Methods and test equipment of technological information sensors

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Abstract. The main aim of research is establishing dependence between a distance from inductive and capacitive technological information sensors to the acting element and imprecision of its operating in track mode. A track mode is understood as the passage of the acting element past the sensor. It is shown that with a decrease in the distance, the sensor imprecision will increase twice. This circumstance should be taken into account while designing automation systems.

1. Introduction

Over the past decades, there have been dramatic changes in industrial production and, especially, in industrial automation systems. Processor technology in automation expanded the range of tasks and the solution of traditional tasks has changed dramatically. Digital trends in automation are: the price of technological information sensors has fallen 100 times over the past few years; the price of figuring is reduced; the security of cloud technologies is increasing; the share of mobile data transmission increases.

All this leads to the need of additional studies of sensors in connection with the changed situation in this area.

An inductive sensor, detecting iron shavings in oil for lubricating aggregates and devices in order to diagnose early wear and tear, is considered in the work [1]. The runout is fixed not only qualitatively, but also quantitatively. The possibility of using inductive sensors in the interface of microcontrollers is investigated in [2]. A study of the effect of sensor parameters on the quality of signal transmission is being carried out. In [3], the effect of ambient temperature on the position measurement accuracy by an inductive sensor is investigated. It is noted that the decrease in accuracy is stronger with uneven heating of the sensor. The material for the synthesis of measurement error compensation algorithms is given. In work [4] a new capacitive sensor is proposed for detecting microdrops of a liquid. It is characterized by low cost, high accuracy and ease of manufacture. The sensor can also be used to measure the dielectric constant of a fluid. In work [5] methods of calibration of capacitive sensors for measuring the content of fluid in the soil, taking into account the high content of organic substances in it, are proposed.

With reference to the above mentioned, the task of studying the technological information sensors and the synthesis of new methods and test equipment is relevant.

2. Materials and methods

The aim of the study is to determine the dependence on the errors in the track mode sensors operation from the distance between a sensor and an acting element. Track mode is the passage of the acting element past the sensor. Objects of the study are two sensors: inductive contactless capacitive limit
switch CSN E5A5-31P-10-LZ and the contactless inductive limit switch ISN E4A-31P-8-LZ BK. The choice of these types of sensors is due to the widespread application of them in industry. Performance specifications and connection diagrams of sensors are given in the documentation [6]. The principle of the sensors’ operation is described in [7].

All the sensors under investigation are made structurally of the same type. Sensors have a cylindrical body with a screw on the outer surface for fastening with two nuts at the installation site. The sensing element and semiconductor equipment houses are in frame. All investigated sensors are matched with the same diameters of the mounting cylindrical part and therefore the research is carried out consequence on the same module [8, 9].

Research setup (Fig. 1) consists of a base 1 on which there are the sensor console 2, micrometer console 3, and a jack 4 for power supply connection. Also on the front panel there are terminals 5 for connecting the sensors to the power supply, 6 LEDs indicate the status of the sensor output and terminals 7 for connecting a measuring device to the sensor output. The digital indicator of the module is used as a measuring device [10].

The test sensor 8 is installed in the console 2 in the upper or lower terminal. Micrometer 11, with a division value of 0.01 mm, is installed in the console 3 and fixed to the screw 10. Acting element 12 is fixed on the sliding part of the micrometer (Fig. 2). The micrometer allows moving the element acting on the sensor and measuring its position depend on the sensor [11, 12].
The sensor is installed in the upper mounting hole of the sensor console for study in the track mode (see Fig. 2). In this case, the effect on the sensor of the "mustache" of the VE is investigated, that is, the rotation of the acting element is used. The distance between the end of the sensor and the acting element with the turn on state is divided into 3 approximately equal parts, which will correspond to the position of the acting element for study the sensor in the track mode. When micrometer turns handhold, then a "mustache" of acting element turns on, which lead to turn on/turn off the sensor. For each of the three positions, the sensor turn on or turn off n times.

The connection of the investigated sensor SQ1 to the power supply circuit of the module (Fig.3) is carried out with the help of male plug of the corresponding color. Direct current power supply of 24 Volts is provided through the socket XS4. The LEDs VD1 and VD2 respectively indicate the state of the output of investigation sensor and power supply on the module. Resistors R1 and R2 are limiting the current in the LED circuit. The sockets XS5 and XS6 are used to monitor the output signal of the investigation sensor.

![Figure 3. Electric schematic diagram of the module](image)

After the sensor is switched on and the value is fixed, the micrometer is rotated in the opposite direction (in the direction of the sensor disconnection) [13]. After fixing the micrometer values, when the sensor is turned off to avoid the influence of backlash, the "mustache" should be removed from the sensor, so that at the beginning of the next cycle of the experiment the switch-off position in the direction of movement to the switch-on.

3. The study of the structure of the modified lead-tin-base bronze

The results of measurements are used to calculate the arithmetic mean value of the observations by the formula:

$$l_{cp} = \frac{\sum_{i=1}^{n} l_i}{n}$$

(1)

where $l_i$ is the result of i observation; $n$ is the number of observations.

All the results are determined according to AUSS 8.009-72 average error values in the measurements from the smaller (larger) values:

$$\Delta_u = \frac{\sum_{i=1}^{n} \Delta_{ui}}{n} = \frac{\sum_{i=1}^{n} (l_{ui} - l_{cp})}{n}$$

(2)

$$\Delta_b = \frac{\sum_{i=1}^{n} \Delta_{bi}}{n} = \frac{\sum_{i=1}^{n} (l_{bi} - l_{cp})}{n}$$

(3)
where \( l_{\text{in}} (l_{\text{bi}}) \) – the measured value when changing from the smaller (larger) values; \( n \) is the number of experiments in the determination \( \tilde{\Delta}_u (\tilde{\Delta}_\phi) \).

The mean square deviation of the random component of the error is determined by the formula:

\[
\sigma = \sqrt{\frac{\sum_{i=1}^{n} (\Delta u - \tilde{\Delta}_u)^2 + \sum_{i=1}^{n} (\Delta \phi - \tilde{\Delta}_\phi)^2}{2n - 1}}
\]

(4)

The results of the study are presented in the Table. 1. Five experiments were taken.

| Distance, [mm] | Imprecision 1, [mm] | Distance, [mm] | Imprecision 2, [mm] |
|---------------|---------------------|---------------|---------------------|
| 2             | 0.211               | 4.5           | 0.256               |
| 4             | 0.203               | 6.5           | 0.239               |
| 6.5           | 0.094               | 7             | 0.112               |

The imprecision 1 is understood as the quadratic deviation of the random component of the error for the sensor ISN E4A-31P-8-LZ BK, under the imprecision 2 – CSN E5A5-31P-10-LZ.

4. Conclusion

Based on the research findings, we conclude that a decrease in the distance sensor error will increase by 2-2.5 times. This fact should be taken into account in designing automation systems with inductive contactless capacitive limit switch CSN E5A5-31P-10-LZ and the contactless inductive limit switch ISN E4A-31P-8-LZ BK. The obtained experimental material can be used for the synthesis of measurement error compensation algorithms.

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