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Thermo-elasto-hydrodynamic analysis of triangular textured mechanical face seals

Key words: TEHD; mechanical seal; surface texturing; triangular dimple; aviation piston pump

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Geometric model

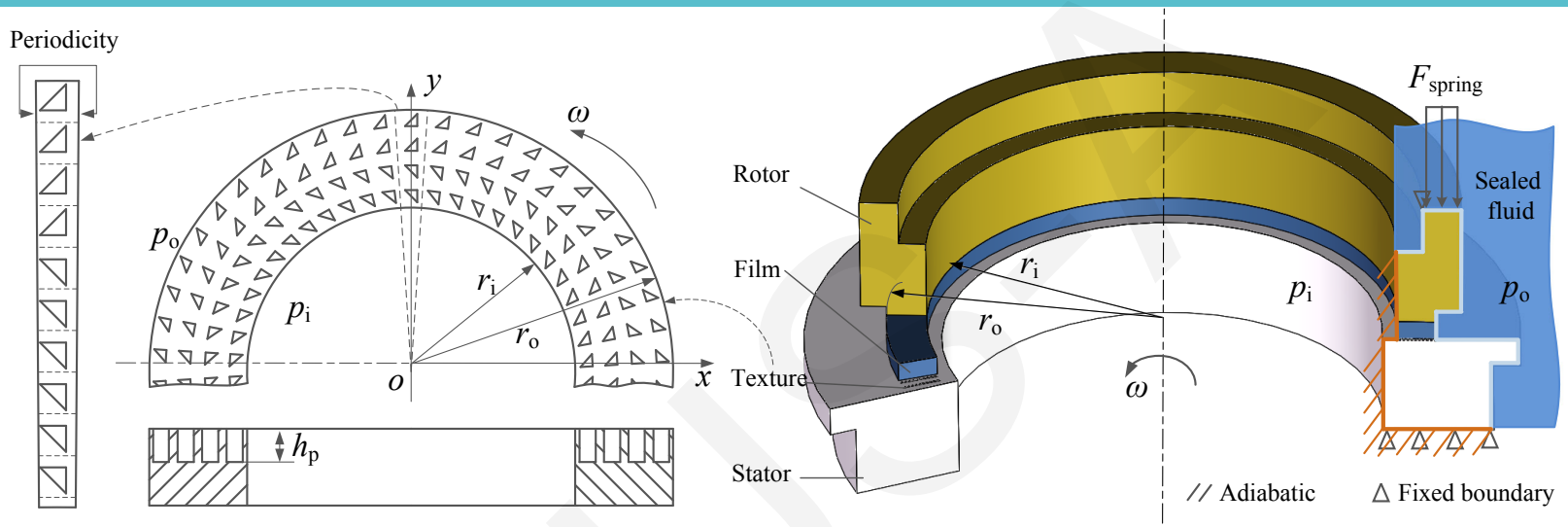
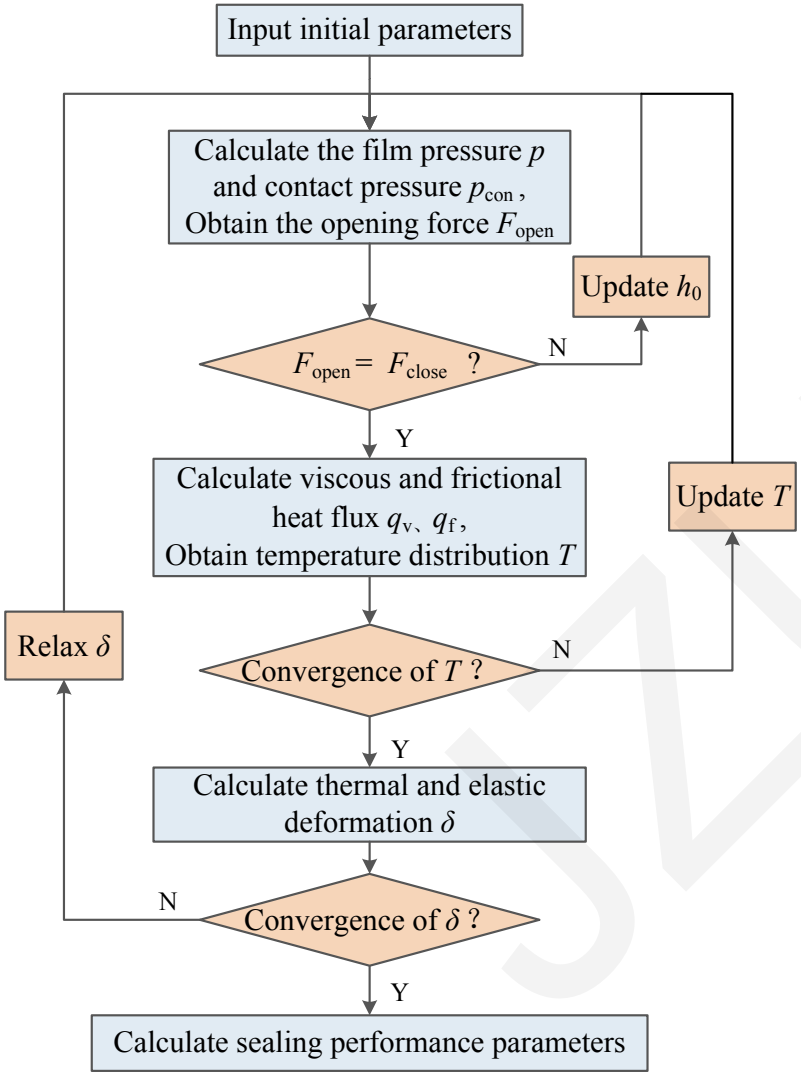


Fig. 1 Geometric structure of the textured mechanical seal

- Surface texturing can be used to enhance the load-carrying capacity and reduce the leakage and friction of mechanical seals.
- A three-dimensional (3D) thermo-elasto-hydrodynamic (TEHD) model is presented to study the effects of triangular dimples on load-carrying capacity, leakage and friction of a mechanical seal.

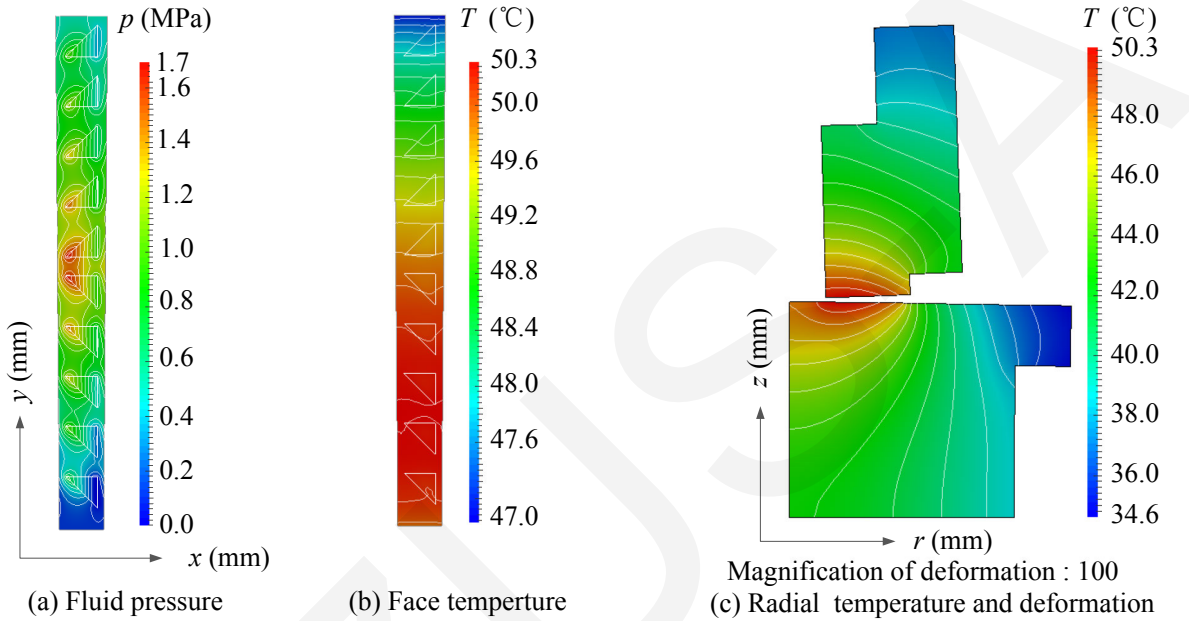
Theoretical model



- The TEHD model takes into account the effects of Jakobsson-Floberg-Olsson (JFO) cavitation boundary condition, surface roughness, elastic-plastic contact, thermo-elastic deformation, and temperature-viscosity relation.
- The finite element method (FEM) is used to solve the theoretical model.
- The numerical results of the TEHD model are quite different when compared with those of the HD and THD models, especially at high speeds.

Fig. 2 Calculation flow chart of the THED model

THED analysis



(a) Fluid pressure (b) Face temperture (c) Radial temperature and deformation

Fig. 3 Film pressure, temperature and deformation of the mechanical seal (*n*=10000 r/min)

The highest temperature is at the surface near the inside diameter, and the lowest temperature is at the outside diameter. Because of that uneven temperature distribution, the radial thermal deformation varies with radial position, and the resulted thermal and mechanical deformation leads to a convergent film thickness.

THED analysis

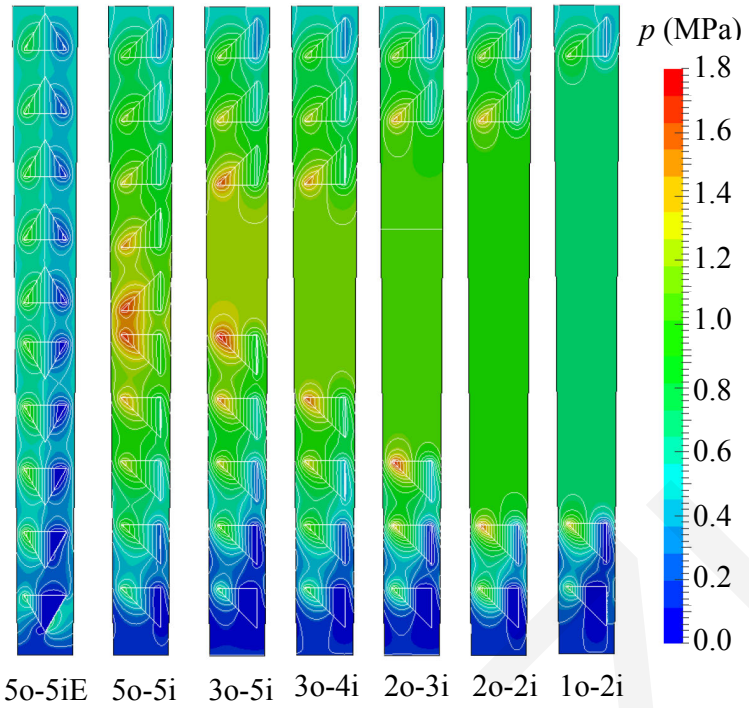


Fig. 4 Fluid pressure of textured surfaces with different distributions (*n*=10000 r/min)

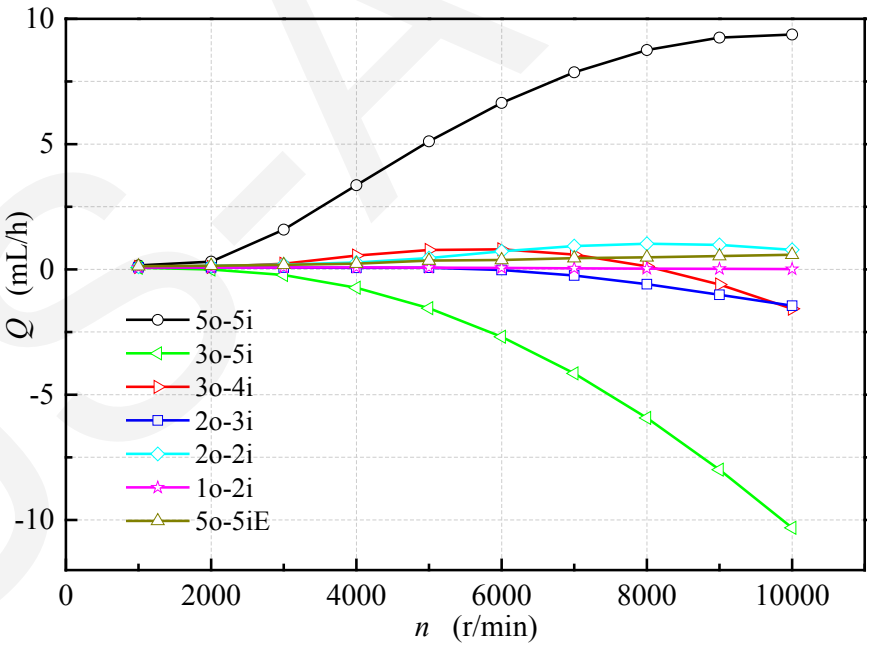


Fig. 5 Effects of different dimple shapes and distributions on leakage at different speeds

The leakage of the distribution 1o-2i is near zero. Sealing surfaces textured with the distributions 5o-5i, 2o-2i and 5o-5iE have a positive leakage. The distributions 3o-5i and 2o-3i show a pumping flow, and the 2o-3i distribution has a lower absolute pumping flow, so it can be regarded as the optimum distribution.

Experimental results

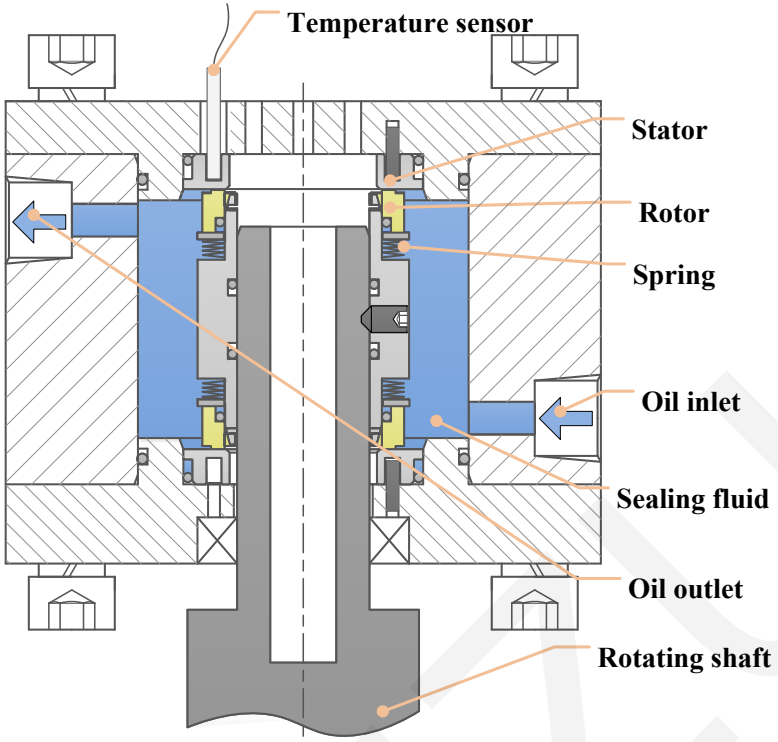


Fig.6 The experimental device of mechanical seals

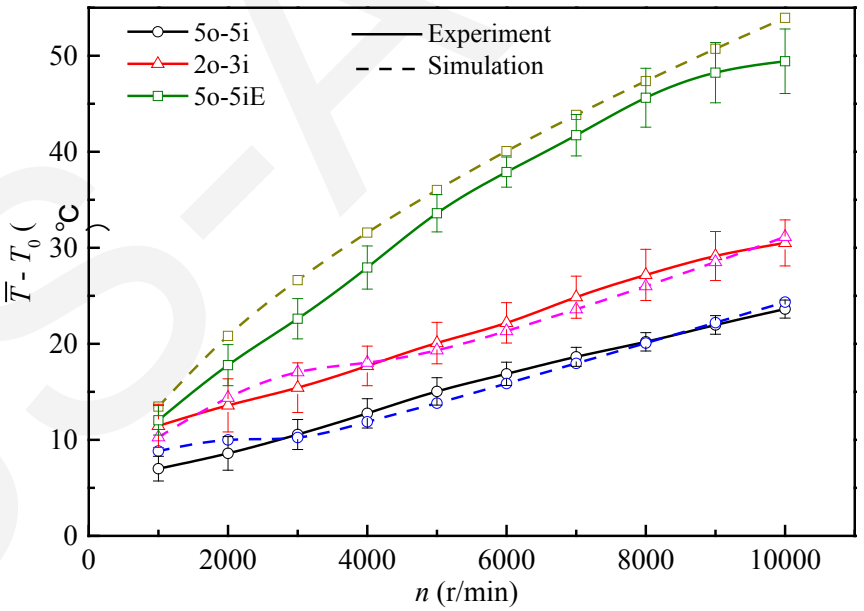


Fig.7 The average temperature increase of the sealing surface with different distributions

- The temperature of the textured surface increases with the increase of the rotational speed.
- The theoretical and experimental results are thus in good agreement.

Conclusion

This paper presents a 3D TEHD model to analyze the effects of triangular dimples on the load-carrying capacity, leakage and friction of a mechanical seal for an aviation piston pump. From the results presented above, the following conclusions can be obtained:

1. The temperature and the deformation in the TEHD model have significant influence on the film thickness, load-carrying capacity, leakage and friction.

2. Increasing the number of dimples at the inner rim helps to reduce leakage, but when the number of dimples at the inner rim is much larger than that at the outer rim, the load-carrying capacity will decrease due to the imbalance between the pumping and reverse pumping effects.

3. The hydrodynamic effect of the isosceles right triangular dimple is stronger than that of the equilateral triangular dimple.

Thanks!