ASME Information Storage and Processing Systems Conference
Santa Clara, CA 2002

DETERMINATION OF WINDAGE INDUCED DISTURBANCE SPECTRUM IN A COMMERCIAL HARD DISK DRIVE

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Introduction

The current trend in Hard Disk Drives (HDD) is towards higher rotational speed of the disks on which information is stored. This trend is in response to the higher demands on storage density and data transfer rates. With the increasing rotational speeds of HDDs come the negative effects of flow-induced vibrations or windage effects. These disturbances are especially detrimental for the track following servo controller since they produce a non-repeatable run out (NRRO). The effect of windage on the position error signal for servo applications requires a modeling approach that captures the stochastic nature of the windage disturbance. In this paper, a stochastic approach based on a prediction error framework is used to model the windage effects on the control system servo. The prediction error framework enables the use of system identification techniques to estimate windage induced noise models by measuring the position error signal in the presence of windage (noise). These models characterize the spectral contents of the windage induced track misregistration relevant for optimal servo design to suppress NRRO. The method is illustrated on data collected from a modified commercial HDD (shown in Figure 1) in which the position of the slider can be directly measured by an LDV. An added benefit of the proposed method is that the disturbance model can be used as a shaping function in H_∞ and μ-synthesis control design techniques [1,2] for HDDs.

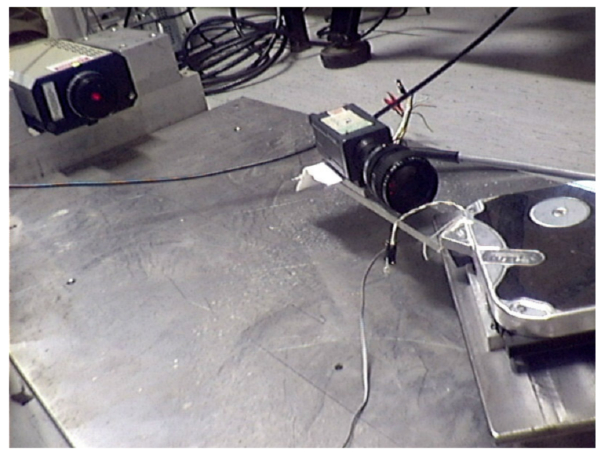

Figure 1 Experimental Setup

Windage Modeling

The stochastic properties of windage are represented in a spectral model that can be formulated as follows: let $v(t)$ denote the contribution of the windage induced disturbance on the Position Error Signal (PES) $y(t)$, and $H(q)$ a stable and stable invertible monic discrete time filter; then the following assumption is made:

$$v(t) = H(q)e(t) \qquad (0.1)$$

where $e(t)$ is a discrete white noise process. In

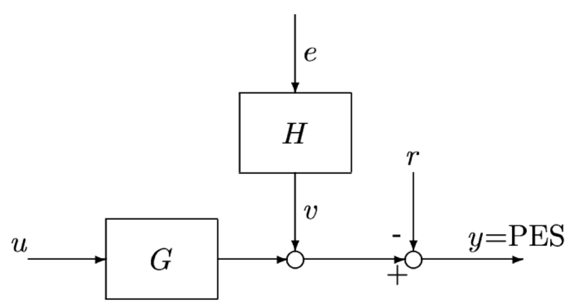

Figure 2 Block Diagram of Modeling Assumption

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(1.1) $H(q)$ is used to model the spectral content of the windage, whereas $e(t)$ is used to represent the stochastic nature of the disturbance. For modeling purposes the measured PES $y(t)$ is considered to be composed of the windage induced disturbance $v(t)$ and the difference between the actual track position $r(t)$ and the servo actuator position $G(q)u(t)$, where $G(q)$ denotes the dynamic behavior of the servo actuator and $u(t)$ the input to the VCM. This is illustrated in Figure 2 and expressed mathematically as

$$y(t) = r(t) - \left[G(q)u(t) + H(q)e(t)\right] \quad (0.2)$$

<u>Prediction Error Method</u>

Let $H(q,\theta)$ and $G(q, \theta)$ represent the noise and system models, where θ is used to denote the unknown parameters which need to be estimated. The one step ahead predictor of $y(t)$ is given by:

$$y(t\,|\,t-1) = H(q,\theta)^{-1}\left[G(q,\theta)u(t) - \left(1 - H(q,\theta)\right)y(t)\right] \quad (0.3)$$

In the prediction error framework [3] the prediction error $\varepsilon(t,\theta) = y(t) - y(t|t\text{-}1)$ is minimized w.r.t. θ in a least squares sense. Both $H(q,\theta)$ and $G(q, \theta)$ are assumed to have the common resonance modes. This is a viable assumption given the fact that the natural modes of the system are excited only if the excitation force includes the system dynamics. The order of the models is based on satisfying two consistency tests: the first is the cross correlation between the predicted error and the input signal and the second is the auto correlation of the predicted error. Only when both tests are satisfied is the model and model order considered acceptable.

Typical results obtained from the method described above are shown in Figure 3, where the magnitude and phase of a 12th order model for $H(q,\theta)$ are shown. In the magnitude plot it can be seen that the windage induced disturbance acts predominantly at low frequency, but is also responsible for exciting the sway mode of suspension as is evident from the 9kHz resonance peak in the figure.

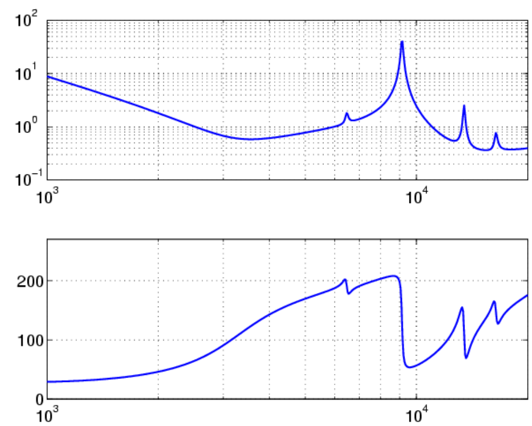

Figure 3 Twelfth order noise model $H(q,\theta)$ of Windage disturbance on PES signal

<u>References:</u>

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