Effects of Side Structural Components on Vehicle Side Impact Safety

Xike Wang

School of Automotive Engineering,

Zibo Polytechnic University

Zibo, Shandong, China

Abstract: The side of the car is a relatively weak part in the body. It is particularly important to optimize the stiffness and strength of the side parts to enhance the collision resistance of the car side. Establish a side impact finite element model for a domestic SUV, and conduct a side impact simulation according to the regulations, and analyze the energy in the system to verify the effectiveness of the model. By comparing the values of the speed, intrusion amount and acceleration of the key points before and after, based on the basis of the test design and the response surface method, the scheme for the improvement of the side impact resistance is proposed and the effectiveness of the response surface method in improving the impact resistance of the structure is verified.

Keywords: side impact resistance; optimized design; rigid strength matching; test design; response surface method

1. INTRODUCTION

At present, the response surface method is widely used in the structural optimization research of nonlinear problems (such as collision resistance). As a statistical and mathematical method, the response surface method is mainly used for "development, improvement and optimization". Nowadays, the response surface method is used in optimization design, that is, by constructing reasonable test design to construct the approximate function between target and design variables[2]。 By constructing the response surface model, the computation of solving optimization problems can be reduced and the optimization efficiency can be improved.

In terms of improving the collision resistance of automobiles, the often used methods and measures are: the application of high strength steel plate, modifying the section shape of the parts, increasing the thickness of the plate, and the use of structural reinforcement parts.

In this paper, the rigid strength of the side circumference is optimized by using the high strength steel plate and increasing the plate thickness. During the study, use orthogonal test design and comprehensive balance method; use uniform test design to optimize the thickness of side parts and response surface method.

2. TEST DESIGN AND RESPONSE SURFACE METHOD

2.1 Test design

Trial design (Design of Experiments, DOE) belongs to the category of mathematical statistics and is an important tool for scientific research. The task of trial design is to combine theoretical expertise and practical experience, scientifically arrange the experiment, effectively control the interference, obtain reliable information to the greatest extent, find out the way to solve the problem and obtain the optimal solution.

Orthogonal test design is one of the most commonly used test design methods, and "balanced distribution, comprehensive comparable" is its most remarkable feature. The basic tool of orthogonal trial design is orthogonal table, and equilibrium distribution is the core of orthogonal table.

As a test design method, uniform design only considers the "uniform distribution" of the test site within the test range, but not the "neat contrast", so the test number of times is greatly reduced. When the change range of test factors is large and the number of selected levels is large, the use of uniform design can greatly reduce the number of tests. Uniform design also uses a set of tables to arrange the experiment, and the table used is called the uniform design table[3], Each design table is accompanied with a use table.

2.2 Response surface method

Response surface method (Response Surface Method, RSM), as an approximate model technology, is a mathematical regression method that predicts the response value of the unknown point according to the response information of known points. It fits a polynomial regression function that can approximate the relationship between the output and design variables by a certain amount of test value. The most commonly used response surface model is the first-order and second-order power polynomial. The structure function is simulated by the second-order model, which can accurately approximate the actual engineering and has high use value.

3. OPTIMIZE THE MATERIALS

3.1 Orthogonal test design

Please use a 9-point Times Roman font, or other Roman font with serifs, as close as possible in appearance to Times Roman in which these guidelines have been set. The goal is to have a 9-point text, as you see here. Please use sans-serif or non-proportional fonts only for special purposes, such as distinguishing source code text. If Times Roman is not available, try the font named Computer Modern Roman. On a Macintosh, use the font named Times. Right margins should be justified, not ragged.

3.2 Selection and verification of the optimization scheme

The comprehensive balance method was used to select the optimization scheme. In this paper, the maximum intrusion in the middle of the inner plate was selected as the main evaluation index, and the body acceleration was selected as the secondary evaluation index. According to Figures 1 and 2,

the order and preference of the factors affecting the acceleration are D> B> C> A and A1B2C1D3, and the order and preference of the factors affecting the intrusion are A> D> B> C and A3B2C3D3. Comprehensive analysis, the final selected optimization scheme is A3B2C3D3. The finite element model was modified according to the optimization scheme, and the comparison between the acceleration of the body and the intrusion of the middle part of the B-pillar inner plate was arranged before and after the improvement after calculation, as shown in Figure 1 and Figure 2.
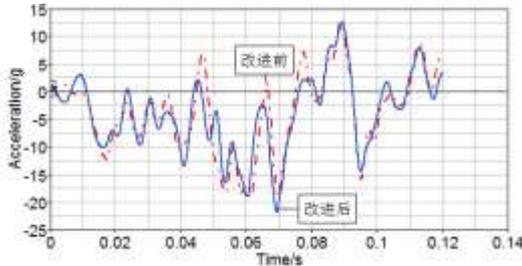

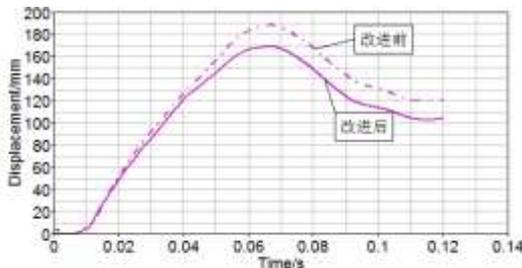Figure 1 Comparison of acceleration before and after improvement

Figure2 Comparison of intrusion before and after improvement

According to the comprehensive analysis, as the main target value for the optimization improvement, the maximum value of the middle volume of the inner plate decreased from 187.7 mm before the improvement to 168.4 mm, which decreased by 10.3%. Although the acceleration of the body increased from the original 19g to 21.7g, the increase is not very large. Therefore, it can be considered that the modification of the material can improve the body collision resistance to some extent.

3.3 Parametric Optimization of Side Circumference Parts for Lightweight Body Design

The main side circumference structure components in the body include internal and outer plate of B-column, B-pillar reinforcement plate, internal and outer plate of the door, threshold beam, roof side beam, anti-collision rod, floor beam, etc. Through research and analysis, the thickness of the door interior plate, B-column outer plate, B-column reinforcing plate and the middle floor beam are selected t (t1, t2, t3, t4) Design variables for the optimization problem.

When establishing the optimized model, the maximum intrusion amount L in the middle of the inner plate of the B column was selectedThe max and the maximum invasion speed, VAs a constraint to evaluate crashability, considering the requirement of lightweight body, the total mass m of the four parts is selected as the optimization goal to minimize it.

On the basis of ensuring the reliability and lightweight requirements of the structure, the maximum intrusion amount

and maximum intrusion speed are equal to or less than the initial value, that is, the constraint condition is set as: the intrusion amount is less than or equal to 168.4 mm and the intrusion speed is less than or equal to 5638 mm · s-1. Literature indicates that when the invasion speed of the lateral structures is controlled at 8000mm · sCan meet the requirements of side impact occupant protection when within the range. In this optimization problem, the constraint value range setting is more reasonable..

3.4 Response surface construction based on the uniform test design

To obtain sufficient design samples, the uniform test design method was used in this study. Reference [6] construct Uniform Table U25(254), each factor in the table has 25 levels, a total of 25 trials, and in this study, a quadratic polynomial model was used to simulate the maximum intrusion L in the middle plate of the B columnAnd max, maximum invasion speed VMax these target quantities and the design variable thickness t (t1, t2, t3, t4) Nonlinear relationship between the nlinfit function in MATLAB software, and the final mathematical model is as follows:

$$
\begin{aligned}
L_{max} &= 484.48 - 24.649t_1 - 221.948t_2 - 145.83t_3 \\
&\quad + 35.38765t_4 - 6.7503t_1^2 + 34.1788t_2^2 \\
&\quad + 17.60234t_3^2 - 6.9984t_4^2 + 17.3187t_1t_2 \\
&\quad + 7.7831t_1t_3 - 9.2986t_1t_4 + 35.19t_2t_3 \\
&\quad - 2.24705t_2t_4 - 4.09903t_3t_4
\end{aligned}
$$

(5)

$$
\begin{aligned}
V_{max} &= 10856.431 + 106.7018t_1 - 1176.493t_2 \\
&\quad - 4456.286t_3 - 907.771t_4 - 405.697t_1^2 \\
&\quad - 147.919t_2^2 + 777.117t_3^2 + 284.381t_4^2 \\
&\quad + 46.6278t_1t_2 - 60.5122t_1t_3 - 222.03t_1t_4 \\
&\quad + 586.235t_2t_3 - 58.072t_2t_4 + 231.316t_3t_4
\end{aligned}
$$

(6)

$$
m = -1.296 + 9.998t_1 + 17.8949t_2 + 4.41t_3 + 1.62t_4
$$

(7)

Lmax、 VComplex correlation coefficient R for max and m2 and the value of the modified complex correlation coefficient, R R_{adj}^2 The values of 2 and are all close to 1, indicating that the fit accuracy of the three functions is high and can be used for subsequent optimization calculations.

3.5 Multi-objective optimization and result verification

The optimal value of the objective function was solved using the fmincon function in the MATLAB software, and the resulting optimization result was t1=0.89 mm, t2=0.65 mm, t3=2.4 mm, t4=0.8 mm。

According to the optimal solution obtained above, the parameters of the corresponding structure are adjusted in the vehicle model and calculated by LS-DYNA software simulation. By comparing the result value of the response surface function and the finite element simulation result, the target prediction value obtained by the response surface function and the target value calculated by the model simulation are similar, and the error of both is controlled within ± 5%. It can be obtained that the result of optimizing

the function constructed by the response surface method has some confidence..

3.6 Page Numbering, Headers and Footers

Do not include headers, footers or page numbers in your submission. These will be added when the publications are assembled.

4. CONCLUSION

The vehicle and trolley model for side impact analysis is established, and the validity of the model building is verified. Orthogonal test design is used to analyze the materials of the side circumference parts and select the better scheme. Based on the uniform test design and response surface method, and the principle of reducing the intrusion amount and the intrusion speed, the thickness of the main components was optimized, the optimal solution was obtained by MATLAB software, and the effectiveness of the response surface method was verified by finite element simulation calculation. Using the response surface method, and it has some applicability in the engineering field.

5. REFERENCES

[1] Liu Jingbo. Simulation analysis and experimental study on the passive safety of a side crash of a car [D]. Changchun: Jilin University dissertation, 2011:1.

[2] Sui Yunkang. Improvement of the response surface method and its application to engineering optimization [M]. Beijing: Science Press, 2010.

[3] Li Yunyan, Hu Chuanrong. Trial design and data processing [M]. Beijing: Chemical Industry Press, 2005:87,114-121.

[4] Sun Guangyong, Lee Kuan Yew, Zhong Zhihua. Optimized design of multi-target particle swarm of automobile structure based on sequence response surface method [J]. Journal of Mechanical Engineering, 2009,45 (2): 224-230.

[5] Li Yiwen, Xu Tao, Xu Tianshuang, et al. Optimized design of low-speed collision energy absorption structure [J]. Journal of Beijing Institute of Technology, 2010,30 (10): 1175-1179.

[6] Xu Tao, Hao Liang, Xu Tianshuang, et al. Rapid optimization of collision resistance of doors in car side collision [J]. Journal of Jilin University (Engineering Edition), 2012,42 (3): 677-682.