Olessya YUCHSHENKO[1], Waldemar WÓJCIK[2]

K.I. Satpayev Kazakh National Technical University (1), Lublin University of Technology (2)

Stress dependence on the band thickness in a continuous hot zinc-plating line

Abstract: *The article describes the dependence of stress on the thickness of a metal band during heat treatment. As a result of simulation the directly proportional dependence of the stress force on the band thickness was established.*

Streszczenie: *Artykuł opisuje zależność naprężenia od grubości taśmy metalowej, podczas obróbki cieplnej. W wyniku analizy modelowania symulacyjnego ustalono wprost proporcjonalną zależność siły napięcia od grubości taśmy.* ***Zależność naprężenia od grubości taśmy metalowej, podczas obróbki cieplnej***

Keywords: band pulling force, coefficient of rigidity, the input collector, simulation model
Słowa kluczowe: siła ciągnienia taśmy, współczynnik sztywności, magazynek wejściowy, model symulacyjny

doi:10.12915/pe.2014.01.14

Introduction

To improve the corrosion resistance of cold rolled metal band it has to be galvanized on a continuous hot zinc-plating line.

Electromechanical system of a continuous hot zinc-plating line (HZPL) presents a multimotor actuator which is interconnected with the use of a band [10].

The central technological part of the unit consists of the mechanisms for transporting the band: pulling station number 1, a vertical input collector, pulling station number 2, and rollers of thermo-chemical oven (TCO). In the thermo-chemical oven the band undergoes thermo chemical treatment in protective atmosphere.

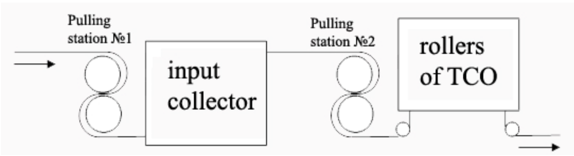

Fig.1. Central technological part of HZPL

Before the galvanization the band is heated in a thermo-chemical oven, TCO.

The following operations take place in TCO, the thermo-chemical oven:

- band heating in the flame oven in the atmosphere of incomplete combustion of propane-butane products;
- final heating and band exposure in the oven with radiation tubes in the atmosphere of hydrogen shielding gas;
- band cooling in the area of a closed cooling system.

The main influence on the mechanical properties of the treated metal is exerted by the maximum heating temperature and the speed of the band moving through the unit.

Dependence of stress on the band thickness

Band pulling force *F* appearing in the band is determined by the following formula [9]:

(1) $$F = C \cdot \Delta l = C \cdot l \cdot \varepsilon$$

where: *C* – a coefficient of band rigidity, Δ*l* - the absolute lengthening, *l* – the length of section tension, ε - modulus of elongation.

The coefficient of band rigidity is determined by the following formula:

(2) $$C = E \cdot S$$

where: *E* – elasticity modulus, *S* – cross sectional area of the band.

From the given formulas it is evident that the band pulling force is directly proportional to the cross sectional area of the band.

For structural steel there is dependence between the elastic modulus and the temperature [7]. The coefficient of band rigidity in different zones of the oven depends on the heating temperature. Therefore, in a simulation model for calculating the tension of the band stiffness coefficient in various areas of the furnace was put different [8].

There were performed a wide range of different analyses on determining the dynamic properties of the treated metal band in the HZPL [4].

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 stress in the treatment zone. As a result, in the treated 0,3 mm or less thick 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 [6].

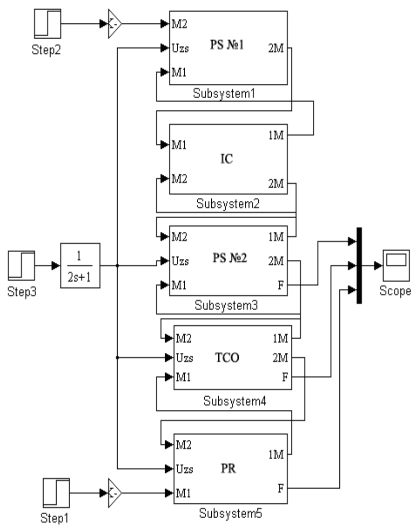

Fig.2. Simulation model of the HZPL middle technological part

Let us consider the dependence of the stress on the band thickness during the heat treatment in the TCO oven on the electric drives simulation model of the HZPL middle technological part shown in Figure 2. The mathematical models and block diagrams of the electric drives of the middle technological part were described in [3, 5].

The figure shows: PS №1 – pulling station №1, IC – input collector, PS №2 – pulling station №2, TCO – area of oven treatment; PR – pulling rollers of the oven. The input values of the model are: U_{zs} is stress result, M1 and M2 is moments of electric mechanisms resistance; 1M and 2M is the output values are moments of electric mechanisms resistance and F, band pulling force.

Simulation models subsystems 1 - 3 is presented in figures 3 - 5 respectively.

Simulation models of electric drive of area of oven treatment and pulling rollers of the oven (Subsystem 4 - 5) are identical to the simulation model of electric drive of pulling station №2.

Figure 6 (a, b, c) represents band pulling force oscillograms at the different band thickness in the given model: 0.4, 0.3 and 0.2 mm respectively [1, 2].

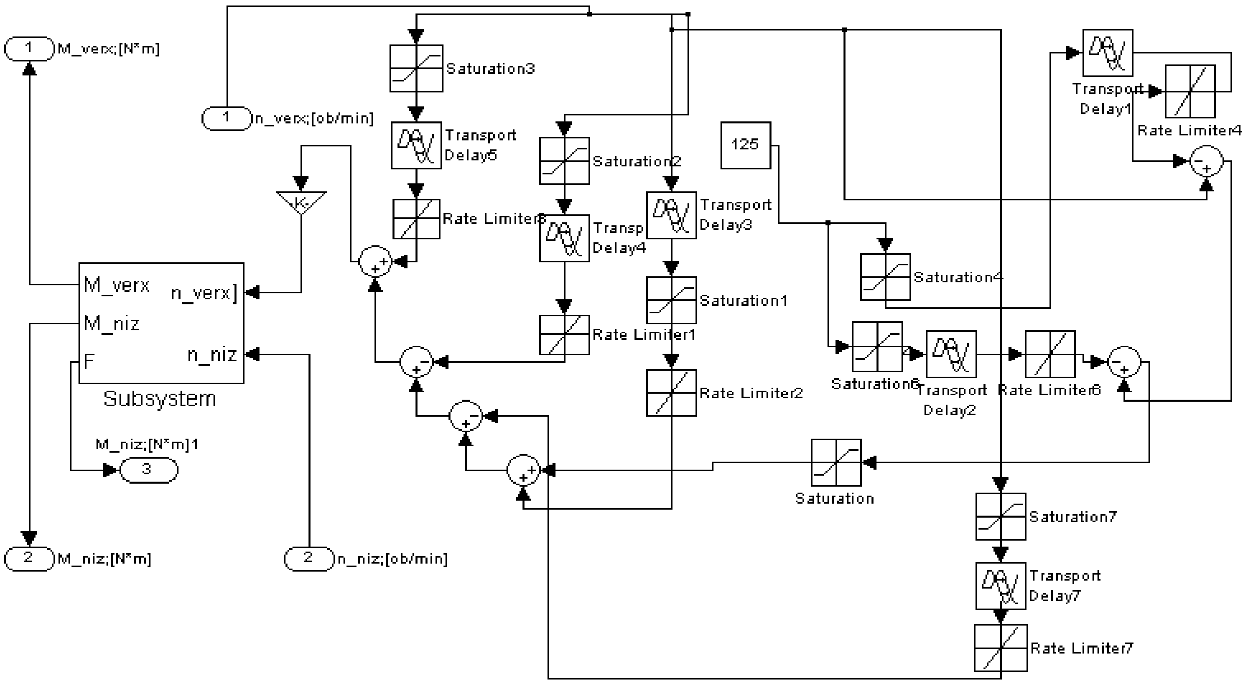

Fig.3. Simulation model of electric drive of pulling station №1

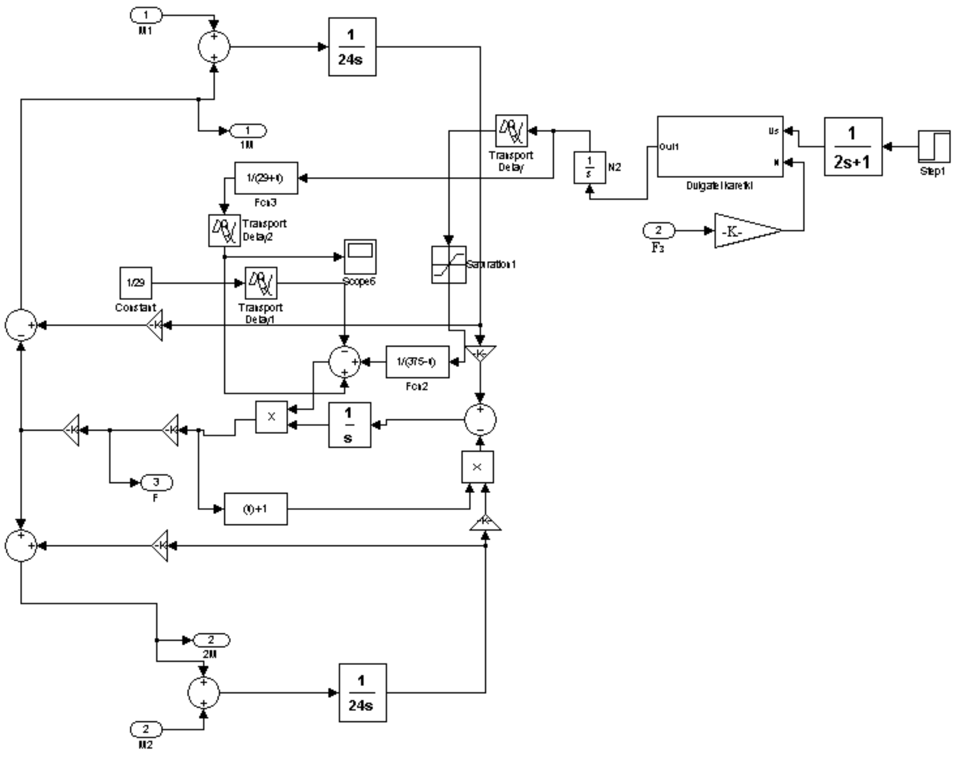

Fig.4. Simulation model of electric drive of input collector

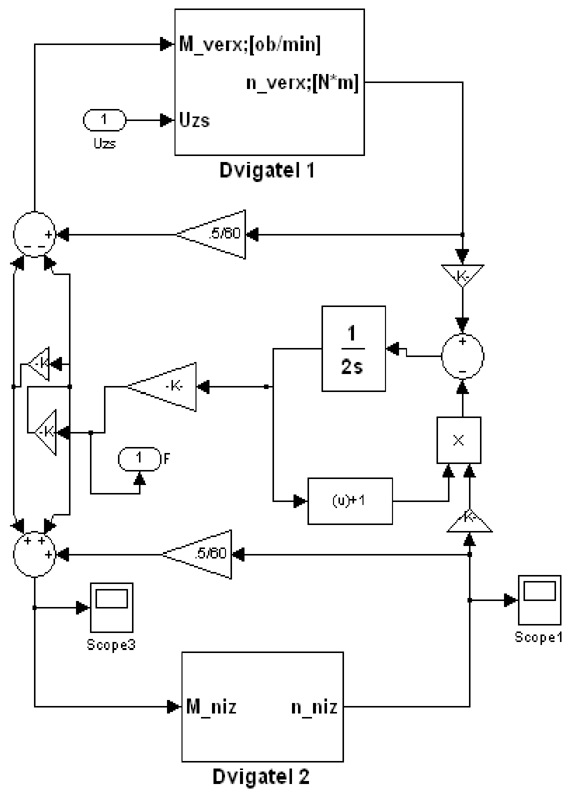

Fig.5. Simulation model of electric drive of pulling station №2

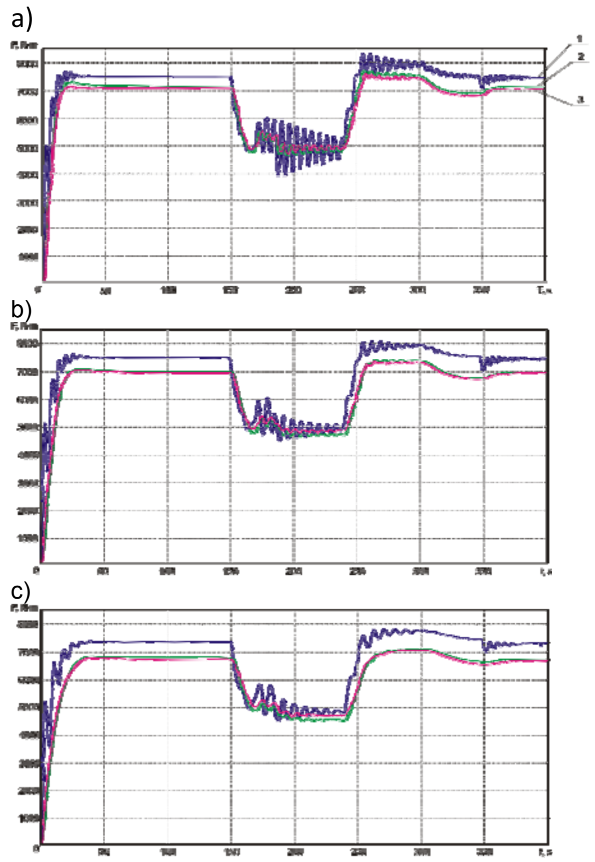

Fig.6. The band pulling force oscillograms: 1 – in the pulling station №2, 2 – in the TCO oven on the treatment area, 3 – in the TCO oven on the area with the pulling rollers; a) at the band thickness of 0,4 mm, b) at the band thickness of 0,3 mm, c) at the band thickness of 0,2 mm

The graphs from the top to the bottom on the oscillograms show the band pulling force in the pulling station №2, in the TCO oven on the treatment area, in the TCO oven on the area with the pulling rollers.

During the analysis of the oscillograms there can be seen a dramatic decrease of the amplitude and vibrational frequencies during the band transition from the pulling station №2 to the TCO oven treatment area, which is due to the increase of metal plasticity under the influence of high temperature. The oscillograms analysis in Figure 3 (a, b) showed that for the 0.3 mm thick band the pulling force is falling as compared to the 0.4 mm thick band: at 56 N in the pulling station №2, at 222 N in the TCO oven treatment area, at 167 N in the TCO oven area with the pulling rollers.

If the we reduce the band thickness by 0.1 mm the band pulling force will also decrease in comparison with the band pulling force at the 0,3 mm thick band: at 166 N in the pulling station №2, at 278 N in the TCO oven treatment area, at 111 N in the TCO oven area with the pulling rollers.

Conclusions

Thus, as the result of the simulation modeling analysis of the metal band pulling force at different thickness there was found the directly proportional dependence of the band pulling force on the band thickness during the heat treatment.

The received results are intended for optimization of HZPL methods of operation for band pulling force vibrations damping during the heat treatment and ends welding.

REFERENCES

[1] Alekseev V.V., Kozyaruk A.E., Zagrivny E.A. *Electrical Machines. Simulation of electrical machines drives of mining equipment*. Textbook. - St. Petersburg State Mining Institute (Technical University). St. Petersburg, 2006 (rus.)
[2] Dyakonov V., *Simulink 5/6/7*: Teach-yourself book. M., 2008 (rus.)
[3] Limonov L.G., *Automatic electric drive of the industrial machinery*. Karaganda, 2009 (rus.)
[4] Yuchshenko O., Experimental investigations of tension in the electro-chemical heat treatment furnace system. *Proceedings of the University. 4/2008.* Karaganda, Kazakhstan, pub.office KSTU, 2008. 77-79 (rus.)
[5] Yuchshenko O., Mathematical models of the electromechanical system of permanent hot zinc-planting line. *Proceedings of the University. No.3.* Karaganda: pub.office KSTU, 2010. - 87-89 (rus.)
[6] Yuchshenko O., Wojcik W., Development of electromechanical system of a vertical collector of permanent hot zinc-playing line. Informatyka, automatyka promiary w Gospodarce i Ochronie Środowiska, 03/2012, 5-8
[7] Pisarenko G.S., Yakovlev A.P., Matveev W.W., *Reference on materials resistance* - Kiev, «Naukova dumka», 1975 (rus.)
[8] Sharakshane A.S., Zheleznov I.G., Ivnitskii V.A., *Complex systems*. - M.: High school, 1977 (rus.)
[9] Sivyakova G.A., *The interconnected electric drive of the permanent annealing unit*. Abstract dissertation for the degree of candidate of technical sciences: 6/2/2007, Almaty, AIEC, 2007 (rus.)
[10] Svetlichnyi A., Leykovsky K., Information and control systems in the industry. *Modern automation technology*, № 3, Moscow, 2006, 18-26 (rus.)

Autors: *M.Sc. Olesya A. Yushchenko, K.I. Satpayev Kazakh National Technical University, Institute of Information and Communication Technologies. E-mail: olessyayuchenko@hotmail.com; prof. Waldemar Wójcik, Lublin University of Technology, Institute of Electronics and Information Technology, ul. Nadbystrzycka 38A, 20-618 Lublin, E-mail: waldemar.wojcik@pollub.p*