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# HDDスピンドルモーター用のスラスト空気軸受の最適化
# Optimization of HDD Thrust Air Bearing for Spindle Motor

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## 1. Introduction

HDD has been playing a big role in the area of informative multimedia. The shape of bearings located in HDD spindle motor consists of journal bearing and thrust bearings. In this paper, the bearing design being considered is the thrust bearing located in spindle motors as shown in Fig. 1(a). In previous research made by Hashimoto et al. [1], it has been proved that the optimization calculated from conventional type of spiral groove and herringbone groove eventually showed a change of shape towards spiral groove shapes. Hence, in this paper, the initial shape being chosen to get high dynamic stiffness is the conventional type of spiral groove.

Annually, Japan government also has its own aims for the improvements of the media storage performances goals [2]. In order to cope with the storage capacity demands, the current oil bearings designs are nearly coming to its limit where high revolutions leads to high friction losses, wear problems, and oil seal problems due to oil lubrications leakage as the revolutions get higher. Therefore, a much higher revolutionary of air bearing with a high dynamic stiffness and does not face these problems as the next bearing is highly expected.

## 2. Optimization of Bearing

The improvement of the performance of the air bearing lies in the improvements of the dynamic stiffness. Therefore, in this paper the objective function for HDD thrust air bearing is the dynamic stiffness. From there, firstly the line geometry of the initial spiral bearing groove is being divided equally into four nodal points ($\varphi_1 \sim \varphi_4$) as design variables. In additional, another four design variables is then set making eight design variables consisting of groove number $N$, seal width ratio $r_s$, groove depth $h_g$, and groove width ratio $\alpha$. In this paper, the most probable highest objective function value is determined using the direct search method. Then, from direct search method, the highest peak of the objective function from the graph is taken.

From there, the optimized value for dynamic stiffness will be able to be determined using the Successive Quadratic Programming (SQP) method. The vectors of the eight design variables are shown in Eq.1. The constraints conditions for the design variables, state variables, allowable film thickness and damping coefficients which are not equal to 0 to avoid self-induced oscillation are shown in Eq.2.

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

$$g_i(X) \geq 0 (i = 1 \sim 18) \quad (2)$$

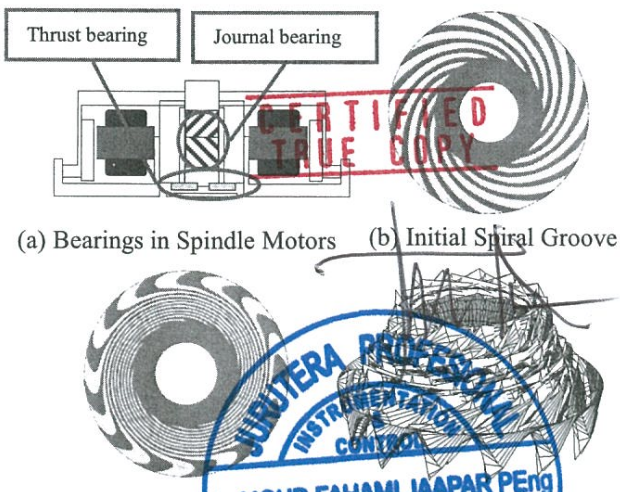
In the meanwhile, the optimization problem for HDD thrust air bearing is formulated as in the following Eq.3.

$$\max f(X) \text{ subject to } g_i(X) \geq 0 (i = 1 \sim 18) \quad (3)$$

Since the thrust air bearing does not have drastic changes towards the operational temperature constraints, in this paper the temperature was set as 320K (46.85°C) considering the operational temperature for any HDD is along that range.

Table 1 Comparison of Bearing Specifications

| Variables | Spiral Grooved | Opt. 1 | Opt. 2 |
|---|---|---|---|
| $\varphi_1$ | 0 | 36.75 | 3.36 |
| $\varphi_2$ | 0 | -27.93 | -18.86 |
| $\varphi_3$ | 0 | 138.11 | 135.66 |
| $\varphi_4$ | 0 | 112.89 | 87.29 |
| $N$ | 16 | 13 | 16 |
| $r_s$ | 0.58 | 0.55 | 0.54 |
| $h_g$ | 11 | 10 | 10 |
| $\alpha$ | 0.636 | 0.572 | 0.636 |




(a) Bearings in Spindle Motors　(b) Initial Spiral Groove

(c) Optimized Spiral Groove　(d) Pressure Distribution

Fig.1　Optimized Grooved Bearing