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The process of simulation system modeling of automatic band tension stabilization in a permanent hot zinc-plating line in dynamic modes

Abstract. *The article describes the peculiarities of the simulation system modeling process of band tension control in a permanent hot zinc-plating line. There is also described the results of simulation modeling.*

Streszczenie. *W artykule zostały rozpatrzone szczególne przypadki symulacji modelu systemu regulacji natężenia taśmy w linii do ciągłego cynkowania na gorąco. Przedstawiono wyniki symulacji. (**Symulacja modelu systemu automatycznej stabilizacji natężenia taśmy w warunkach dynamicznych w linii do ciągłego cynkowania na gorąco**).*

Keywords: hot zinc-plating line, thermo-chemical treatment oven, band pulling force, active roller, resistance moment, electric drives, simulation model.
Słowa kluczowe: linia to cynkowania na gorąco, piec do obróbki termochemicznej, pasmo siły, aktywna rolka, moment oporu, napęd elektryczny, model symulacyjny.

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Introduction

A permanent hot-zinc plating line (HZPL) is a complex electromechanical system whose functioning reliability and quality depends on the physico-mechanical properties of a treated metal band and on the modes of operation of the multi-motor drive interconnected through a band.

When the head part of the line is stopped to replace a roll of metal band, the technological part of the unit continues to move at a working speed during the welding of the ends of the band, which is due to the band extraction from the vertical loop device. After the start of the head part the metal band begins to fill the loop device, which causes the dynamic processes that lead to longitudinal vibrations of the tension in the treatment zone. As a result, in the treated band there occur the so-called "folds" during the process in the thermo-chemical treatment oven (TCO) under the high temperature, thus leading to a defect.

Development of mathematical models

Some experiments were carried out on HZPL in order to define the dynamic properties of the treated metal band [1].

In order to stabilize the band tension in the oven during the stop of the head part of the line we suggest the installation of a roller operating in an intermittent mode before the TCO oven. The lower roller of the Pulling Station 2 (active roller) will be used for this part. During the movement of the loop device carriage the roller will make translational movements against the band direction, thus creating additional tension in the band. The value of the mismatch of the actual and given tensions will be applied as the moment of static resistance to the motor shaft of the roller.

The resistance moments of electric drives of the Pulling Station 2 are described by the following formula [2]:

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

where: M_{c5}, M_{c6} - the resistance moment of the upper and lower rollers, $F_{5,6}$ - band pulling force, F_{fr} - friction force, r_5 and r_6 - the radiuses of the upper and lower rollers, i_5 and i_6 - the reduction ratio of the upper and lower rollers, a - the dissipation coefficient, characterizes the process of damping of natural oscillations in the system, n_5 and n_6 - electric motors rotation frequency of the upper and lower rollers, K_{red} - the reduction coefficient, takes into account the reduction to the shaft of the adjacent interacting masses, F_4, F_7 - the band pulling force in a loop device and in the area of the T_{CO} oven treatment respectively.

The force of the active roller which will work on a treated band is determined by the following formula [6]:

$$F_{\text{p}} = \frac{md\upsilon}{dt} \tag{2}$$

where: m - the weight of the active roller, υ - linear speed of the active roller, d/dt - differentiation operator.

The transmitted by the band static moment given to the rollers of the Pulling Station 2 during the movement of the active roller is determined by the following formula [4]:

$$M_{\text{add}} = \frac{r}{i}F_{\text{p}}\,, \tag{3}$$

where r - the radius of the drum of the active roller, i - the reduction ratio.

Due to the translational movement of the active roller the formula (1) will be as follows:

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

where M_{add} - the moment, transferred to the band by the translational movement of the active roller.

During the translational movement of the active roller on the motor shaft of the lower roller of the TCO oven there will operate the static moment transferred by the band.

The formula of the resistance moment of the lower roller of the TCO oven treatment area will be as follows [5]:

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

where: $F_{7,8}$ - band pulling force, which occurs between two interacting masses of the TCO oven rollers, F_{fr} - friction force, $r_{7,8}$ - the lower roller radius, i_8 - the reduction ratio, a

- the dissipation coefficient, n_8 - rotation frequency of the lower roller, K_{red} - reduction coefficient, takes into account the reduction of the shaft to one of the interacting mass, F_6 - the band pulling force in the Pulling Station 2, M_{add} - the moment of static resistance transferred by the band during the translational movement of the active roller.

Structural schemes and simulation models

The structural schemes of mathematical models of electric drives of the Pulling Station 2 and the TCO oven treatment area including the effects from the active roller are shown in Figures 1,2 [3].

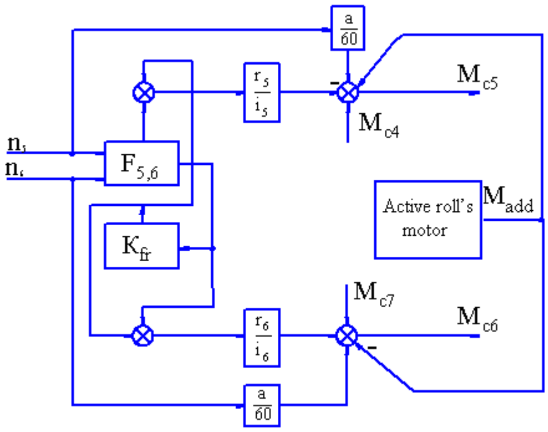

Fig.1. The structural scheme of mathematical model of electric drive of the Pulling Station 2

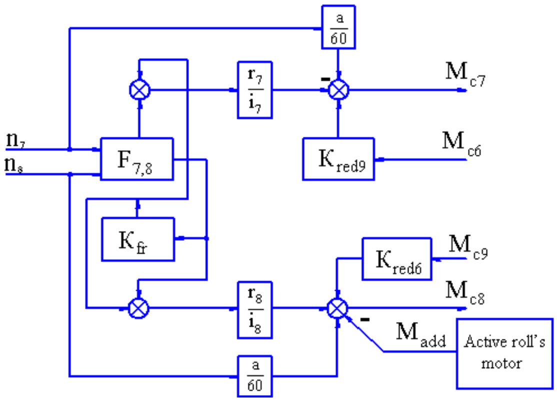

Fig.2. The structural scheme of mathematical model of the TCO oven treatment area

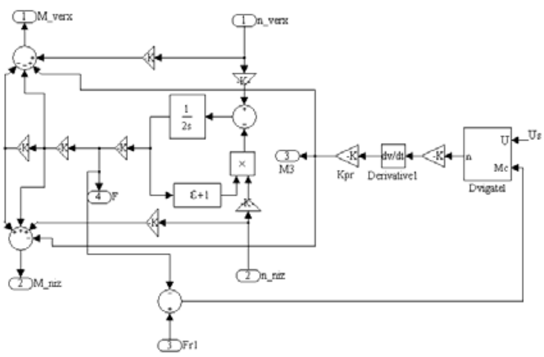

Fig.3. The simulation model of electric drive of the Pulling Station 2

According to the obtained structural schemes in the MATLAB 7 Simulink package there were built seven simulation models of HZPL electric machinery including the movement of the active roller [8]. The electric drive simulation model of the Pulling Station 2 is shown in Figure 3.

The input values in the model are: the tension applied to the stator winding of the active roller motor; the rotation frequency of the upper and lower roller motors of Pulling Station 2; moment of the static resistance applied to the shaft of the active roller motor formed by the difference of the signals of the actual F and given Fr1 tensions. The output quantities are the moments of resistance of the upper and lower rollers of the pulling station №2. The active roller motor is described by the Dvigatel subsystem [7].

Simulation results

The band pulling force oscillograms before and after the action of the active rollers are shown in Figures 4,5.

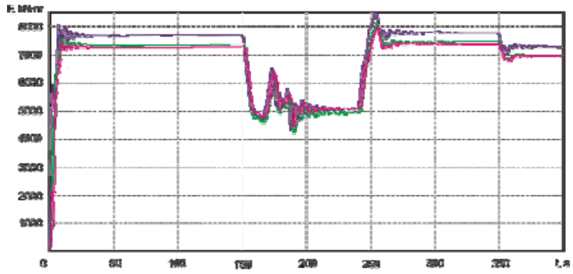

Fig.4. The band pulling force oscillograms before the action of the active roller

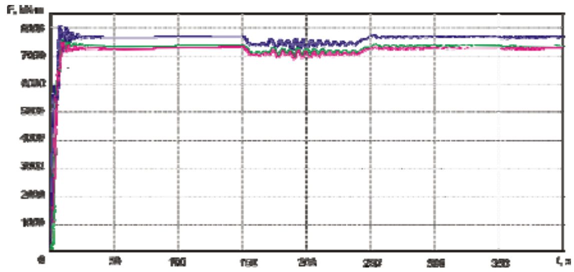

Fig.5. The band pulling force oscillograms after the action of the active roller

According to the oscillogram figures there are located from top to bottom, respectively, the pulling force signals of the pulling station №2, on the TCO oven treatment area and on the oven area with tension rollers.

Conclusion

The analysis of the oscillograms shows that after the action of the active roller the amplitude decreased on 85%. The amplitude of the oscillation-frequency component of the band pulling force is 0,3 kN, which is the norm. There was a 45% increase in high-frequency component of oscillations at the end of the process of pulling out the band from the loop device. It was connected with the increase of the band tension in the loop device in connection with the decrease of its length. Since the high-frequency component is not involved in the process of fold formation in the band, the change in its amplitude is neglected.

Thus, the developed mathematical and simulation models adequately reflect the processes in the band treated area in the dynamic mode.

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