OPTICAL SIZE CONTROL SYSTEM OF EXTRUDED PRODUCTS

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ABSTRACT

In this work, an optical computerized control system for the extruded product size has been described, analyzed, built, and tested. Also an error analysis has been carried out along with a simple stability analysis.

I. INTRODUCTION

In a manufacturing system, one of the problems is the size control of the product being produced. Due to the voltage level variations, the speeds of the motors change randomly. This causes variations on the size of the product being produced. To solve this problem, there are different methods [1-5]. All the methods sited are expensive to implement. The method we propose uses cheep digital camera and related software along with computer, motor control unit interface circuit. The system controls both DC motors as well as the AC motors. The computer produces necessary voltage to control the motor speed through one of its ports.

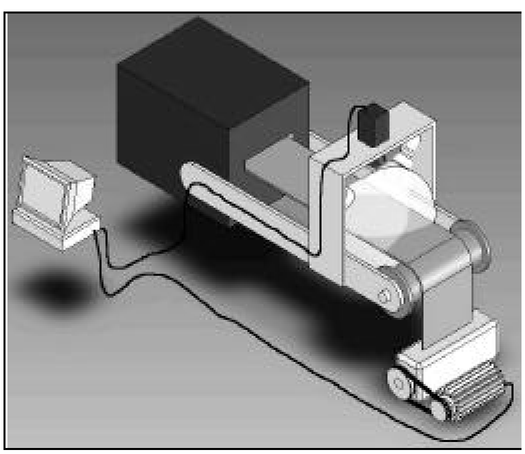

Figure 1. Illustration of the production line

II. SYSTEM DESCRIPTION

The optical control system is shown as a block diagram in **Figure 2**. In order to prevent measurement errors the product is lightened at enough level. The camera takes the picture of the product every second. The computer program computes the pixel size of the product along with the direction we are interested in. This measured size is compared with the size we like to have for the product. The software produces an error voltage proportional to the difference between the desired size and the measured value. This voltage is supplied to the motor driving units.

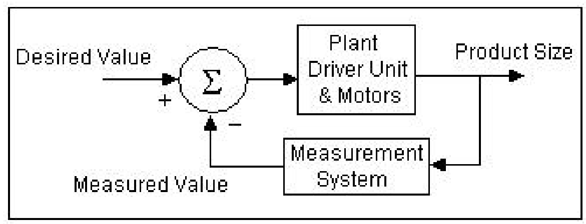

Figure 2. Block diagram of control system

III. STABILITY ANALYSIS

The block diagram shown in Figure 3 can represent the system.

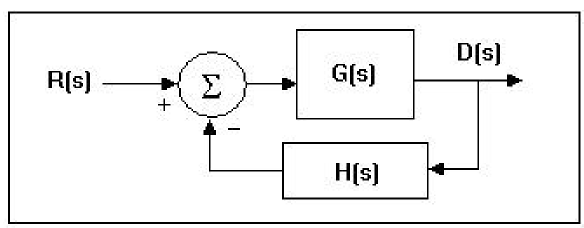

Figure 3. Linear representation of the control system

$$G(s) = \frac{KK_sK_m}{1+t_m s} \tag{1}$$

$$H(s) = e^{-sT} \tag{2}$$

Where K, K_s, K_m are the gain for driver, angular angle to the size multiplier, and the motor gain, respectively. τ_m is the motor time constant, T is the delay introduced by the optic measurement system and the computer processing together. R(s) is the s transform of the desired size function and D(s) is the s transform of the size function obtained. The characteristic equation for the closed loop control system is:

$$1 + t_m s + KK_mK_s e^{-T} = 0 \tag{3}$$

If $|1-Ts|$ is small enough we write

$$e^{-Ts} \approx 1-Ts \quad [6\text{-}8] \tag{4}$$

Replacing this in Eq. 3 we get

$$(T_m - K.K_m K_s T)s + 1 + K.K_m K_s = 0 \tag{5}$$

The pole for the closed loop transfer function is as

$$s_p = \frac{1+K.K_m K_s}{K.K_m K_s T - T_m} \tag{6}$$

From Eq.6 we see that the stability condition is

$$K.K_m K_s T < t_m \tag{7}$$

Therefore K must be adjusted to satisfy the condition.

$$K < \frac{t_m}{K_m K_s T} \tag{8}$$

Otherwise the system becomes unstable. For three term Taylor representation of e^{-sT} we find characteristic equation as

$$1 + T_m s + K.K_m K_s (1 - ST + 0.5S^2 T^2) = 0 \tag{9}$$

Applying the Routh criteria for this equation we find the same stability condition as given in (8). The gain K is adjusted to get a stable system depending on other system parameters. If the delay process is random and bounded with known statistics we can find the driver gain to make the system stable [9].

IV. RESULTS

We used a low priced Logitech camera. The software has been written in C++. The measurement system is tested first by using a standard product whose measurements are known precisely. The computer computes necessary scaling factor. Next, we enter the required size in millimeters. Then, the motor speed is adjusted by the control system to obtain the rubber band with the required width size The system sensitivity is adjusted by driver circuit gain very easily. The same control system can be used for cable manufacturing processes because of the same nature of production method. Figure 5 shows a sample picture of a rubber band produced by using the control system. For different sizes of the band we found relative errors depicted in Figure 4.As seen from the picture for small sizes the error is large. For the large products, relative error seems to be smaller compared to the small size products. The proposed system is relatively low cost compared to the commercial high priced systems.

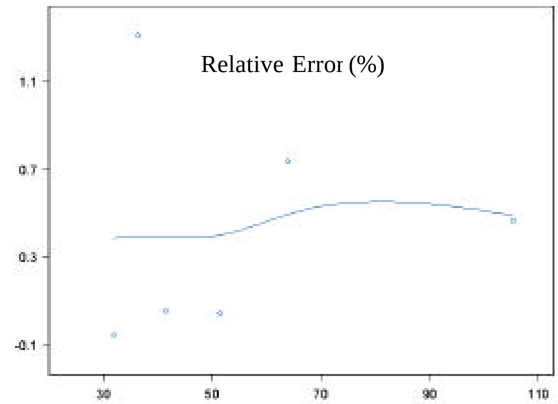

Figure 4. Relative error for different sizes

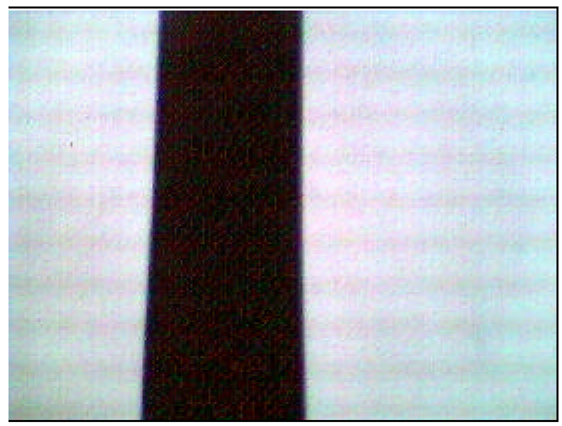

Figure 5. A sample image for the rubber band was captured from the digital camera.

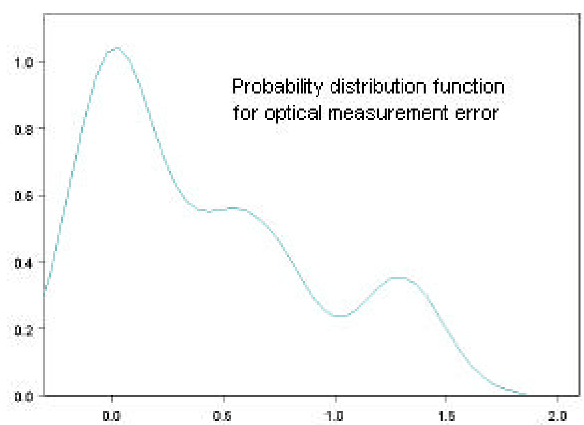

Figure 6. Probability density function for the optical measurement system

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