The optical method for condition control of flowing medium

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Abstract. In the article a new design of the optical part of a refractometer for monitoring the state of liquid medium is considered. The method for medium state control at the light-shadow boundary is substantiated. The experimental results of different liquid media are presented.

1. Introduction
The experimental and theoretical researches of different liquid media stream are one of the urgent problems of applied physics [1-7]. The non-contact methods are considered to be the most effective for liquid stream researches [3, 6-11]. Unlike other methods refractometric method makes it possible to carry out these researches without changing the physical structure and chemical composition of the liquid medium [9, 12-15].

Today the refractometry method, as well as refractometric instruments and systems are widely represented in the production market and are used throughout the pulp and paper industry, chemical industry, medicine, food industry, and also in laboratories for applied research.

Using refractometric methods create devices for monitoring liquid media - refractometers. Refractometers can be of different types as a model of the optical part of the device. This depends on the optical phenomenon, which is the basis of the device's operation. For example, the phenomenon of interference or total internal reflection.

Refractometers based on the work of which the phenomenon of total internal reflection lies must be in contact with the optical part with the liquid being studied. Therefore, they are installed in the vessels or on the pipelines in which the investigated liquid is located.

The advantage of this type of instrument is the measurement in real time in the liquid flow with the solution being investigated.

On the foreign market, a wide range of optical devices is available, allowing to monitoring the state of liquid fluids. But for the domestic consumer they have a number of shortcomings. For example, they need to be adapted to each specific production. And the universality of instruments of this type is accompanied by their increased dimensions. In addition, such devices are of high cost, which makes them less accessible.
2. The optical part of the device and the results of experiments

Usually the main elements of the refractometer are the probe, which is immersed in the liquid under investigation (it contains the optical part of the device), and the data acquisition and processing unit (electronic unit, figure 1).

Figure 1 Structural diagram of the refractometer: 1 - the electronic unit, 2 - the optical part of the instrument.

As a rule, in liquids there are gas bubbles, insoluble components, etc. This creates additional difficulties in the measurements [2, 9, 14-17].

The results obtained earlier have shown that in case the researched liquid media contains large insoluble compounds (for example, juice with pulp, medical suspensions, biological solutions, etc.), it is most expedient to control their state in the liquid flow by registering the position of the light-shadow boundary on the photodiode ruler.

Experiments with the standard design of the refractometer [17-20] have shown that there are a number of significant limitations in determining the state of the liquid medium from the shift of the light-shadow boundary. The limitations are related to the vignetting of the laser beam and a decrease in the contrast of the light-shadow boundary. There were many problems with sealing the optical part of the refractometer when measuring in high-pressure flows in a pipeline, etc.

For solving these problems we changed the optical part design of the refractometer (figure 2).

Figure 2 The Structural diagram of the optical part of the refractometer.
For this part the new the new prism design of leukosapphire prism design was calculated and manufactured (figure 3).

![Prism Design](image)

**Figure 3** Geometric shape and dimensions of the prism.

Research has shown that new design of the prism allowed us to use laser radiation with a plane angle of the radiation pattern of about 22.6° for measurements. The position of the semiconductor laser is moved along the base of the prism within 12 mm. Because the center of the laser beam must fall on the top face of the prism, which borders with the flow at a critical angle \( \alpha_c \):

\[
\alpha_c = \arcsin \left( \frac{n_m}{n_p} \right)
\]

where \( n_p \) is the refractive index of the material from the prism is made.

In figure 4 is shown, as an example, the intensity of laser radiation recorded by a photodiode line [21] at different concentrations of potassium \( N_k \) in the liquid aqueous solution of potassium nitrate.

![Intensity Distribution](image)

**Figure 4.** Distribution of the intensity I along the length d of the photodiode line. Graphics 1, 2, 3 corresponds to \( N_k \) в %: 30; 44; 52.

The results show a decrease in the contrast ratio of the light-shadow boundary as it moves along the length of the photodiode ruler (\( d_1 \) and \( d_3 \)) to the first graduation (\( d_2 \)) when the value of \( N_k \) changes. This makes it possible to adjust the position of the laser relative to the base of the prism. Because center of the laser radiation beam must fall on the upper face of the prism at an angle \( \alpha_c \). The geometry
of the new prism made it possible to apply a sealing gasket of conical shape in the optical probe of the refractometer. The gasket makes the influence of the vignetting effect of the laser beam on the faces of the prism not significant as compared to the prism of the trapezoidal geometry with an annular gasket previously used in the refractometer. The conical gasket also provides greater sealing reliability because sealing of the probe is very important for fast fluid flows of high pressure in the pipeline.

For example, on the concentration of N or T. Figure 5, as an example of the refractometer operation, studies of flowing aqueous solutions of various media at a temperature $T = 293.1$ K.

![Figure 5. Dependence of the refractive index of aqueous solutions of some substances on concentration: 1 - gelatin, 2 - sodium glutamate, 3 - sucrose, 4 - ethyl alcohol.]

3. Conclusion
Modernization of the optical design of the refractometer has made it possible to improve the accuracy of monitoring the state of the liquid medium, expand the temperature range $T$ of the liquid medium at which this control can be carried out. This is important during the continuous process. Expanding the $T$-range allows increasing the $n_m$ measurement range for monitoring the state of transparent media. The new device design allows carrying out measurements of $n_m$ from 1.2246 to 1.6120 with an error of 0.1% in the liquid medium. This result makes it possible to expand the use of the refractometer especially in the medical industry: the control of the state of phenylhydrazine ($n_m = 1.6105$) in the manufacture of medicines (eg, antipyrine, amidopyrine).

4. References
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