Experimental Galvanomagnetic Transducers of Linear and Angular Offset – Part II

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Abstract - **Instrumentation and automatic control need trancducers of mechanical quantities which should have high precision, sensitivity and reliability fundamentally defined by the magnetosensitive element parameters.**

Conversion characteristics of the sensor for linear and angular offsets have been presented and described. Their theoretical-experimental models have been developed.

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

I. INTRODUCTION

Transducers of mechanical quantities are widely applied in instrumentation and automatic control. They should have high precision, sensitivity and reliability fundamentally defined by the magnetosensitive element parameters [2-4, 6].

The object and aim of the present elaboration is to realize and investigate experimental constructive variants of galvanomagnetic transducers of linear and angular offset on a Hall element of the type VHE101 basis and to enable their future project.

II. PRESENTATION

On the basis of the synthesized and investigated galvanomagnetic transducers [5] different constructive variants of galvanomagnetic transducers of linear and angular offset have been elaborated and investigated. They consist of a magnetic system, magnetosensitive element (Hall element of the type VHE101) and signal processing system. Their action is based on energy double conversion. The linear offset L alteration is converted into magnetic field B values change which in a Hall element is transformed into a electrical signal. Three constructive variants created by means of a permanent magnet have been investigated. A magnet arrangement in relation to a Hall element defines a magnetic field influence in different constrictions. The investigations have been fulfilled at constant temperature T_O = 25°C on an especial standard installation equipped with indicative watch with precision 0,001 mm. The measuring amplifier gain is picked out so that an output voltage working interval should be closed from -10V to +10 V.

The investigated sensor constructions are:

- Sensors with closed magnetic systems. In the first version the Hall element is fixed stationary at a permanent magnet pole (Fig. 1a). In the second version it is fixed (Fig. 1b) between homonymous poles of two permanent magnets. The magnetic field action on the Hall element sensitive surface is bilateral (orthogonal);
- Sensor for angular offset with open magnetic system (Fig.1b). A Hall element and control part is immovable. An angle of a magnetic field action is changed.

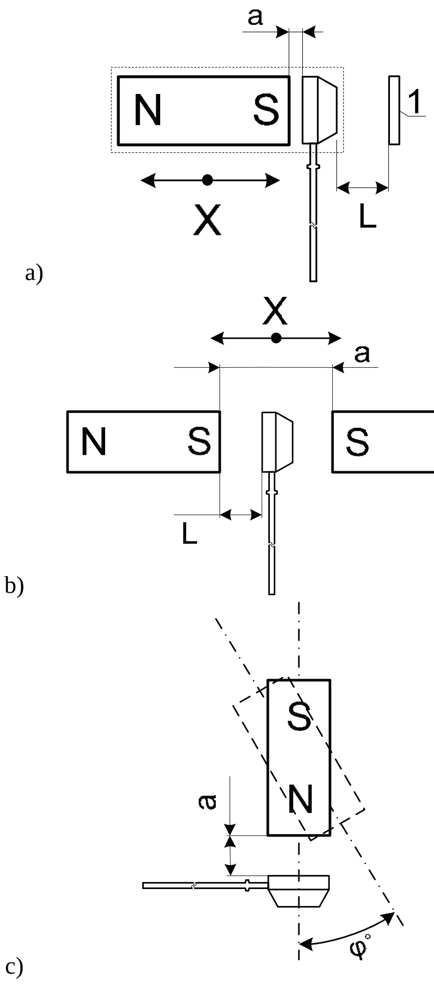

Fig. 1. Galvanomagnetic transducers for linear and angular offset.

It is necessary to have in mind there are linear output characteristics only if an inductance B is in a sensor linear range.

In first constructive variant the ferromagnetic object 1 in Fig. 1a is moved. It has a concentrative role. When this object is moved to a Hall element the magnetic field action is

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increased and is decreased if it is gone away. Experimental conversion characteristics are shown in Fig. 2. Their shape is defined by the magnetic induction value and ferromagnetic substance properties from which the mobile object is produced. The control current I_S influence is equal in whole distance L alteration. The deduced theoretical-experimental equation is:

$$U_O = a.L^3 + b.L^2 + c.L + d \tag{1}$$

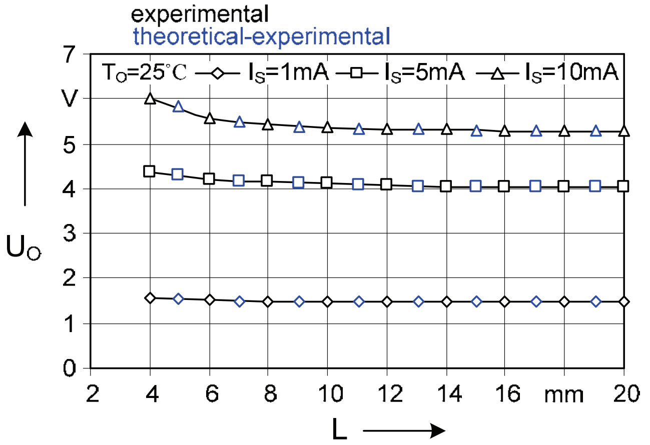

Fig. 2. Conversion characteristics U_O= f (L) for constructive variant in Fig. 1a.

Model coefficients are defined by means of the least squares method. Theoretical-experimental characteristics coincide with experimental ones. The obtained dependence (2) describe with high accuracy the experimental characteristics in the limits of a investigated linear offset L and control current I_S alterations at a temperature T_O = 25°C.

$$U_O = -(0{,}1.L^3 - 4{,}1.L^2 + 56{,}7.L - 1743).10^{-3}, \quad \text{at } I_S\text{=1mA}$$

$$U_O = -(0{,}2.L^3 - 7{,}5.L^2 + 122{,}7.L - 4727).10^{-3}, \quad \text{at } I_S\text{=5mA} \tag{2}$$

$$U_O = -(0{,}6.L^3 - 25{,}5.L^2 + 370.L - 7071).10^{-3}, \quad \text{at } I_S\text{=10mA.}$$

Another sensor construction for linear offset is depicted in Fig. 1b. A Hall element is arranged between homonymous poles of two permanent magnets. They are immovable each to other at a distance a = 40mm. The permanent magnets disposition provokes with a same polarity and magnitude of magnetic fields simultaneously action on a Hall element both opposite surfaces. When Hall element is placed an equal distance to both magnets (L = 0) the output voltage will be U_O=0 because of the both equal magnetic fields synchronously action. The measured on Hall electrodes voltages separately towards ground will not be zero but will have equal absolute magnitudes |UH2| = |UH4| ≠ 0. When Hall element is moved to one of both directions of X the magnetic field influence will be amplified at another one expense. This will cause a change of the Hall voltages absolute magnitudes |UH2| ≠ |UH4|. Their difference will be amplified by the amplifier.

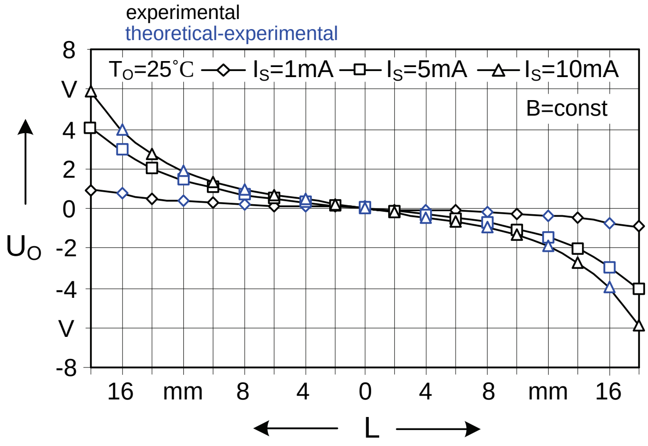

Fig. 3. Conversion characteristics U_O= f(L) for constructive variant in Fig. 1b.

Experimental conversion characteristics U_O = f (L) at I_S=const, B=const and T_O=const are depicted in Fig. 3.

Their analysis shows a characteristics symmetry in second and fourth quadrants of co-ordinates and nonlinearity in whole investigated offset range (L = 0÷20) mm. The obtained experimental characteristics U_O = (L) can be described by means of regressive cubic equations of type (1). Their coefficient are defined by the least squares method. The output voltage U_O alteration in the interval L = (0÷18) mm is described by the following models:

$$U_O = -(0{,}2.L^3 - 8{,}6.L^2 + 144.L).10^{-3} + 1{,}607, \quad \text{at } I_S\text{=1mA}$$

$$U_O = -(1{,}3.L^3 - 47{,}2.L^2 + 676{,}9.L).10^{-3} + 4{,}707, \quad \text{at } I_S\text{=5mA} \tag{3}$$

$$U_O = -(2{,}3.L^3 - 80{,}8.L^2 + 1058{,}5.L).10^{-3} + 6{,}47, \quad \text{at } I_S\text{=10mA.}$$

Theoretical-experimental characteristics are drawn on the equations (3) basis. Their analysis shows they are fully analogical to the experimental ones.

A constructive variant intended for rotation angle reading, for little slope e. t. is depicted in Fig. 1c. A Hall element is arranged stationary at distance a = 1mm towards the permanent magnet. In according to a sensor purpose the in the center fastened permanent magnet can rotate or fastened in opposite end towards a Hall element can incline. The proposed constructive variant is investigated at a permanent magnet rotation to an angle φ = ±(0÷90)deg. The conversion experimental characteristics U_O = f(φ) obtained at constant control current (I_S = const) and constant temperature (T_O=const) are depicted in Fig. 4.

Their analysis shows they are nonlinear in whole investigated range φ = ±(0÷90)deg but symmetrical in first and second quadrants of co-ordinates. The highest slope is received at big angles. For example, the slopes are S_A=0,03; 0,09; 0,065V/deg at I_S = 1; 5; 10mA respectively. At little angular offset φ = (0÷10)deg the slope is S_A = 0,01V/deg at I_S=10mA i.e. it is 6 times less than at big angles.

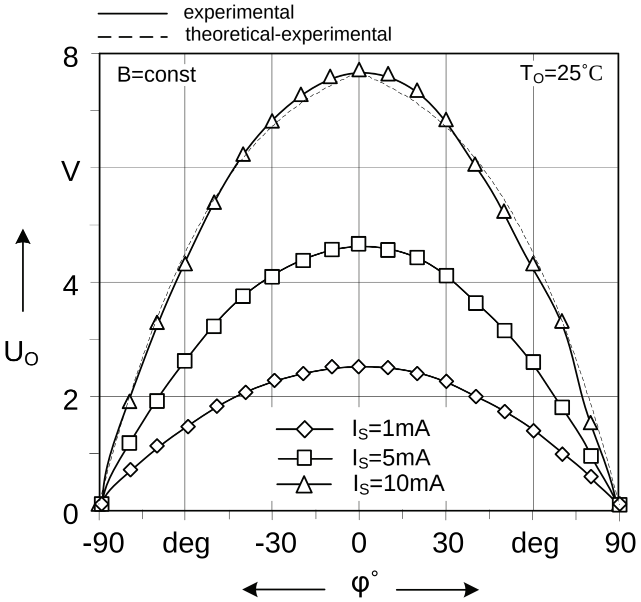

Fig. 4. Conversion characteristics U_O= f(L) for constructive variant in Fig. 1c.

Regressive equations (4) which describe constructed experimental characteristics at angular rotation φ = (0÷90)deg have been obtained.

$$U_O = -(0{,}2.10^{-3}.\varphi^3 + 90.10^{-3}.\varphi^2 + 3.9.\varphi).10^{-3} + 2{,}621, \quad \text{at } I_S\text{=1mA}$$

$$U_O = -(3.10^{-3}.\varphi^3 + 0{,}2.\varphi^2 + 8{,}5.\varphi).10^{-3} + 4{,}681, \quad \text{at } I_S\text{=5mA} \qquad (4)$$

$$U_O = -(6.10^{-3}.\varphi^3 + 0{,}2.\varphi^2 + 22{,}2.\varphi).10^{-3} + 7{,}759, \quad \text{at } I_S\text{=10mA.}$$

Theoretical-experimental characteristics are depicted in Fig. 4 by doted line. Their analysis shows at control current I_S=1; 5mA these characteristics fully concur to experimental ones and at I_S = 10mA approach with accuracy ±5%.

III. CONCLUSION

1. Three constructive variants of galvanomagnetic sensors for linear and angular offset have been realized and investigated.

2. Experimental conversion characteristics U_O = f (L) of the synthesised galvanomagnetic sensor for linear offset illustrated an output voltage alteration towards a distance and an angular rotation have been investigated.

3. Theoretical-experimental models of these sensors have been developed which aid their modeling and elaboration.

4. Created constructive sensor variants for linear and angular offset can be practically applied in different spheres of science, instrumentation and automatic control and mathematical equations obtained on their experimental characteristics basis aid its modeling and elaboration.

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