Control and Validation for Original-feeding System of Adf

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***Abstract*-An automatic document feeder (ADF) is an important part of a copier, which is capable of feeding a document for double-sided scanning, includes mechanical structure and control system. Control system is the core unit, which is responsible for original feeding, original separation, original registration, original conveyance, etc. Control system will directly affect the accuracy of machine efficiency. In order to design control system, mathematical model should be well-designed first. The original-feeding system of an ADF is controlled and validated in this paper. The ADF studied here is a prototype developed by Konica, a company that develops professional printing systems. We construct a model of original-feeding system for the ADF in Simulink, and software which is using for modeling dynamic system, simulating and analyzing, and express the PID gains. Next, we contrast original feed motor's speed on real condition to simulation results for checking whether the PID gains are reasonable. The comparison shows the upward trend in motor speed is similar, and the actual rise time is shorter. The reason for that is: the test data on real condition focus on the moment when the original feeds in, all the loads involved in simulation are not added to motion control system. In this sense, in addition to finding better PID gains in the ADF motion control system, our analysis also led to a better understanding of system.**

Keywords-ADF, Simulink, PID gains, Motion control

I. INTRODUCTION

ADF is an important part of a copier, which is capable of feeding a document for double-sided scanning [1]. ADFS produced by different companies vary from functions to structures. Control system is an integral part of an ADF, which is responsible for original feeding, original separation, original registration, original conveyance, etc. Control system will directly affect the accuracy of machine efficiency In order to design control system, mathematical model should be well-designed first.

In this report, we apply electromagnetism and mechanical dynamics technologies to analyzing the model of ADF's document feeding motion control system. In particular, we study a prototype of an ADF called DF315 which is produced by Konica. The ADF automatically feeds original to the scanner of the copying machine. It moves the sheet in its input tray over the scanner one at a time and places every sheet into an output tray after it has been scanned [2]. We construct a model of the ADF's original-feeding system by analyzing principle of ADF, and express PID gains in Simulink. Next, we apply the PID gains to control circuits and compare the test results to simulations.

We describe the ADF's principle and translate its original-feeding system to mathematical model in section 2. We also calculate parameters of model in details. In Section 3 we express the PID gains in Simulink, which applies in control system. The hardware and software of motion control system are described in section 4. We conclude in section 4, with comparison of simulation results and test results.

II. SYSTEM DESCRIPTION

A. ADF Hardware components

An overview of the ADF is given in Figure.1. The ADF consists of rollers (R1,R2,…), clutches(C1,C2,...), sensors (S1,S2, ...), motors(M1,M2,...), pinches (P1,P2, ...), a flapper (F1) and trays. A pinch can hold a sheet in conjunction with a roller. A sensor can be either covered or uncovered, which is indicated by its high or low electronic output signal respectively. A clutch can be set to either on or off. If on, the motor on one side of the clutch is connected to the pinch on the other side. If off, the motor and the pinch are disconnected, meaning that no transmission between them is possible. There are two types of motor: motors that can run at various speeds in one direction only (M2) and motors that can run at various speeds and in two directions (M1).

M1 is used for feeding original, has a controller and an encoder attached to it. The encoder monitors the distance that the motor has covered thus far and can be asked to return this value. The controller can be in one of two states: controlled and idle. When a control signal from the main body is received, C1 (original pick-up) goes on, and after the specified time M1 starts to rotate in the forward direction. This causes the paper feed roller to be lowered, applying pressure to the original. After the specified time, M1 and K1 go OFF, but the pressure on the original is maintained [2].

B. Mathematical model

The feeding motor NA4565 is the executing instruction for original-feeding system. The motor can be described by two coupled differential equations. The first one is a mechanical differential equation dependent on the motor's angular velocity ω:

$$T(t) = J\frac{d\omega(t)}{dt} + B\omega(t) + T_d(t)$$

(1)

Where J is the equivalent moment of inertia and B is damping coefficient, which are converted on motor axis.

The second differential equation is an electrical one, which is dependent on the current i_a and induced voltage E_a:

$$u_a(t) = R_a i_a(t) + L_a\frac{di_a(t)}{dt} + E_a(t)$$

(2)

The motor constant and couples the equations above:

$$\begin{cases} E_a(t) = K_e\omega \\ T(t) = K_t i_a(t) \end{cases} \tag{3}$$

(1), (2) and (3) can be represented in the following equation. It shows the transfer from voltage input into angular velocity output.

$$\frac{\Omega(s)}{U_a(s)} = \frac{K_t}{L_a J s^2 + (L_a B + R_a J)s + R_a B + K_e K_t}$$

(4)

C. Parameters calculation

1) K_e and K_t calculations

The motor constant K_e and K_t can be calculated easily in accordance with the following equation

$$\begin{cases} I_a(t) = \dfrac{1}{K_t}T(t) + I_0 \\ K_t = 0.955K_e \end{cases} \tag{5}$$

Where $I_0 = 0.2A$, we can calculate $K_e = 0.029$, $K_t = 0.0278$.

2) Moment of inertia calculations

The original-feeding system is muti-axis control system，which is composed of feeding-motor, feeding roller, separation roller and other accessories. Figure.2 shows the transmission relation between all parts. The moment of inertia J in total is equal to the sum of all inertias J_n , which is showed as :

$$J\omega_n^2 = J_1\omega_1^2 + J_2\omega_2^2 + J_3\omega_3^2 + J_4\omega_4^2 + J_m\omega_m^2$$

(6)

Where ω_n is corresponding rollers' angular velocity and ω_m is motor's angular velocity.

According to the quality, radius and the transmission ratio of each roller, the corresponding rollers' angular velocity can be described as:

$$\begin{cases} \omega_{in} = 355.87\text{rad/s} \\ \omega_{out1} = \omega_{in}/i_{19} = 182.11\text{rad/s} \\ \omega_{out2} = \omega_{in}/i_{1,11} = 252.69\text{rad/s} \\ \omega_{out3} = \omega_{4'}/i_{4'14} = \omega_{in}/(i_{4'14}\cdot i_{14}) = 129.96\text{rad/s} \end{cases} \tag{7}$$

3) Resistance calculations

The resistance can be get in two steps. First, 10K resistor is serried in motor circuit when motor is running with no load, and test the current in circuit. Repeat the step above three times. B and La can be obtained from the manufacturers B=5×103，La=2.3mH,

As seen above, the equation (4) can be represented as follows

$$\frac{\Omega(s)}{U_a(s)} = \frac{1.098\times10^6}{s^2 + 4.6446\times10^4 s + 3.5278\times10^4} \tag{8}$$

It also can be represented in the following block diagram (Figure. 3). It shows the transfer from voltage input into angular velocity output.

III. TUNING THE P.I.D. LOOP

There are two primary ways to go about selecting the P.I.D. gains. Either the operator uses a trial and error or an analytical approach. Using a trial and error approach relies significantly on the operator's own prior experience with other motion control systems. To address the need for an analytical approach, Ziegler and Nichols [3] proposed a method based on their many years of industrial control experience. Although they originally intended their tuning method for use in process control, their technique can be applied to servo motion control. Their procedure basically boils down to these two steps [3].

Step 1: Set Ka and Kd to zero. Excite the system with a step command. Slowly increase Kp until the shaft position begins to oscillate. At this point, record the value of Kp and set K0 equal to this value. Record the oscillation frequency f0.

Step 2: Set the final P.I .D. gains using following equation:

$$K_p = 6K_0,\ K_i = 2f_0K_p,\ K_d = K_p/8f_0.$$

Figure.4. shows the result of using the Ziegler Nichols gains. The response is somewhat better than just a straight proportional gain.

IV. MOTION CONTROL SYSTEM CONSTRUCTIONS

In order to check the PID gains is reasonable, we design the motion control system, which is consist of hardware and software. A C8051F005 Processor is responsible for motion control of feeding motor and conveying motor. The monitoring system is consist of PC [4].

In order to manage the program for starting and monitoring the run we have also developed a Graphical User Interface (GUI) written in Delphi. A snapshot of the main window of this application is shown in Figure.5. The Application Window is logically divided into four regions. A buttons region, in the bottom of window, the buttons allow the user to close ('STOP'), start ('START') and cancel the task. A communication configure on the left, is a blank region that allows the user to see the messages coming from the controller C8051F005. The third region is the monitoring window on the right, where it is possible to find the run information: paper size detection, motor speed, malfunction display. The fourth region, where communication between C8051F005 and PC can be initialized, is in the lower part of window.

V. TEST RESULTS

A slice of the control system was assembled in order to integrate and test the feeding motor speed under real conditions. The speed which focuses on the feeding as follows:

If we compare Figure.6 to Figure.4, we notice how strikingly similar the rising trend. This suggests that we make model in Simulink and PID arithmetic based on motion system are available. Why the rising time is shorter than the simulation results in Figure.4 is that test on real condition focuses on the moment when original feeds original. The real situation is feed motor should be working with conveying motor together, more load should be added to test system. In this sense, in addition to finding better PID parameters in the ADF, our analysis also led to a better understanding of the system.

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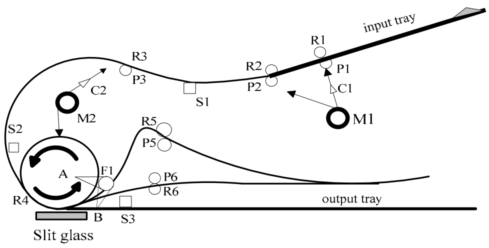

Figure 1. Overview of an ADF (DF315)

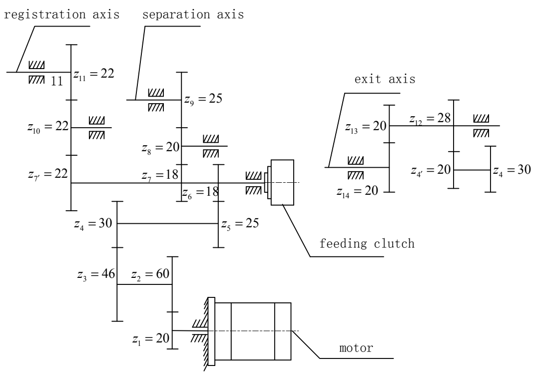

Figure 2. Transmission Schematic

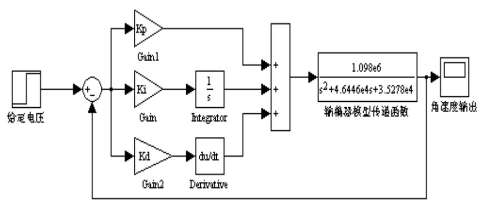

Figure 3. Model in Simulink

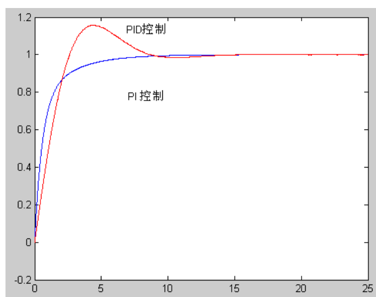

Figure 4. Sep Response schematic

Figure 5. Run Control window

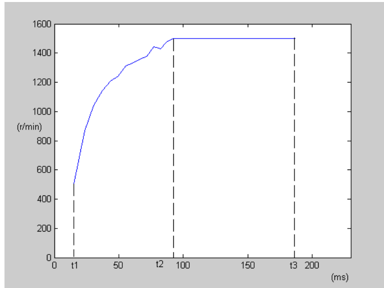

Figure 6. Motor speed test on real condition