A Spindle Motor Servo Using a Disturbance Observer

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Abstract This paper presents an advanced spindle servo system with a disturbance observer for an optical disc drive. The system reduces steady state deviation to 0.2% or less with wide range of rotational speed and 50% variation of torque coefficient. Stable control by transient state was confirmed by changing low pass filter function.

Keyword Optical disc, Video Camera, Servo Control, Temperature Change

1. INTRODUCTION

The recent market trends of optical disc drives are large storage capacity, high-speed recording, and adapting to a variety of optical discs.

Storage capacity of the optical disc was realized by making recording-area density high. High-speed recording of the optical disc was realized by making rotation speed high.

For the reason, a spindle motor of the optical disc drive is adapted to high-speed rotation and must cover wide range of rotation speed.

Figure 1 shows the rotation speed, which the optical disc drive covers. The speed control of the wide range is very difficult, because steady state deviation is greatly influenced by the variation of torque coefficient.

In order to stabilize the motor control in the wide range, it is necessary to use the spindle motor with little variation of torque coefficient. But a motor with little variation of torque coefficient is expensive.
An advanced spindle motor servo system, which controls a low cost motor even if the motor has a large variation of torque coefficient was developed. The stability of the spindle motor servo system is confirmed with following two points.

The first point is steady-state stability.

Steady-state stability represents that actual rotation speed is controlled toward the target speed. The stability affects recording and reading quality.

The second point is transient-state stability.

Transient-state stability represents that actual rotation speed is well controlled while changing target speed. The optical disc drive changes target rotational speed when it starts up and accesses to data recorded at different radius of the optical disc, etc. The stability affects access time and vibration.

This paper presents a disturbance observer system, which is suitable for the spindle motor servo system of the optical disc drive.

2. DISTURBANCE OBSERVER SERVO

The disturbance observer servo controls the real motor like an ideal motor. Figure 2 shows the block diagram of the spindle motor servo system. Figure 3 shows the detail of block diagram of the disturbance observer servo.

The spindle motor servo system has the motor model whose transfer function is based on the ideal characteristic in the disturbance observer circuit. And, the spindle motor servo system always monitoring these outputs from the real motor and the ideal motor model, and revises the difference.

![Figure 2: The block diagram of the spindle motor servo](image)

Table I shows the speed range and a target steady-state deviation of the optical disc drive system.

<table>
<thead>
<tr>
<th>System</th>
<th>MAX speed</th>
<th>MIN speed</th>
<th>Steady-state deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD</td>
<td>160 Hz</td>
<td>13 Hz</td>
<td>&lt;0.5%</td>
</tr>
<tr>
<td>DVD</td>
<td>170 Hz</td>
<td>10 Hz</td>
<td>&lt;0.5%</td>
</tr>
<tr>
<td>CD</td>
<td>160 Hz</td>
<td>3 Hz</td>
<td>&lt;0.5%</td>
</tr>
<tr>
<td>LabelPrint</td>
<td>1.7 Hz</td>
<td>0.6 Hz</td>
<td>&lt;1.5%</td>
</tr>
</tbody>
</table>

2.1. Steady state stability

The disturbance observer system controls a real motor like the ideal motor. So, the steady state stability should consider only the characteristics of the ideal motor. Formula (1) shows the normal spindle motor function.

\[
G(s) = \frac{Kvi \cdot Kt \cdot J \cdot s}{1 + J \cdot s \cdot B}
\]

(1)

Kvi: Voltage-to-current-conversion coefficient of a motor driver (V/A)
Kt: Torque coefficient of the ideal motor (N·m/A)

In this time, the steady state deviation depends on a denominator. If the denominator is constant, steady-state deviation becomes zero. So, the transfer function of the ideal motor so that the value of B is set to zero was developed.

Figure 4 shows a bode diagram of the disturbance observer system and a conventional servo system. It turns out that the disturbance observer system increases the gain at low frequency from Fig. 4.
Table II shows comparison of the system effect by steady state deviation.

<table>
<thead>
<tr>
<th>Torque coefficient dispersion</th>
<th>50%</th>
<th>70%</th>
<th>100%</th>
<th>130%</th>
<th>150%</th>
</tr>
</thead>
<tbody>
<tr>
<td>The conventional servo system</td>
<td>28</td>
<td>24</td>
<td>18</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>The disturbance observer system</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Table II The comparison of the system effect by steady state deviation.

It is confirmed that the new system reduces steady-state deviation.

2-2. Transient state stability

In transient state, an overshoot against a step input is a problem. The disturbance observer servo has the characteristics of integral function. So, an overshoot is generated theoretically.

The overshoot is suppressed by optimizing the low pass filter condition of the disturbance observer servo in transient state. And it changes the low pass filter function for transient state and steady state by actual rotation speed. A damping factor of the system is determined by the filter condition used at the time of steady state. First overshoot rate is determined by the damping factor of each low pass filter function and a low pass filter function change rate.

Figure 5 shows the step response with the disturbance observer servo. The advanced system suppresses a first overshoot in comparison with the current disturbance observer servo system.

It is confirmed that the new system suppresses the overshoot.

3. Conclusion

The coexistence of motor variation and wide range disc rotation was realized. The spindle motor servo system with disturbance observer achieved the stability of rotational speed. The system reduces the steady state deviation to 0.2% or less. And, transient-state was stabilized by optimized the filter condition. The system reduces the overshoot to 5% or less. The observer circuit is integrated in DSP (Digital signal processor) easily.

REFERENCES
