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Analysis of Radial Air-shear Force on Magnetic Disks for Reducing the Spin-off of Lubricants

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To reduce the spin-off of lubricants on a magnetic disk, which is caused by the radial component of shear force between the disk and air, we analyzed the air-velocity distribution and the air-shear force by three-dimensional large-eddy simulation (LES). This sensitivity analysis, on five design parameters, showed that disk/arm clearance and arm thickness have a greater effect on the mean radial air-shear force than the other parameters. The force on a disk optimized according to the optimum parameters is 12% less than the force on a conventional disk.

Keywords : Magnetic Disk Drives, Lubrication, Numerical Analysis, Shear Flow, Sensitivity Analysis

1. INTRODUCTION

Magnetic disk drives for servers are operated under severe conditions, namely, high rotational speed and long-term continual use. Such high-speed continual operation causes the lubricants on the disk surfaces to go to outer edge of the disk (spin-off), thereby decreasing inner-lubricant thickness.

The spin-off of lubricant is caused by four factors: (i) centrifugal force of the lubricant; (ii) pressure distribution under the head-slider; (iii) physical contact between the head-slider and the lubricant; (iv) radial component of air-shear force on the disk.

With regard to the air-shear force, only the force in a simplified model (i. e., without an arm) has been simulated. Our present research purpose is to improve the drive's reliability by simulating the air-shear force in a real model (i. e., with an arm), and by optimizing the design parameters to minimize the force. The drive can then be operated under higher rotational speed, with the same reliability, than currently possible.

2. SIMULATION METHOD

We used three-dimensional large-eddy simulation (LES) to solve the non-steady turbulent air flow in the disk drive. The drive model has a carriage arm that affects the air-flow distribution, but the other parts are simplified to decrease the simulation time as follows:

- Only the arm is inserted between the disks; the slider and the suspension are omitted.
- The shape of the disk shroud is a complete cylinder (Fig. 1).
- In the axial direction, symmetric boundaries are set in the center sections of the disk and the arm (Fig. 2).

Disk/arm clearance is divided into 15 elements, while arm thickness and disk thickness are divided into 16 elements each. The mesh division in the planer direction is shown in Fig. 3. The total mesh number is 100,000-150,000. The total number of time steps is 20,000, which is equivalent to the time for two rotations of the disk.

The six parameters (five drive dimensions plus rotational speed) used in the analysis are shown in Fig. 1. The head position is fixed to inner position.

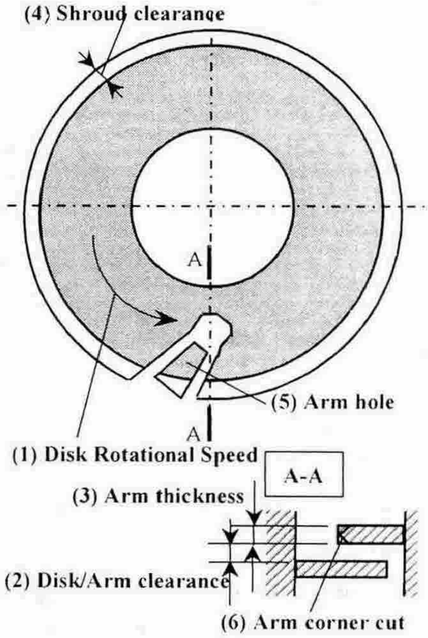

Fig. 1 Analysis parameters

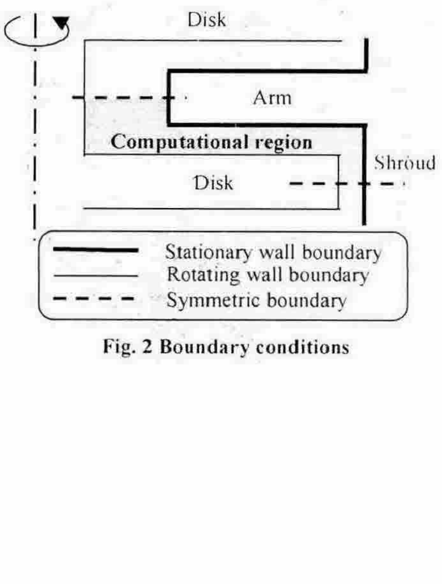

Fig. 2 Boundary conditions

3. RESULTS AND DISCUSSION

3.1 Generation of air-shear force

Figure 4 shows a contour map of the radial component of air-shear force on the disk surface in the standard case. A positive value means an outward force. The unit of the force is Pascals (Pa).

At position (a) in the stream, the air-flow path becomes narrower and the air pressure increases. At position (c) in the downstream, the air-flow path suddenly widens and pressure decreases. This pressure difference in front of and behind the arm produces an accelerated flow under the arm at position (b). Because the arm is inserted obliquely, the accelerated flow has an outward component, which causes the lubricant to spin-off.

At position (c), the air flows outward along the surface of the disk, then returns inward between the disks.

3.2 Parameter survey

Table 1 lists the effects of the six parameters on the mean radial air-shear force on the whole disk. It is clear from the table that the air-shear force is proportional to the disk rotational speed; disk/arm clearance and arm thickness have relatively large effects on the force because the amount of the radial air flow is assumed to be small when these two parameters are small; and the existence of arm-hole and arm-corner cut have relatively small effects on the force. Low shroud clearance decreases not only the air-shear force but also disk flutter [4].

3.3 Parameter optimization

The four parameters (nos. 3, 5, 7, and 9 in Table 1) were changed at the same time, and the radial air-shear force was decreased by 12%, compared to a current drive at a wide rotational-speed range of 10,000-20,000 min^{-1} (Fig. 5). As mentioned above, radial air-shear force is proportional to rotational speed. A drive with these optimized parameters can thus be operated at 14% higher rotational speed, but with the same amount of lubricant spin-off and the same reliability, than current drives.

4. SUMMARY

To reduce the spin-off of lubricants on a magnetic disk, we simulated the air-shear force between the disk and air. The results of a parameter survey show that the air-shear force on the disk with the optimized parameters is 12% less than the force on a current design disk.

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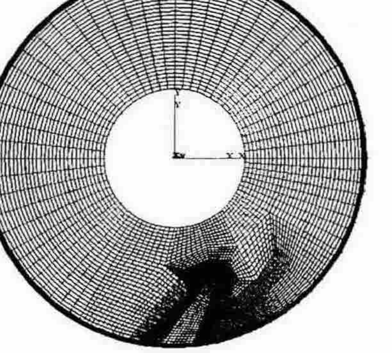

Fig. 3 Mesh division

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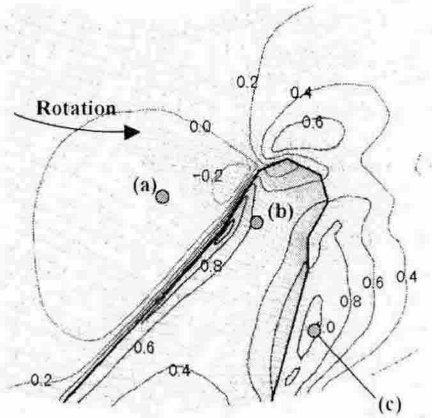

Fig. 4 Distribution of radial air-shear-force (Pa)

Table 1 Calculated air-shear force

	Parameter	Change	Air-shear force
1	Rotational speed	x 1.5	x 1.52
2		x 2.0	x 2.05
3	Disk/Arm clearance	- 10%	- 2.7%
4		+ 10%	+ 2.4%
5	Arm thickness	- 10%	- 4.5%
6		+ 10%	+ 4.2%
7	Shroud clearance	- 38%	- 1.6%
8	Arm hole	Without → With	+ 1.6%
9	Arm corner cut	Without → With	- 0.6%
	3, 5, 7, and 9 at the same time		- 12%

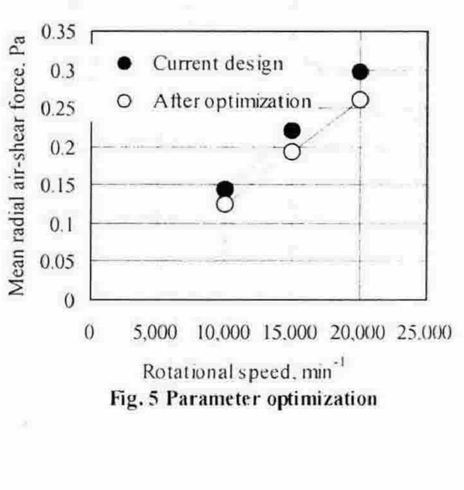

Fig. 5 Parameter optimization