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MULTI-SCALE SIMULATION FOR SLIDING FRICTION PROCESS OF EPDM RUBBER SEALS

TRACK OR CATEGORY

Seals

AUTHORS AND INSTITUTIONS

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INTRODUCTION

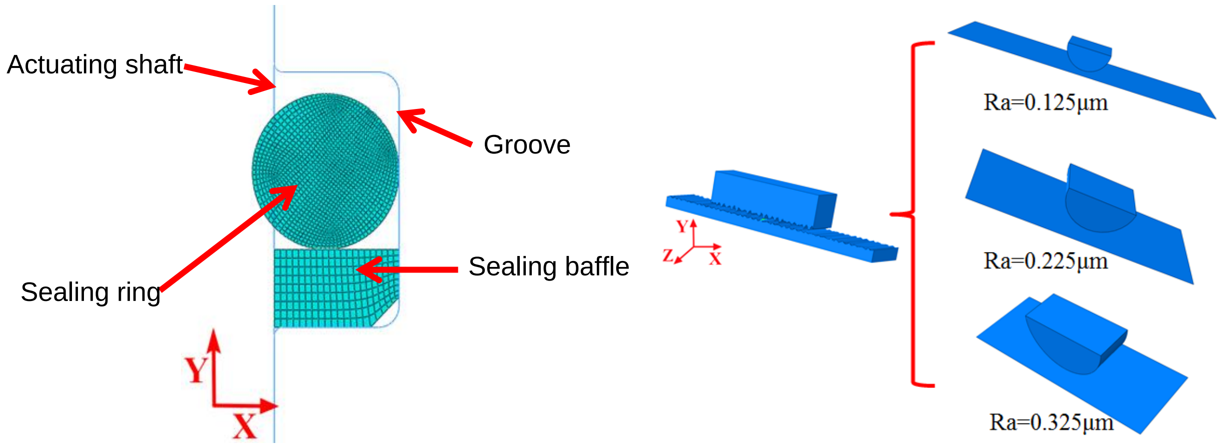
EPDM O-ring sealing structure has become one of the key components in industry sealing devices due to its simple structure, excellent sealing performance. Sealing structure failure generally reduces the equipment execution efficiency. Sliding friction process is the key for sealing performance. Therefore, the in-depth study on friction characteristics of sealing structure can improve the sealing performance of the seal equipment and extend its service life.

With the growth in computing technologies, finite element method becomes an important analysis tool to describe the engineering physics model. Finite element model of O-ring radial seal structure was developed for the sealing performance of electromagnetic measurement in drilling instrument [1]. Sealing performance of combined seal structure of rubber O-ring and wedge-ring was investigated by using finite element analysis[2]. A numerical study of grooved shaft under transient conditions was carried out and the effect of shaft roughness on elasto-hydrodynamic lubrication of rotary lip seals was also conducted by Gadari [3-4]. Results showed that the numerical results have a good agreement with the experiments. In above, most of current researches were developed on the sealing performance of macroscopic sealing structure. However, the multi-scale studies of frictional properties is also very important for sealing performance.

In this paper, a new macro-micro contact model is developed in sliding friction process based on Hertz contact theory and fractal theory. Firstly, micro surface morphology of shaft and seal is obtained by OLYMPUS DSX510, and fractal contact model is established. Then, multi-scale finite element model of sliding friction is developed by ABAQUS, and influence of roughness and fractal parameters on contact characteristics are investigated. Finally, influence of compression ratio, temperature, and hydraulic pressure on the contact characteristics are investigated.

FINITE ELEMENT MODEL

The seals and shaft surface morphologies are observed by DSX-510 Optical Digital Microscope with the magnification of 416X. The cross-sections are obtained by the post-processing software with paralleled to the X-axis every 100μm. Then, the surface fractal model is developed by the structural function method. Here, plynomial model based on continuum mechanics theory is used to describe the property of EPDM rubber[5]. Macro-micro contact model is developed by ABAQUS, seen in Fig.1. Compared to the detailed whole real sealing model, the 2D symmetry model is developed for minimizing the total times of analysis. Besides, the micro sealing properties are also investigated by considering the effect of surface morphology on the sealing properties.

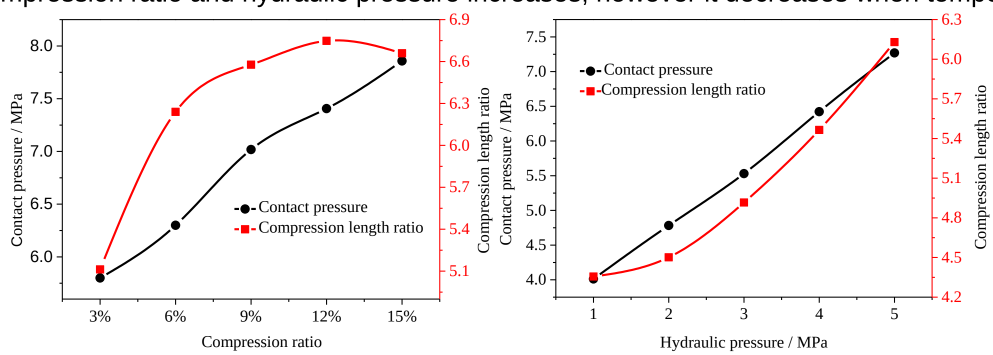


(a) 2D symmetry macro-contact model (b) Simplified micro contact model

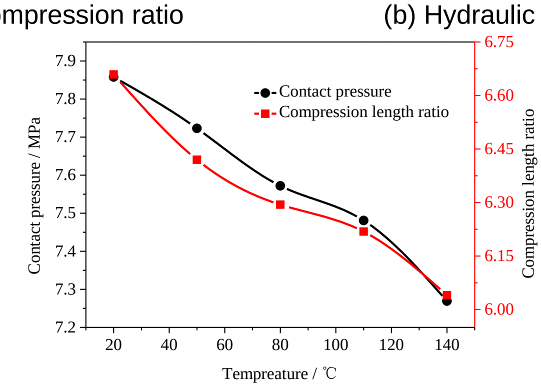
Fig.1 Macro-micro contact model

RESULTS AND DISCUSSION

The effect of compression ratio, temperature, and hydraulic pressure on the contact characteristics is shown in Fig.2. Results indicate that contact pressure and compression length ratio increases when compression ratio and hydraulic pressure increases, however it decreases when temperature increases.



(a) Compression ratio (b) Hydraulic pressure



(c) Temperature

Fig.2 Contact characteristics under no frictional conditions

The evolution of surface morphology has many typical features. Therefore, it has limitation to describe seal properties only depend on contact pressure. Thus, the compression length ratio λ is defined, which can be written as

$$\lambda_w = \frac{\pi D}{4R(4-D)} \frac{(2-D)^2}{D^2 \psi^{2-D}} f(T) E_0^* \tag{1}$$

where E^*_0 is the Young's modulus of EPDM rubber obtained by experiment, R is the curvature radius of

single asperity, D is the fractal dimension, ψ is the plastic coefficient, $f(T)$ is a factor introduced to correlate Young's modulus.
Theory analysis results of compression length ratio under different temperature are compared with the simulation results of the real contact model, seen in Fig.3. It can be seen that the theory analysis results are larger than finite element analysis results, the maximum error is about 7%.

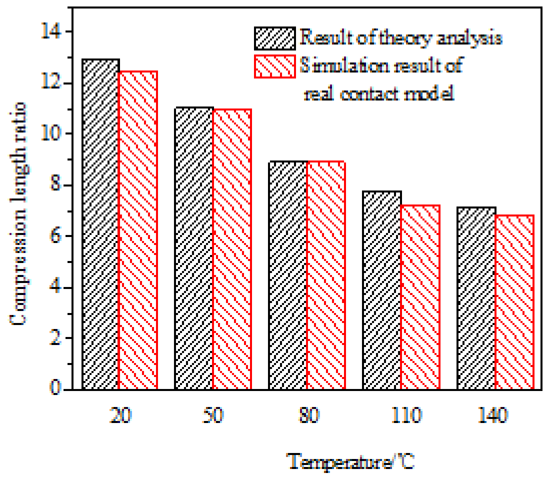


Fig. 3 Theory and simulation results of real contact model

CONCLUSION

The macro-micro contact characteristics of EPDM rubber O-ring is studied by finite element simulation. According to the analyses results above, we mainly have the following points:
(1) Contact pressure and compression length ratio increases when compression ratio and hydraulic pressure increases, however it decreases when temperature increases.
(2) A new method for calculating the real compression length ratio in sliding friction process is developed on the basis of the theory and finite element coupling analysis method, which provides a reference for the design and application of seals.

ACKNOWLEDGMENTS

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KEYWORDS

Applied Tribology:Aviation, Seals:Elastomeric Seals, Friction:Friction Mechanisms.