Research on the Specific Servo System Applied for DVD Traverse Tester

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ABSTRACT
This paper principally analyses the influence of the DVD traverse manufacture and assembly error to the servo system, presents a specific servo system applied for DVD traverse tester, which is a digital servo based on general DSP. The repetitive control scheme is adopted to enhance the robustness to the periodic disturbance.

Keywords: servo system, DVD traverse tester, DSP, repetitive control

1. INTRODUCTION
A DVD traverse consists of a DVD optical pickup, motors and the transmission and fixing mechanism. Every of those can directly influence the servo accuracy and the character of readout signals. In the DVD traverse production, the eligible DVD optical pickup and motors are used. So the servo system is mainly influenced by the manufacture and assembly error of the transmission and fixing mechanism. The specific servo system applied for DVD traverse tester should overcome the influence mentioned above, and accomplish a certain servo accuracy within a large range of manufacture and assembly error, in order to satisfy the requires of the DVD traverse testing.

2. INFLUENCE OF MANUFACTURE AND ASSEMBLY ERROR ON SERVO SYSTEM
We assume that the X axis of the PD(photo detector ) parallels the tangential direction of the disc, and the Y axis of that parallels the axial direction of the disc. Under ideally conditions, when the facial point is on the surface of disc, the reflection light spot will be positioned just in the geometrical center of PD. But due to the manufacture and assembly error, the light axis is not perpendicular to the disc surface. The radial tilt angle $\phi$ and tangential tilt angle $\theta$ are not zero. As a result, the offset of the reflection light spot will exist. The tangential tilt angle $\phi$ causes the offset in the direction of Y axis, as shown in Fig.1.

![Fig.1. the influence of the tangential tilt angle on the reflection light spot](image-url)
Assuming the clockwise is positive, the offset at the direction Y,
\[ \Delta Y = O O_1 = 2 \varphi f \]  
where \( f \) is the focus of the object lens. Similarly, the offset at the direction X,
\[ \Delta X = 2 \theta f \]  
So, when correctly focusing, the reflection light spot on PD has offset at both X and Y direction, as shown in Fig. 2. the FE output caused by the offset is
\[ FE_1 = 4 K I_0 \frac{4 \Delta X \Delta Y}{\pi r^2} \]  
Where \( K \) is the coefficient of photoelectric transformation, \( I_0 \) is the light intensity, and \( r \) is the radius of the light spot. From (1) (2) and (3), we get
\[ FE_1 = 4 K I_0 \frac{4 \varphi \theta f^2}{\pi r^2} \]  
Neglecting the influence of the disc and optical pickup, the factors ruin the perpendicularity of the optical axis and the disc surface are as follows: ① the rotation axis of spindle motor does not parallel to the light axis;
② the wobbling of the motor axis;
③ the motor salver and the motor axis are not perpendicular;
④ the wobbling of the sliding guide apparatus at the direction parallel to the disc surface. Among those, each can cause both radial and tangential tilt angle. ① causes a constant tilt angle, ②③ causes a periodic changing one, whose periods is the same as the rotation of the spindle motor. ④ causes one, that is determined only by the position on the guide apparatus of the optical pickup.
So \( FE_1 \) can be described as below
\[ FE_1 = P_1(t) + P_2(l) + C_1 \]  
Where, \( P_1(t + T) = P_1(t) \), \( T \) is the rotation periods of the spindle motor, \( P_2(l) \) is determined only by the distance between the optical pickup and the disc center, \( C_1 \) is a constant value.
Also, \( \Delta X \) and \( \Delta Y \) can reduce the sensitivity of the FE signal. It can be considered that FE is multiplied by a gain \( K_1 \). \( K_1 \) has a similar form to \( FE_1 \).
\[ K_1 = G_1(t) + G_2(l) + C_2 \]  
Where \( G_1(t) = G_1(t + T) \).
Neglecting the influence of the disc, radial tilt angle \( \theta \) can change the distance between the object lens and the disc surface at the direction of the light axis. The added distance is
\[ H_1 = l \theta \]  
Similarly, \( H_1 \) can be described as below
For DVD, tracking error $TE$ is obtained by the phase difference of the output signals of PD, as shown in Fig. 3.

![Fig. 3 error detection](image)

$TE$ can be described as below[3],

$$
\Delta \varphi = \frac{\Delta \phi_{CD} + \frac{V_C}{V_A} \Delta \phi_{AB}}{1 + \frac{V_C}{V_D}} + \frac{(1 - \frac{V_C}{V_A})(\phi_A - \phi_C)}{1 + \frac{V_C}{V_A}}.
$$

where $V_A$ and $V_C$ are the amplitudes of signal of PD quadrant A and C, respectively. $\Delta \phi_{AB}$ and $\Delta \phi_{CD}$ are the phase difference of 2-segment PD A, B and C, D, $\phi_A$ and $\phi_C$ are phases of signal of PD quadrants A and C at a fixed time. We assume that the amplitude of quadrant A is equal to that of quadrant D, and that of quadrant C is equal to that of quadrant B.

Through analysis, the first term of (9) is caused by the offset of light spot $\Delta X$, $\Delta Y$. Similarly, the added $TE$ causes by non-perpendicularity is

$$
TE_1 = P_3(t) + P_4(l) + C_3
$$

where $P_3(t) = P_3(t + T)$

Including the influence of the light spot offset, the eccentricity of the spindle motor can also introduces disturbance, which is periodic with a period equal to the rotation period of the spindle motor.

From the discussion above, the manufacture and assembly error causes the tilt angle of the disc. The tilt angle can cause the offset of the light spot on PD, which introduces disturbance to the servo system. The disturbance contains a periodic composition, whose period is equal to the rotation period of the spindle motor.

3. DESIGN OF SERVO SYSTEM AND ALGORITHM

Because tracking servo is similar to the focusing servo, we only principally discuss the focusing servo.

A servo system based on general DSP IC is built. Fig. 4 shows the block diagram of the focusing system, in which the disturbance is considered.
In Fig. 4, FE1, H1, K1 are the disturbances discussed above. Apart from the disturbance and DSP control algorithm, the transfer function of the controlled objective has the form as below [4],

\[
W(s) = G_s(s)G_d(s)P(s) = \frac{A}{s^2 + a_1s + a_2}
\]  

(12)

Through experiment, we can figure out the values of the coefficients. Because the main composition of the disturbance is periodic, so adopting repetitive control algorithm can enhance the robustness of the system. Apart from the disturbance, the block diagram of repetitive control is as shown in Fig. 5 [5], in which \( l \) is equal to the rotation period \( T \) of the spindle motor.

The close-loop system is steady and has the most broad bandwidth when the conditions below are satisfied [5],

\[
|1 + G(j\omega)| > 1, \omega < \omega_r
\]

(13)

\[
|1 + W(j\omega)| > |F_j(\omega)|, \text{ and } |F_j(\omega)| = 1, \forall \omega < \omega
\]

(14)

Where \( \omega_r \) is the upper limit of the servo bandwidth.

According to the runout and response error, we can get the least gain of the system. Then adopting step-space method and (13), we can figure out \( C(s) \), then \( G(s) \), often we let

\[
F(s) = \frac{1}{1 + \mathcal{N}}, \text{ though (14) and the Bode diagram, we can get } F(s).
\]

Then can figure out \( C(z) \) and \( F(z) \). Applying bilinear transform, according to which, we can write the DSP program.

### 4. EXPERIMENTAL RESULT

Using this servo system, we can not only test the characteristic parameters under open-loop condition, but also the ones under close-loop condition. RF signal can directly reflect the quality of the servo system. So here we give the picture of the RF signal when this servo system, standard disc and eligible DVD traverse are used. (Fig. 6)
We can see that, the RF signal has a very high quality. Jitter is a comprehensive parameter to evaluate a system. Through measurement, the Jitter of DVD is around 7%.

5. CONCLUSION

Using the eligible DVD optical pickup, the character of the DVD traverse is mainly influenced by the transmission and fixing mechanism. The manufacture and assembly error can introduce disturbance to the servo system, which contains a main periodic composition. A servo system based general DSP is built, in which repetitive control is adopted. According to the experimental result, this system has a high accuracy and can satisfy the requires for a DVD traverse tester.

REFERENCES