Optimized Design of Aluminium Bumper by Impact Test and Computer Simulation Analysis

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Abstract. Aiming at target steel car bumper new lightweight design, with a target vehicle steel bumper static crushing, three static pressure and impact test and simulation analysis based on the performance parameters, design targets bumper car aluminum alloy box, the section size of anticollision beam and the energy absorption and the materials they need to determine the aluminum bumper performance. The three-point static pressure method is used to optimize the design of the anti-collision beam. Because the loading condition is relatively simple, the optimization function of optistruct is used to optimize it to determine the cross-section shape and size of the anti-collision beam.

Keywords: lightweight design, aluminum bumper performance, optimization function

1. Introduction

The three-point static pressure method is used to optimize the design of the anti-collision beam. Because the loading condition is relatively simple, the optimization function of optistruct is used to optimize it to determine the cross-section shape and size of the anti-collision beam. The collision safety performance of energy absorbing box should be considered more in practical use. In recent years, the research on structural crashworthiness with finite element tools has been increasingly in-depth, but it is still difficult to apply traditional simulation methods to the optimization design of structural crashworthiness. The reasons are as follows: 1) the impact simulation costs a lot of computation time and resources; 2) As collision analysis is highly nonlinear, it is difficult for traditional gradient-based optimization methods to find the correct optimization solution. In order to solve these problems, a new optimization method, response surface method (RSM), has been developed in recent years, which is a global approximation method of objective function and constraint function based on finite element simulation calculation. It can solve these problems well. In this paper, based on the traditional optimization theory and collision simulation, the response surface method is applied to optimize the design of the aluminum alloy energy absorption box based on the crashworthiness parameters of a steel bumper energy absorption box, in order to obtain a more ideal result [1-3].
2. **Strengthen beam optimization design**

Topology optimization is to explore the mutual connection mode of structural components, the structure has no holes, the number of holes and other topological forms, so that the structure can meet the constraints of balance, stress, displacement and other conditions, to transfer the external load to the support, and at the same time make the structure of a certain performance index to achieve the optimal. Topology optimization often takes the most reasonable distribution of materials as the most basic design idea, which also meets the requirements of our pursuit of lightweight parts development. Therefore, topology optimization is an important design method in the conceptual design stage of component lightweight development. An important function of the bumper strengthening beam is that the collision force can be transmitted back as evenly as possible along the left and right energy absorbing boxes, regardless of the frontal impact or bias impact conditions. Therefore, the bumper strengthening beam must meet certain strength indicators. In this paper, three point static pressure test and simulation analysis are used to study the stiffness of each bumper reinforced beam. In order to facilitate the optimization design, the equivalent static load method is used to approximate the load of the head in the static pressure process, and the topology optimization design of the beam is carried out. The 1/2 model of the reinforced beam was taken as the research object, and the whole model was taken as the design space. A section of X and Y degree of freedom was constrained, and Z degree of freedom was constrained on the symmetrical surface of the beam. The extrusion constraint in the bending direction was applied on the whole, and the optimized target mass was minimum, and the constraint was that the stress was less than the material yield stress at the peak load.

![Figure 1. Topology optimization model of aluminum alloy bumper](image)

According to the optimization of the anticollision beam cross section in the form of form, in the form of mouth type as a basic section of a beam section form, finally identified the target as shown bumper car aluminum alloy strengthening beam cross section shape of concrete section parameter as shown in figure 1, the plate thickness of 1.8 mm, material yield strength 280 Mpa, to establish three static simulation model in ABAQUS.

3. **The cross section shape of aluminum alloy energy absorption box is determined**

Aluminum alloy bumper production mode is extrusion manufacturing, considering its manufacturing ability and in order to reduce the cost, the impact performance of four kinds of cross section forms of aluminum alloy pipe fittings was studied, the impact force peak, the maximum deformation and other properties were examined, and compared with the steel energy absorption box these parameters were analyzed. Four kinds of aluminum alloy pipe fittings with different section shapes are made of the same material, with a circumference of 240mm and a wall thickness of 1.8mm. The length of the energy absorption box is 167mm as the original steel energy absorption box. The material parameters of aluminum alloy were obtained through material test on the samples provided by the manufacturer.
LS-DYNA 24 material was used, with density $2.7 \times 10^3 \text{kg/m}^3$, elastic modulus $7.1 \times 10^4 \text{MPa}$, Poisson's ratio 0.3, and yield strength 181MPa. The working condition setting of simulation analysis is completely consistent with that of steel energy absorbing box analysis. The simulation deformation of hexagonal pipe fittings in collision is shown in Figure 2.

By comparing the data, it can be concluded that the peak value of the square and hexagonal aluminum tubes is smaller than that of the steel absorbing box, while the peak value of the octagonal and circular aluminum tubes is larger. As the peak value of the collision force is smaller, the better, it can be seen that the square and hexagonal aluminum tubes have better performance. From the deformation analysis, the deformation of octagonal aluminum pipe is the smallest, followed by hexagonal aluminum pipe. The smaller the deformation of pipe, the greater the impact energy absorption potential, and the more beneficial to collision safety. From the analysis of average impact force and energy absorption, the octagonal aluminum tube is the largest, followed by the hexagon. In summary, it can be seen that the overall energy absorption performance of the octagonal aluminum tube is relatively outstanding, but its collision peak is too large, and all parameters of the hexagonal aluminum tube meet the requirements. Therefore, the basic section form of the extruded aluminum alloy energy absorbing box is regular hexagon structure.

4. Parameter optimization of aluminum alloy energy absorbing box

The side length L and wall thickness T of the energy absorbing box are taken as structural design variables. In order to take into account the influence of mechanical properties of materials on impact performance, the stress-strain curves of aluminum alloy samples provided by the manufacturer were obtained by material tests, and the stress-strain curve clusters which could be achieved by different heat treatment processes were formed. The variation range of these curves was within the permissible range of the production process. The yield strength of these curves was used as a material design variable. The response surface curve is shown in Figure 3. Latin Cube test method was used to select 21 groups of samples in the design space, and the corresponding collision models were established and imported into LS-DYNA for calculation. Hyperview was used to calculate the peak collision force, maximum deformation and maximum energy absorption of each model. A second-order response surface model was used to characterize the peak impact force, maximum deformation and maximum energy absorption of hexagonal aluminum box. The optimized performance parameters were compared with the performance parameters obtained from the simulation analysis, and the error
between the two was within a reasonable range, indicating that the optimization results were accurate and credible. Compared to the original steel can suction box, aluminum box quality $g$ decreased from 676 to 250 g, 63% weight loss, and energy absorption peak and the original steel box of collision force energy absorption box of basic quite, and the average collision force is greater than the steel box of absorbing energy, the maximum deformation is less than steel, is the new development of aluminum alloy box in collisions with good energy absorption properties of the potential for increased its energy absorption.

![Response surface model for peak impact forces](image)

**Figure 3.** Response surface model for peak impact forces

5. Conclusions

Through the topology optimization method, the optimal structure distribution of the aluminum alloy reinforced beam is obtained and the section form and size of the aluminum alloy reinforced beam are finally determined. The final design of the aluminum alloy bumper reinforced beam beam mass is 1.3kg; The section size and material property parameters of aluminum alloy bumper energy absorption box were optimized by approximate model approximation model optimization method. The final optimized mass of single energy absorption box was 0.25kg. The total weight of the target car's steel bumper is 5.3kg, and the newly developed aluminum alloy bumper is 2.4kg. The weight reduction effect reaches 55%, so it better meets the lightweight requirements.

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