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APPLICATION OF AUTOMATIC DYNAMIC BALANCING SYSTEM TO THE OPTICAL DISK DRIVE

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ABSTRACT
In order to reduce the vibration and noise of the high-speed optical disc drive (CD-ROM, DVD-ROM drive), we developed a self-compensating dynamic balancing system called "Auto Balancer". The Auto Balancer is composed of balls and race with viscous lubricant. The influences of parameters on the performance of the Auto Balancer were studied. As the results, we found out the grade and characteristics of balls, cross sectional shape of the race, volume and viscosity of lubricant which maximize the performance. Especially we found that the magnetic characteristic of the ball is a very important factor which determines the performance of the Auto Balancer.

1 - INTRODUCTION
The demand for higher speed of the optical disc drive requires increase of the rotating speed of the spindle motor. Rotating speed of current disc drive is above 10,000 RPM. Therefore a small amount of unbalance will cause a read error and the severe vibration and noise problems. Moreover, as discs of the optical disc drive are usually removable types, the position or amount of unbalance is indefinable. It was thought that applying a self-compensating dynamic balancing system would be a good solution to resolve those problems. In this paper we developed an Auto Balance and discussed several factors which determine the performance of the Auto Balancer.

2 - EXPERIMENTAL STUDY ON PARAMETERS
An Auto Balancer that is implemented in the turntable of an optical disc drive is shown in Figure 1. In the practical application of the Auto Balancer, improvement of stability and durability is required. The simple solution can be achieved by adding small amount of lubricant. But the most difficult problem to solve is how to make the performance of the Auto Balancer repeatable.
To improve the performance the force exerted on the ball was analyzed. As shown in Figure 2, the force on the ball is dramatically decreased as the ball approaches near the compensation position. So for the good compensation, the moving resistance of balls should be very small and following factors must be considered:

- Race geometry:
  - Eccentricity of rotation center and race center
  - Circularity of Race.
- Friction:
  - Rolling friction between balls and race.
  - Sliding friction between balls.

Figure 1: Auto Balancer implemented drive.

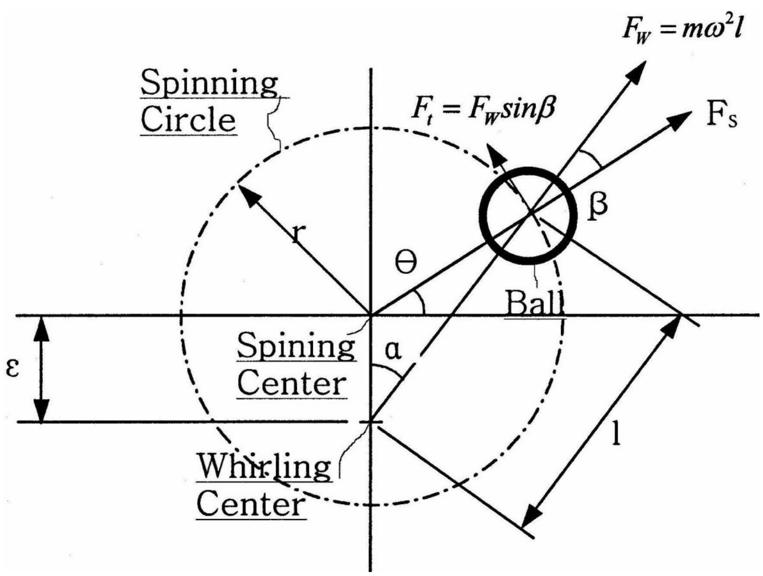

Figure 2: Force exerted on the ball.

Because the balls move to the farthest position from the whirling center, eccentricity of rotation center and race center, and distorted race circle limit the performance of the Auto Balancer. To reduce the friction, we studied the influence of cross sectional shape of race, oil volume, grade of balls and magnetism of balls.

Cross sectional shape of race

As shown in Figure 3, three types of races were tested. The design concept of circular or wedge type race is to avoid the sliding friction between race and balls, because the friction coefficient of sliding motion is much larger than that of rolling motion.

As the turntable spins up, the balls are separated from the bottom of race. The results are shown in Figure 4, and the wedge type race shows the better performance than the round type race. It is because the contact area between ball and race of wedge type is less than that of round type.

Volume and viscosity of lubricant

Balls in the Auto Balancer sometimes do not find the equilibrium position. In order to stabilize the system, slight damping is necessary, and small amount of oil is helpful. The oil not only increases the stability of the system but also decreases the sliding friction between the balls. Figure 5 shows the performance of the Auto Balancer with the variation of the volume of oil. When the volume of oil is not sufficient, the sliding friction between balls increases. On the other hand, when it is excessive the surface tension increases the rolling friction of balls. Both of the cases can deteriorate performance of the Auto Balancer. The viscosity of oil acts similarly and shows a similar result. Besides, adding lubrication to the system, the durability increases more than 1 million cycles.

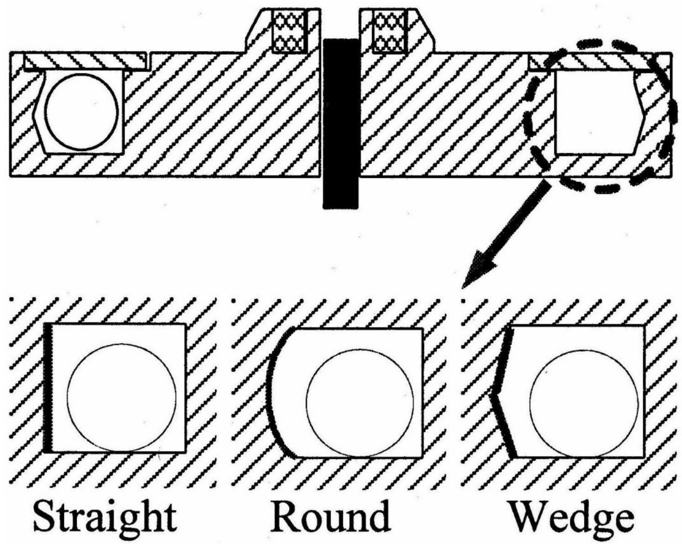

Figure 3: Cross sectional shape of race.

Quality of balls

Table 1 shows the Quality of balls used for the evaluation. The grades were classified arbitrary.

Grade	Roughness (μm)		Shape Error (μm)	
	Ra	Rt	Ra	Rt
A	0.01	0.1	0.025	0.25
B	0.03	0.3	0.15	0.8
C	0.08	0.4	0.2	1.0

Table 1: Grades of balls.

Figure 6 represents the performance of Auto Balancer versus quality of balls. As expected, when the quality of balls is better the performance increases. But, because the cost of using balls grouped "grade A" is very high, the balls grouped "grade B" are acceptable.

Magnetism of balls

The Auto Balancer operates in the environment of in the magnetic field of clamper magnet and spindle motor, therefore the balls made of magnetizable material can be magnetized easily. As shown in Figure 7, performance of the Auto Balancer using magnetizable balls is poor compared to the Auto Balancer using non-magnetizable balls. This is because that the magnetized balls draw each other magnetically, thereby the sliding friction between balls increases.

Figure 8 shows the application result in the real optical drive for the unbalanced and balanced disc. The performance on the balanced disc is satisfactory, and as the unbalance increases, the ability of reducing unbalance also increases. In conclusion, the Auto Balancer reduced the vibration and the vibration-induced noise of the optical disc drive dramatically.

3 - CONCLUSIONS

Vibration and vibration-induced noise of the high-speed optical disc drive can be reduced greatly by applying the Auto Balancer. Reduction of friction between balls, and balls and race is the most important factor in designing the Auto Balancer. The wedge type race removes sliding friction between balls and race. Small volume of oil improves the stability, performance and durability. Quality of balls is one of the important factors of the performance, on the other hand magnetized balls degrade the performance of the Auto Balancer.

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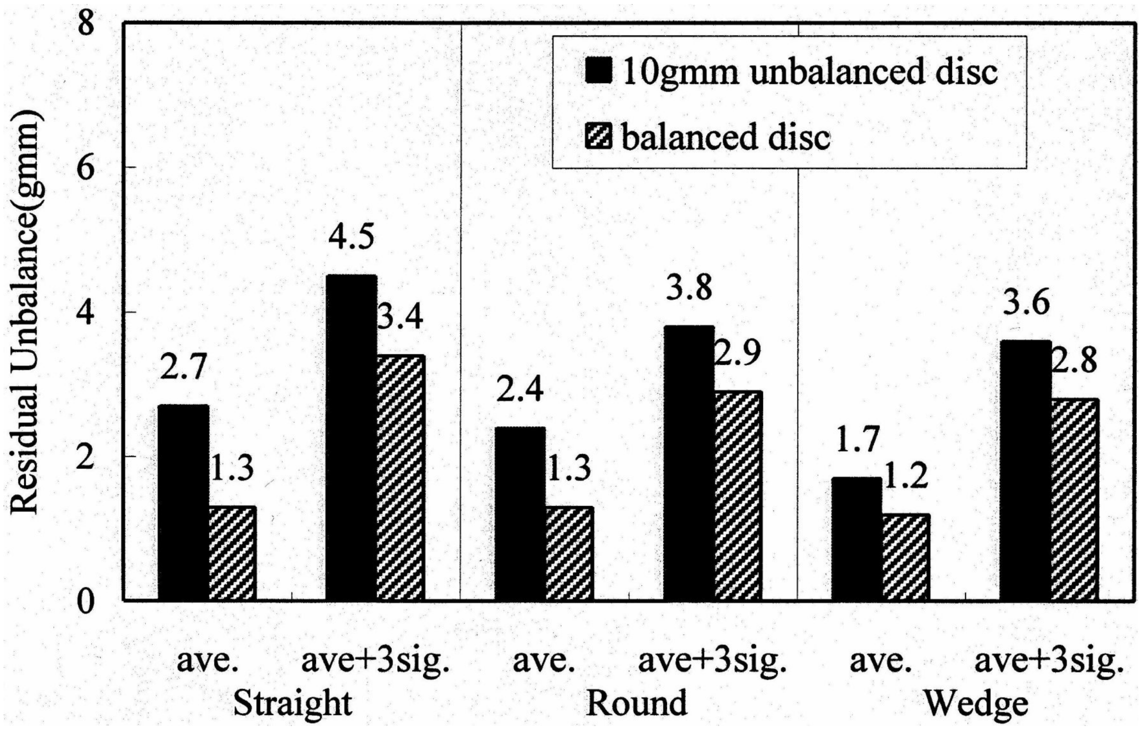

Figure 4: Performance versus race shape.

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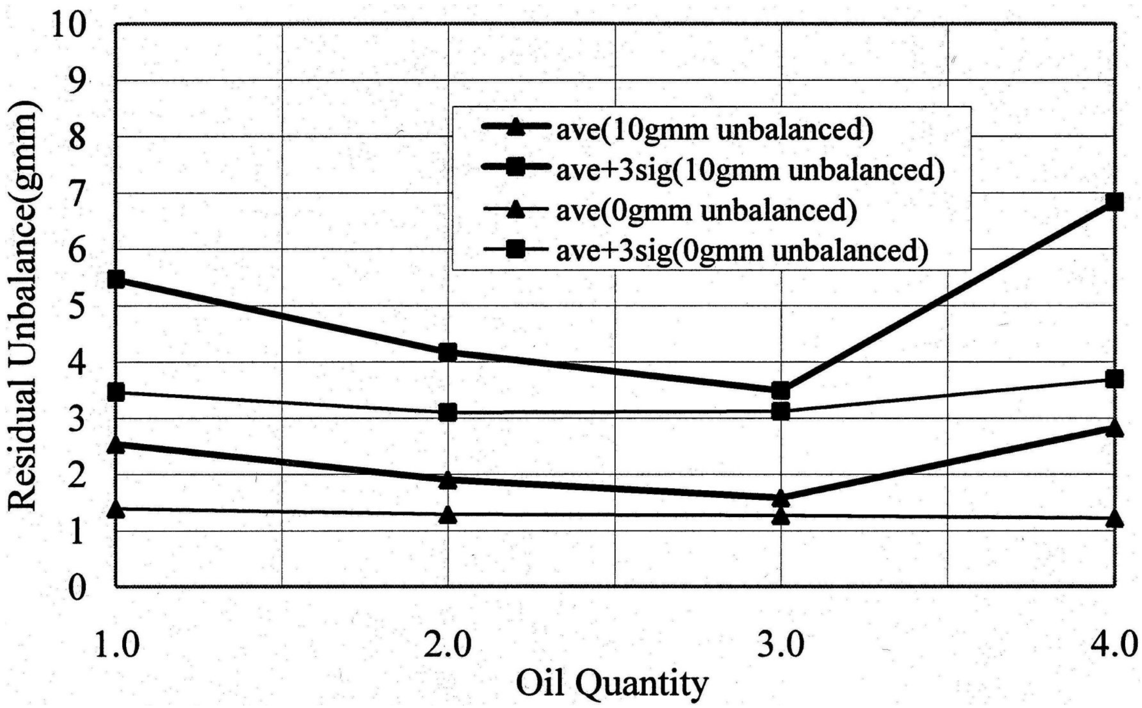

Figure 5: Performance versus volume of oil.

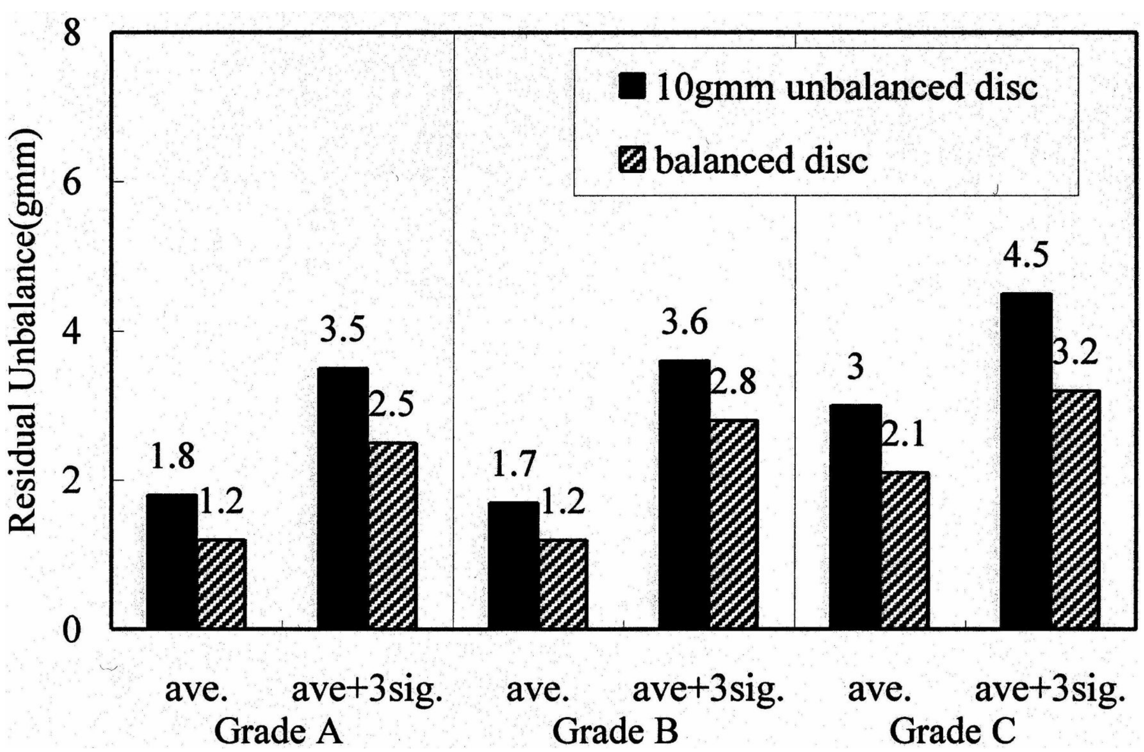

Figure 6: Performance versus quality of balls.

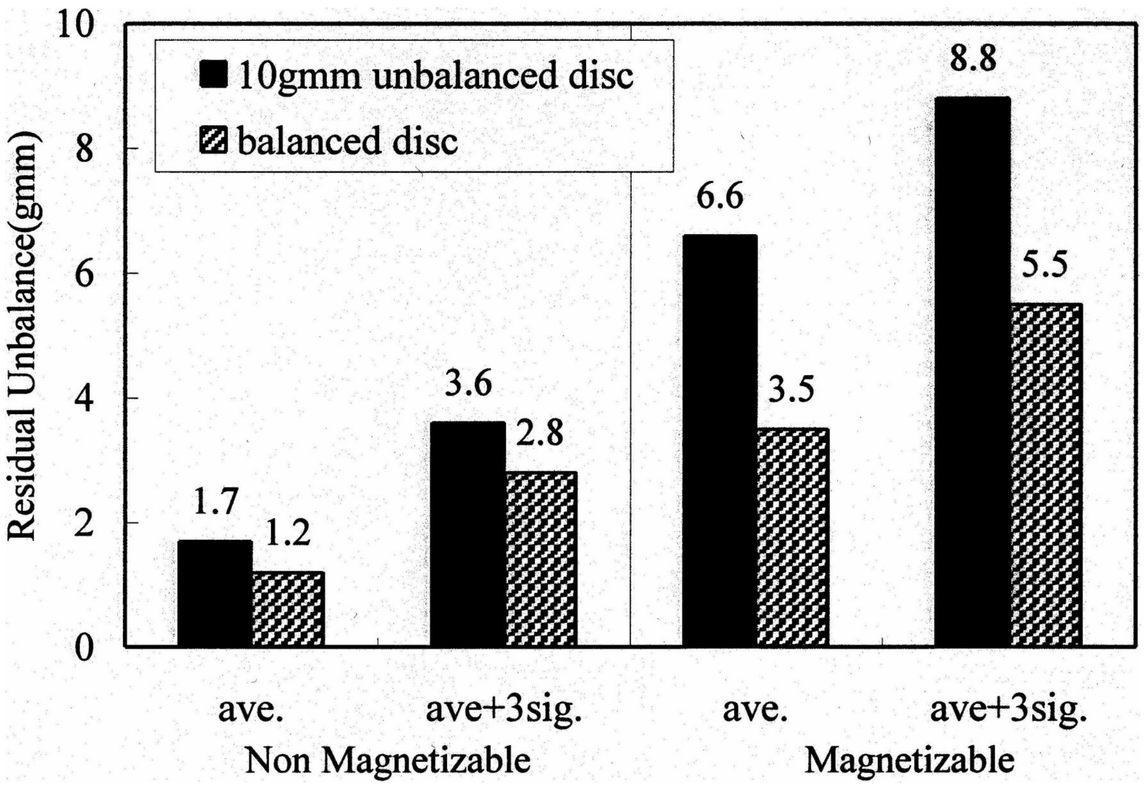

Figure 7: Performance versus ball magnetism.

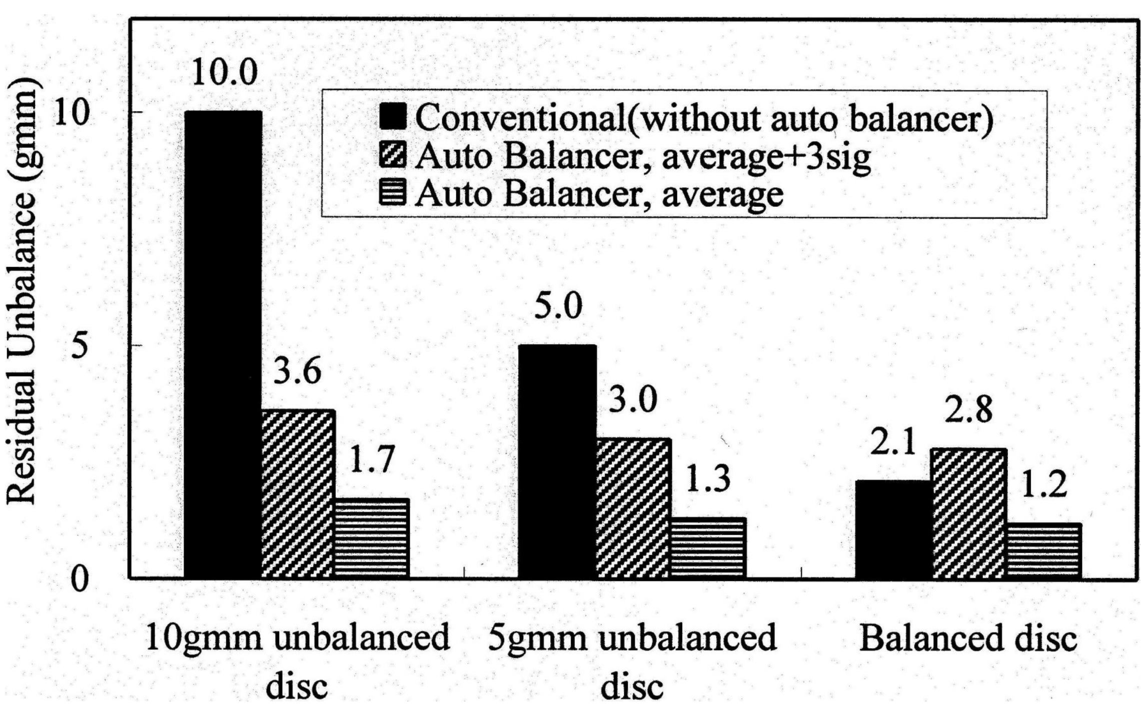

Figure 8: Performance of Auto Balancer.