Intelligent Auto-Tuning for Adaptive Control of DC Motor System with Load Inertia of Great Variation

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Abstract

The intelligent auto-tuning method for a strongly stable adaptive control system of a DC motor with great load inertia variation is proposed. The stable characteristic polynomial that is designed by an optimal servo is specified for the adaptive pole placement control system. The appropriate adaptive control system can be derived, by adjusting automatically the weight of a performance criterion in optimal control by means of the fuzzy inference on the basis of the stability index.

1. Introduction

In industrial fields, many control systems whose dynamic characteristic of controlled process greatly changes during actuation exist. A control performance usually deteriorates when applying many conventional control methods with fixed parameter as controller. It is well known that the adaptive control [1], [2] is very effective method for such systems. When the load inertia of motor system changes over a wide range, a series controller having an unstable pole is derived in the adaptive pole placement control system frequently, even if the closed-loop characteristic was designed as a stable system. The appearance of the unstable controller is not desirable with respect to both stability and reliability. Recently, authors announced some effective design methods [4], [5] that constructs a strongly stable adaptive pole placement system, even if the plant parameter changes greatly. This paper is the application result of the previous research.

An optimal servo system [6] is recursively designed estimating a DC motor speed-control system. The series controller is automatically constructed by solving *Bezout* identity on the basis of the characteristic polynomial of this derived optimal servo. After the stability index [7] of a series controller is examined, the weight in an optimal control design is appropriately updated by means of the fuzzy inference [8]. In other words, the proposed method automatically adjusts the weight of an optimal servo system so that the adaptive system can place the stability index of the series controller into the specified region. Consequently, this method not only ensures the stability of both closed-loop system and controller but also can achieve a fine control performance.

2. Modeling a DC motor speed-control system

The controlled system examined in this research is shown in Fig.1 and it includes the designed speed controller based on type-1 servo design. The control of equivalent disturbance and the reduction of uncertainty are realized by this system constitution, and the original performance of the adaptive control is skillfully achieved. The symbols used in the modeling are defined as follows:

L : armature inductance $[H]$
i : armature current $[A]$
R_a : armature resistance $[\Omega]$
r : applied voltage of power amplifier $[V]$
K_e : back electromotive force constant $[V\sec/rad]$
K_τ : torque constant $[Nm/A]$
J_m : momentum of rotor inertia $[kgm^2]$
J_ℓ : momentum of load inertia $[kgm^2]$
ω : rotor speed $[rad/\sec]$
ω_V : voltage output of rotor speed $[V]$
τ_f : disturbance torque $[Nm]$
S_V : conversion constant ω to ω_V $[V\sec/rad]$
R_i : resistance for armature current detection $[\Omega]$
K_p : gain of power amplifier

In this case, the state-space description of DC motor is expressed by disregarding a disturbance torque as follows:

$$\left.\begin{aligned} \dot{x} &= A\,x + B\,r \\ y &= C\,x \end{aligned}\right\} \tag{1}$$

where the variables x and y are given by $x=[\omega \quad i]^T$ and $y=\omega_V$, respectively, and A, B and C are defined as

$$A=\begin{bmatrix} 0 & K_\tau/J \\ -K_e/L & -R/L \end{bmatrix},\ B=\begin{bmatrix} 0 \\ K_p/L \end{bmatrix},\ C=[S_V \quad 0],$$
$$J=J_m+J_\ell,\quad R=R_a+R_i\ . \tag{2}$$

At this time, type-1 servo system is used for DC motor speed control. The extended system introduced with an integrator is described as

$$\begin{bmatrix} \dot{x} \\ z_1 \end{bmatrix}=\begin{bmatrix} A & 0 \\ -C & 0 \end{bmatrix}\begin{bmatrix} x \\ z_1 \end{bmatrix}+\begin{bmatrix} B \\ 0 \end{bmatrix} r \tag{3}$$

and actuating value is constructed by the following control:

$$r=-F\,x+K_1 z_1\ ,\quad F=[f_1 \quad f_2], \tag{4}$$

where f_1, f_2 and K_1 are feedback gains, respectively.

In general, the feedback gains can be decided by the pole placement method or the optimal servo design. The procedure of the optimal servo design is summarized as follows. The extended deviation system of DC motor described as (1) is