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COMPUTER SIMULATION OF THE ELECTROMECHANICAL SYSTEM OF A SECTION OF THE TRANSPORT ROLLER LINE

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Using the results of previous theoretical studies, we have developed a general computer model of the electromechanical system of the roller line section in the software MatLab/Simulink. The model takes into account the peculiarities of the driving asynchronous motor, the complex multi-mass spring mechanical part with three rollers, and the variable loads on the rollers when the slab of a given length is passing on them. The resulting computer model makes it possible to carry out simulation studies in order to analyze the influence of the parameters of the electrical and mechanical subsystems on the performance of the roller line section.

Key words: roller line, multi-mass spring mechanical part, computer modeling.

ІМІТАЦІЙНЕ КОМП'ЮТЕРНЕ МОДЕЛЮВАННЯ РОБОТИ БАГАТОМАСОВОЇ ЕЛЕКТРОМЕХАНІЧНОЇ СИСТЕМИ СЕКЦІЇ РОЛЬГАНГУ

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За результатами попередніх теоретичних досліджень у середовищі MatLab/Simulink розроблено загальну комп'ютерну модель електромеханічної системи секції рольганга, яка враховує особливості привідного асинхронного електродвигуна, складну багатомасову пружну механічну частину з трьома роликами, а також змінні навантаження на ролики секції при проходженні по них сляба заданої довжини. Отримана комп'ютерна модель дає можливість проводити імітаційні дослідження з метою аналізу впливу параметрів електричної та механічної підсистем на показники роботи секції рольганга.

Ключові слова: рольганг, багатомасова механічна система, комп'ютерне моделювання.

PROBLEM STATEMENT. Among the systems of electric machinery of rolling mills, roller lines have an important place [1]. Transport roller lines typically have a group electric drive in which a section of 3 to 10 rollers is driven by one or two motors. The rollers clip together by a mechanical transmission of either a conical gear or a gear chain [2]. Such an extensive mechanical system is characterized by a number of distributed and concentrated masses connected by spring ties and gears with gaps. It is most appropriate to study the dynamics of the group electric drive in a transport roller section by using computer simulation in the software MatLab/Simulink.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS. For the kinematic scheme of the mechanical part of a roller line section with three rollers, shown in Fig. 1, a mathematical model describing the dynamics of the system with 12 concentrated masses was developed in our work, based on the Lagrange equation of the second kind [3]. We developed the mathematical model that describes the time dependences of loads on three rollers when slabs of given length pass on them [4]. On the basis of these models, computer models that simulate the load on the rollers were developed in the software MatLab/Simulink. For the electric drive of roller sections, special induction motors are typically used. In our work [5], we have developed a series of computer models of an induction machine (IM). Using these models, it is easy to model in various combinations such phenomena as magnetic saturation in the core of the machine, the displacement of current in the bars of the rotor, and iron losses.

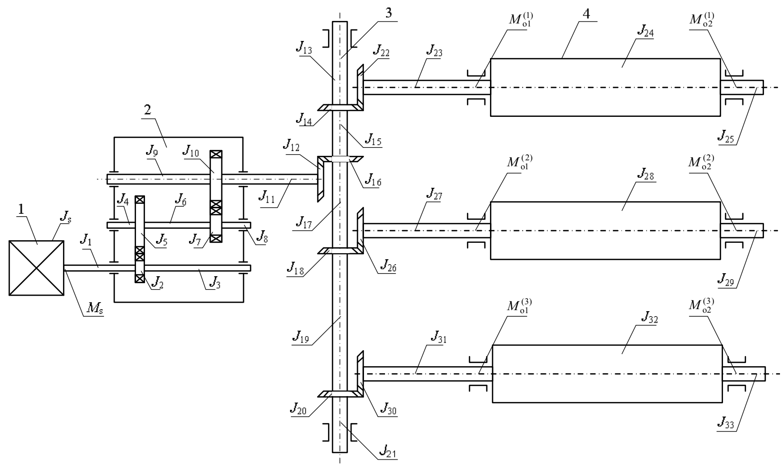


Figure 1 – Kinematic scheme of the roller line section with three rollers linked by gear transmission: 1 – IM; 2 – double step gear box; 3 – transmission with conical gears; 4 – transport roller

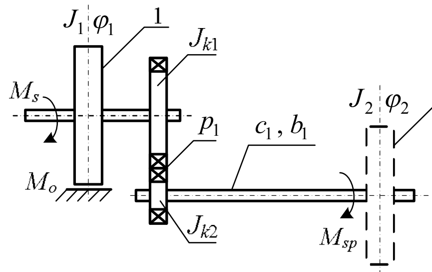
The aim of this work is to develop a simulation computer model of the entire electromechanical system of a section of the roller line, which will include a driving IM, a complex multi-mass mechanical part, and the transport of a slab on the rollers, causing variable static loads that are shared between the individual rollers, the moments of inertia variable over time, additional mechanical connections between the individual rollers, and more.

In order to facilitate the construction of computer models of complex mechanical systems in the software MatLab/Simulink, we have developed a number of specific models of standard subsystems from which you can easily make up any necessary models of systems.

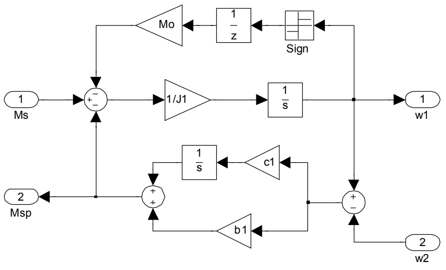
Fig. 2, a gives the kinematic scheme of the mechanical subsystem in which the concentrated mass (disk) with the moment of inertia J_1 is connected by gears with gear ratios $p_1 = d_{k1}/d_{k2}$ (d_{k1}, d_{k2} – diameters of gear wheels with moments of inertia J_{k1} and J_{k2}) with the spring axis, the parameters of which include the coefficient of elasticity c_1 and the damping factor b_1 due to internal viscous friction. To the input shaft of the subsystem the driving moment M_s and the moment of resistance of friction M_o are applied, and the elastic moment M_{sp} is obtained in the output shaft. The equation of motion of such a subsystem, obtained from the Lagrange equation of the second kind, is as follows:

$$J_1^{'}\frac{\mathrm{d}}{\mathrm{d}t}\omega_1 + p_1 b_1(p_1\omega_1 - \omega_2) + p_1 c_1(p_1\varphi_1 - \varphi_2) = M_s - M_o, \quad (1)$$

where $J_1^{'} = J_1 + J_{k1} + p_1^2 J_{k2}$ is the total moment of inertia of a disk with the gearbox reduced to input shaft, and φ_i, ω_i $(i = 1, 2)$ are the angles of position and angular speeds of input and output shafts correspondingly.



a)



b)

Figure 2 – Kinematic scheme (a) and the computer model (b) of one-mass mechanical subsystem connected through gear with an elastic shaft (Subsystem Masa-1sp_wal)

Based on equation (1), the computer model of one-mass subsystem with an elastic shaft is constructed (Fig. 2,b).

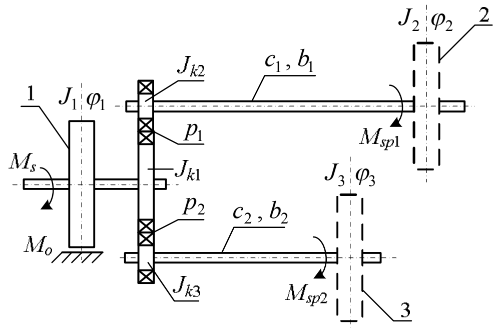
When a rotary mass is bound by the gear with two spring shafts (Fig. 3,a) that have corresponding parameters, the subsystem is described by the following equation of motion:

$$J_1^{'}\frac{d}{dt}\omega_1 + p_1 b_1(p_1\omega_1 - \omega_2) + p_1 c_1(p_1\phi_1 - \phi_2) + \\ + p_2 b_2(p_2\omega_1 - \omega_3) + p_2 c_2(p_2\phi_1 - \phi_3) = M_s - M_o. \quad (2)$$

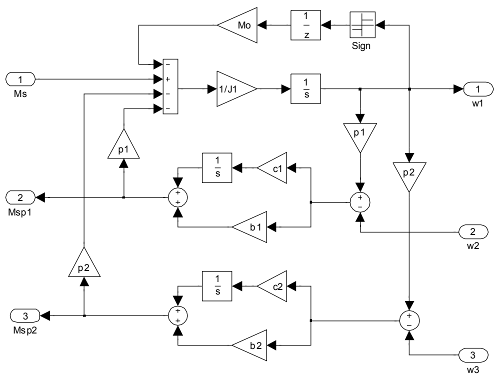
The computer model of such one mass subsystem with two spring shafts is shown in Fig. 3,b. On the outputs of the subsystem, two spring moments for each of the shafts are obtained:

$$M_{sp1} = b_1(p_1\omega_1 - \omega_2) + c_1(p_1\varphi_1 - \varphi_2); \quad (3)$$

$$M_{sp2} = b_2(p_2\omega_1 - \omega_3) + c_2(p_2\varphi_1 - \varphi_3). \quad (4)$$



a)



b)

Figure 3 – Kinematic scheme (a) and the computer model (b) of one-mass mechanical subsystem connected with two spring shafts through a gear with gaps (Subsystem Masa-2sp_wal)

The computer model of the 12-mass mechanical system of the section with three rollers, the kinematic scheme of which is shown in Figure 1, can be created using two types of subsystems shown in Fig. 2 and 3, marked as 1 and 2 correspondingly (Fig. 4).

In accordance with this scheme, the total computer model of the electromechanical system of a roller line section was built, which is shown in Fig. 5. Under each of the subsystems, its type is marked and the moment of inertia and the elasticity that this subsystem models are displayed.

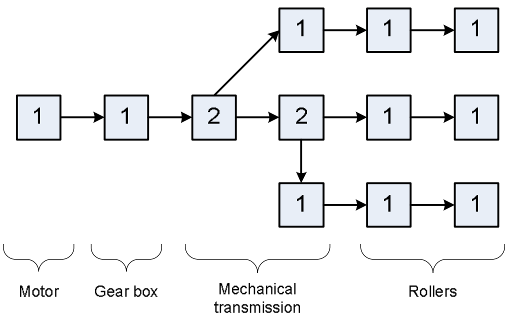


Figure 4 – The construction blueprint for the computer model of the elastic mechanical system of a roller line section with three rollers

Besides the model of the mechanical system, the full model includes the subsystem of IM Motor Subsystem [5] and one of the developed subsystems [4], which calculates the load on each of the rollers when the slab passing on them (Fig. 5 shows the Subsystem "Obciazenie rolki 2–3," corresponding to the length of the slab $2m < l_s < 3m$, where m is the module of the section – the distance between the axes of the rollers).

The model of each of the rollers is shown in Fig. 6. It includes two subsystems of the first type (Fig. 2,b) and the Subsystem obciazenia zewnetrznego, which divides the loads g, defined in the Subsystem "Obciazenie rolki 2–3," between the halves of rollers depending on the asymmetry of the slab's position.

Also, this subsystem changes the moments of inertia of concentrated masses when their loads are changing. In addition, through input Msp.tr the links between neighboring rollers by significant moments are made when the slab rests on them.

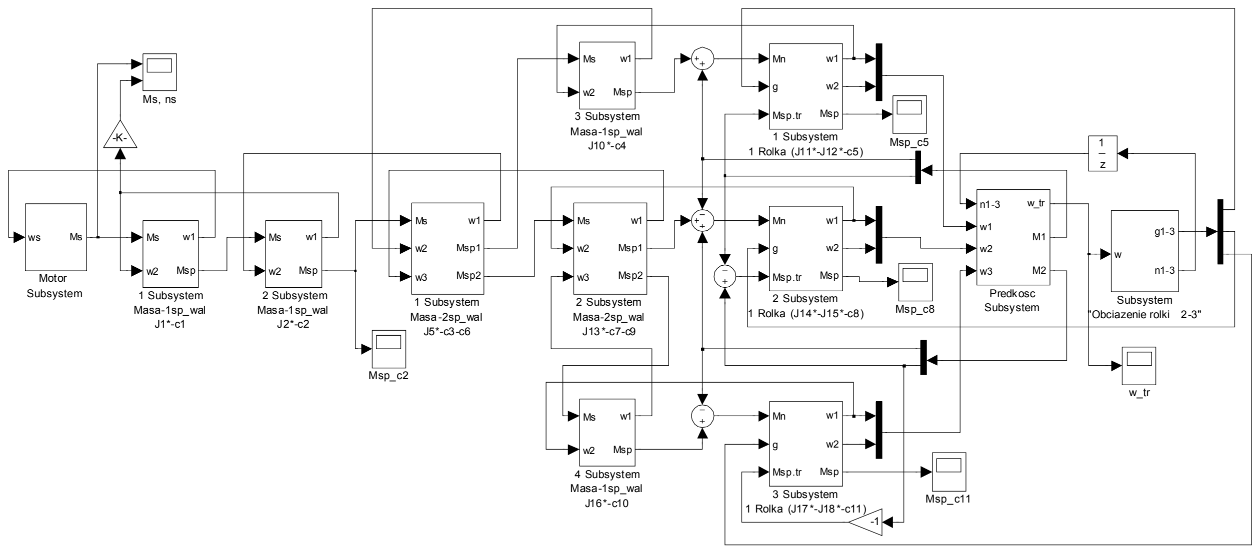


Figure 5 – The general computer model of the electromechanical system of a roller line section with three rollers, which is driven by IM and on which the slab with length $2m < l_s < 3m$ is transported

This is provided by the Predkosc Subsystem (Fig. 5), which identifies the position of the slab against the rollers and defines the linear velocity of the slab according to the known values of the instant angular velocities of the rollers on which the slab is transported.

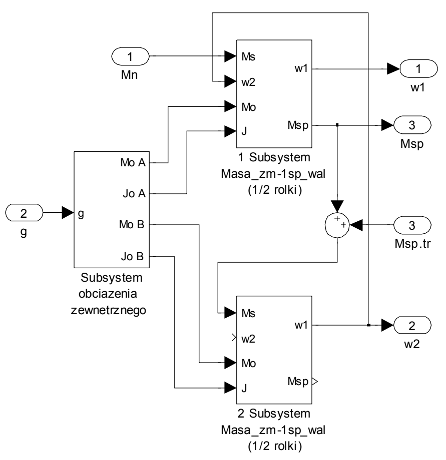
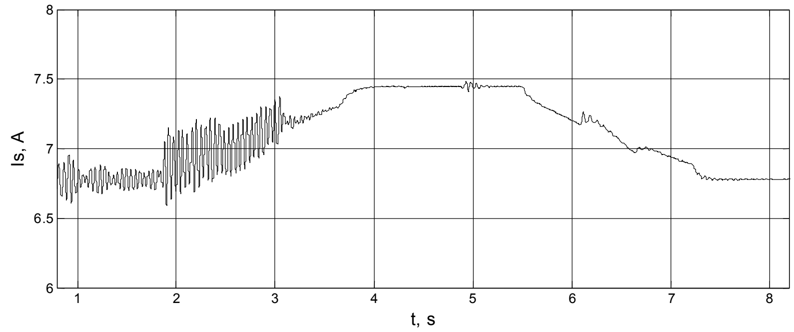


Figure 6 – The computer model of the Subsystem 1 Rolka

Fig. 7 gives the oscillograms of basic coordinate of the electromechanical system of roller line section received on general computer model shown in Fig. 5. Slab, which is transported, goes to the first roller at time 1.8 s. As a result of downloading by it of first roller the oscillation of angular velocity of past that have not settled down yet after the direct start of driving motor, reduces (darker line in Fig. 7,e). At time 3.05 s, as shown in Fig. 7, slab has already reached the second roller, and in resulting of binding by him the 1st and 2nd rollers their vibrations are reducing, and the angular velocities are almost identical. It also causes a reduction of vibrations of spring moment at the output gear (Fig. 7,d). The difference between the specified angular velocities appears at time 4.8 s, when the end of the slab leaves a 1st roller. At time 6.1 s slab reserves also 2nd roller (Fig. 7,f), remaining only on the 3rd roller of the studied section, causing slight vibration of angular velocities of the 1st and 2nd rollers (Fig. 7,e). At different loading of section rollers by transported slabs the moment of IM (Fig. 7,b), its phase current (Fig. 7,a) and angular speed (Fig. 7,c) change respectively.

CONCLUSIONS. The MatLab/Simulink overall computer model of the electromechanical system of roller line section, which takes into account the peculiarities of driving induction motor, complex many mass elastic mechanical part with three rollers, and variable loads on rollers when slab of given length is passing on them was developed. This model makes possibility to conduct simulate studies of working of electrical and mechanical subsystems within the system with the aim to improve the operation of roller line section. In further research on the model we can simulate a variety of additional effects, such as the appearance of gaps in mechanical gears and their influence on system work etc.



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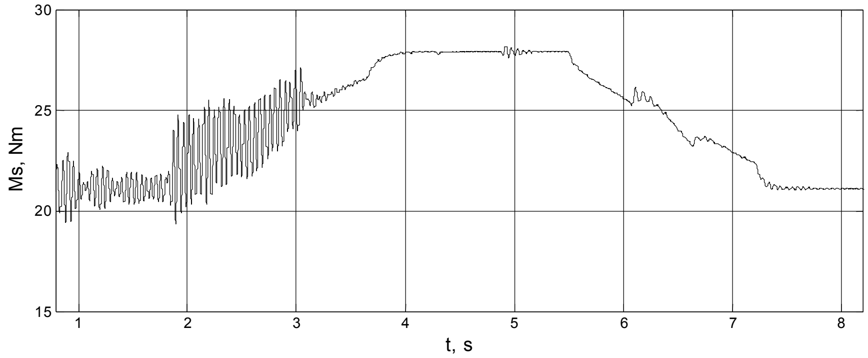

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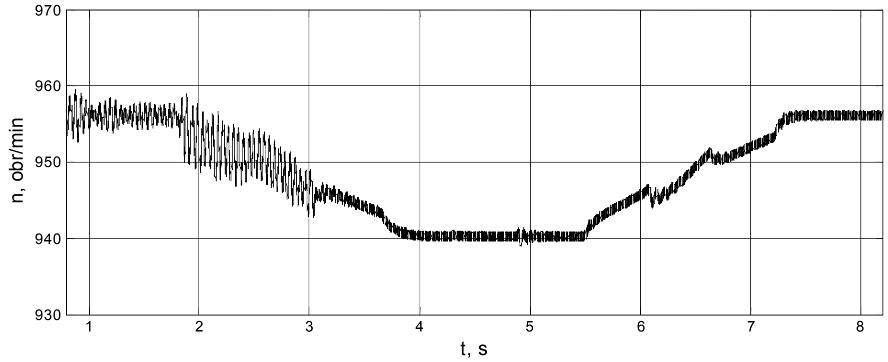

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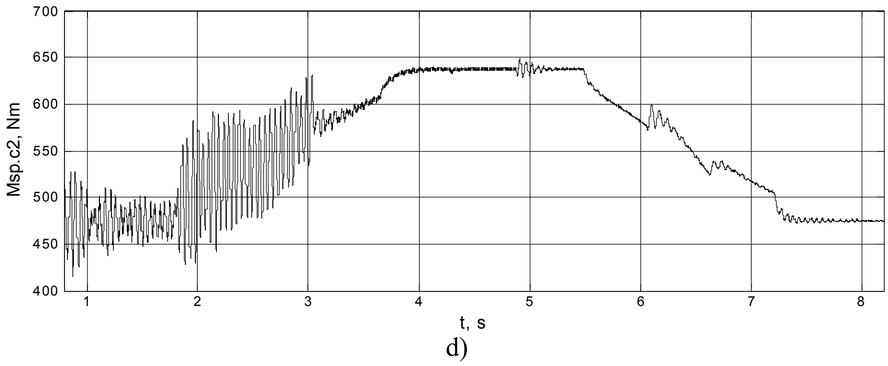

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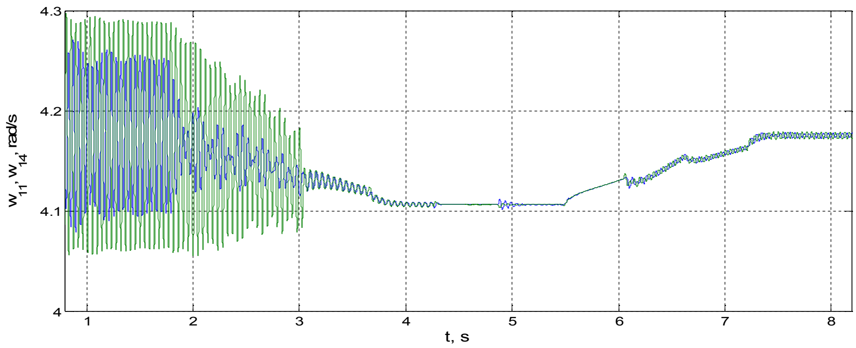
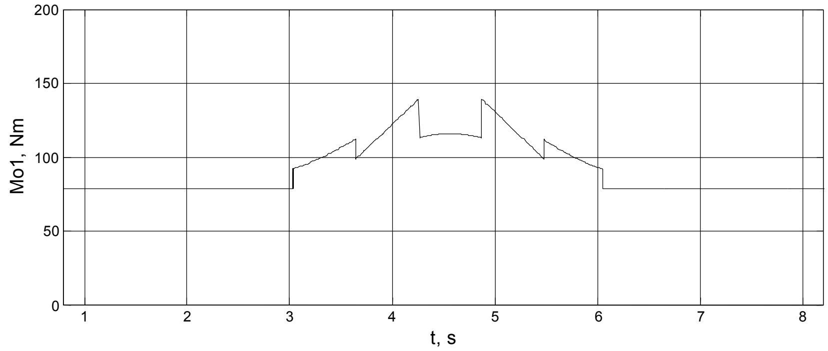


e)



f)

Figure 7 – The responses of the main coordinates of the electromechanical system of roller line section when slab passing through rollers:
a) the effect value of IM current; b) electromagnetic torque of IM; c) rotation speed of IM; d) spring moment at the output shaft of gear; e) the angular velocities of the first two rollers on one side of the roller line; f) moment of static load on axis 2 of roller line section

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ИМИТАЦИОННОЕ КОМПЬЮТЕРНОЕ МОДЕЛИРОВАНИЕ РАБОТЫ МНОГОМАССОВОЙ ЭЛЕКТРОМЕХАНИЧЕСКОЙ СИСТЕМЫ СЕКЦИИ РОЛЬГАНГА

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По результатам предварительных теоретических исследований разработана в среде MatLab/Simulink общая компьютерная модель электромеханической системы секции рольганга, которая учитывает особенности приводного асинхронного электродвигателя, сложную многомассовую упругую механическую часть с тремя роликами, а также переменные нагрузки на ролики секции при прохождении по ним сляба заданной длины. Полученная компьютерная модель позволяет проводить имитационные исследования с целью анализа влияния параметров электрической и механической подсистем на показатели работы секции рольганга.

Ключевые слова: рольганг, многомассовая механическая система, компьютерное моделирование.

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