Finite element analysis of new energy vehicle scroll compressor shell under working pressure

Shunan Hu\textsuperscript{1}, Mengyi Tang\textsuperscript{1}, Dawei Ge\textsuperscript{2} and Huaming Guo\textsuperscript{2}

\textsuperscript{1} School of automobile engineering, Changshu Institute of Technology, Suzhou, China
\textsuperscript{2} Invotech Scroll Technologies Co., LTD., Suzhou, China

Abstract. The interference design between the mating surface of shell and retainer in new energy vehicle scroll compressor were important parts of the design of the shell assembly. The finite element analysis of static structure was used to analyze the strength of shell and the deformation value of the mating surface under the working pressure, and minimum surplus were used to analyze whether the matching surface surplus design meet the design requirements. An analytical method was provided for the design of new energy automobile scroll compressor shell by static structure analysis of shell and the interference of mating surface.

1. Introduction

New energy vehicles mainly consisted of electric vehicles, hybrid vehicles and fuel cell vehicles, etc. [1], whose power system was electric transmission. Due to the change of power system, scroll compressor air conditioner was used in new energy vehicle. As the base of the scroll compressor, its shell assembly was the all parts' installation foundation. As figure 1 shown, the shell assembly of scroll compressor was mainly composed of upper sealing body, shell, frame, lower sealing body and bottom sealing cover. The frame and housing were interference fit, and the strength and amount of interference was a key point of housing assembly design.

![Figure 1. New energy automobile scroll compressor shell assembly](image-url)

Interference fit was widely used to transfer torque or axial force between components [2]. It fits of rough surface of two parts, and the size of interference will affect the stress and fit relationship of the fit surface. However, the interference design need to be checked and analyzed. Xiangdong etc. had verified...
that under the condition of no external load, the theoretical values of pressure and interference calculated by the mating surface basically coincide with the finite element analysis [3]. Finite element method can be used to conveniently calculate the stress of the mating surface under different wall thickness, different axle diameter size and the interference amount distributed on the mating surface of the part [4].

2. Finite element analysis under working pressure
Materials of cast A380 and HT250 were used in scroll compressor shell and frame separately. Because the elastic modulus of cast A380 was smaller than that of HT250, the deformation of shell was larger.

Stress distribution of scroll compressor shell and deformation of shell matching surface were analyzed under the working design pressure 2.7 MPa. Because of structure and constraints, the deformation of shell mating surface was not symmetrical which was shown in figure 2, so it was segmented to obtain the deformation of the corresponding point in the diameter. By summing the deformation values of two points in diameter, the method of average value was adopted to estimate the overall deformation at the mating surface. And the maxim deformation value of shell matching surface diameter was analyzed. The Φ 104.8 mating surface point arrangement of shell was shown in figure 3.

Material of shell was cast A380, whose yield strength is 150MPa, elastic modulus is 71000MPa, and poisson's ratio is 0.33.

Under the working pressure, the Mises stress at different places of the shell was shown in figure 4, and its maximum stress was 186.63MPa, which occurs near the constraint position. The stress value was related to the constraint position and it existence stress singularity. So the stress at this point could be ignored. The Mises stress in other parts of the shell didn't exceed 80MPa. In order to calculate the deformation of shell mating surface radius, the cylindrical coordinates were established, and the value direction was X axis of the cylindrical coordinates. The deformation value was shown in figure 5. Mating surface deformation value at every point was shown in table 1. The total deformation The total deformation of each diameter point was expressed by U. Taking A diameter point deformation as an example, A diameter had tow piont in diameter, which the total deformation was expressed by \( U_A \).
As the table 1 and figure 5 shown, the deformation was asymmetry. In order to conservative design, maximum deformation diameter point was taken into account. The deformation value of A to F and maximum deformation diameter point were summed and the mean deformation of mating surface was calculated which was expressed by $U_\Phi$.

$$U_\Phi = \frac{(U_A + U_B + U_C + U_D + U_E + U_F + U_{max})}{7}$$

$$=\frac{(-0.0073 + 0.0020 + 0.0135 + 0.0392 + 0.0066 - 0.0035 + 0.0447)}{7}$$

$$=0.0136 \text{ mm}$$

3. Finite element analysis of shell mating surface under the minimum magnitude of interference

The amount of the magnitude of interference in scroll compressor shell mating surface was 0.05 mm to 0.1 mm. At this time, it was necessary to consider whether the interference amount of the shell meets the design requirements in the case of the minimum interference amount.

In the process of analysis, the offset to the half of the value was 0.025 mm and the friction coefficient was 0.45. The shell mating surface distribution of the deformation of cylinder was shown in figure 6. The distribution of average radius direction was about 0.0205 mm. So the distribution of deformation was 0.0410 mm at the diameter direction.
4. Conclusion
Under the working pressure of 2.7 MPa and the minimum magnitude of interference, the Mises stress of the scroll compressor shell of the new energy vehicle didn't exceed 160 MPa. So the strength of the shell met the design requirements under these two working conditions. Working in 2.7 MPa pressure, casing Φ104.8 mating surface, expansion quantity of about 0.0136 mm; According to the minimum magnitude of interference analysis, the interference value assigned to the shell was about 0.04 mm. Therefore, at the working pressure of 2.7 MPa, there is still an interference amount of at least 0.026mm, and the interference met the design requirements. Through the finite element analysis of working pressure and minimum magnitude of interference, the shell design strength and the interference design requirements could be analyzed. It provided a good design method for the new energy vehicle scroll compressor shell design.

Acknowledgments
This work was financially supported by science and technology achievements transformation special fund of Jiangsu province, BA2017021.

References
[1] Liu Zhaoguo, Han Haochen. A Comparative Analysis on the Policies of NEV Industry Between China and Japan: From the Perspectives of Policy Tools and Industrial Ecosystem [J]. Contemporary Economy of Japan, 2018(2):65-76.
[2] Qing-song, Xiao-bing, Guo-liang, etc. Analysis of contact stress on interference fitted surface of the train axle-bearing [J]. Machine Tool & Hydraulics, 2015(24):30-33.
[3] Xiang Dong, Shen Gang, Zhu Kan, etc. Interference contact characteristics of planetary gear train for wind turbines [J]. Journal of Vibration and Shock, 2017, 36(5):17-22.
[4] Zhao Jun, Lin Tengjiao, Zhong Sheng, etc. Fatigue Life and Its Influence Factor Analysis of Interference Fit Position of of Planetary Gear and Bearing [J]. Journal of Dalian University of Technology, 2016, 56(4):355-361.