large deformation, the reduction of nodes and mesh distortion should be considered to cause serious hourglass problems. In this paper, 2D shell elements are used for the box body and bracket, 3D solid elements are used for the module, 1D and 2D elements are used for the bottom bearing beam, 1D RBE2 elements are used for short bolts, and RBE2 and BEAM elements are used for long bolts[10].

(2) Then the density and quantity scale of the grid. In the grid division process of battery heat dissipation management components, the smaller the cell size, the more the number, the higher the grid density, the higher the calculation accuracy and reliability, and the simulation results are closer to the actual. However, as the number of nodes increases, the number of degrees of freedom becomes more and the number of equations to be solved increases, resulting in a huge amount of matrix computation and increased consumption of hardware resources such as computing processor and memory.

(3) Finally, unit quality standards. Hypermesh's mesh inspection criteria check the mesh according to the requirements of each solver. And 1D unit mainly check whether there is rigid body excessive constraint and whether the free node is in line with the actual problem. There are many standards for 2D and 3D elements, mainly including: a. Warp age: the plane deviation between the element used to simulate the fitting of the geometric model and the real model, which is controlled within 5° in this paper; b. Aspect ratio of cells: the value of the longest side ratio of the shortest side of cells in the divided grid, and the aspect ratio of battery heat dissipation management grid should be less than 5:1; c. Jacobian: Measurement of deviation between grid elements and elements of ideal shape. The Jaco ratio ranges from 0. 0 to 1. 0, where 1. 0 represents a cell whose shape perfectly fits a digital module. However, a jCobian value of 0. 7 or higher is generally acceptable; d. The maximum Angle and minimum Angle of the quadrilateral should be controlled between 45° and 135° as far as possible; e. For tetrahedron, there is also Tetra collapse ratio, which is a very important indicator when tetrahedron is used. This paper tries to use this kind of element as little as possible. Although this kind of element is fast in meshing, its calculation speed is far less accurate than that of hexahedron.

In the finite element simulation, it is very important to create the connection contact attribute, which is the key step of the transmission response of two material parts with different attributes. Under different working conditions, the connection unit can more effectively and accurately simulate the constraint relationship and connection state between various parts in the real situation. In some cases where the analysis is not focused on the join part, the simplified join appears to be advantageous.

5. Conclusion

In this document, the battery heat dissipation management is mainly connected by bolts and welding. The first is the bearing beam and box body, box body and module support between the connection, the actual production and the structure of steel beam and steel plate between the use of welding, and this paper does not consider the strength of welding, analysis is focused on box and beam; Finally, the connection between the battery heat management cover box body, and the bolt fixed connection between the module and the bracket; For this kind of parts that need later maintenance and disassembly, most of them are connected with bolts. The force between the thin-walled parts of the box body is relatively small, and the studs using bolts are also small. RBE2 unit can be directly used to fix them.

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