Methods and means of control and diagnostics of technological units in the treatment of industrial wastewater based on optoelectronic and hollow light guides

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Abstract. Prevention of pollution of water bodies by wastewater, as well as protection of surface waters from pollution by wastewater are the most important tasks facing modern society. In the field of industrial wastewater treatment, there are many models of single processes. This article highlights some issues of development and research of individual designs of optoelectronic transducers based on hollow light guides. The principles of construction, mathematical models, questions of errors of optoelectronic converters based on hollow light guides are outlined and devices of information and measuring equipment and automation made on the basis of hollow light guides with moving elements are given. The types and frequencies of optical volcanic waves for the treatment of industrial wastewater based on optoelectronic and polycyclic fibers are presented. And also the issues of diagnosing technological units in the treatment of industrial wastewater and the state of optoelectronic converters based on fiber and hollow light guides are considered. Currently, the problem of wastewater treatment is one of the most important in industrial ecology. Therefore, the development of new more efficient methods and means of wastewater treatment of production using waste products of enterprise waste is currently especially relevant.

1. Introduction

For countries with water pollution problems, it is unlikely that wastewater treatment technologies based on fiber optics and porous materials will become the only treatment system capable of processing complex pollutants from industrial facilities or remediation programs.

Today, much attention is paid to the protection of the environment from anthropogenic impacts. The rapid development of industry and the increasing use of transport lead to the release of large amounts of waste into the environment. Pollution of the environment (water, air, soil) leads to disruption of the normal functioning of the hydrosphere and biosphere, climate change, extinction of plant and animal species, deterioration of human health. The environmental problem of pollution of the hydrosphere with sewage is relevant all over the world, including in Uzbekistan [1].

In order to reduce and prevent environmental pollution, effective management and protection of water resources in our country and abroad, relevant laws are being developed, various technological, sanitary-hygienic, organizational and other measures are being taken [1]. Wastewater quality is deteriorating for several reasons. Wastewater usually has a weak taste and can cause a negative
physiological reaction in the consumer. Wastewater is also unsuitable for many industrial applications. Solid analyses are important for monitoring technical and physical wastewater treatment processes and assessing regulatory compliance with wastewater discharge restrictions [2].

The impact of industrial wastewater on wastewater ranges from beneficial to problematic hazardous poison. While some metals are needed for plant and animal growth, others can be harmful, negatively affecting consumers, wastewater treatment systems and intake water [2].

When treating industrial wastewater, it is useful to encourage the use of fiber optic and porous conduction technologies. The article deals with the modeling of industrial wastewater treatment. This is the main difference between the diagnosis of technological effluents and industrial effluents. Understanding high-current generation, a separate description of processes and the main influencing flows is a key factor for effective data collection, model development and effective state analysis. Another big difference is the expansion and modification of the diagnostic process in many frequently changing industrial applications, because wastewater components and plant operating conditions are specific [3].

2. Object and methodology

The choice of the optimal design of optoelectronic converters based on hollow light guides begins with the analysis of the initial data and the requirements for the converters and the compilation of an array of a priori information, including data on the properties of the transducer structures suitable for implementing the required transformation, information on similar technical solutions, etc.[5].

The process of designing optoelectronic converters based on hollow light guides includes two main stages: the choice of structure and the choice of design. At the first stage, variants of the structure of optoelectronic converters based on hollow light guides based on a priori information are formed. From these options, the preferred one is selected and, by checking it for compliance with the specified requirements, a final conclusion is made about its acceptability. If these requirements are met, the resulting transformer structure is selected. If the specified requirements are not satisfied, then, varying the generalized techniques discussed above, the structure of the converter is changed to achieve compliance with these requirements. At the second stage, using a priori information, the formation of designs of optoelectronic transducers based on hollow light guides is carried out, from which the preferred one is selected and, if it meets the requirements, a decision is made. If the requirements for optoelectronic transducers based on hollow light guides are not met, then by changing the elements of the converter, the design of optoelectronic transducers based on hollow light guides is brought to compliance with the requirements [5-6].

The transmission of laser radiation through optical fibers, the development of optical fibers are inextricably linked with an increase in intensity. The nonlinear effects used in fiber optic windows clearly limit the increase in intensity. It is a nonlinear gas or vacuum in this process. The proportion of radiation in such light guides propagating through glass is less than 0.01%. This feature of optical fibers is a new technological tool for the transmission of high-intensity radiation.

Light in optical and hollow fibers is reflected in two directions, and the air-glass interfaces (e.g., from the capillary wall in Fig. 1) are stored in the hollow core. In this case, the walls are Fabry-Perot interferometers with a high transmittance, and if the wall is suitable, then when the resonance condition is met, the entire number of half-waves appears. In this case, light effectively escapes from the hollow core, forming zones in wavelength ranges that satisfy this condition. Within the wavelengths between the resonant values, light is efficiently reflected from the coating, and fiber-conducting lines are formed in these ranges [9]. This type of hollow fiber is called "antiresonance" in the literature. The photos taken by the scanner are connected with an electron microscope, the principle of operation of two optical fibers with a hollow core and so-called rotating optical fibers, as shown in Figure 1.

Based on studies [8] and analysis of other works [9-15] of the movements of optoelectronic converters at small and large ranges made of hollow light guides, the following conclusions were obtained: with small limits of movement, maximum sensitivity is achieved at minimum values of the
diameter of the hollow light guide, and with large limits of movement, respectively, at maximum values of the diameter of the hollow light guide. Their design features are also discussed here [8, 16, 17, 18].

Figure 1. Photographs of the ends of hollow turret light guides, made with a scanning electron microscope.

On the basis of (1) and (2), the distribution of the relative value $F(x)/F_0$ is constructed with some average value of the reflection coefficient, for example, $\rho = 0.5$, for several possible diameters of the hollow light guide. Figure 2 shows the distributions $F(x)/F_0$ with four diameters of the hollow light guide [8]. $D = 0.02; 0.055; 0.08$ и 0.12 м.

Figure 2. Graph of distribution $F(x)/F_0$ at different diameters of hollow luminous guide

In the following formulas (1) and (2), it is advisable to use optoelectronic transducers to move hollow fibers of different shapes with a diameter of about 0.022 or 0.054 μm.

\[
F(x) = \int x^2 e^{-Kx^2} \left[ e^{-Kx^2 - \frac{1}{x^2}} e^{-12 \int \frac{u_0}{x^2} \cos u u_0 \tan u \cos u u_0} \right] du. \tag{1}
\]

\[
F(0) = \int x^2 \left[ e^{-Kx^2 + \frac{1}{x^2}} e^{-12 \int \frac{u_0}{x^2} \cos u u_0} \right] du. \tag{2}
\]
3. Research results

Radiation sources must have small dimensions and weight, long service life, high stability, noise immunity, high efficiency and low supply voltage.

Measuring circuits of optoelectronic transducers based on hollow light guides with a moving element can be quite diverse depending on the types of radiation receiver, types of designs of optoelectronic transducers based on hollow light guides and other factors. Voltage dividers, bridges and differential circuits are the main circuits used.

Bridge-type optoelectronic converters and optoelectronic converters made of porous fibers are suitable for industrial use. From the diagram below, we can conclude that the use of bridge circuits can compensate for thermal errors and reduce nonlinearity.

**Figure 3.** Angular displacement converter based on curved hollow light guide:

- a – division of the entire range into sub-bands: \( \varphi_1, \varphi_2 \) and \( \varphi_3 \);
- b – optoelectronic transducers based on hollow light guides with sub range \( \varphi_1 = 45^0 + 50^0 \)

The calculation of optoelectronic transducers based on hollow light guides of angular displacements presents some difficulties due to the complexity of calculating the trajectory of oblique rays [8], so let us first consider a curved light guide, in which, in order to simplify the calculation, the entire range of angular displacements is conditionally divided into three sub ranges (Figure 3, a).

In optoelectronic transducers based on hollow light guides, the concentrated radiation source is located along the axis of the hollow light guide at the point, the point of intersection of the tangent with the plane of the location of the radiation receiver along the line will determine the boundary at which the entire cross-section of the light-sensitive surface of the radiation receiver is covered at an angle. The formula for calculating the total flux \( F(x) \) (where \( x \) is the length of the moving element along the axis of the hollow light guide, m) will be similar to formula (3), but it is necessary to consider the variable angle: \( \alpha = \frac{\varphi}{2} \)[8]

\[
F(x) = I_x \int \frac{Z}{x^2} e^{-K_x x + \left( \frac{Z}{x^2} \right)} e^{-K_{x_{\varphi}} x_{\varphi} \cos \frac{\varphi}{2}} \frac{1}{\rho_0 \tan u} d\varphi
\]

\[
F(-\alpha) = 4I_x \frac{Z}{x^2} \cos \frac{\varphi}{2} e^{-K_x x_{-\alpha} + IS \left( \frac{1}{x_0^2} - \frac{1}{x^2} \right)} e^{-K_{x_{-\alpha}} x_{\varphi} \cos \frac{\varphi}{2}} \frac{1}{\rho_0 \tan u} d\varphi
\]
\[
F(\varphi) = (5)I \frac{Z}{x^2} \sin \frac{\varphi_2}{2} e^{-K_{x-x}+\frac{1}{x^2} \left( \cos x - \frac{1}{x^2} \right)} e^{-K_{x-x} \int_{0}^{\varphi_0} \frac{1}{x^2} \sin u \, du} \int_{u}^{\varphi_0} \frac{u^2}{x^2} \cot u \, du
\] (5)

From the triangle \( \triangle O_1 O_2 \) (Figure 3, b) we find that

\[
\cos \varphi_1 = \frac{R_{C+D/2}}{R_C+D/2},
\] (6)

The calculation of the change in the luminous flux in the section \( 0 \) is carried out according to the formula \( \varphi_2 \leq \varphi \)

\[
F(O_x) = I(7) Z(x) \cos \frac{\varphi_2 - \varphi_1}{2} e^{-K_{x-x}+\frac{1}{x^2} \left( \cos x - \frac{1}{x^2} \right)} e^{-K_{x-x} \int_{0}^{\varphi_0} \frac{1}{x^2} \sin u \, du} \int_{u}^{\varphi_0} \frac{u^2}{x^2} \tan u \, du
\] (7)

\[
F(O_x) = I(8) Z(x) \sin \frac{\varphi_2 - \varphi_1}{2} e^{-K_{x-x}+\frac{1}{x^2} \left( \cos x - \frac{1}{x^2} \right)} e^{-K_{x-x} \int_{0}^{\varphi_0} \frac{1}{x^2} \sin u \, du} \int_{u}^{\varphi_0} \frac{u^2}{x^2} \cot u \, du
\] (8)

Equations (7) and (8) also show that the number of optical fibers in a hollow fiber should increase compared to the number of optical fibers in a linear light guide.

4. Findings

On the basis of optoelectronic transducers made of hollow light guides, new designs of automation devices and measuring equipment have been developed, characterized by high reliability, sensitivity, a wide range of input and output values, simplicity of design and economy. Some of them are implemented in process control systems. The most characteristic designs of optoelectronic converters based on hollow fibers, their properties and areas of application are considered. Linear and bridge optoelectronic transducers used as hollow fiber-based optoelectronic transducers with a movable element have the following advantages over other types of shear transducers:

1) active resistors, receivers and radiation sources are elements of bridge-type optoelectronic converters, and they can be powered by DC and AC voltage;

2) electric and magnetic fields almost do not affect the operation of bridge-type optoelectronic transducers;

3) optoelectronic converters of bridge type are simple and productive;

4) transducers have high sensitivity.

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