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DEVELOPMENT OF SIMULATION MODEL OF STRIP PULL SELF-REGULATION SYSTEM IN DYNAMIC MODES IN A CONTINUOUS HOT GALVANIZING LINE

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Abstract. *The paper deals with the peculiarities of development of simulation model of strip pull self-regulation system in a continuous hot galvanizing line. The results of simulation modelling are provided.*

Keywords: continuous hot galvanizing line, control system, dynamic mode

EWOLUCJA MODELU SYMULACYJNEGO SYSTEMU SAMOREGULACJI NAPRĘŻENIA TAŚMY W TRYBIE DYNAMICZNYM W LINII CIĄGŁEGO CYNKOWANIA NA GORĄCO

Streszczenie. *W artykule rozpatrzono cechy szczególne konstruowania modelu symulacyjnego systemu regulacji naprężenia taśmy w linii ciągłej cynkowania na gorąco. Przedstawiono wyniki badań symulacyjnych.*

Słowa kluczowe: linia do ciągłej galwanizacji na gorąco, system sterowania, tryb dynamiczny

Introduction

A continuous hot galvanizing line (CHGL) is a complex electromechanical system, the functioning reliability and quality of which depends on physical and mechanical properties of the treated metal strip and work modes of a multimotor drive interrelated through the strip.

When the line head end is stopped for the metal strip coil change and welding of the strip ends, the unit's middle technological part continues movement at the operating speed as the strip is being pulled from the vertical looper. At this time the dynamic processes leading to longitudinal vibrations in the treated strip occur. As a result, the so-called "riffles" are formed in the treated strip during treatment in the thermochemical treatment (TCT) furnace under the effect of high temperature that leads to rejection of the material.

1. Development of simulation model

On CHGL there were held experiments on definition of dynamic properties of the treated metal strip [9].

For strip pull stabilization in the furnace during the stopping of the line head end it is offered mounting of a roller working in the torque mode before the TCT furnace. A lower roller of the Pulling Station 2 (the active roller) will be used for this purpose. During the movement of the looper car the roller will make progressive motion against the strip movement, thereby creating additional pull in the strip. The error ratio of the effective and preset pulls will be applied to the motor shaft of this roller as a static resistance moment.

The resistance moments of the Pulling Station 2 motor actuators are described by the equations [2]:

$$\left.\begin{aligned} M_{c5} &= \left(F_{5,6} + F_{fr}\right)\frac{r_5}{i_5} + \frac{a \cdot n_5}{60} + K_{red}F_4 \\ M_{c6} &= \left(-F_{5,6} + F_{fr}\right)\frac{r_6}{i_6} + \frac{a \cdot n_6}{60} + K_{red}F_7 \end{aligned}\right\} \quad (1)$$

where M_{c5}, M_{c6} are upper and lower rollers' resistance moments, Nm; $F_{5,6}$ is the pulling capacity in the strip, N; F_{fr} is the friction force, N; r_5 and r_6 are the upper and lower rollers' radii; i_5 and i_6 are the upper and lower rollers' gear reduction rates; a is the dissipation factor which characterizes natural vibrations damping process in the system, N·m·s; n_5 and n_6 are the upper and lower roller motors' speed of rotation, r/min; K_{red} is the reduction factor that takes into consideration the reduction of the neighbouring interrelating masses to one shaft; F_4, F_7 are the pulling capacities in the strip in the looper and in the work site of the TCT furnace relatively, Nm.

The force which the active roller will act with on the treated strip is defined from the equation [6]:

$$F_p = \frac{m d\upsilon}{dt}, \quad (2)$$

where m is the active roller mass, kg; υ is the active roller linear speed; d/dt is the differentiation operator.

A static moment given by the strip to the pinch station 2 rollers during the movement of the active roller is defined by the formula [4]:

$$M_{add} = \frac{r}{i}F_p, \quad (3)$$

where r is the radius of the active roller block; i is gear reduction rate.

Based on the progressive motion of the active roller the equations (1) will take on the form [10]:

$$\left.\begin{aligned} M_{c5} &= \left(F_{5,6} + F_{fr}\right)\frac{r_5}{i_5} + \frac{a \cdot n_5}{60} + M_{add} + K_{red}F_4 \\ M_{c6} &= \left(-F_{5,6} + F_{fr}\right)\frac{r_6}{i_6} + \frac{a \cdot n_6}{60} - M_{add} + K_{red}F_7 \end{aligned}\right\} \quad (4)$$

where M_{add} is the moment transferred to the strip by the active roller's progressive motion.

The static moment transferred by the strip will influence the motor shaft of the lower roll of the TCT furnace at the active roller's progressive motion [1].

The equation of the resistance moment of the lower roller of the furnace treatment site will be as follows [5]:

$$M_{c8} = \left(-F_{7,8} + F_{fr}\right)\frac{r_8}{i_8} + \frac{a \cdot n_8}{60} + K_{red}F_6 + M_{add} \quad (5)$$

where $F_{7,8}$ is pull capacity taking place between the two interrelating masses of the TCT furnace rollers, N; F_{fr} is the friction force, N; $r_{7,8}$ is the lower roller (reduction) radius, m; i_8 is the gear reduction rate; a is the dissipation factor that characterizes natural vibrations damping process in the system N·m·s; n_8 is the lower roller's speed of rotation, r/min; K_{red} is the reduction factor that takes into consideration the reduction of the neighbouring interrelating masses to one shaft; F_6 is the pulling capacity in the strip in the Pulling Station 2; M_{add} is the static resistance moment transferred by the strip at the active roller's progressive moment.

The structural flowcharts of mathematical models of the Pulling Station 2 and the TCT furnace treatment site with consideration of introduction of the active roller's influence are given in Figures 1, 2 [3].

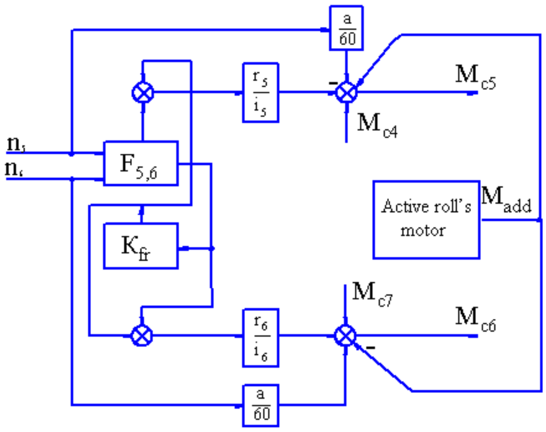

Fig. 1. The structural flowchart of the Pulling Station 2 motor actuator mathematical model

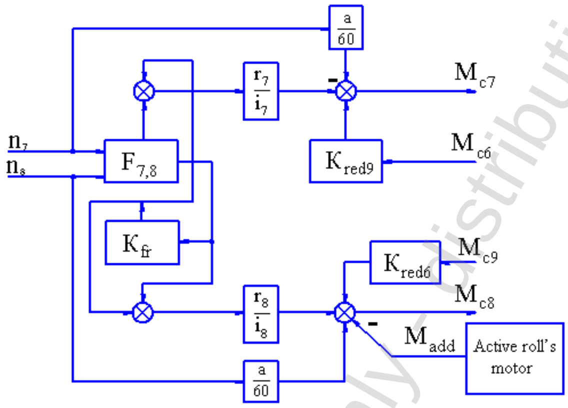

Fig. 2. The structural flowchart of the TCT furnace treatment site mathematical model

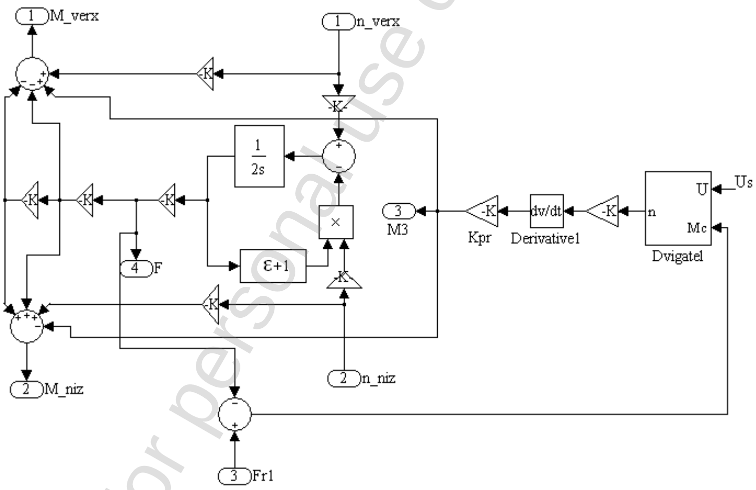

Fig. 3. The simulation model of the Pulling Station 2 motor actuator

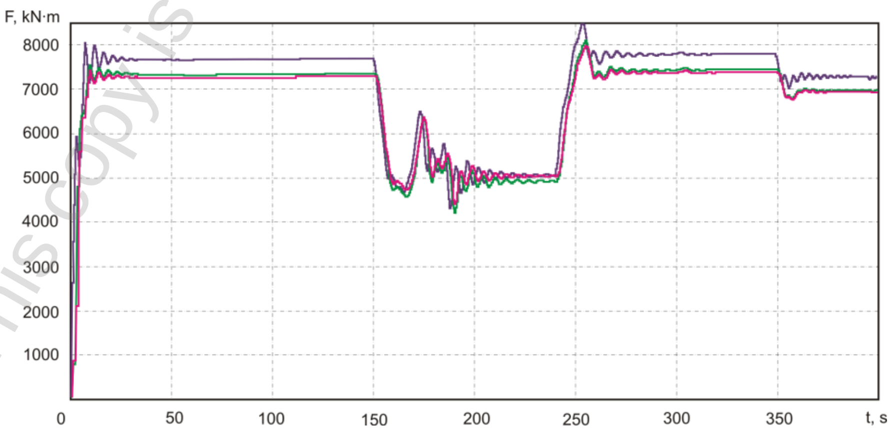

Fig. 4. The oscillograms of pulling capacities in the strip before the introduction of the active roller's action

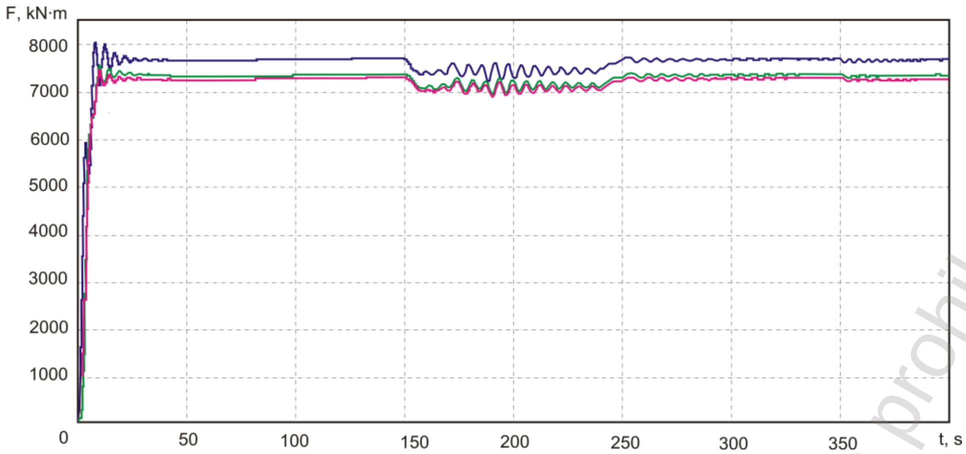

Fig. 5. The oscillograms of pulling capacities in the strip after the introduction of the active roller's action

By the received structural flowcharts in the Simuling package of the MATLAB 7 system there were built simulation models of the mechanisms of CHGL motor actuators with consideration of the active roller motion [8]. The simulation model of the Pulling Station 2 motor actuator is given in Figure 3.

The input values in the model are: the voltage supplied to the stator winding of the active roller's motor; the rotation frequencies of the motors of the Pulling Station 2 upper and lower rollers; the static resistance moment applied to the active roller's motor shaft formed by difference of signals of the effective F and preset F_{r1} pulls. The output values are the resistance moments of the Pulling Station 2 upper and lower rollers. The active roller's motor is represented by the "Dvigatel" subsystem [7].

The oscillograms of the pulling capacities in the strip in the TCT furnace before the introduction of the active roller action and after it are given in Figures 4, 5.

The oscillograms display (from top to bottom relatively) the signals of the pull capacities of the Pulling Station 2 at the strip treatment site in the TCT furnace and at the site of the furnace with pullers.

2. Results

The analysis of the oscillograms shows that after introduction of the active roller's action the amplitude of pull capacities vibrations reduced by 85%. The amplitude of the low-frequency component of pulling capacity vibrations in the strip makes up 0,3 kN, that is a norm. There is observed an increase of the low-frequency component in the end of the process of pulling the strip from the looper by 45%. It is connected with the increase of the strip pull in the looper in connection with the reduction of its length. As the high-frequency component does not take part in the process of folding, so we neglect its amplitude change.

3. Conclusion

Therefore, the developed mathematical and simulation models adequately reflect the processes in the treated strip in dynamic modes.

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