Robust Time Optimal Controller Design for HDD

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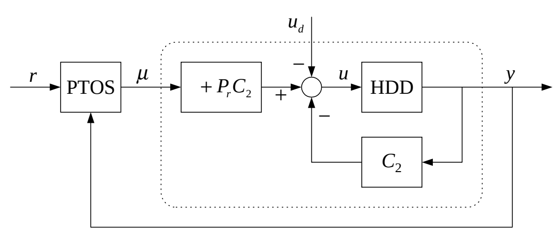
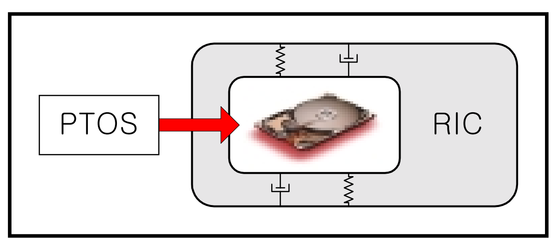
HDD Head Positioning Control

HDD servo control requires advanced technology to meet the need of high capacity, small size storage devices. HDD servo control technology has two main purposes. The first is to move the head to target track for reading or writing data as quickly as possible, and the second is to keep the read-write head on the desired track precisely under disturbance conditions. So, the overall control algorithm requires minimum time control during track seeking and minimum variance control during track following. In this paper, proximate time optimal servo(PTOS) based on robust internal-loop compensator(RIC) is proposed. RIC can isolate HDD system from the uncertain disturbances including modeling error, external disturbances, shock and control torque saturation. By combining the desirable features of PTOS and RIC, we show that the position error does not exceed 1% of track width even for usual shock and periodic disturbances. The performance of the proposed controller is verified via simulation works.

Time Optimal Controller Based on RIC



Block Diagram



Conceptional Diagram

Figure 1: Robust Time Optimal Controller Structure

The requirement of the minimum time and minimum variance servo algorithm is difficult to meet because we have to consider the uncertain disturbances. This requires the "robustness" of the control algorithm as well as the time optimality. A new robust time optimal controller described in Fig.1 is proposed in this paper. We used PTOS algorithm to give time optimality and RIC to give robustness and saturation avoidance capabilities.

The basic equations of PTOS and RIC is written as Eq.(1) and Eq.(2).

$$\mu = u_{max} \cdot \mathrm{sat}\left(k_2 \left[f(y_e) - v\right]/u_{max}\right)$$
$$f(y_e) = \begin{cases} (k_1/k_2) y_e & \text{for } |y_e| \le y_l \\ \mathrm{sgn}(y_e)\left[\sqrt{2 u_{max} a \alpha |y_e| / k_y} - u_{max}/k_2\right] & \text{for } |y_e| > y_l \end{cases} \qquad (1)$$

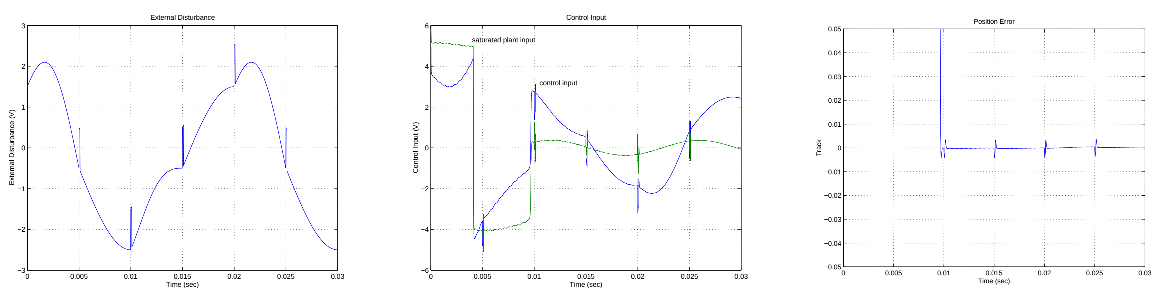
$$u = (1 + P_r C_2)\mu - C_2 y \qquad (2)$$

If the reference model P_r and controller C_2 are stable, the whole system has robust time optimal properties. The structure of the proposed controller in Fig.1 resembles that of DOB(disturbance observer) but it has more general capability in designing the internal controller C_2. The robust stability can be proved in this controller frame work.

Characteristics of the Proposed Controller

1. The servo controller has time optimal properties due to the PTOS.
2. Repetitive disturbance, shock, internal resonance of system and uncertainties of real system is successfully rejected by RIC.
3. Due to RIC properties, the overall system can be easily designed using the 2nd order reference model.
4. Even under the torque saturation, RIC guarantees the robust stability.

Results of Numerical Simulation



(a) Disturbances (b) Control Input (c) Error

Figure 2: Simulation Results

When there are input saturation and external disturbances, Figure 2 shows the simulation results. The target track was 2000 tracks and saturation voltage was set to 5.0 volt. The external disturbance has a shape of Figure 2(a) with sinusoidal plus series of impulses. As can be seen here, the tracking error shows good performance even for the large disturbances of the system and control input saturation.