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DEVELOPMENT AND RESEARCH OF A FIBER OPTIC SYSTEM FOR DETERMINING THE SHAPE OF A FLEXIBLE TOOL AND ITS POSITIONING IN SPACE

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Introduction. The development and research of a fiber optic sensor retaining the shape of a flexible instrument is of great relevance in the modern world, especially in the field of industry, medicine, and robotics.

In modern industry, such sensors can be used to monitor the state of flexible tools such as manipulators, pipes, and cables. This will improve production processes, increase safety, and prevent accidents. In medicine, fiber optic sensors can be used to develop flexible endoscopes that allow doctors to perform more accurate and safe procedures, as well as to improve disease diagnosis. In robotics, these sensors can be used to create more compact and precise robots capable of performing complex tasks in inaccessible locations.

The fiber-optic implementation of the sensor provides a promising opportunity to determine the shape of the object in real time. Such sensors are used to implement the orientation and position of the optical fiber relative to its starting point or to implement the shape of the object.

Fiber optic shape sensors have clear practical advantages over their analogues, such as the ability to remotely surveying the sensor, no need to provide electricity to the measuring point, small dimensions, and resistance to external electromagnetic fields.

While studying the analogues of the established system, various schemes were found, as well as a trend of development of fiber-optic sensors retaining the flexible tool shape from the simplest sensors based on fiber Bragg gratings (FBG) (1980’s) [1] to sensors on continuous FBG in multi-cored optical fibers (2017) [2]. Two significant shortcomings were identified in the schemes considered:

1. use of expensive equipment (spectrum analyzer, multi-cored fibers, and equipment for surveying them);
2. need for temperature compensation.

These shortcomings can be corrected using the proposed fiber optic sensor scheme. In addition, the suggested concept can operate at significantly higher sensor response rates, which may be of potential interest for some applications.

Main body. As a sensitive element in the flexible tool shape retention sensor, it is proposed to use the FBG array and as a flexible tool itself a cable with a groove in the core and three grooves arranged symmetrically around the cable center. Four optical fibers with FBG arrays are placed in the grooves. Consider as an example of the principle of operation of the sensor pair FBG in the core of the cable and FBG in the top groove of the cable. In the dormant state, the FBGs have wavelengths $\lambda 1$ and $\lambda 1^*$ respectively. FBGs are sensitive to deformation so when the cable is bent, the FBG in the core of the cable will remain almost in its original state $\lambda 1$, and the FBG in the top groove of the cable will stretch. Due to this extension, the wavelength $\lambda 1^*$ will shift to the longwave region and become $\lambda 1^*$. Further, knowing $\Delta\lambda = \lambda 1^* - \lambda 1^{**}$, it is possible to calculate the axial deformation of the optical fiber and therefore the cable [3].

The proposed scheme eliminated the shortcomings of the analogue schemes considered in the review:

1. there is no need for temperature compensation because this scheme provides for automatic compensation, as FBGs’ spectra will shift by one value when temperature changes;

2. There is no need to use expensive equipment (spectrum analyzer or interrogator) to survey the sensor. In the proposed scheme, there is a transition from a spectral to an amplitude method - it uses a tunable filter, which is FBG, as well as an optical power meter using as a photoreceiver.

Conclusion. In this work, the simulation of the above-mentioned sensitive element in the COMSOL program was carried out under various environmental influences, such as deformation and temperature. The simulation showed the efficiency of the proposed method. Thus, the suggested scheme makes it possible to eliminate the shortcomings of the considered analogues, while illustrating the prospect of the above-described method for determining the shape of flexible tools and their position in space.

References:

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