Sealing Analysis of Joint Surface of Transmission Case of An Electric Vehicle

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Abstract. In view of the oil leakage failure of the joint surface of the transmission case of an electric vehicle, a contact non-linear finite element method was used to analyze the tightness of the joint surface of the transmission case of an electric vehicle. Based on the workbench software, a finite element model of the transmission case is established. Determining the sealing performance of the case by calculating the distribution of the surface pressure and the opening of the case under static and high-speed conditions. Two optimization methods are proposed. The first method is to widen the box contact area of the oil leakage area; the second method is to increase the tightening bolts in the oil seepage area. After comparing the data obtained by the two optimization methods with the original data, it shows that reducing the sealing bolt spacing and widening the sealing surface where the sealing performance is poor makes the sealing performance greatly improved. This method provides an effective way to determine the tightness of the transmission case, provides a basis for optimal design, and lays the foundation for experimental research.

1. Introduction
The transmission is an important part of the automobile transmission system, and its tightness plays a key role in performance. Poor sealing will cause problems such as environmental pollution and driving safety [1]. Deng Xiaomei [2] and others mainly discussed the sealing problem from the design of the transmission coupling surface and the arrangement of the shell bolts, indicating that the bolt preload, the width of the coupling surface and the number of bolts are the key factors affecting the sealing of the transmission coupling surface. Chen Yun used finite element analysis to analyze the static clearance of the joint surface of the housing, and carried out the surface pressure experiment. The finite element analysis method was consistent with the experimental results, proving that both methods can be used to study the sealing performance of the joint surface of the transmission case.
This paper applies the workbench finite element analysis software to analyze the sealing performance under static and high-speed working conditions of an electric vehicle transmission case, and evaluates its sealing effect. According to different working conditions, various schemes are used to optimize the local structure, and to verify the effectiveness of various methods to improve the sealing of the joint surface.

2. Sealing analysis
The transmission case is mainly composed of a left case, a right case and bolts. As shown in Figure 1(a), the left case and the right case are connected by bolts and a sealant. The thickness of the sealant is only about 0.01mm, and its rigidity is negligible relative to the transmission case. Ansys Workbench software
is mainly used. In consideration of the bolt preload, the contact nonlinear finite element analysis method is used to analyze the left case under specific working conditions. The surface pressure and gap of the joint surface of the two cases are used to comprehensively determine the sealing performance of the joint surface of the cases.

![Figure 1. The state of the cabinet model.](image)

2.1. Finite element model
The finite element model of the transmission case is shown in Figure 1(b). Due to the complex structure of the case, a tetrahedral mesh is used for division. The grid size is 5mm, and a total of 575,618 cells and 888,819 nodes are obtained after division. Establish a friction contact pair between the joint surface of the left case and the right case with a friction coefficient of 0.2. Bonded connections are established between threaded holes. The material is die-cast aluminum alloy (YL113).

2.2. Boundary conditions and working conditions
The left case of the transmission and the drive motor housing are bolted. During the analysis, a fixed constraint is placed on the bolt holes at the input end of the left case. Sealing analysis is divided into two working conditions. The first working condition is a static working condition, and only the sealing performance of the joint surface under the action of the bolt preload is considered. As shown in Figure 1(c), the tightening torque of the transmission case bolt is 10N · m, and the axial pre-tightening force is calculated to be 6250N.

The second working condition is an extreme working condition. According to the tightness analysis of the transmission gear meshing force under high-speed working conditions, according to the calculation results of the dynamics software, the load at the bearing seat hole under high-speed working conditions is shown in Table 1. Simulate the sealing performance of the joint surface under extreme working conditions of the transmission. As shown in Figure 1(d).

| Table 1. Load at the bearing seat under high-speed conditions. | N |
|---------------|---|---|---|
|                | $F_x$ | $F_y$ | $F_z$ |
| Input shaft right bearing | 960 | 2120 | -3740 |
| Input shaft left bearing | 1160 | 0 | -450 |
| Intermediate shaft right bearing | -5120 | 2240 | -1180 |
| Intermediate shaft left bearing | -6190 | 0 | 2150 |
| Output shaft right bearing | 2680 | 0 | -2190 |
| Output shaft left bearing | 6540 | -4360 | 5050 |

3. Analysis results

3.1. Static analysis results
Under static conditions, the surface pressure distribution cloud diagram of the joint surface of the left case and the right case is shown in Figure 2(a), bolts 1 ~ 2, bolts 2 ~ 3, bolts 9 ~ 10, bolts 10 ~ 11, 1 ~ 12 The surface pressure between No.11 and No.11 ~ 12 bolts is low. The opening amount cloud diagram is shown in Figure 2(b). The maximum opening amount is between No. 1 to No. 2 bolts and No. 10 to
No. 11 bolts, which is only 0.16 \( \mu m \), which is far less than the thickness of the sealant, and no lubricant leakage will occur under static conditions.

![Figure 2. The state of the cabinet model under two working conditions.](image)

3.2. High-speed operating conditions analysis results
The surface pressure distribution cloud diagram of the joint surface of the left case and the right case under high-speed working conditions is shown in Figure 2(c). The surface pressure between bolts 1-12, 11-12, and 9-11 is low. The opening amount cloud diagram is shown in Figure 2(d). The maximum opening amount appears between No. 10 and No. 11 bolts, which is 11.2 \( \mu m \). It is greater than the thickness of the sealant.

4. Comparative analysis of sealing performance before and after structural optimization

4.1. Widen the case surface
In the original scheme, the joint surface of No. 9 ~ 11 bolts has a width of 20mm. Under the conditions of other working conditions, the joint surface of this part of the shell is widened, and the outer circles of the bolts are tangentially connected to increase the joint surface to 40mm. As shown in Figure 3(a). After the structural optimization of the cabinet, the tightness analysis under high-speed conditions was conducted again. The opening amount cloud diagram is shown in Figure 3(b). The maximum opening amount is between No. 10 and No. 11 bolts, which is a reduction of 4.35\( \mu m \) by 61.2%. The sealing performance of the original oil-permeable area has been significantly improved.

![Figure 3. Widened case surface model.](image)

4.2. Increase the bolts
Add a bolt 13 between the No.10 and No.11 bolts to reduce the bolt spacing in the oil seepage area, as shown in Figure 3(c). After the structure is optimized, the tightness analysis under the high-speed working condition is performed again. The opening amount cloud diagram is shown in Figure 3(d). The maximum opening amount is between No. 11 and No. 12 bolts, which is reduced by 70.5% for 3.3\( \mu m \). The sealing performance of the original oil-permeable area has been further improved significantly.

5. Conclusion
(1) By analyzing the sealing performance of the joint surface of the two cases under static working conditions, the transmission case meets the sealing requirements under static working conditions.
(2) The sealing performance of the joint surface between the left case and the right case is analyzed under high-speed conditions. The maximum opening is 11.2\( \mu m \), which exceeds the thickness of the sealant, and the transmission case will have oil leakage failure under high-speed conditions.
(3) Widening the area of the case surface in the oil leakage area reduced the maximum opening amount by 61.2%, and increased the bolts in the oil leakage area, adjusting the bolt spacing to reduce the
maximum opening amount by 70.5%, the sealing performance was significantly improved, and the oil leakage was effectively avoided the occurrence of the phenomenon.

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