Parameters Optimization Design and Analysis of Bow-shape Seat in Segmented Tire Mould Structure

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Abstract. Parameters optimization research of bow-shape seat structure is done through SolidWorks and ANSYS Workbench build collaborative simulation platform, which is an important part of segmented tire mould. The optimal values of bow-shape seat belt, outer surface length and inner diameter of bottom surface are determined. By comparing with prototype, the results indicated that the improvement on structure of bow-shape seat reduce weight in the condition of satisfying strength. The temperature difference between upper and lower point of the pattern segment decreased from 0.75℃ to 0.13℃. The temperature field on pattern segment was more uniform and the tire vulcanization quality was improved.

Introduction

The mould cavity's temperature field in the process of tire vulcanizing has played a decisive role in tire vulcanizing quality [1]. During the tire mold opening and closing, bow-shape seats as the important part of tire mold, which are fastened together with the block and generate mutual movement with the guide ring slide. When the mold is heated, thermal energy transfers to the inner tire mold cavity through the bow-shape seat. Therefore the structure of bow-shape seat is one of the important factors, which determine the temperature distribution inside the mold cavity, its structural parameters design is particularly important. This paper introduces the thinking of optimal design, readjust the bow-shape seat structure in the original design. Optimization research of key parameters of bow-shape seat belt, outer surface length and inner diameter of bottom surface is done through SolidWorks and ANSYS Workbench build collaborative simulation platform. Compared with the original plan to get a set of the optimal solution, in order to provide theoretical basis for the development of new products.

Heat transfer simulation analysis

Segmented tire mould is approximately 360 ° axial symmetry. They are made up of 10 blocks, 10 bow-shape seats and other components [2]. In the heat transfer simulation process, the heat transfer condition is symmetrical, so take the tenth of the model to heat transfer simulation analysis. Three-dimensional model of the 9.00R20 mold chart in Fig. 1. According to the mold vulcanization heating conditions in current actual production, the steam in the gas chamber and upper and lower hot plate of the vulcanizing machine are heat source. So take temperature of 160℃ in gas chamber and take temperature of 150℃ on the upper and lower plate. There are heated capsule inside the cavity. Because capsules are rubber, which is a poor conductor of heat. Its temperature is ignored. The initial temperature of mold is 20 ℃. Tire vulcanization quality changes with the mold temperature field of tire change. Cavity temperature gradient is smaller, better uniformity, better the quality of tires and higher the production efficiency.

Analysis set conditions in ANSYS Workbench: Mold material steel is 45 #, which the physical properties as follows: Thermal conductivity 47W • m-1 • K-1, density 7.8E-9kg • mm-3, Specific heat 475E6kJ • kg-1 • K-1. The total solution time is 18000s and other settings as default values. To accurately describe the temperature distribution within the pattern segment. The length of the pattern segment unit is set to 20mm and other parts are 50mm. Because some parts are too complicated, the meshing main apply Tetrahedrons.

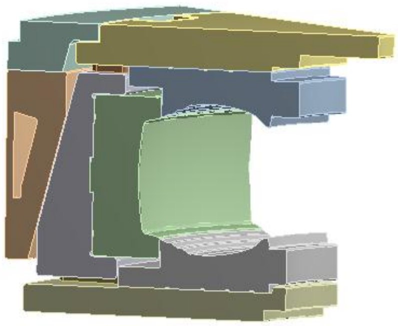

Fig. 1 Three-dimensional model of the 9.00R20 mold chart

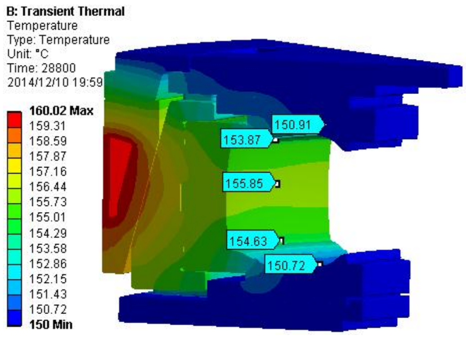

Fig. 2 The temperature chart after 5 hours' warming up

After 5 hours' warming up, we conclude that temperature reaches a steady state when the time is about 2.2h in the mold cavity and the temperature chart. To facilitate observation uniformity of the mould cavity temperature field. Select five points on the pattern segment and the upper and lower side plates, as the temperature measurements in mould cavity.

According to the temperature chart after 8 hours' warming up can be seen in Fig. 2. The temperature of the upper and lower side plates is relatively uniform, so the temperature difference can be neglected. There are relatively obvious gradient on the pattern segment. It is 0.76 ℃.Will have some impact on the quality of the tire vulcanization.

Optimization Research of Bow-shape Seat

AWE Optimization Principle. Optimizing exploration tool in ANSYS Workbench uses the principles of experimental data method (DOE) for optimizing the data. Acquisition design variable sampling point by using the Monte Carlo sampling technique. Calculate corresponding results of each sample point and measure the weight relationship between sample point and the target variables by sensitivity analysis and response analysis between parameters. Eventually, optimal solution was obtained. [3-4]

Structural Design and Parameter Optimization Analysis of Bow-shape Seat. To complete the mould opening and closing, the temperature transfer becomes asymmetric due to the special structure of the bow-shape seat, which led to temperature difference in the mold cavity. Therefore, mainly from the bow seat structure to study. As shown in Figure 3. When the tire vulcanized, there are several forces in the mould. Mainly includes the total pressure when machine pressing mould and hot water pressure in the mould cavity, etc. In addition, thermal stress due to temperature and the gravity of mould, etc [5]. According to the actual situation, the inner surface pressure of the bow-shape Seat (p) is 2.2MPa; the force is applied to the model on the hot plate (Q) is 2.6MPa, as shown in Figure 4.

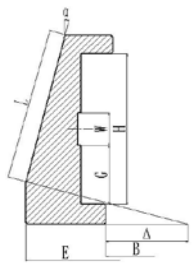

Fig. 3 The structure of bow-shape seat

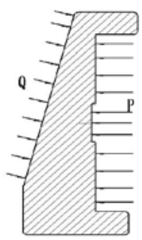

Fig. 4 Stress of bow-shape seat

The closing process of segmented mould is mainly depending on the inner surface of guide ring matched up with the outer surface of the bow-shape seat to achieve [6]. In principle of the design, the greater the length of bow-shape seat external surface and the bottom, the better for the bow-shape seat sliding stability. Increasing bow-shape seat belt width can reduce the temperature difference in the mould cavity. In favor of tire curing. However, due to limitations, the values cannot arbitrarily increase. There is a reasonable choice problem.

Set up three parameters as a global variable through the above analysis and as input parameters of optimizing the structure of the bow-shape seat. L is a control parameter of the seat outer surface length; B is a control parameter of the bottom diameter and W is belt width. The max-equivalent stress P4 and mass P5 for output parameters. The initial value of input parameters and domain is shown in Table.1.

Tab. 1 Initial value of input parameters and domain unit: mm

	L	B	W
Initial Value	274.82	1094	60
Lower limit	241.93	986.4	60
Upper limit	362.89	1205.6	270

Sensitivity Analysis. Get 15 sets of input parameters groups by DOE methods. As shown in Figure 5 sensitivity analysis between input parameters and output parameters are obtained. That in order to reduce the max-equivalent stress would reduce the three input parameters and reduce the quality would increase the three input parameters, thus need to find a compromise point.

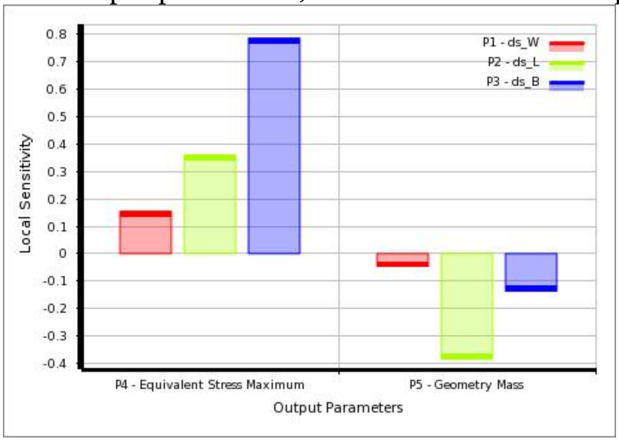

Fig. 5 Sensitivity analysis between input parameters and output parameters

Optimization Analysis. In the construction of the collaborative simulation platform, the minimum value of max-equivalent stress P4 and mass P5 as the objective function. 10000 sample points were selected for screening the optimal solution that they meet the objective function in the domain of design variables. Obtain three groups of candidate designs after optimizing and screening in Table 2.

Tab. 2 Three groups of candidate designs

Groups	ds_W/mm	ds_L/mm	ds_B/mm	P4/Mpa	P5/kg
Candidate A	151.4	302.4	1091.9	65.2	64.3
Candidate B	103.0	302.8	1101.8	64.8	64.5
Candidate C	127.2	302.0	1095.1	64.6	64.7

Tab. 3 comparison table of optimized parameters before and after

Parameters	Design variables /mm			Max-equivalent stress	Mass
	ds_W	ds_L	ds_B	P4/Mpa	P5/kg
Original	60.0	274.8	1096.0	50.9	89.0
Optimization	151.4	302.4	1091.9	65.2	64.3

By analyzing the above three groups alternates and considering two aspects of the max-equivalent stress and mass. Candidate A is the best choice for this design, so as the optimization results. The max-equivalent stress of bow-shape seat is 65.2Mpa in optimal solution and allowable pressure of 45# steel is 235Mpa, so it meets the strength requirements. Its mass is 64.3kg, to make the mass of the bow-shape seat mitigation. The table 3 shows comparison table of optimized parameters before and after.

Improved Structure and Results Analysis

According to the optimization of the bow-shape seat structure, update the bow-shape seat structure and heat transfer simulation again. As shown in Figure. 6.

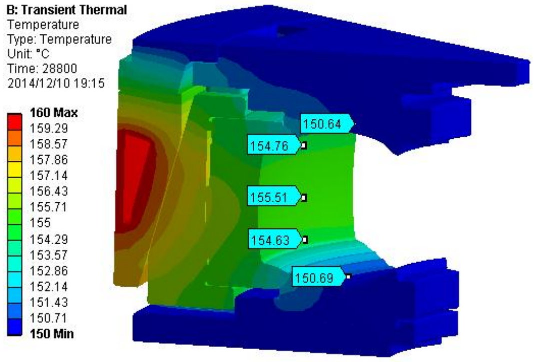

Fig. 6 temperature map of improving bow-shape seat after 8 hours' heating

Compare with the initial model, the temperature of upper and lower side plate were little changed. The time to reach steady state temperature in the mold is substantially the same. Upper and lower temperature difference becomes 0.13℃, which will help to improve the quality of tire vulcanization. The results show that the bow-shape seat structure is optimized to achieve good effect.

Conclusions

The bow seat made parametric modeling and optimization of the structure by the SolidWorks parametric modeling software and the ANSYS Workbench general finite element simulation software build collaborative simulation platform. Taking the max-equivalent stress and mass as the objective function to obtain the optimal design plan. Segmented tire mould is analyzed for heat transfer .Then the temperature field of tire mould in the process is gotten. Compared with the initial model, mould cavity tends to be more uniformly. Provide theoretical guidance for the design of the tire mould。

References

[1] Wang Wei, Deng Tao, Optimization of tire vulcanizing process conditions [J],Tire Industry, 2006,26(4):225~227.

[2] ZHANG Bai-jun, The Optimization of Tire Die Structure Based on Numerical Simulation Analysis [J], Control Engineering of China,2013,7,20(4):688~670.

[3] WANG Xiao-yun, YUAN Si-song, Optimization Design of Connecting Rod of 485Q Based on AWE [J]. Coal Mine Machinery, 2010, 3(31):39-41.

[4] HUANG Zhi-xin, LIU Cheng-zhu, ANSYS Workbench14.0 Super Learning Guide [M]. Beijing: People Post Press, 2013: 314-353.

[5] Van Emmerik M J G M, Interactive design of parameterized 3D models by direct manipulation [J], Ph Dhesis, Netherlands: Delft University of Technology, 1990:15~20.

[6] Shanghai Science and Technology Press Code, Practical Hardware Manual [M], Shanghai: Science and Technology Press, 1967:3-31.