



# Human-Computer Interaction for Control Technological Process-Based PLC of Covering Coat Inside the Pipe

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# Human-computer interaction for control technological process-based PLC of covering coat inside the pipe

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**Abstract** -The paper aims to reduce the formation of micro-cracks by adjusting parameters in the technological process in high-temperature conditions. Currently, in the oil industry, due to corrosion and the appearance of micro cracks, pipes are disrupted during oil transportation. Consequently, many companies suffer economic losses. Due to eliminating this problem, the thesis demonstrates how an operator can control the technological process for high-quality pipe coating based on PLC. The applied Control System reduces macro and micro-cracks in silicon-coated pipes to a minimum by automating technological processes and adjusting their technical parameters. The coating process is controlled remotely with the application of the Panasonic FWiNPro7 controller. As a result of the quality coating inside the pipe, their longevity and reliability increase 2-2.5 times.

**Keywords**—*Micro cracks, silicon-coated pipes, technological processes, coating process, high-temperature condition*

The pipelines of oil-mining and oil-processing equipment operating in high temperatures, pressures, and chemically active environments become defective after a short period of operation. Intensive corrosion processes, deviations, cracks are formed on the inner surfaces of such pipelines and they fail.

To avoid defects, the inner surfaces of the pipes are covered with various metal (non-metal) and organic (inorganic) materials. The most effective of such coatings, silicate coatings, differ in their modernity and prospects, and are more widely applied. The quality of the silicate coatings resistant to chemical and thermal environments is an essential issue [1].

Experimental studies and procedures have shown that the main defects in silicate coated pipes are irregularities on the inner surface of the pipe, small bubbles, and microcrystalline layers, which greatly reduce the life of their operation. The causes of such defects are due to improper selection of the technological mode when laying silicate-enamel coating on the inner surface of the pipes. The choice of the technological mode upon laying the coating depends on the geometric dimensions and technological parameters of the pipes. Such technological processes are operated automatically.

Nevertheless, micro-cracks are formed on the surfaces upon laying silicate coating inside the pipes of various geometric dimensions [2]. The formation of such micro-cracks is due to the non-accuracy of the process of laying silicate coating, automatic adjustment of technological parameters and failure of diagnostic analysis to meet modern requirements, so their solution proves the relevance of this thesis.

The silicon coated pipes that enter the oven are treated as double cylinders. As the temperature in the oven is stable at 1000 °C, it is accepted that the heat is evenly distributed along the surface of the pipes, since upon heating the temperature changes only in the radial direction of the pipe.

By applying the differential equation of thermal conductivity of the double cylinder to the coated pipe, using the initial and boundary conditions of the heating of the pipes, the mathematical expression of the regulatory parameters is obtained as follows:

$$T = 600 + \left[ 200 \frac{V_1^2}{n_1^2} \ln \left( \frac{D_2}{D_1} \right) + (D_2^2 - D^2) \right] k \quad (1)$$

Where:  $D_2$  – is the metal pipe outer diameter;

$D_1$  -is the coating outer diameter;

$D$  -is the coating inner diameter;

$k=10^1-10^3$ °C/mm<sup>2</sup> is changeable conversion coefficient of measurement units;

$n_1$ - the number of rotational cycles of the pipe ;

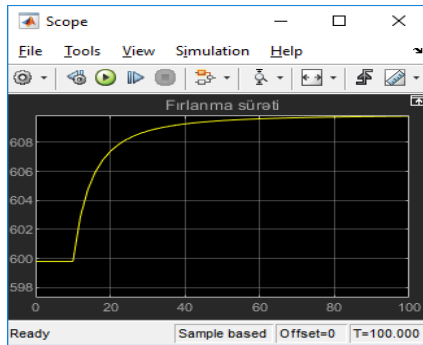
$V_1$  -the speed of its progress;

$D$ -the diameter of the cover;

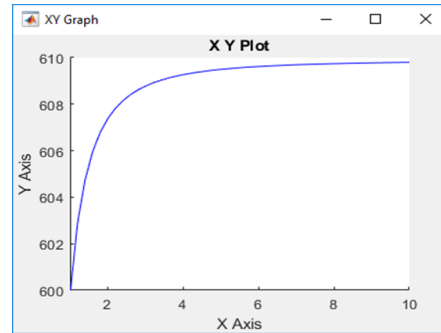
The system that is modeled in the technological process depends on the number of rotational cycles of the pipe, the speed of its progress and the diameter of the cover. The values for the construction of this model vary and are accepted within the following value range;

$$n_1 = 1.0 \div 10 \text{ r/sec}, \quad V_1 = 5.0 \div 20 \frac{m}{\text{sec}} = 0.005 \div 0.02 \frac{mm}{\text{sec}}, \quad D_2 = 50 \div 500 \text{ mm} = 0.05 \div 0.5 \text{ m}$$

A result of the imitation model are shown in Graphic 2.



a) Time dependence of tube temperature



b) The dependence of tube temperature on its rotation speed

Fig 1. Pipe temperature dependence

The dependence of the temperature on the simulation time at continuously variable values of the tube rotation and advancement speed within the interval is presented in Fig.1 a) As can be seen from the graph, after the 80 th second of the simulation model time, the tube temperature remains unchanged. Fig.1 b) corresponds to the case where the tube rotation speed is 8 m/sec. This means that after the tube rotation speed reaches 8 m/s, its temperature remains constant. Therefore, this speed is optimal at the given values of the parameters, and the process is correct.

The adjustment parameters of the coating drawing process and the model of the control system are shown in Fig 2. The pipe (7) moves towards the oven with a certain speed of rotation and forward through conical rollers of different diameters and angles (6). Rotation and forward movement (5) are performed using special (8) rotating units and electric motors. Additional mechanical displacements are carried out using mechanical agitators (1) and electric motors (3). The forward and rotational movement of the devices is one of the main parameters of the technological process.

Regulating the pipe's movement should be done initially. Our calculations result in the operator being shown the movement parameters for pipes of various diameters. Using the controller's control buttons, the operator inputs the system with the number of rotation cycles and speed of the advance movement based on the coated pipe's diameter and controls the manufacturing process on the PLC monitor.

The moving pipe enters the oven (10) after a certain time. In the oven, at a temperature of up to 1000°C, the coating heating process takes place. At this time, the temperature change on the surface of the coating (11) is determined by the pyromete.

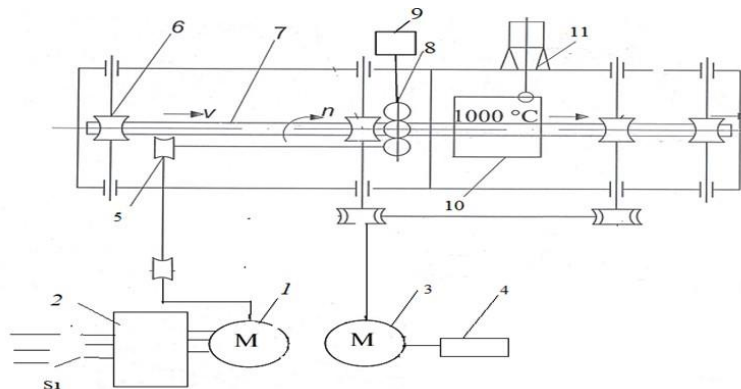


Fig 2. Functional scheme of the automatic control system of coating pipe

1-rotation regulating electric motor; 2-invertor; 3- forward movement regulating motor; 4-tachometer; 5-mechanical trans-mission; 6- conical bearing; 7-pipe; 8-rotating unit; 9-encoder; 10-oven; 11-pyrometr.

The technological process control system consists of transmitters and an executive mechanism, as well as indicators and alarms, which measure the pipe advance speed  $V$ , the number of rotation cycles  $n$ , and the temperature  $T$  on the surface of the pipe leaving the furnace. The red indicator shows that the pipe is of improper quality, and the green indicator shows that the pipe is of proper quality. If the pipe transmission speed is  $V=5.0\pm 20$  m/sec and the temperature is in the range of 600-800 °C, the pipe is considered to be of proper quality

The pyrometer measures the temperature on the surface of the pipe by absorbing rays from the surface of the coating and transmits the result to PLC [3],[4]. In order to monitor the temperature regime of the pipe during the measurement, when the temperature on the surface of the pipe leaving the furnace exceeds 600–800 °C, the pyrometer signals and informs the operator about the deviation of the pipe from the given technological regime. This tells the operator that the coated pipes are of poor quality, and they are sent for remanufacturing.

The encoder transmits the number of circuits that the electric motor makes per minute to the PLC in the form of an electrical impulse, allowing the operator to simultaneously adjust the  $V$ –forward speed of the pipe and the rotation number ( $n$ ). An electromechanical tachometer and a converter are provided to adjust the number of rotational cycles of the pipe in the calculated mode [3],[4]. Functional model for PLC-based technical process control, which has been applied to ensure that the parameters shown are within the specified value range, is shown in Figure 3.

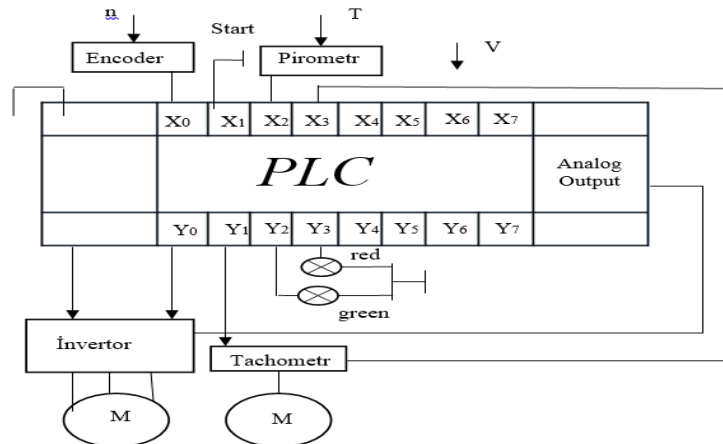


Fig 3. Functional model for PLC-based technical process control

An encoder is connected to the  $X_0$  input of the PLC, a 24 V power supply is connected to  $X_1$ , and a pyrometer is connected to the  $X_2$  input. The encoder transmits the number of revolutions of the electric motor in one minute to the PLC in the form of an electric pulse and allows the operator to adjust the number of  $n$  revolutions of the tube. The  $Y_0$  output of the PLC is connected to the inverter. The PLC turns on the inverter, checks the accuracy of the number of cycles it regulates, and turns on the appropriate indicators for monitoring. If the number of cycles is not in the range of  $n = 1-10$  r/sec and  $V = 0.005-0.02$  m/sec, the red indicator connected to the  $Y_3$  output of the controller lights up, otherwise the green indicator connected to the  $Y_2$  output lights up. According to theoretical calculations, the tube advance speed and the number of revolutions are fully adjustable. This guarantees the purchase of a quality cover. Based on the built-in control system, the operator can control the production process remotely [5],[6].

The silicon coating procedure adjusts itself automatically. As a result, during the technical process, an automatic adjustment system based on a logic controller programmed to change the rotational frequency ( $n$ ) and forward speed ( $V$ ), ( $d$ ) of the rotating tube to a given value dependent on its diameter was presented. The control system that is being demonstrated guarantees automated adjustment of the technical process and permits process control from a distance. All of this finally guarantees an enhancement in the silicon coating's quality when it is pulled into the pipe. Thus, the management system of the technological process has increased the efficiency and accuracy of production.

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