Experimental Galvanomagnetic Transdusers of Linear Offset – Part I

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Abstract – **Instrumentation and automatic control need transducers of mechanical quantities which should have high precision, sensitivity and reability fundamentally defined by the magnetosensitive element parameters. An experimental investigations of various sensors constructive solutions of linear offset with open magnetic circuit have been presented and described in the report. Conversion characteristics have been obtained and theoretical-experimental models developed, which illustrate their properties.**

Keywords – **Hall elements, Offset transducers, Transducers characteristics modelling.**

I. Introduction

Various areas (spheres) of instrumentation and automatic control need transducers of mechanical quantities which should have high precision, sensitivity and reliability fundamentally defined by the magnetosensitive element parameters [2-4, 6].

The object to this elaboration is to realize, investigate and describe different variants of galvanomagnetic transducers for linear offset based on Hall element of the type VHE101 and to premise their future projection and application.

II. Presentation

Different constructive variants of the magnetosensitive transducers of linear offset with open magnetic circuit based on the synthesized and investigated galvanomagnetic transducer [5] have been developed. They consist of magnetic system, magnetosensitive element (Hall element of type VHE101) and signal processing circuit [5]. They transform the linear alteration L into magnetic field value B alteration which magnetosensitive element converts into electrical signal, i.e. there is a double energy transformation. The magnetic field course of action in different constructions is defined by the permanent magnet disposition according to a Hall element. The investigations have been fulfilled at constant temperature T_O = 25°C on especial installation equipped with standardized watch with precision 0,001mm. The measuring amplifier gain is so picked out that output voltage working range should be closed from – 10V to +10V.

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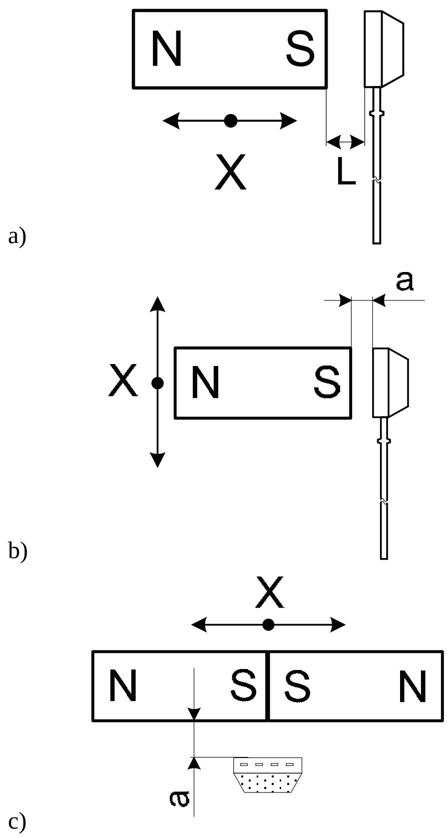

Fig. 1. Galvanomagnetic transducers for linear offset

In case of open magnetic circuit sensor the magnetic field action is one-sided (unilateral) in relation to a Hall element sensitive surface (Fig.1a, b, c). It is necessary to know there are only linear output characteristics if the inductance B is in a sensor linear range. The first constructive variant is depicted in Fig.1a. The permanent magnet is so arranged that its magnetic lines pass across sensitive surface of Hall element which is immobile. When the magnet is moved to a direction of X the distance L between it and Hall element is changed. It is registered by Hall voltage U_O alteration as a result of magnetic field B change effect. Conversion characteristics U_O= f(L) are shown in Fig. 2. They have been measured at constant temperature (T_O = const) at three values of control current. Their analysis shows there is output voltage U_O nonlinear alternating when a distance L is increased. The characteristics slope is not equal in whole investigated range L. For offsets from 2 mm to 6 mm the slope is 0,11; 0,46; 0,6V/mm at a control current I_S=1; 5; 10mA respectively. In case of offsets from 15mm to 20mm it is 0,04; 0,045; 0,5V/mm at I_S = 1; 5; 10mA respectively.

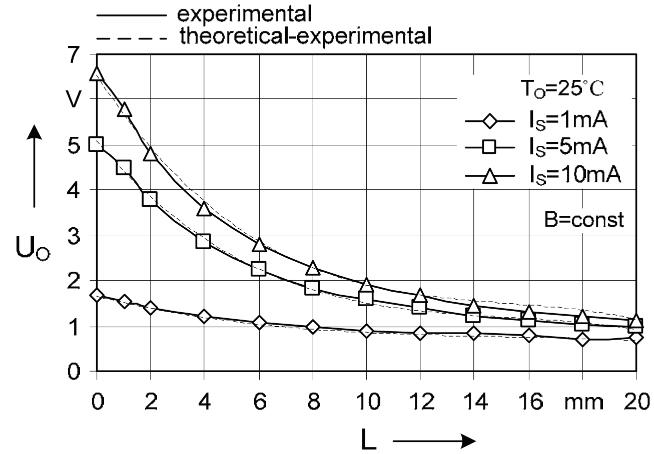

Fig. 2. Conversion characteristics U_O= f(L) for constructive variant in Fig. 1a.

The control current I_S influence on output level U_O decreases when the distance increases. At L=0 output level is U_O = 1,69 to 6,6V at control current I_S = 1 to 10mA respectively. At L = 20mm there is U_O = 0,76 to 1,1V at control currents I_S = 1 to 10mA respectively, i.e. it is fourteen times less in comparison with a case L = 0.

The obtained characteristics have been described by the equation:

$$U_O = a.L^3 + b.L^2 + c.L + d \quad (1)$$

The model coefficients have been defined by the least squares method [1]. The theoretical-experimenral equations are valid for distance changing from 0 to 20mm. They are:

$$U_O = -0{,}0013.L^3 + 0{,}0589.L^2 - 0{,}9329.L + 6{,}5696, \text{ at } I_S=1mA$$
$$U_O = -0{,}0009.L^3 + 0{,}0426.L^2 + 0{,}6851.L + 5{,}0379, \text{ at } I_S=5mA \quad (2)$$
$$U_O = -0{,}0002.L^3 + 0{,}0088.L^2 - 0{,}149.L + 1{,}6878, \text{ at } I_S=10mA.$$

Constructed on a basis of (2) theoretical-experimental characteristics are depicted in Fig. 2. They present experimental results with ±5% accurasy.

It has been realised and investigated a constructive variant which enables offset watching of magnetic object in parallel to a Hall element sensitive surface direction (Fig. 1b). The Hall element is stationary arranged at a constant distance (a=1mm) from a permanent magnet. The experimental characteristics are depicted in Fig. 3. They are obtained at room temperature (T_O= const), three values of control current I_S = 1; 5; 10mA and distancce changind ΔL=16mm. Their analysis shows that the magnetic object provokes an outpput voltage U_O decrease. It is typically of this construction which generates a same output voltage when there is a offset at the same distances L in both direction of X. Therefore this sensor is not suitable to determination of linear offset direction. The sensor sensitivity is comparable to that determinated for the circuit in [5]. There is a higher sensitivity for offset alterating L from 0 to 2 mm (0,15V/mm at I_S = 1mA; 0,58V/mm at I_S=5mA and 1V/mm at I_S = 10mA respectively) and smaller one for L = 6 ÷ 8 mm (0,05; 0,2; 0,25V/mm at I_S=1; 5; 10mA respectively). This trend is valid for both direction of X.

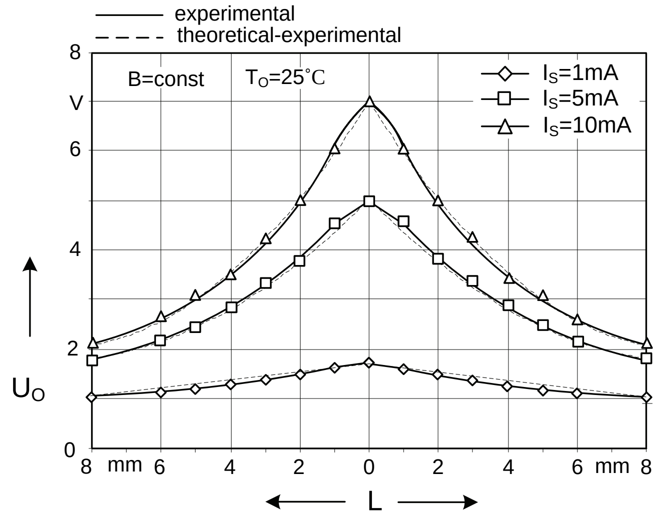

Fig. 3. Conversion characteristics U_O= f(L) for constructive variant in Fig. 1b.

The regressive equation (3) have been obtained by the least squares method [1]. They describe experimental characteristics and results at alteration L from 0 to 8 mm in both directons of X.

$$U_O = -0{,}084.L + 1{,}696, \text{ at } I_S=1mA$$
$$U_O = 0{,}038.L^2 - 0{,}707.L + 5.051 \text{ at } I_S=5mA \quad (3)$$
$$U_O = 0{,}061.L^2 - 1{,}091.L + 6{,}951, \text{ at } I_S=10mA.$$

Theoretical-experimental characteristics are depicted in Fig. 3. They repeat the experimental characteristics with accuracies ±2; ±1,1; ±1% at I_S = 1; 5; 10mA respectively.

The constructed sensor for linear offset depicted in Fig 1c is fulfilled by means of two permanent magnets brought together with homonymous poles. Hall element is fixed immovably at constant distance (a = 1mm) to the magnets. The analysis of the obtained at constant control current (I_S = 1mA), constant temperature (T_O=const) and constant magnetic field (B=const) conversion characteristics (Fig. 4) shows raised output voltage values at small transfers (L = 0 ÷ 1mm). Characteristics are arranged in four quadrants of the coordinates and are symmetric in first to second and in third to fourth quadrants respectively. Constructed magnetomodulating system defines a conversion chracteristics type and output voltage values.

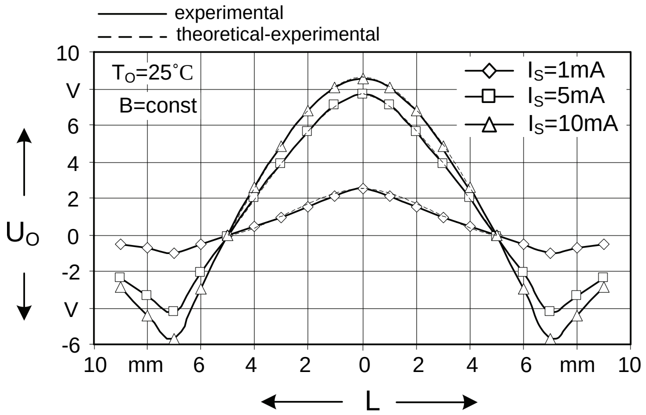

Fig. 4. Conversion characteristics U_O= f(L) for constructive variant in Fig. 1c.

There is a magnetic induction B falsery raisind where homonymoys magnetic poles are in contact. Therefore at L=0 there are the bigest output voltage values (U_O = 8,5V at I_S=10mA). But output voltage U_O is zero when the magnet is moved in distance L = 5mm in both direction of X. In this case as a result of a neutralization of positive and negative magnetic lines the magnetic induction B is zero. Magnetic lines direction and magnetic field action are changed when a distance is increased and became 5 to 7mm. As a result the output voltage changes its sign and has a maximum value U_O=-5,8V at L = 7mm and I_S = 10mA. At L>7mm output voltage U_O decreases again since the magnet is moved away and magnetic field action on Hall element is grown weak. The output voltage alteration is kept for a whole investigated control current range. The characteristics slope is not constant and is dependet on control current value. The highest slope value 2,5V/mm is obtained at control current I_S=10mA and L= 4 ÷ 5mm until the smallest one 0,4V/mm at I_S = 1mA and L= 8 ÷ 9mm. These values are valid in both directions of X. The obtained experimental characteristics can be described by means of equations of type (1). They are a mathematical presentation of output voltage alteration dependet on a transfer L = 0 ÷ 5 mm in both direction of X. The least squares method [1] is used for regressive equations coefficient finding. Then the equations are:

$$U_O = 0{,}023.L^3 - 0{,}195.L^2 - 0{,}051.L + 3{,}121, \quad \text{at } I_S=1mA$$
$$U_O = 0{,}039.L^3 - 0{,}465.L^2 - 0{,}21.L + 8{,}534, \quad \text{at } I_S=5mA \qquad (4)$$
$$U_O = 0{,}028.L^3 - 0{,}475.L^2 - 0{,}035.L + 9{,}401, \quad \text{at } I_S=10mA.$$

Constructed theoretical-experimental characteristics which look like experimental ones with ±1.48% accurasy at the all investigated control currents are depicted in Fig. 4.

III. Conclusion

1. Three constructive variants of galvanomagnetic transducers of linear offset have been realized and investigated.
2. Their experimental conversion characteristics have been obtained and investigated.

It has been established:

- obtained characteristics are symmetrical and disposed in first and second quadrants of co-ordinates;
-constructions for linear offset depicted in Fig.1a and Fig.1c have conversion characteristics with higher slope which is 1V/mm at L = 2 mm and I_S = 10 mA.

3. Theoretical-experimental models of sensor characteristics have been developed which aid their modeling and elaboration.
4. Created consructive sensor variants for linear offset can be applied in instrumentation and autimation. Mathematical equations obtained on the basis of the experimental characteristics aid the sensor modeling and elaboration.

References

[1] Aleksandrova, I.S. Basis of Engineering Investigations. Technical University Issue “Vasil Aprilov”, Gabrovo, 2003.
[2] Takov, T. Semiconductor Sensors. Issue “Techniques”, Sofia, 1986.
[3] Aleksandrov, A., N. Draganov. Monitoring System of Pulsation Processes in a Milking Machine. Proceedings of papers – ICEST, p.711-714, Ohrid, Macedonia, 24-27 June 2007.
[4] Draganov, N., A. Aleksandrov. Galvanomagnetic Antilock Braking System. ELMA, p.134-136, Sofia, 15-16 September 2005.
[5] Draganov, N., A. Aleksandrov. Galvanomagnetic Transducer with Analogue Output. Conference ELEKTRONICA`10, Sofia, to print.
[6] Roumenin, C. S. Solid State Magnetic Sensors, Amsterdam, Elsevier, 1994.