

# Research on Lightweight Structure of New Energy Vehicle Power Battery Package

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**Abstract:** In the past few decades, research on battery pack boxes has mainly focused on functionality, and now there has been research on other aspects of performance, such as lightweight design. Currently, demand also considers these factors when purchasing. In this paper, the power battery case of a pure electric vehicle is taken as the research object. Based on the analysis of its structural characteristics, a three-dimensional model is established. Based on the ANSYS software, the two optimization methods of topology optimization and size optimization are compared. After topology optimization, the weight of the case is reduced by 5%, and the weight is reduced by 15% through size optimization.

**Keywords:** Battery pack, Modal analysis, Topology optimization, Size optimization.

## 1. Introduction

With the continuous progress of electric vehicle technology, the development of various fields of technology is also constantly improving. With the further development of the layout of electric vehicles, people are paying more and more attention to power tram technology, especially the optimization technology of battery pack boxes. Currently, more and more people are studying the optimization technology of battery pack boxes [1]. In the past few decades, research on battery pack boxes has mainly focused on functionality, and now there has been research on other aspects of performance, such as lightweight design. Currently, buyers also consider these factors when purchasing. The improvement of comprehensive performance in all aspects of the battery pack box can improve market competitiveness for manufacturers, and its structure is a key part of the overall performance, especially for battery pack box bodies with high stability requirements. The structural role is more obvious, which has led more experts and scholars to start studying the structure of battery pack boxes.

In previous studies, many battery pack box structures had large volume and complex structures. By establishing models in virtual prototypes and simulating and analyzing the performance parameters of the battery pack box structure, the model was often simplified in the analysis. The simplification of the model ignored many factors, and the actual simulated structure was significantly different from the actual one, making it difficult to truly reflect the actual working status of the battery pack box structure [2].

## 2. Overview of Battery Pack

### 2.1. Battery pack type

Lithium ion battery packs are composed of multiple monomers, each with different capacity, voltage, and other parameters. Therefore, when selecting a battery pack, it is necessary to calculate the voltage, internal resistance, and other parameters of each monomer before selecting a suitable battery pack. Lithium ion battery packs also require charging, discharging, and other charging and discharging operations. The advantages of lithium-ion battery packs are high energy

density and long service life, but the disadvantages are large volume and heavy weight[3].

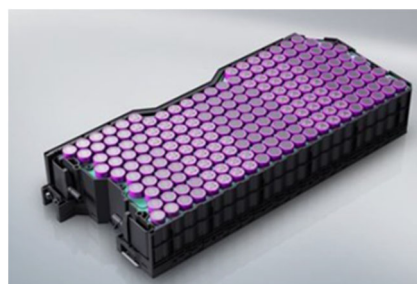


Figure 1. Lithium Battery Pack

The advantages of nickel hydrogen battery packs are high energy density, light weight, and long lifespan. But the disadvantage is its large size and heavy weight.

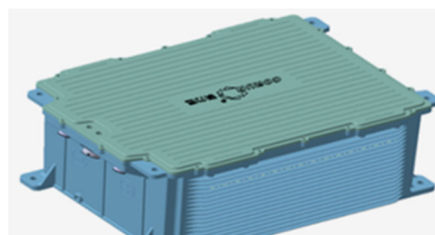


Figure 2. Nickel hydrogen battery pack

The lithium iron phosphate battery bag has the advantages of small size, light weight and high energy density; The disadvantage is that the cycle life is short and is greatly affected by temperature.



Figure 3. lithium iron phosphate battery package

When selecting a battery pack, it is necessary to choose the appropriate type of battery pack based on the actual application scenario. The nickel hydrogen battery pack has a small volume but low capacity; The lithium iron phosphate battery package has large volume but high capacity; The nickel hydrogen battery pack has a large internal resistance and short lifespan; The lithium iron phosphate battery package is small in size but large in capacity. For hybrid vehicles, the requirements for battery pack energy density and reliability when using powertrain should be considered. For pure electric vehicles, factors such as vehicle cost, charging convenience, and charging time should be considered to select the appropriate battery pack type [4].

## 2.2. Battery pack composition

In order to ensure the long service life and high energy density of lithium-ion batteries, electric vehicle power battery packs typically use high rate performance lithium-ion batteries as their main components. In electric vehicles, the power battery pack generally consists of the power battery pack (the battery pack contains a single battery cell), BMS (battery management system), charger, drive motor, on-board charger and related control circuits [5].

The power battery pack is composed of individual cells, which are connected together through connecting wires and harnesses to form the battery pack. As the management system of the entire battery pack, BMS is responsible for information management and fault diagnosis of the entire battery pack, monitoring the status of each individual battery cell, and providing protection measures and management control strategies for the power battery pack. The energy release of the power battery pack during the charging process can be controlled through BMS to prevent overcharging and discharging, ensuring that the power battery operates within its normal range.

## 3. 3D Model Establishment and Finite Element Analysis

### 3.1. Establishment of a three-dimensional model of the battery pack

As shown in the figure, this article selects a three-dimensional model and physical image of the battery pack, as well as specific parameters.

Table 1. Battery pack parameter table

Voltage	Rated capacity	rated energy	mass	length	width	Height
193V	160Ah	30kWh	222Kg	98cm	41cm	38cm

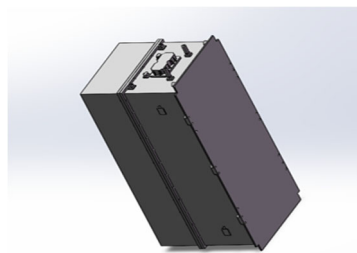


Figure 4. 3D model of battery pack



Figure 5. Physical battery pack

### 3.2. Model simplification and parameter selection

This time, modal analysis, statics and topology optimization analysis are carried out for the battery pack. Therefore, it is necessary to simplify the model and delete small holes that do not affect accuracy. The simplified model is shown in the figure.

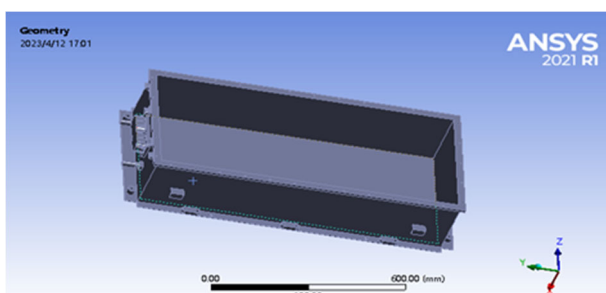


Figure 6. Simplified model

### 3.3. Statics analysis

The road surface and road conditions on which electric vehicles operate in real conditions are usually complex and

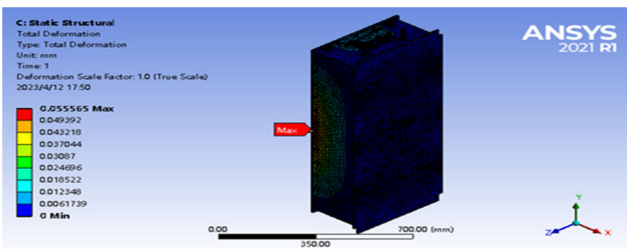
variable. It is not in line with the actual working conditions to accurately replicate and simulate the load situation of the vehicle during driving on the road. At the same time, the load received by the battery pack during the operation of the electric vehicle on the road is not directly affected by the external actual situation, but comes from various conditions such as braking, turning, and bumps [6]. The battery pack inside the power battery pack causes significant inertia and impact force on the structure of the battery pack due to shaking. In addition, the twisting force generated by the suspension or lifting of tires on different sides of electric vehicles under bumpy and uneven road conditions. Therefore, when studying the static loading of power battery packs, in order to express the stress distribution and displacement changes of the battery pack as much as possible, several typical extreme working conditions should be taken for analysis. The power battery pack under the chassis of electric vehicles is subjected to intense loads under extreme conditions such as bumps, sharp turns, and sudden braking. Therefore, this article conducts research and analysis on three road conditions: bumpy and sudden braking, bumpy and sudden turning, bumpy and reverse braking on the following types of bumpy roads. The static analysis is conducted according to the following working conditions (Tabl2).

**Table 2.** Statics analysis condition

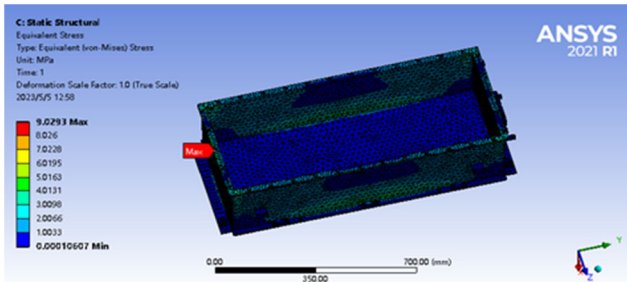
Working condition type	X direction (driving direction)	Y direction	Z direction (gravity direction)
Bump+emergency braking	1	0	2
Bump+sharp turn (left)	0	0.75	2
Bump+reverse braking	-0.75	0	2

**3.3.1. Bump and emergency braking conditions**

The simulation results are shown in the figure. Here, the main focus is on the stress and total displacement vectors. From Figures 3-4 and 3-5, it can be seen that the maximum stress of the battery pack plate is 9.023Mpa, which is lower than the yield strength of 235MPa, and the deformation and strain are both within an acceptable range. Therefore, the strength and stiffness are very large, and there is room for optimization.



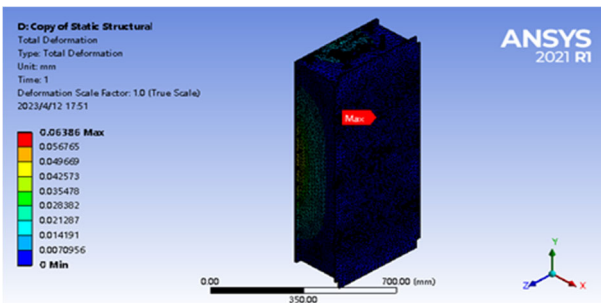
**Figure 7.** Deformation cloud map



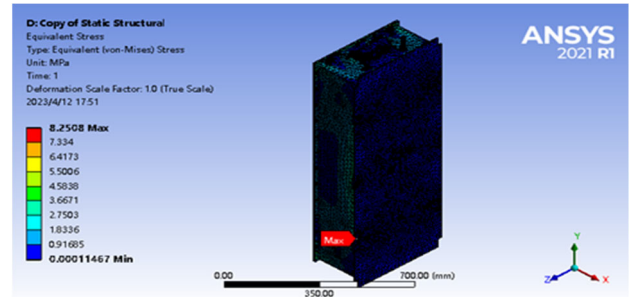
**Figure 8.** Stress nephogram

**3.3.2. Bump and sharp turning conditions**

The simulation results are shown in the figure, where the main focus is on the stress, total displacement vector, and. From Figures 3-6 and 3-7, it can be seen that the maximum stress of the battery pack plate is 8.25Mpa, which is lower than the yield strength of 235MPa. The safety factor is large, and the deformation and strain are within an acceptable range. Therefore, the strength and stiffness are very large, and there is room for optimization.



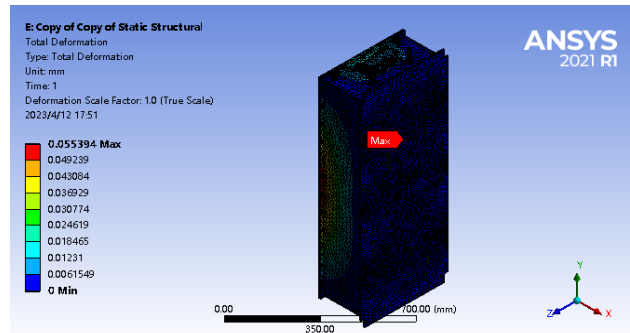
**Figure 9.** Deformation cloud map



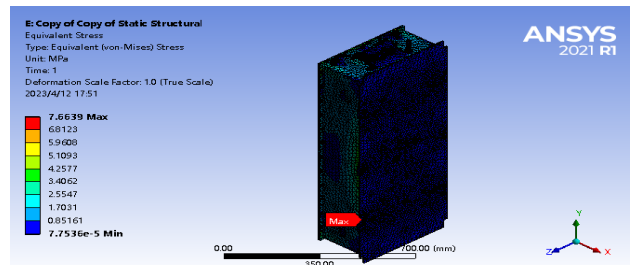
**Figure 10.** Stress nephogram

**3.3.3. Bump and reverse braking conditions**

The simulation results are shown in the figure, where the main focus is on the stress, total displacement vector, and. From Figures 3-8 and 3-9, it can be seen that the maximum stress of the battery pack plate is 7.7 MPa, which is lower than the yield strength of 235 MPa. The safety factor is high, and the deformation and strain are within an acceptable range. Therefore, the strength and stiffness are very large, and there is room for optimization.



**Figure 11.** Deformation cloud map



**Figure 12.** Stress nephogram

**4. Lightweight Optimization Analysis**

**4.1. Optimization Plan**

At present, lightweight design schemes mainly include topology optimization and size optimization. First, topology optimization reduces the mass or volume of the optimized object by optimizing the shape, and second, size optimization reduces the mass by optimizing the set size parameters. Both

schemes in this article are simulated and analyzed, and the optimal scheme is selected through comparison.

### 4.2. Topology optimization analysis

The objective function of topology optimization is to maximize the stiffness, and the limiting condition is to retain 50% of the mass.

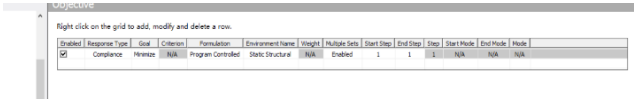


Figure 13. Set conditions

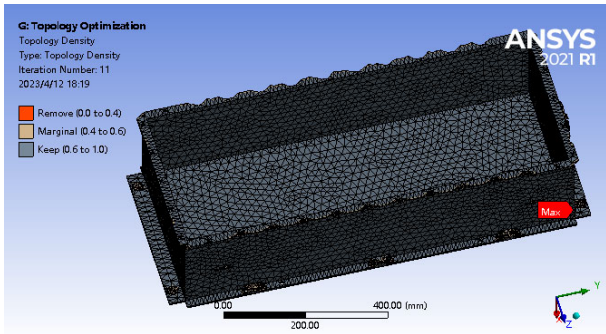


Figure 14. Optimal Results

The final mass before optimization was 86.802 kg, and after optimization was 82.158 kg, which met the requirement of mass reduction by 4.644 kg and achieved lightweight design. However, the mass reduction was relatively less than 5% of the total weight of the box before optimization, so parameter optimization analysis is needed.

### 4.3. Size optimization analysis

Set the thickness  $t$  on both sides as a parameter, with the minimum mass as the objective function, and the constraint that the maximum stress is less than the yield strength. The original mass is 86.61 kg.

The optimized results are shown in the figure. Thirty groups were calculated, and three groups were selected as the optimal.

A	B	C	D	E	F	G
1	Reference					
2		P1-P3(80%_t)@P1-P3(7-Par)	P2-567 Mass (kg)	P3-Equivalent Stress Maximum (MPa)		
3	Candidate Point 1	7.651	X: 61.572 0.00%	25.546 0.00%		
4	Candidate Point 2	6.815	XX: 64.125 4.15%	21.587 -15.50%		
5	Candidate Point 3	6.025	XX: 66.678 8.20%	18.313 -24.40%		
*	New Custom Candidate Point	4.05				

Figure 15. Three sets of optimal parameters

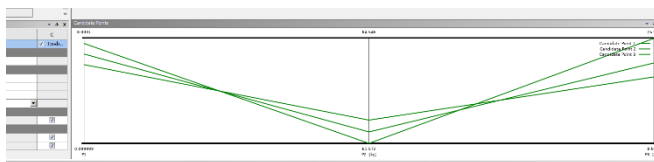


Figure 16. Parameter comparison

From Figure 4-4, it can be seen that after optimization, when the thickness is 2.4mm, the mass is 61.572Kg, and the maximum stress is 25.546MPa, the total mass decreases by more than 15%.

#### 4.3.1. Modal analysis after optimization

Modal analysis is the process of establishing a mathematical model between a structure and its environment

by utilizing its own physical parameters or the relationship between structural parameters and environmental excitation, and then obtaining the inherent characteristics of the structure by solving the model. Modal analysis is an important means of conducting dynamic analysis and research on structures, usually obtaining the modal parameters of each order of the structure. The modal parameters include frequency, damping, mode shape, and modal shape diagram. By solving the modal parameters, the inherent characteristics of the system can be obtained. The 6th modal frequency is shown in Table 3.

Table 3. First 6 modes

modality	1	2	3	4	5	6
Frequency/Hz	110.08	115.56	255.53	270.57	333.84	335.81

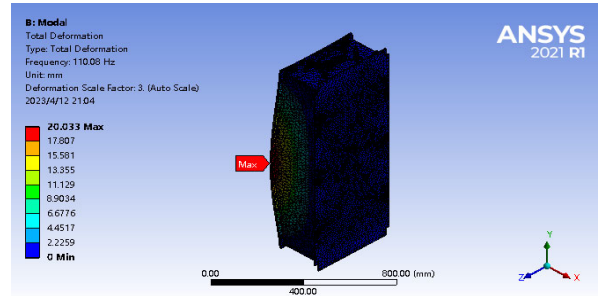


Figure 17. First order modal total deformation cloud map

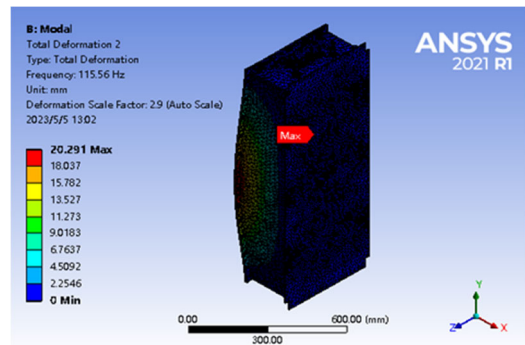


Figure 18. Second order modal total deformation cloud map

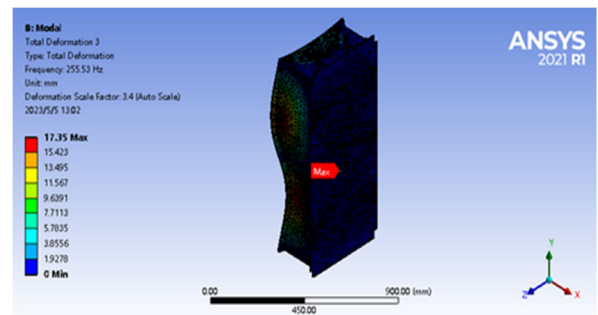


Figure 19. Third order modal total deformation cloud map

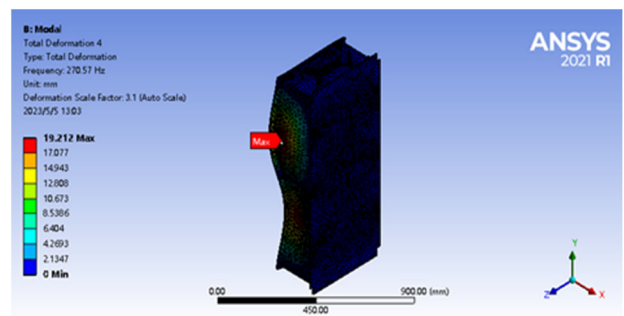


Figure 20. Fourth order modal total deformation cloud map

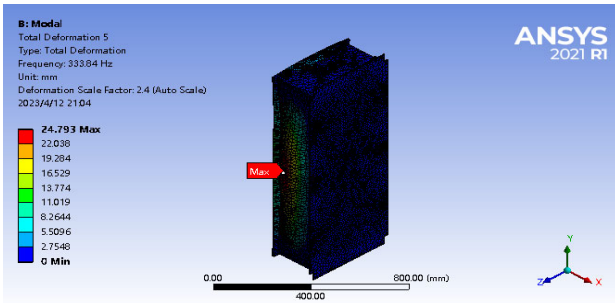


Figure 21. Fifth order modal total deformation cloud map

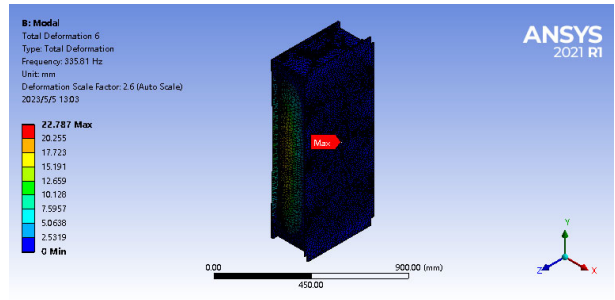


Figure 22. Sixth order modal total deformation cloud map

Generally speaking, modal analysis is mainly used to determine the distribution of various modes (natural frequencies and modes) in the system and their interrelationships. In finite element analysis, the main task is to establish a mathematical model of the vibration system based on finite element theory and conduct modal analysis to obtain the inherent characteristics of the system. Before conducting structural finite element analysis, it is often necessary to conduct modal analysis of the structure to obtain the vibration characteristics of the vibration system. It is necessary to conduct modal analysis of the structure during the design phase to avoid resonance phenomena. In the actual production process of products, it is often necessary to predict various vibration faults that may occur during product operation through finite element simulation, in order to take corresponding measures in advance. From the above, it can be seen that the natural frequency has decreased compared to before optimization, but the stiffness and strength meet the requirements.

#### 4.3.2. Static analysis after optimization

The simulation results are shown in Figures 4-11 and 4-12, where the main focus is on the stress, total displacement vector, and,

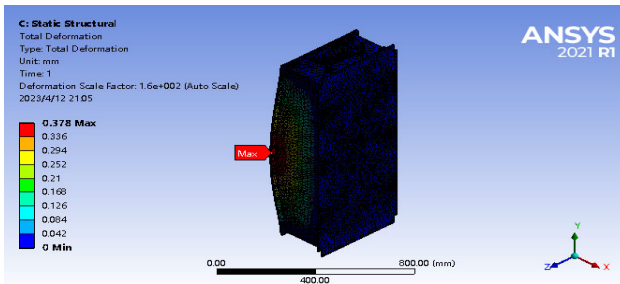


Figure 23. Deformation cloud map

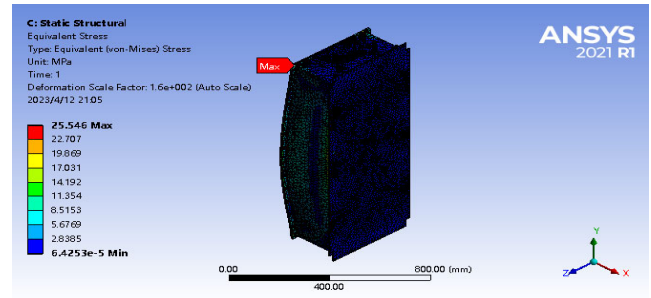


Figure 24. Stress nephogram

In static analysis, the areas with high stress in the battery pack are at the connection between the left side and the top of the battery pack (maximum stress area), and at the connection between the right side and the bottom of the right side (maximum stress area). These two parts are the top cover and bottom connection bolt hole areas of the battery pack. When conducting finite element analysis at these two locations, it is necessary to reinforce the bolt holes. In addition, when analyzing the static force of the battery pack, it is also necessary to consider the stress distribution in the bolt hole area connecting the upper cover and bottom of the battery pack. Therefore, it is necessary to reinforce the bolt hole area. From the above figure, it can be seen that the maximum stress is 25.546Mpa, and the safety factor is to divide the maximum stress by the yield strength exceeding 1. The larger the value, the stronger the safety factor.

## 5. Conclusion

In this paper, the statics analysis of the battery pack under three working conditions is carried out first, then the topology optimization and size optimization are carried out, and the following conclusions are drawn:

(1) The topology optimization takes the objective function as the maximum stiffness, and the limiting condition is to retain 50% of the mass for analysis. After optimization, 82.158 kg of the weight is reduced by 4.644 kg, which is 5% of the total weight of the box before optimization. The lightweight design is realized;

(2) The size optimization takes the thickness  $t$  on both sides of the battery pack as the parameter, and the mass as the objective function is the minimum. The constraint is that the maximum stress is less than the yield strength, and the original mass is 86.61 kg. After optimization, when the thickness is 2.4mm, the mass is 61.572Kg, and the maximum stress is 25.546MPa, the total mass decreases by more than 15%.

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