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THE MODEL OF THE CONTROL SYSTEM OF STRIP THICKNESS ON PRESSURE SCREWS OF THE FIRST STAND COLD ROLLING MILL

Abstract. *With modern demands for quality cold rolled steel, there is often a need to improve or test of optimality of the existing system of regulation of the strip thickness. For these purposes, there is needed the model to minimize the amount of field experiments. The purpose of system of automatic regulation of the strip thickness at the housing screws of the first stand is maintaining of minimum deviation from the desired thickness behind the first stand. Such regulators operate as a function the thickness deviation behind of the first stand and respectively have a transport delay measurement control parameter. Model synthesized in modeling complex Simulink Matlab software package (version 7.4.0.287 R2007a), and adjusted for the speed of the first stand V1 = 5,7 m / s, the thickness of 1,7 mm. To assess the adequacy of the model was comparable testing of an identical impact actual object and the model. There were fixed graphics of three parameters: the deviation of thickness behind 1stand %; RTC output, % (reference to the drive); the absolute position of one of the two housing screws of first stand, mm. The resulting model is adequate to the actual controller of the strip thickness and can be used for debugging and setting of real system of automatic regulation.*

Keywords*: model, automatic regulation, the strip thickness, pressure screw, mill, Matlab, transport delay*

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МОДЕЛЬ СИСТЕМЫ АВТОМАТИЧЕСКОГО РЕГУЛИРОВАНИЯ ТОЛЩИНЫ ПОЛОСЫ ПО НАЖИМНЫМ ВИНТАМ ПЕРВОЙ КЛЕТИ СТАНА ХОЛОДНОЙ ПРОКАТКИ

Аннотация. *В статье приводится опыт построения модели САР толщины полосы по нажимным винтам первой клети стана холодной прокатки в моделирующем комплексе Simulink программного пакета Matlab. Модель создана для стана 1700 холодной прокатки АО «АрселорМиттал Темиртау».*

Ключевые слова*: модель, автоматическое регулирование, толщина полосы, нажимной винт, клеть, прокатный стан, Matlab, транспортное запаздывание*

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МОДЕЛЬ СИСТЕМИ АВТОМАТИЧНОГО РЕГУЛЮВАННЯ ТОВЩИНИ СМУГИ З НАТИСКНИМ ГВИНТАМ ПЕРШОЇ КЛІТІ СТАНА ХОЛОДНОЇ ПРОКАТКИ

Анотація. *У статті наводиться досвід побудови моделі САР товщини смуги з натискним гвинтам першої кліті стана холодної прокатки в моделюючому комплексі Simulink програмного пакету Matlab. Модель створена для стану 1700 холодної прокатки АТ «Арселорміттал Теміртау»*

Ключові слова*: модель, автоматичне регулювання, товщина смуги, натискний гвинт, кліть, прокатний стан, Matlab, транспортне запізнювання*

Introduction. In the control system of the strip thickness of continuous cold rolling mills, generally, two independent regulation systems are used: rough, supporting strip thickness after the first stand by influence on the pressure screws of this stand (RTC1) and slim, provides regulation of the thickness at the outlet mill influence on the tension between the last and penultimate stands. The purpose of system of automatic regulation of the strip thickness at the pressure screws of the first stand is maintaining of minimum deviation from the desired thickness behind the first stand. Such regulators operate as a function the thickness deviation behind of the first stand and respectively have a transport delay measurement control parameter, because the thickness gauge is installed at a distance of 1,5 – 2 m from the axis of stand. Transport delay depends on the speed of the strip and it decreases with its increase. This circumstance, as well as the non-linearity of the system "stand-strip" is responsible for the engineering complexity of the synthesis of the control system of the strip thickness [1 – 4].

Purpose of the work. Synthesis of mathematical model of the control system of the strip thickness at the pressure screws of the first stand cold rolling mill, and checking of optimality of the existing system of regulation by mathematical modeling methods.

Peculiarities of the modeling object. With modern demands for quality cold rolled steel, there is often a need to improve or test of optimality of the existing system of regulation of the strip thickness. For these purposes, there is needed the model to minimize the amount of field experiments.

Let us point out some important elements of the object, characteristics and principles of their work, which are important for the preparation of model of the control system [5 – 8]. Thus, the pressure device is designed to set the required gap between the rolls and consist of two turns with nuts, globoid gears, electric drive and synchronization system of the pressure screws. To determine the position of the pressure screws on the gears of each stand (separately for each screw) installed sensors-encoders.

The drive for each of the pressure screw carried out by the DC electric drive DP-82 with the total gear ratio of reducer 653,12. Electric drives of the pressure screws controlled by thyristor converters of type SIMOREG 6RA70. Moment of resistance during the motion the screws has the character of the moment of dry friction.

Transfer coefficient of rolling stand (ratio of the strip thickness increment to the increment of movement of the pressure screws) varies depending on the profile strip and is as follows: TQ =Δh/Δl=0,1-0,6 mm/mm [9].

Block diagram of the existing RTC-1 system is shown in Fig. 1. There are designated: SP- thickness set point enter device; G – thickness gauge Robotron-24; PLC – programmable logical controller Simatik S7-416; DZ – dead zone; LIM – limited of the output value of the regulator of position (±70 %); RL – rate limiter (70 % from 0,5 s); DC conv – DC converter; DCM- direct current motor; H_{SP} – thickness set point value; H_{ACT} – actual thickness value; TQ-transfer coefficient (Δh/Δl – ratio of thickness increment by corresponding position increment), mm/mm.

Loop current and speed are realized in thyristor converter SIMOREG 6RA70. Regulators of the power and speed have the PI-structure and customized by modular optimum. The contours of the position and the thickness are realized in PLC Siemens S7-416. The position controller – proportional, feedback – sensors-encoders (used as position sensors). Contour of the thickness is the outer the most inertial loop and regulates the main parameter – the thickness of the rolled strip. PI-type regulator thickness is used as a feedback signal from the isotopic thickness gauge ROBOTRON-24. Thickness gauge set to a distance of about 2 m from the axis of the first stand, which leads to transport delay of the control system of the strip thickness.

Synthesis of model. Model synthesized in modeling complex Simulink Matlab software package (version 7.4.0.287 R2007a), and adjusted for the speed of the first stand V1=5,7 m/s, the thickness of 1,7 mm. Structure of the model is shown in Fig. 2.

The constant "Thickness Setpoint" is defined a predetermined thickness in mm. Block "Thickness Gauge" – it is comparator of thickness gauge, which are served a predetermined and the measured value thickness of the strip. The measured value is supplied with delay of 0,35 s (for speeds of 5,7 m/s). The unit produces a signal relative deviation from the specified thickness in percent.

In the model of the PI-controller of thickness linearized – is used the transfer function of the PI-controller, corresponding to operation original controller at V1 = 5,7 m/s.

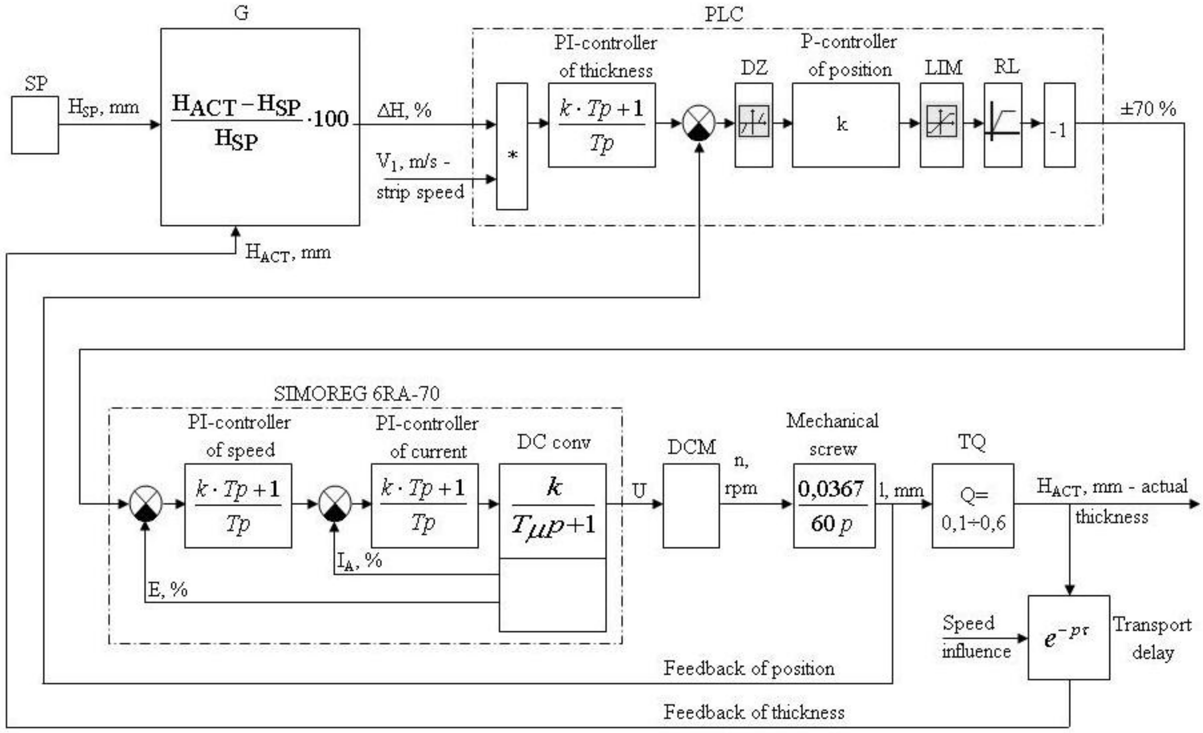

Fig. 1. Block diagram of the existing RTC-1 system

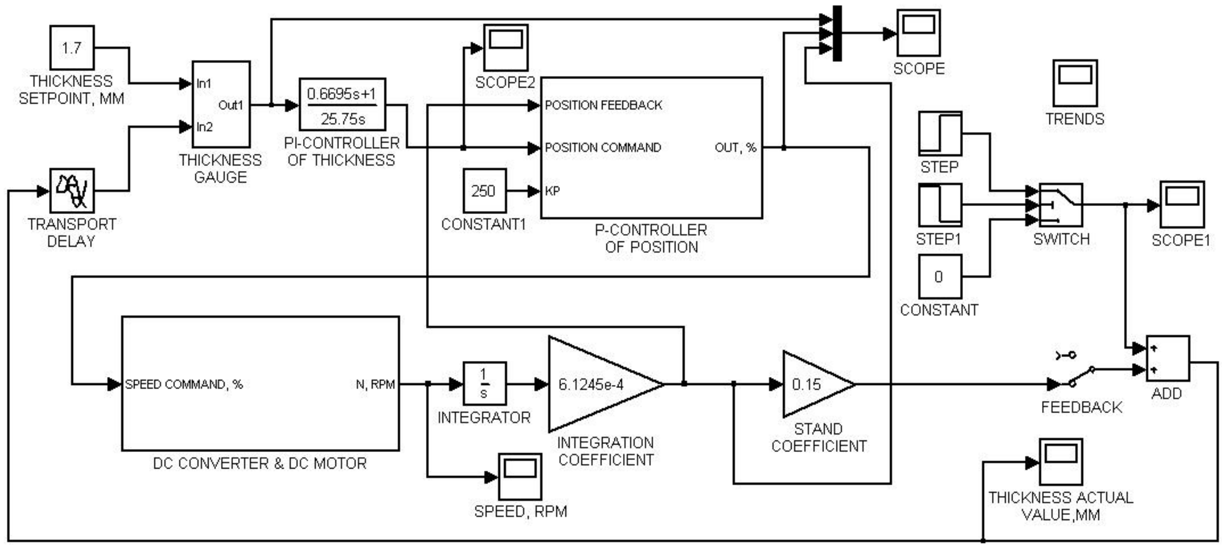

Fig. 2. Structure of the model RTC-1

Block "P-controller of position" (Fig. 3) corresponds to the software unit of the position controller and comprises, besides itself regulator, comparator, dead zone, the block limits and speed setpoint.

At the input of unit the comparator subtracts from the average value of sensors of position of the pressure screws the setpoint. The setpoint includes the reference value, which in the real position controller loads at the start of operation of the regulator and means the actual position of the pressure screws in the beginning of rolling, when the roll gap is already optimal. Necessity of such a reference value caused by the specifics of processing signals from the position sensors in the camp program controller-the number, indicating the position of the pressure screws, are not tied to the rolling line, or to some original "zero" position; calibration of indications when transshipment rolls are not available. At the elements "Abs", "Constant", "Switch" formed the dead zone controller: modulo signal is less than level 0,01 mm (the difference between the actual and the set position of the pressure screws) on the regulator input fails.

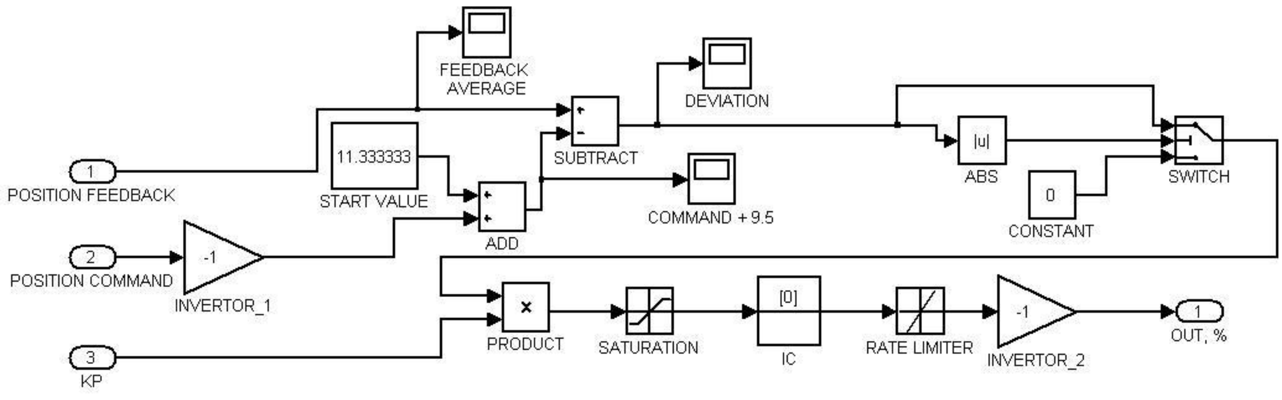

Fig. 3. Block "P-regulator of position" of the model RTC-1

In the element "Product" input signal is multiplied by a coefficient proportional controller CP = 250. Further, the output signal of the controller passes through the unit "Limit", where is limited in the range of – 70 % ... 70 %, and is supplied to the speed setpoint, built on elements "IC" and "Rate Limiter" which sets the pace of the speed reference ± 70% for the 0 , 5 (140 %/s). On elements "Step", "Step1", "Constant", "Switch" implemented impulse generator to simulate the of thickness deviation.

Block "The drive" (Fig. 4) includes a transfer functions regulators of current, speed rotor of the DC motor and components compensation of EMF and torque. The output of block has dimension "rpm". Calculation regulators made to scale the nominal control signal for the analog system (10 V) according to the method described in [10], so that the maximum input signal of the block – 100 % divided by 10.

Electromechanical pressure screws are modeled by integrating link, because task to drive this mechanism is given as speed and signal position of the pressure screws is a signal of moving. Coefficient relating to an integrator depends on the gear ratio of the cylindrical and globoid gear of the pressure screws and pitch of the screw.

Transfer coefficient of rolling stand TQ varies depending on the profile of the strip and metal rigidity and amounts 0,1 – 0,6 mm / mm. Feedback at the thickness is closed through of the transport delay block "Transport Delay" with a constant delay time of 0,35 s (for speeds of 5,7 m/s).

In the integrator there is given initial conditions – a number which when multiplied by the coefficients C_{INT} and the C_P allow to have a strip thickness at time t = 0, equal to a predetermined thickness of 1,7 mm.

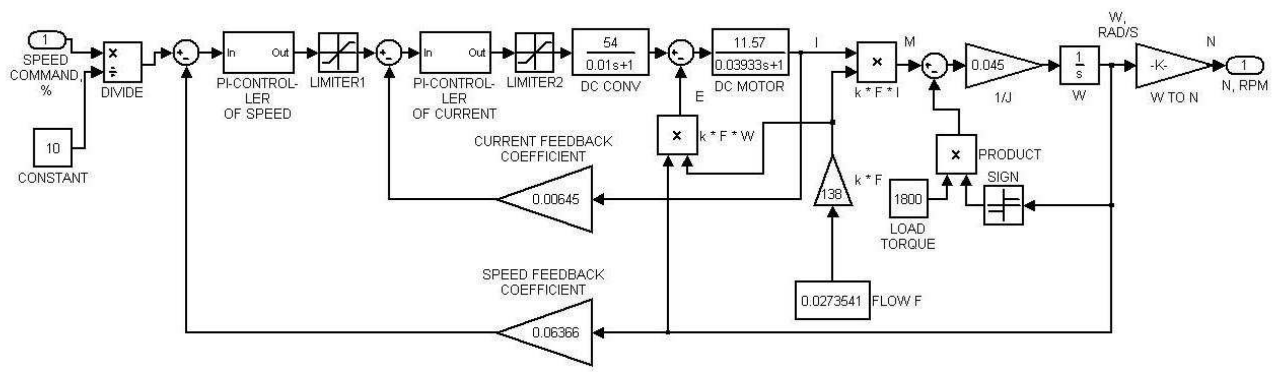

Fig. 4. Block "Drive" model RTC-1.

To assess the adequacy of the model is comparable testing of an identical impact actual object and the model (strip thickness in both cases - 1,7 mm, the first stand speed 5,7 m/s). In the program the camp management controllers, at some time during the rolling, to the value of the real deviation of thickness add the impulse with amplitude of 3 % and duration of 2 s. Fix a graphic of three parameters: the deviation of thickness behind 1stand %; RTC output, % (reference to the drive); the absolute position of one of the two pressure screws of first stand, mm.

Work of real RTC-1 system is shown in Fig. 5.

The shaded part of the graph of deviation thickness corresponds to the interval impact impulse. In this model, at time t=3 s, pulse is applied amplitude of 0,051 mm (which corresponds to a deviation of 3 %) and duration also 2 s, which is summed with the variable actual thickness. After 0,35 s (transport delay) pulse is applied to the input of the system. The result of working off of thickness deviation is shown in Figure 6.

Conclusions. From the comparison of graphs of real object and model, it can assess the adequacy of the model on several points.

When the input control system the thickness deviation occurs of 3 % from the set, the actual system and the model increase at the same rate the task to the actuator until it reaches a value of 21 – 22 %; then as the system decreases to 7 % (curve, No. 2 – output RTC – on both charts).

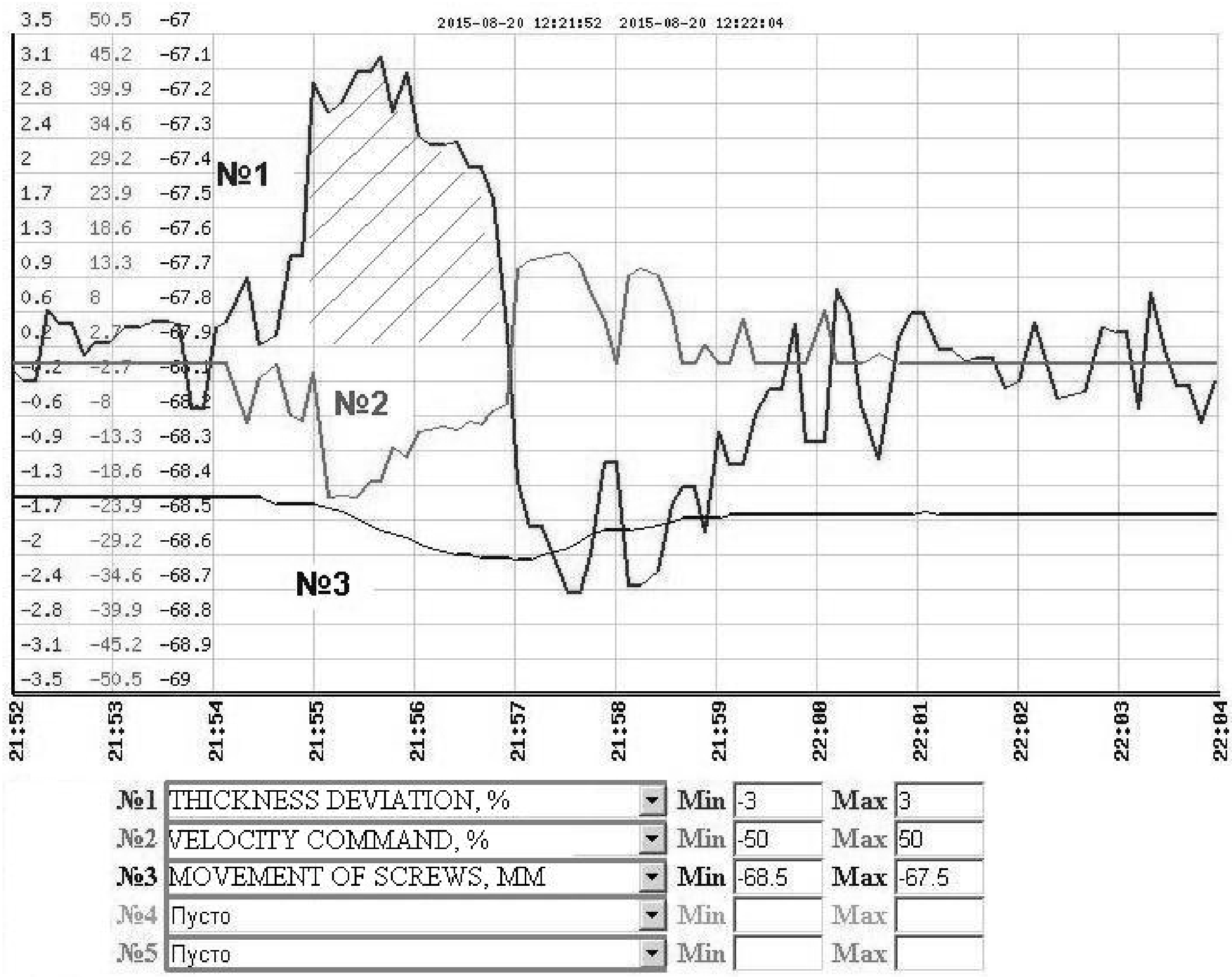

Fig. 5. Transient processes of the real system RTC-1 to simulate the deflection of thickness 0,051 mm

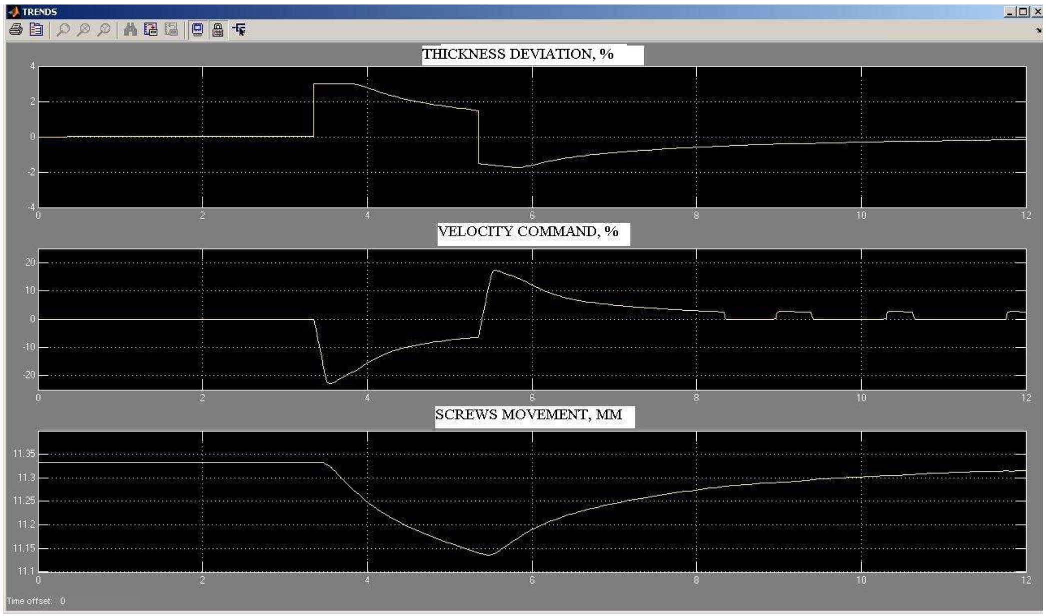

Fig. 6. Transient processes model RTC-1 on working off of thickness deviation 0,051 mm (3 % of the set)

During the period of exposure impulse and operation of the control system, position of the pressure screws in the real system is changed to 0,16 mm, in the model to 0,18 mm (this value depends on the transmission ratio KP rolling stand, i.e. depends on the rigidity of the metal).

At the time of removal of impulse (taking into account transport delay in measuring thickness of 0,35 s) in a real system RTC-1 and model the thickness deviation is about -1,7 %, i.e. for the period of exposure to the momentum and work of the control system actual thickness decreased by 0,029 – 0,03 mm in both cases.

The distortion of the real graphics and feed the rectangular pulse in the form and amplitude are caused by that the metal strip has its own variable gage.

Thus, the resulting model is adequate to the actual controller of the strip thickness and can be used for debugging and setting of real system of automatic regulation.

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