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Research of Object Form Converters

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ABSTRACT: The article examines a method for constructing sensors (optoelectronic converters) that detect and control the geometric dimensions and volumes of objects with non-standard shapes in technological and other processes. The conditions for the conformity of the form of a non-standard object with the form of a standard object are considered. A block diagram of an optoelectronic converter with a set of intersecting vertical and horizontal photodiodes controlling the geometric dimensions and volumes of objects of various non-standard shapes is described. The results of the research study will make it possible to design highly sensitive optoelectronic converters of control objects with non-standard and complex shapes.

KEYWORDS: mechatronics; sensor; optoelectronic converter; the form; volume; oval without an interception; photodetector; photo receiving ruler; conversion algorithm; light guide; photo block.

I. INTRODUCTION

Historically, mechatronics developed from electro mechanics and, relying on its achievements, goes further by systematically combining electromechanical systems with computer control devices, built-in sensors and interfaces.

Sensors (primary converters) are one of the main elements in devices for remote measurements, registration and control, robotics and mechatronics, as well as in various instruments and devices for measurements in physics, biology and medicine to control the vital activity of humans, animals or plants. And also, in connection with the automation of production, sensors for measuring and recording the density of solutions, displacement, geometric dimensions, volume and other parameters that characterize technological processes have become very important.

II. MATERIALS AND METHODS

In practice / 1, 2 / the volume of an object with a non-standard shape is determined by a calculation method, likening it to any geometric body. For example, an oval-shaped object is considered as a body of revolution, consisting of two hemispheres at the ends of two truncated cones (for convex and concave shapes) and two cylinders (for a cylindrical shape.

Numerically, the shape of an object is most simply expressed by the length *D* by the largest width *d*. In the case of an oval shape, without an interception, the largest transverse diameter of the object is considered to be the largest width; in the case of a shape with an interception, the largest transverse diameter of the convex parts of the object.

The shape of an object with an interception (Fig. 1, c) is more fully characterized by the length of the interception width d_n and the hemispheres d_1 and d_2. In this case, the value that determines the shape of the object is conveniently represented as the following record / 2 /:

$$\frac{D, dn}{d_1, d_2} \qquad (1)$$

For the numerical expression of the shape of an object with hemispheres, the concepts of "degree of narrowness" and "degree of interception" / 1 / are known. The degree of narrowness Cn is the ratio of the length D to the average length of the hemispheres $\frac{d_1+d_2}{2}$ of the object, i.e. :

$$C_n = \frac{D}{\frac{d_{1+}d_2}{2}} = \frac{2D}{d_{1+}d_2} \qquad (2)$$

$d_n \frac{d_1+d_2}{2}$the degree of interception C_i is the ratio of the average width of the hemispheres to the width of the interception, i.e.

$$C_i = \frac{d_1+d_2}{2d_n} \qquad (3)$$

In this case, C_n is always> I, and C_i>, <I, which depends on the shape of the object.

Consider the classification of objects by shape (Fig. 1) and analytical expressions that approximate these shapes of the object shell.

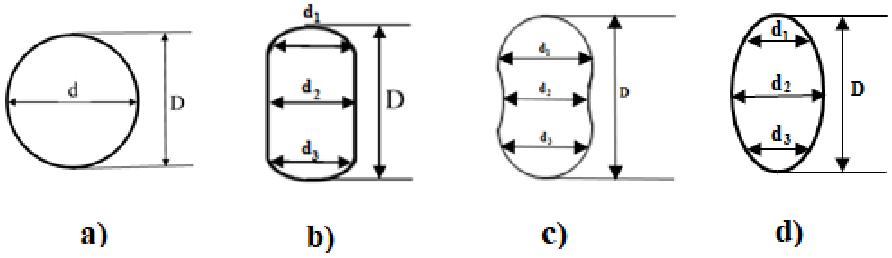


Fig. 1. Schematic representations of the shape of controlled objects

For spherical controlled objects, the condition approximating (with an error of no more than 7%) these forms of the shell of objects (Fig. 1, a.):

$\frac{D}{d} \leq 1,5,\ 0.95 \leq \frac{D}{d} \leq 1.05,$ in this case the formula for calculating the volume:

$$V_s = \frac{\pi D^3}{6} = \frac{\pi}{12}\left(D^3 + d^3\right) \qquad (4)$$

2. Forcylindricalcontrolledobjects (Fig. 1b.):

$D > d,\ d_1 = d_2 = d_3 = d,$ in the current case, the formula for calculating the volume:

$$VC = \frac{\pi}{4} d^2 D; \qquad (5)$$

3. For oval controlled objects without an interception (Fig. 1 c.):

$$D > d,\ d_1 < d_2 or \frac{d_2}{d_1} < 2,\ d_1 \neq d_2 \neq d_3,$$

in the current case the formula for calculating the volume:

$$VOWITHOUT=\frac{\pi}{6}d_2^2D \qquad (6)$$

4. For oval controlled objects with an interception (Fig. 1 d.):

D> d, $d_1 \neq d_2 \neq d_3$ $d_1 > d_2$, in the current case the formula for calculating the volume:

$$VOWITH=\frac{\pi}{6}\left(d_1^3+d_2^3\right) \qquad (7)$$

The adequacy of the A_{mod} models is determined by the formula:

$$A_{mod}=\frac{V_{\text{å}}-V_M}{V_{\text{å}}}100\% \qquad (8)$$

where: $V_Э$ - the actual volume of the object determined by the liquid volume measure; V_M -is the volume of the same object, determined by the corresponding formulas 4 ÷ 7.

Table 1 shows the results of calculating the adequacy of the models:

Table 1.

Forms	Spherical	Cylindrical	Oval without interception	Oval with interception
A_{mod},%	99,64	78,06	87,85	91,74

In the control of geometric dimensions, an optoelectronic converter is proposed, built on the basis of mutually intersecting vertical and horizontal photodetector rows / 3,4 /.

The block diagram of the proposed device (Fig. 2) contains an illuminator consisting of a source I and an objective 2, a counting bar 4, a photodetector unit 5, an interface device 6, a microprocessor 7 and an information display device 8. The structural drawing of a photodetector bar 4 is shown in Fig. 3.

The light-receiving part of the converter consists of photodetectors arranged in the form of a matrix (Fig. 3, a). The joining of optical fibres with photodetectors is illustrated in Fig. 3, b. Each connection of optical fibres to the radiation receiver must be reliable with low loss and distortion of the transmitted signals. The connection is one-piece, but the light guide with the photodetector is rigidly fixed by the dotted line in Fig. 3, b.

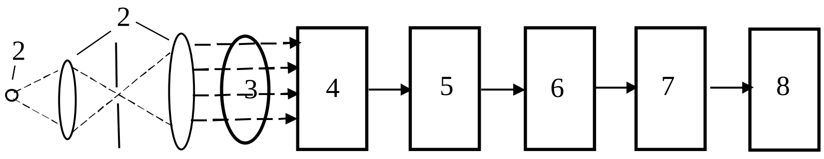


Fig. 2. Block diagram of the optoelectronic converter

The efficiency of joining optical fibres with photodetectors can be described by the expression for the transmitted light power / 5 /:

$$P_f = F_f \frac{n+1}{2})\left(\frac{A_c}{A_r}\right)(NA)^2 P_s$$

where: P_f- is the power of the radiation coming out of the fibre;

P_s - power emitted by the source;

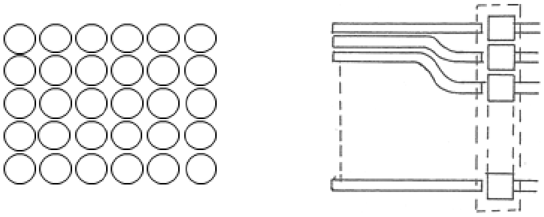
F_f - fill factor;

A_c - is the area of the fibre core;

A_r- is the active area of the receiver;

n - exponent in angular dependence $(\cos\theta)^2$;

NA -is the numerical aperture, which usually ranges from 0.15 to 0.50.



a) b)

Fig. 3. Constructive drawing of the photodetector ruler

The principle of operation of the proposed device is based on the phenomenon of "light-shadow" / 6 /. The monitored object when passing between the illuminator and the light guideline, depending on the geometric dimensions, blocks a part of the light flux of the illuminator. In this case, the corresponding input ends of the fibres are alternately darkened, which causes a change in the signal at the output of the photodetectors.

When the fibre end face is illuminated, the output of the corresponding receiver will be a high-level electrical signal proportional to the digital signal “1”, and when it is shaded - a low-level signal corresponding to “0”.

The number of shaded samples of vertically located fibre-optic lines determine the width of the object, and horizontally located ones - the length / 6 /.

The electrical signals of the photoblock through the interface devices are purchased into the microprocessor for processing according to the appropriate algorithm, after which the display device displays numbers characterizing the geometric dimensions, volume and shape of the object shell.

To determine the shape of the shell of an object, it is necessary to know the length, width of the interception and two hemispheres of the object.

The corresponding conversion algorithm for these values (D, d_1, d_2, d_3) is shown in Fig. 4 (n - the quantization step determined by the number of horizontally located light-guide fibres; m- an arbitrary number equal to 1, 2, 3; N_{vn}, $N_{d\,(n-1)}$ - the number of shaded vertically arranged light-guide fibres at n and (n -1) -th step, respectively, N_{hn} is the number of shaded horizontally located light-guide fibres; A - a zero sensor for counting the beginning and end of control).

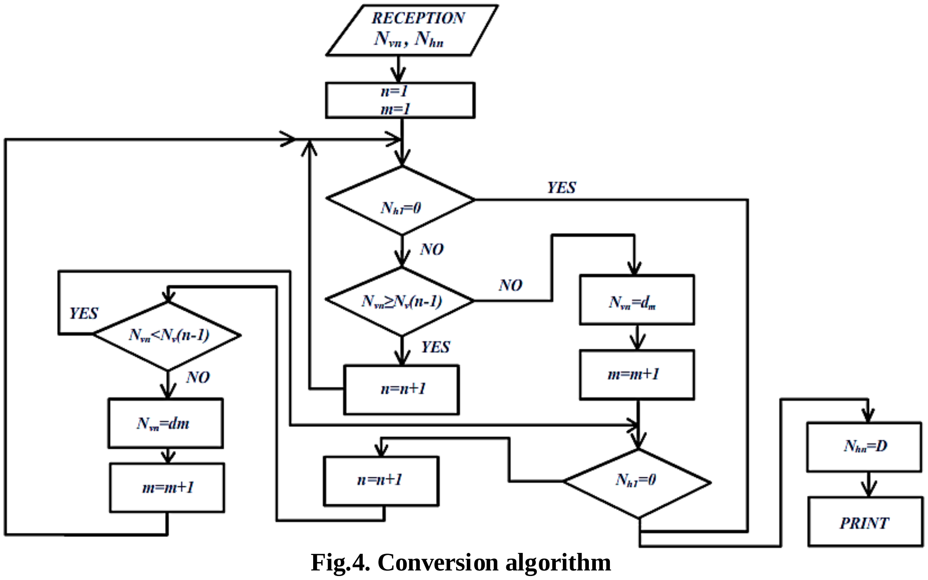


Fig.4. Conversion algorithm

If the input end of the middle fibre is shaded, A = 0, and, therefore, the pulses are counted, at A = I the microprocessor stops removing digital signals from the photoblock. Figure 5 shows an algorithm for determining the shape of the shell of an object and calculating the volume / 7 /. We find the geometric dimensions of the object by the formula:

$$D = P_A \Delta e + B_0$$
$$d_m = P_B \Delta e + B_0 \qquad (9)$$

where: P_A, P_B - the number of simultaneously darkened photodetectors A and B;

Δe - is the width of the photosensitive surface of the photodetector;

B_0 - conditional zero ($B_0 = K\Delta e$, where K is an integer).

The number of photodetectors in each coordinate determines the measurement range of h and L, and the number of photodetectors is found by the ratio:

$$P_A = \frac{L_{max}}{\Delta l}$$
$$P_B = \frac{hmax}{\Delta l} \qquad (10)$$

measuring range

$$h_{min} \geq \frac{d_{max}}{2};$$
$$L_{-min} > D_{-max.}$$

The measurement error is due to the deviation of the real width of the photosensitive surface of the photodetector from the calculated one, i.e.:

$$\Delta = \Delta e' - \Delta e_o.$$

Where:

$$\Delta_k = \sum_{i=1}^{k} \Delta i \qquad (11)$$

Due to the scatter of the actual width Δe relative to Δe_o, the error β has a normal distribution and dispersion.

Thus, the error will have a distribution density:

$$f(\beta) = \frac{1}{\sqrt{2\pi\sigma_0}} \exp(\frac{-\beta^2}{2\sqrt{n\sigma^2}} \qquad (12)$$

If you set the condition $\beta \leq / 0.5\ \Delta e\ /$ taking into account three sigma, then you can determine the smallest value of h with a known Δ_o.

In this case, $3\sigma = 2\ /\ \Delta_o\ /$

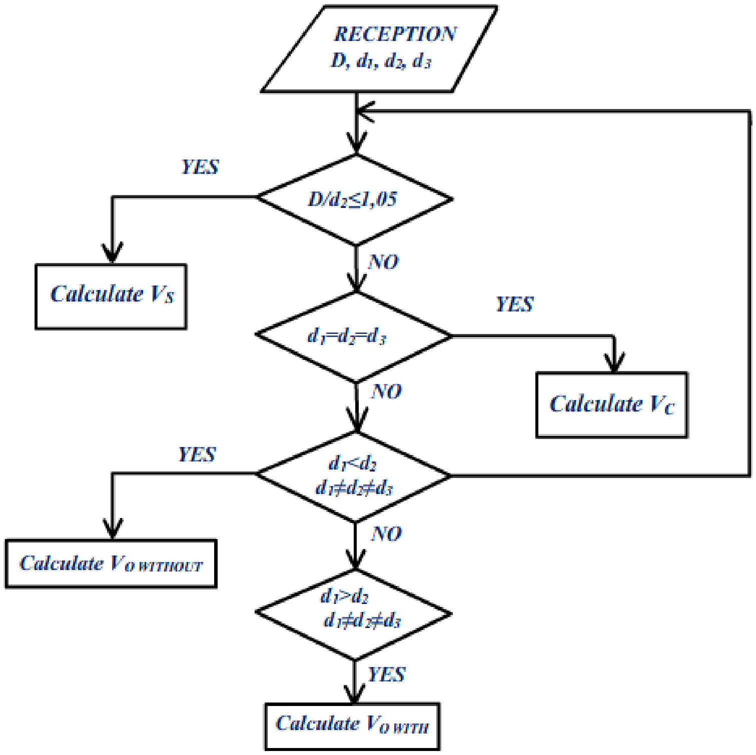


Fig. 5. Algorithm for finding the "model" of the object

We assume that the measurement range is a multiple of n. Then in the measurement range$\sigma = \sqrt{L/\Delta l \sigma_0}$and the required condition will be expressed by the inequality$3\sigma = \sqrt{L/\Delta l < \Delta l}$with which you can choose the width of the photosensitive surface of the photodetector in accordance with the specified range and measurement error.

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