Variable Gain Intelligent Control of Multi-motor Synchronization System

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Abstract - Multi-motor Synchronization Control (MSC) is a key issue in industrial production. Based on the conventional PID algorithmic, a variable gain intelligence control scheme is proposed in this paper. Consequently, this new idea was implemented by PLC controller in the stretch tension & synchronization control system of a wide-fabric heating-shaping machine. Such a system has perfect characteristics, e.g. rapid response, overshoot-less and no steady-state errors. In addition, easy programming, simple wiring and strong anti-jamming ability lead to a stable operating performance. The proposed scheme can be widely used in electrical motor synchronization control demands arising from the spinnery, paper mill and mechanical production lines.

Keywords - Synchro-control Variable Gain Intelligence Control PLC

INTRODUCTION

In the motion control area, one of the most challenging problems is the synchronization control of multiple motors. [1]From the electrical connections between the connection of motors, the synchronization control can be divided into two categories: one is the independent motor, and the other has the connection between the motors. In The first situation, there is no physical link between the motors, synchronous motor driven is the main production process or power needs, such as steel mills, caster and rolling mill belong to such synchronous drive; in the second situation, the state motor mutual influence between the existence of serious coupling, such as many factory production lines, assembly lines or textiles, dyeing and papermaking are in this category, such as synchronous winding drive.

Multi-synchronous motor control study mainly is aiming at the second kind of synchronized form [2], control method is roughly divided into four stages: 1) based on the same voltage to the parallel operation, the motors speed is linking to the same voltage. This approach routes is simple and easy, but the starting of synchronization is poor and anti-jamming ability is bad; 2) based on a given voltage of the same series of operations, the main motor output is used as the speed setting to others. This method is simple, but tracking performance of starting and anti-jamming ability are not very satisfactory ; 3) Based on the control method of the compensation principle, one motor is used as primary motor, while others are driven motors. Output of the primary motor's rotational speed is used to settle the rotational speed of the driven motors. The speeds of the primary and the driven motors are compared, and the differential value is added to the input of the driven motors control. This method of synchronization accuracy and load disturbance has been greatly improved. In practical application it is most widely used. The different ways and means of compensating produce different effects; 4) based on modern control theory, such as fuzzy control to divide fuzzy interval and the corresponding membership function, control parameters are adjusted [3][4][5][6].

Currently, the third control method has been widely used, but because of the various disturbance factors in the course of motor operation, the synchronous error of motors will be produced. So the motor speed loop is remained in the operation. Based on the third control method and practical experience, a variable gain Intelligence control scheme is proposed in this paper.

VARIABLE-GAIN INTELLIGENT CONTROL

In the conventional closed-loop control system, after the parameter of the controller is fixed and no longer change in the course of operation. For proportional control, when the gain value of the setting is big, correcting capability is strong, and the system response quickly, but the system overshoot is big. When the value of the gain is set small, the system has overshoot-less and no shocks, but the system response is slow and steady-state errors are big. For the integral control, integral action is too strong. The response is quick, but it will generate saturated phenomenon of integral; when the integral role too small, system response too slowly.[7]

In order to solve the contradiction of the Conventional PID between rapidity and overshoot, this article proposed variable gain intelligence control scheme. When the error is big, the big gain is selected to obtain the fast response; gradually it reduces along with the error, the gain also changes along with reduces. This is used to guarantee the system does not have the overshoot. In addition, in order to enhance the tracing of position to the precision, when smallest gain is transferred, the PI control is carried out.

The control word can be set by the experiment method. In the low-speed, medium-speed and high-speed cases separately, control parameters have been set through actual operation. Each of cases the parameters is divided into several levels. According to the changing rate of error or size, the controller looks up for corresponding control parameters. The system obtains adjustable parameters in this way, it acts as fuzzy reasoning, but the process is designed to be simple and operated reliably. It has obtained the very good control effect.

This new idea was implemented by PLC controller in the stretch tension & synchronization control system of a wide-fabric heating-shaping machine. The heating-shaping machine sketch map is shown in figure 1. In the heat-setting process, it requests the draw roll and drive roll being parallel, and namely front and rear draw-motors run synchronously. Simultaneously in the process it also requires stretching the fabric vertical tension with the technical requirements.

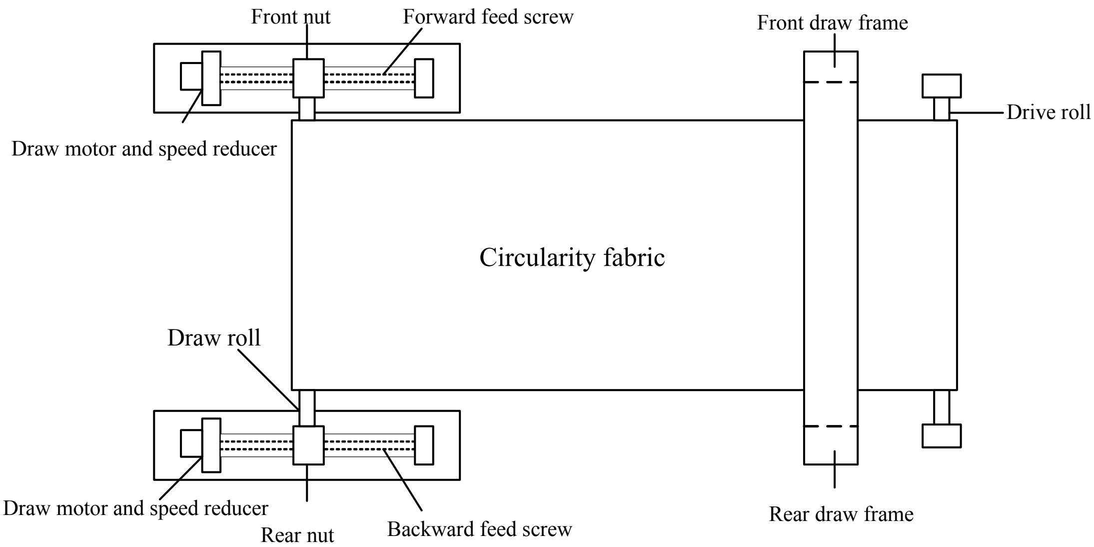

Fig.1: the Heating-shaping Machine Sketch Map

THE STRETCH TENSION AND SYNCHRONIZATION CONTROL SYSTEM

A. The relation of fabrics tension and synchronization control

Fabric tension has been operated by the draw roll and drive roll, the circularity fabric has been drawn by the draw roll in operation, which is equivalent to the linear velocity difference of drive roll and draw roll, the cumulative result of the stretch fabric deformation results in a fabric internal tension. Tension of fabric is F;v1, v2 are the drive roll's and draw roll's linear velocity. The linear velocity of drive roll and draw roll will directly affect the fabric tension. According to the hook's law, fabric tension F is :

$$F = \frac{AY}{L}\int_0^{t_1}(v_1 - v_2)dt \qquad (1)$$

Where Y is elastic mould amount of the fabric; A is sectional area of the fabric; L is the distance between the drive roll and the draw roll; t_1 is running period of equipment. The key question of this system is the speed control, so through control the linear velocity of drive roll and draw roll v_1, v_2, added the fabric tension F detected by the sensor form a closed loop system.

B. System hardware design

The stretch tension & synchronization control system includes OMRON C200HG PLC[7], high-speed counting unit CT021, analog output unit DA003, two 590-type drives[8], two E6B2-CWZ5C type rotary encoders (360P/R) and two 13KW DC motors and reducers. As programmable controller has the features of strong reliability and the ability obvious and simple programming, it is particularly applicable to complex industrial production environment. This system uses PLC as controller. EUROTHERM produce the 590-type drive is a fully digital DC motor speed govemor that can achieve single-quadrant or four-quadrant operation of motor control, high performance and speed feedback control system. It provides guarantee for the synchronous control. Drawing Control System is shown in figure 2.

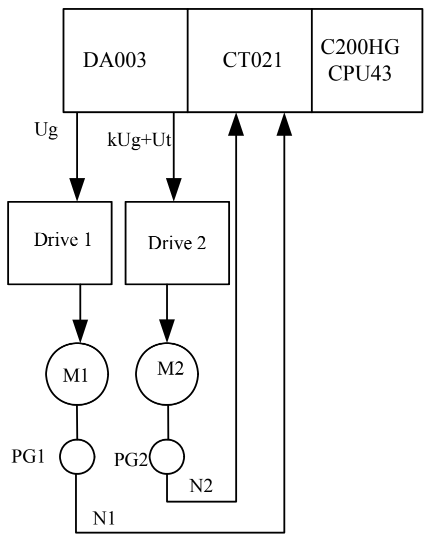

Fig 2: Synchronization Control System Hardware Structure

C. System software design

The stretch tension & synchronization control system belongs to the position following system. As the principal motor, the front-draw motor's moving distance is L1, while moving distance of the rear-draw motor-as the subordinate motor is L2. To ensure draw roll and drive roll axis to be parallel, it requires L1 equal to L2[9]. As shown in figure 2 N1 that is front-draw motor's speed coder that works as the location order of the rear-draw motor; rear-draw motor's speed coder N2 is used as the position feedback It constitutes the position following closed-loop control system. We introduce feed-forward in order to gain synchronization in the low-speed and the start&stop. Control principle is shown in figure 3. Where a1 is Feed-forward coefficient, a2 is the speed coefficient for the two motors.

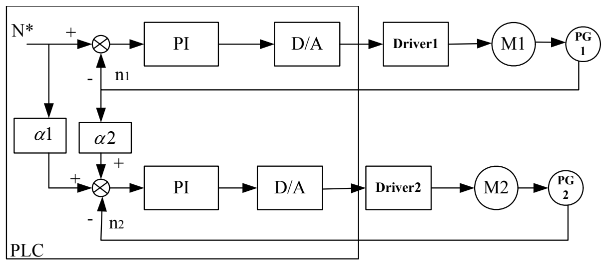

Fig. 3: Synchronization Control Schematic Diagram

Counter A of high-speed counter unit CT021 count the N_1 and it is stored in IR172 and IR173; N2 is counted by counter B and is put into IR174 and IR175, the difference between the two was the error. In the actual operation, the uniformed setting U_g is applied to the driver of front-draw motor, and the signal U_t of counting deviation-position error is added to U_g , which will be applied to the rear-draw motor. This paper designs the stretch tension & synchronization control system, it uses the block compare instruction BCMP (68) to achieve variable gain control.

BCMP(68) command function that compares the source data to 16 ranges (defined by 16 lower limits and 16 upper limits) and turns ON the corresponding bit in the result word when the source data is within a range. In this paper, the error and parameters are divided into 16 intervals. Comparing the error's amplitude of real time detection to the error range set previously, the analog control quantity is output by the output unit using the corresponding gain and integrating parameters according to the comparing result. In this way, the changeable gain intelligence control become true. Specific gain parameters required the object through laboratory and field-testing setting. To improve the accuracy of position, when the smallest gain is transferred, the PI control can be carried out. The variable gain control synchronous flow chart is shown in figure 4.

D. System movement result and analysis

In actual operation of the system, stretch roller moves 6000mm, and accompany error is in the 60~100 pulse scope, namely the error is no more than 83.3 μm . When implementing PI control, the error can converge to zero. The actual operating results show that the system dynamics and stable performance meets the target requirements.

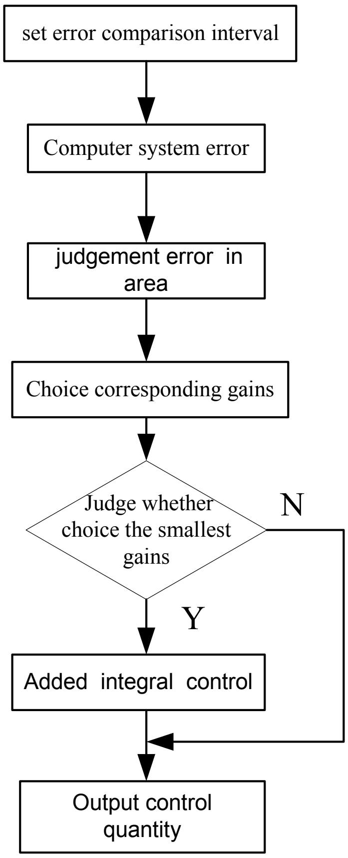

Fig. 4: Process Flowchart

CONCLUSION

The variable gain intelligence control scheme that is proposed in this paper has been carried on in the practice in many engineering project. It obtains the very good control effect, e.g. rapid response, overshoot-less and no steady-state errors. In addition, easy programming, simple wiring and strong anti-jamming ability lead to a stable operating performance. The proposed scheme may be widely used in electrical motor synchronization control demands arising from the spinnery, paper mill and mechanical production lines.

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APPENDIX

Fabrics Tension Mathematical Model

$$dp = dp_2 - dp_1 = (\rho_2 v_2 - \rho_1 v_1)dt \qquad (1)$$

$$\rho_2 d\Delta l = dp \qquad (2)$$

$$d\Delta l = (v_2 - v_1 \frac{\rho_1}{\rho_2})dt \qquad (3)$$

$$\frac{d\Delta l}{dt} = v_2 - v_1 \frac{\rho_1}{\rho_2} \qquad (4)$$

$$\rho_2 = \rho_1 \left(1 - \frac{\Delta l}{l} \right) \qquad (5)$$

$$\frac{d\Delta l}{dt} = v_2 - v_1 \frac{\rho_1}{\rho_1 \left(1 - \frac{\Delta l}{l} \right)} \qquad (6)$$

$$\frac{1}{1 - \Delta l / l} \approx 1 + \frac{\Delta l}{l} \qquad (7)$$

$$\frac{1}{v_1} \frac{d\Delta l}{dt} + \Delta l = \frac{1}{v_1}(v_2 - v_1) \qquad (8)$$

$$T \frac{d\Delta l}{dt} + \Delta l = T\Delta v \qquad (9)$$

$$T \frac{d\tilde{l}}{dt} + \tilde{l} = \tilde{v} \qquad (10)$$

$$F = AE\tilde{l} \tag{11}$$

$$\tilde{F} = AE\tilde{l} \Big/ F_0 = k_0 \tilde{l} \tag{12}$$

$$T\frac{d\tilde{F}}{dt} + \tilde{F} = k_0 \tilde{v} \tag{13}$$

Where ρ_1, ρ_2 are stretch fabrics unit at the district length weight; q_1,q_2 are corresponding weight fabrics; v_1、v_2 are corresponding line speed; Δl is the change of stretch length as compared to the origin; T is is time constant and F is the fabrics tension.