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Optimization of Small Size Thrust Air Bearing with the Consideration of Groove Dimensions and Geometry Variables

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1. Introduction

Under a constant bearing load, the groove geometry handling five objective functions of (i) bearing flying height, (ii) bearing surface friction torque, (iii) bearing dynamic rigidity, (iv) product of the bearing flying height and bearing dynamic rigidity, and (v) ratio of the friction torque and bearing dynamic rigidity was optimized using the SQP method.

2. Groove geometry and dimensions optimization problem formulation

In this optimization problem, the design variables vectors X consist of four groove geometry parameter of and four groove dimensions of groove number N, seal width ratio R_s, groove depth h_g, and groove width ratio α, creating eight variables as in Eq. 1. The optimization design problem for thrust air bearing is formulated as in Eq. 2.

$$X = (\phi_1, \phi_2, \phi_3, \phi_4, h_g, R_s, \alpha, N) \quad (1)$$

$$\min_X f(X) \ \text{or} \ \max_X f(X) \quad \text{sub. to} \ g_i(X) \le 0 \quad (i=1\sim18) \quad (2)$$

3. Examples of bearing optimization

As can be seen from Fig. 1, when the bearing stiffness was set as the objective function, the results showed a tremendous improvement for the optimization of geometry and dimensions compared to the initial spiral groove. The geometry of this bearing is geometry of a new spiral groove where it has bends in the outer region of the groove geometry, similar to the one shown in Fig. 2 (b).

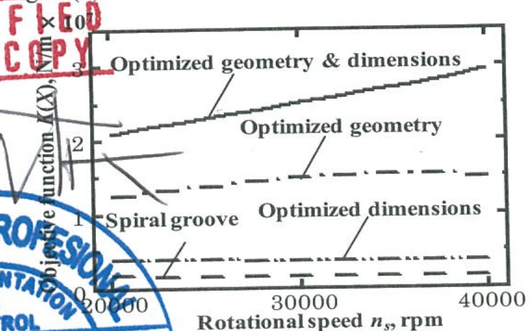

Fig. 1 Objective Function $K(X)$ With Rotational Speed

4. Results and conclusions

The consideration of the optimal groove geometry that corresponds to the various objective functions in designing a thrust air bearing characteristics was studied. All solutions for the five objective functions mentioned above showed either a spiral groove geometry shown in Fig. 2(a) or a modified spiral groove geometry shown in Fig. 2(b). In order to get the highest bearing flying height, the bearing groove should be set as a spiral groove with the conditions of the groove number and groove depth values as the upper limit values of the constraints conditions. Also, in order to get the minimum bearing's friction torque, the bearing groove has to be a spiral groove with the groove number and the groove depth values set as the upper limit values of the constraint conditions. The seal width ratio is suitable with the value of R_s=0.54.

When the modified spiral groove geometry, with a groove number of N=20, seal width ratio R_s=0.75, and groove width ratio of α=0.59, the bearing stiffness was improved 18 times compared to that of the initial spiral groove. Furthermore, for the trade-off relations of bearing flying height and bearing stiffness; and bearing friction torque and bearing stiffness, the vector product of $h_r(X)K(X)$ and the ratio of $T_r(X)/K(X)$ as the objective functions both eventually creates the modified spiral groove geometry. Both of these objective functions' value was improved tremendously.

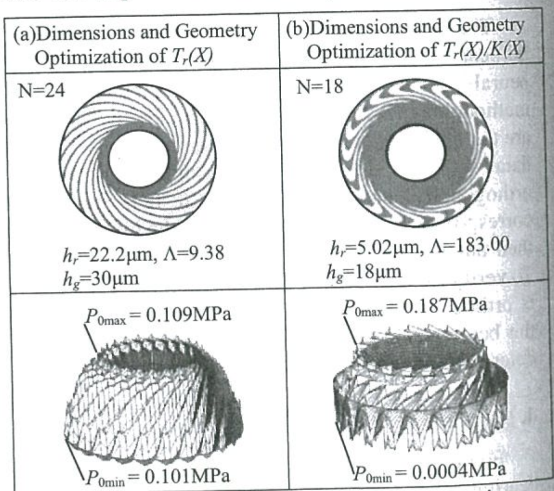

Fig. 2 Example Results of Optimized Bearings

5. References

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