Topography optimization of Workbench gearbox box reinforced bar based on ANSYS

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Abstract: In order to improve the structural performance of gearbox and improve the service life of gearbox, a method based on topology optimization to improve the layout of reinforcement is proposed in this paper. In this paper, a three-dimensional model of gearbox is established in CREO3.0, and the simulation analysis is carried out by using ANSYS Workbench software to optimize the layout of stiffeners and obtain the best scheme. The results before and after optimization are compared and analyzed, and it can be seen that there is a reduction in stress concentration after optimization.

1. Preface
With the growing demand for the development of traction locomotives towards high-speed heavy loads [1], gearboxes are gradually moving towards lightweight and high reliability. In the actual operating environment, the gearbox will be affected by external loads for a long time [2], will lead to fatigue damage [3] and cracking situation, according to the statistical results of professional institutions show that the production of gearboxes in developed countries failure rate of 25%-30%, and China's production of gearbox failure rate of up to 40%-45%. The high failure rate of gearbox has restricted the development of locomotive, so it is very urgent for the optimal design of gearbox. In this paper, the reinforcement bar is designed on the gearbox box to reduce the occurrence of stress concentration [4], and the number position and thickness of the gearbox box bar are topology optimized [5] to achieve the purpose of light quantification of the gearbox.

2. Topology optimization design of gear box reinforcement plate
Gearbox in the process of operation, by the impact of external loads, it is easy to appear fatigue fracture situation, affecting the service life of the gearbox. In view of this situation, the optimization of gear box reinforcement is carried out in this paper.

2.1 Establishment of finite element model of gearbox
A three-dimensional model of the gearbox will be established, and through the seamless link function of CREO3.0 and ANSYS, the three-dimensional model of the gearbox established in CREO3.0 will be imported directly into the ANSYS Workbench, the material of the gearbox is AlSi7mg [6], \( \rho = 2650 \text{kg/m}^3 \), the elastic modulus \( E = 7.4 \times 10^5 \text{PA} \), Poisson \( \mu = 0.3 \). Grid division [7] plays a very important role in the simulation analysis process, the number of grids is too small, will lead to the accuracy of the final results, the number of mesh division is too large, the calculation results are relatively accurate, but the calculation of a lot of quantitative, the operation rate decreases, the time is relatively small and the computer PC performance requirements are relatively high. According to the
This paper adopts the free grid division method, the mesh is mainly generated by the tetrahedron unit. The gearbox model divides a total of 97,876 nodes and 51,833 units, as shown in Figure 1.

Figure 1. Static mesh Division of Gear Box

2.2 Load and constraint applied
Because the gearbox is connected to the motor by bolts, a fixed constraint is applied to the junction. The Force F1 F2 F3 is applied separately at the bearing holes of the boom size, and the force analysis is shown in Figure 2.

Figure 2. Force analysis of gear box

2.3 Finite element results
According to the above boundary conditions, the gearbox model is loaded and analyzed, and the gearbox should be tried, as shown in Figure 3, the strain diagram is shown in Figure 4, and the overall deformation diagram is shown in Figure 5.

(1) Should seek to
3. Optimization Design

Optimization design is a design method that selects the best scheme from a variety of scenarios. Based on the optimization theory in mathematics, taking the computer as the means, according to the performance goal pursued by the design, the objective function is established, and the optimal design scheme is sought under the given various constraints.

(1) Optimization of design parameter selection

The design variable [9] is selected as the number position of the box fascia, the height width thickness of the reinforcement plate, the variation range of the height width thickness of the fascia is 20% above the original value, and the number of the fascia is optimized according to the actual situation in 4-6.

(2) Selection of target variables

In this paper, the stress and strain value and maximum deformation are selected as state variables [10], and the safety factor of empirical value 1.5 is considered in combination with the static calculation results [11], as shown in table 1.
Table 1. Optimization parameters

| Design variable         | Reinforced Plate Position | Reinforced Plate Size | Number of fascia plates |
|-------------------------|----------------------------|------------------------|-------------------------|
| Target variable         | Maximum stress of gear box | Gear box Maximum strain | Total deformation of gearbox |

4. Optimization Results Analysis

In this paper, 40 design samples and 3 candidate points are selected, and the optimal results are optimized by the multi-objective genetic algorithm under Optimization, as shown in table 2.

Table 2. Optimization Results

| Reinforced plate Angle 1 | plate number | 5 |
|--------------------------|--------------|---|
| Reinforced plate Angle 2 | 10°          | 236mm |
| Reinforced plate Angle 3 | 20°          | 22mm |
| Reinforced plate Angle 4 | 30°          | 21mm |
| Reinforced plate Angle 5 | 0°           | 249.08 |

Gearbox maximum strain (mm): 0.0014408
Gearbox Maximum stress (MPA): 83.292
Gearbox maximum deformation (mm): 0.47782

According to the results obtained, the model is re-established, and the results are checked to obtain the best optimization scheme, and the results before and after optimization are shown in table 3.

Table 3. Comparison table of optimization results of gear box reinforcement

| Target variable | Gearbox maximum strain (mm) | Gearbox Maximum stress (MPA) | Gearbox maximum deformation (mm) | plate number |
|-----------------|-----------------------------|------------------------------|---------------------------------|--------------|
| Before optimization | 0.0017984              | 105.34                       | 0.51234                        | 6            |
| After optimization | 0.0014408              | 83.292                       | 0.47782                        | 5            |

Through the comparison before and after optimization, it can be seen that the maximum stress is reduced by 20%, the strain and maximum deformation are smaller, the number of fascia is reduced, the material is saved, and the stress concentration is reduced.

5. Conclusion

In this paper, the finite element analysis and lightweight design of gearbox box fascia are carried out, and the following conclusions are drawn:

(1) The setting of stiffeners on the gearbox box can reduce the occurrence of stress concentration.
(2) Reasonable arrangement of the position of the reinforcement can improve the service life of the gearbox.
(3) Optimizing the size of the reinforcement can initially achieve the purpose of lightweight gearbox.
(4) Through verification, it can be concluded that the scheme is feasible and has guiding significance for the design of the trunk box after the traction gearbox.
References
[1] Min Li. Research on lightweight weight of special gearbox based on topology optimization method [D]. Chongqing University of Technology, 2014.
[2] Guo Lei. Research on virtual prediction and analysis technology of vibration and noise of vehicle powertrain structure [D]. Zhejiang University, 2009.
[3] Zhang Honglei. Numerical simulation of fatigue characteristics of large wind turbine gearboxes [D]. North China Electric Power University (Beijing), 2010.
[4] Ren Lihui, Cheng Zuguo, Zhao Honglun. Research on strain fatigue life of gearbox suspension for moving car steering frame[J]. Urban Rail Transit Research, 2001(04): 30-34.
[5] Xu Junhui, Sun Chenglong, Cui Wei. Research on gear reduction of gearbox based on optimization technology[J]. Auto Parts, 2017(05): 34-37.
[6] Zhige Wang, Kexin Lv, Jingxu Kent Zheng, Bin Chen. Atomic-scale characterization of interfaces between 2A70 aluminum alloy matrix and Cu-enriched layer after electropolishing [J]. Materials Characterization, 2019, 150.
[7] Huang Qinpu. Modal analysis and experimental research of gearbox based on ANSYS [D]. North China University of Water Resources and Hydropower, 2016.
[8] Wang Shidong, Su Xin, Liu Yihu, Ye Shengjian. Simulation Analysis and Structure Optimization of Gearbox Vibration and Noise [J]. Thermal Power Engineering, 2019, 34(01): 92-97.
[9] M. Khadyko, D. Morin, T. Borvik, O.S. Hopperstad. Tensile ductility of extruded aluminium alloy AA6063 in different tempers [J]. Materials Science & Engineering A, 2018.
[10] David L. Westling. Inclusion in the United States: correlations between key state variables [J]. International Journal of Inclusive Education, 2019, 23(6).
[11] Zhao Ying. Design and research of high power wind power gearbox [D]. Jilin University, 2012.