ABSTRACT

for a dissertation on the topic: “Model development and investigation of the temperature control system of the optical fiber drawing process”, PhD doctoral student in the specialty “6D070200 – Automation and Control”
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The dissertation work is devoted to the development of mathematical models and parametric synthesis of an automatic temperature control system for the optical fiber drawing process.

Relevance of the topic. In modern conditions, it is necessary to ensure reliable and high-quality functioning of a complex of interconnected information, computer and telecommunication technologies. The main data transmission medium for medium and long-distance telecommunications is optical fiber. Thanks to its unique transmission properties, resistance to interference, security and relatively affordable price, in exchange for very good durability and aging resistance, it has been applied in many areas of life. On the way to fast and lossless data exchange over optical fiber, a number of difficulties are encountered. These include attenuation, absorption, linear and nonlinear scattering, and the basic limit of fiber bandwidth enhancement, which are related to dispersion. We can get all these undesirable effects due to poor-quality drawing of the optical fiber core.

From the very beginning of the development of fiber optics, the dominant problems in optics have been the stability of the diameter of the original rods and the low light attenuation in them. If the second problem is successfully solved, then the problem of superconstancy of the fiber diameter continues to exist. To solve this problem, constant monitoring and control of the technological process of manufacturing optical fibers is required.

All factors influencing the quality of the optical fiber geometry can be reduced to two groups:

- the physical state of the glass melt from which the light guide is drawn;
- stability of conditions in the zone of fiber formation.

Another important task is to increase the dynamic accuracy of regulation. Low dynamic control accuracy is due to the inertia of the control object and the presence of delay. The latter is determined by the transit time of the drawn glass product from the formation zone to the sensor that determines the cross-sectional dimensions.

Construction of an automatic control system for fiber drawing, in turn, requires the construction of adequate models of the controlled object. The temperature regime of optical fiber drawing, which forms the specified tension and diameter of the drawn fiber, is considered as a control object.

The technological process of drawing optical fiber as a control object is characterized by the presence of nonlinearity and delay, which must be taken into account when developing automatic control algorithms. The nonlinearity of static characteristics must be taken into account when synthesizing control algorithms.

To minimize losses of finished products when drawing optical fiber, it is necessary to ensure the required control efficiency. In this regard, the development of mathematical models and the study of an automatic control system for the temperature regime of the optical fiber drawing process determines the relevance of the chosen dissertation topic.

Goal of the work. Development of mathematical models and research of a sigma frequency-pulse system for automatic temperature control of the optical fiber drawing process.

To achieve this goal, the following tasks are solved:

- analysis of the technological process of optical fiber drawing as a control object;

- development of mathematical models of a sigma frequency-pulse system for automatic control of the temperature regime of the optical fiber drawing process in the form of stochastic differential equations of Langevin and in the Ito form;

- experimental study of the adequacy of mathematical models and the real ∑ - FPACS temperature regime of the optical fiber drawing process;

- parametric synthesis of sigma frequency-pulse system for automatic temperature control of the optical fiber drawing process.

Object of study. The temperature regime of optical fiber drawing, which is the main circuit of the automation process and the main factor influencing the quality of the optical rod.

Research methods. To solve the problems, the work used methods of mathematical analysis, automatic control theory and experimental methods for studying objects and control systems.

The scientific novelty of the work lies in the fact that for automatic control of the temperature regime of the optical fiber drawing, a sigma frequency-pulse modulator is used as a regulator, which differs from existing ones in that it takes into account the property of the object in the form of the presence of delay and its functioning in a stochastic environment. The scientific novelty of the work also lies in the development of mathematical models that adequately describe the process of controlling the temperature regime of optical fiber drawing. In addition, the dissertation work expands and deepens theoretical concepts in the field of mathematical modeling and synthesis of automatic control systems for the technological process of optical fiber drawing.

The following main scientific results were obtained in the dissertation:

- an equivalent model of a sigma frequency-pulse system for automatic control of the optical fiber drawing process, a nonlinear system that ensures both taking into account the properties of an object with a delay and its functioning in a stochastic environment, has been formed;

- mathematical models of the sigma frequency-pulse automatic control system for the process of drawing optical fiber have been developed in the form of stochastic differential equations of Langevin and Ito;

- a parametric synthesis of a sigma frequency-pulse system for automatic control of the temperature regime of an optical fiber drawing, described in Ito form, was carried out;

- a sigma frequency-pulse system for automatic temperature control of the optical fiber drawing process has been developed;

- a device for measuring the diameter of moving dielectric filaments is presented;

- a device for measuring the speed of drawing moving dielectric threads is presented.

Provisions for defense:

- construction of equivalent and majorizing models of sigma frequency-pulse system for automatic control of objects with delay;

- development of mathematical models of the system in the form of stochastic differential equations of Langevin and Ito form;

- experimental study of the $\sum$ - FPCAS model by the temperature regime of the optical fiber drawing process;

- parametric synthesis of an automatic temperature control system for the optical fiber drawing process.

Theoretical and practical value:

- as a result of the research, the dependences of the influence of temperature in a high-temperature furnace on the drawing speed, tension and fiber diameter were found;

- a device for measuring the diameter of dielectric filaments has been developed and described;

- a device for measuring the drawing speed of dielectric threads has been developed and described;

- a sigma frequency-pulse system for automatic control of the temperature regime of optical fiber drawing has been developed. This type of regulator is used for the first time in the specified technological process and is considered the most promising, because it takes into account the properties of an object with a delay.

Implementation of research results:

- the developed sigma frequency-pulse system for automatic control of the temperature regime of optical fiber extraction has undergone scientific experimental, research and testing in the InPhoTech laboratory - innovation photonics technology, operating within the framework of the project “Advanced structure of photonic optical fibers for innovative telecommunication networks” at the Maria Skladovskaya Technical University, g .Lublin, Poland;

- the developed device for measuring the diameter of moving dielectric threads passed scientific and production testing in the InPhoTech laboratory - innovation photonics technology, operating within the framework of the project “Advanced structure of photonic optical fibers for innovative telecommunication networks” at the Maria Skladowska Technical University, Lublin, Poland;

- the developed device for measuring the drawing speed of moving dielectric threads passed scientific and production testing in the InPhoTech laboratory -

innovation photonics technology, operating within the framework of the project "Advanced structure of photonic optical fibers for innovative telecommunication networks" at the Maria Skladowska Technical University, Lublin, Poland;

- the scientific results of the dissertation work were introduced into the educational process of the Department of Automation and Control, Almaty University of Energy and Communications, in the discipline "Nonlinear Automatic Control Systems";

- the scientific results of the dissertation work were introduced into the educational process of the Department of Telecommunication Networks and Systems, Almaty University of Energy and Communications, in the discipline "Guiding Communication Systems".

Approbation of work. The results of the dissertation work were reported and discussed at the following scientific seminars and international scientific and practical conferences:

- seminar of the department "Artificial Intelligence and Big Data" of Al-Farabi Kazakh National University;

- seminar of the department "Automation and Control" of AUPET named after Gumarbek Daukeev;

- seminar of the scientific research laboratory "Cyber-physical systems and Smart technologies", based on the department of "Automation and Control" of AUPET named after Gumarbek Daukeev;

- seminar of the Institute of Information and Computing Technologies, Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan.

Publications. The main results of the research conducted on the topic of the dissertation are presented in 31 publications, of which 10 are in scientific publications recommended by the Committee for Quality Assurance in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, 6 are in international scientific publications included in the Scopus database, 13 in materials of international scientific and practical conferences. 2 patents of the Republic of Kazakhstan for a utility model have been obtained.

Structure and scope of the dissertation. The total volume of the dissertation is 147 pages. The dissertation consists of an introduction, 3 sections, a conclusion, a list of sources used from 119 titles and 5 appendices.

The introduction provides a rationale for the relevance of the dissertation research topic. The purpose of the work, the object and methods of the research are formulated, the scientific novelty of the work is revealed, the provisions submitted for defense are indicated, the theoretical and practical significance of the work is presented, as well as the implementation of the research results. Data on testing the results of the dissertation work are presented.

The first section is devoted to the study of the technological process of optical fiber drawing as an object of automatic control. The applied systems for automatic control of optical fiber drawing have been studied: PID controller, adaptive control

system, robustly predictable system, intelligent automated situational control system, and the research problem has been formulated.

The second section describes the operating principle of the sigma frequency-pulse control system with delay. The construction of an equivalent sigma frequency-pulse control system with a delay of a nonlinear system is described. Mathematical models of the sigma frequency-pulse automatic control system for objects with delay were constructed in the form of stochastic differential equations in Langevin form and Ito form. The results of an experimental study of the mathematical model are presented.

The third section shows the structure of the control system and describes the developed sigma frequency-pulse system for automatic control of the temperature regime of the optical fiber drawing process. Mathematical models for controlling the temperature regime of optical fiber drawing are presented. A parametric synthesis of the developed system for automatic control of the temperature regime of the optical fiber drawing process has been implemented. The developed devices for measuring the drawing speed and diameter of dielectric threads are presented.

The conclusion outlines the main results and conclusions of the dissertation.

The appendix provides information about experimental tests and the use of work results for practical purposes. Patents and author certificates for scientific inventions are also provided.