Investigation of biparametric resonance sensors with distributed parameters

Sulton Amirov[1], *Absaid* Sulliev[1*], *Kamolbek* Turdibekov[1]

[1]Tashkent State Transport University, Tashkent, Uzbekistan

Abstract: This article describes the ways to preserve the resonant mode in biparametric circuits with distributed parameters and studies the effect of changes in the circuit parameters and power supply on the resonant mode. During the moving part's movement of the sensor due to the influence of the distributed magnetic resistance of the steel part of the circuit, the law of change in the electrical inductance of the resonant circuit (distribution of magnetic flux in long magnetic conductors) differs from the linear one.

1. Introduction

Automation of various technological processes, requiring the use of a complex of primary converters - sensors, makes it quite easy to perform labor-intensive processes, save energy resources, reduce the cost of manufactured products and improve its quality by providing close to optimal operating modes of control and management objects both in normal and in emergency situations. Meanwhile, one of the main obstacles to this is the lack of motion sensors (displacement, speed, acceleration, vibration, etc.) that meet modern requirements when working in extreme operating conditions with increased dust, humidity, significant temperature differences, etc. [1,2,3].

A comparative analysis of the main characteristics of existing motion sensors shows that the most promising direction in solving the actual problem of more efficient use of monitoring and control systems is the use of biparametric resonant motion sensors (BRMS), which, by their properties (high reliability and stability of characteristics in extreme operating conditions, and also high output power) best meet the modern requirements of monitoring and control systems. However, the existing motion BRMS are practically unusable due to sensitivity instability over the entire measurement range, non-linearity of the static characteristic, and low measurement accuracy. As a result, the accuracy of control and management is reduced, and in some cases the stability margin of the system is reduced. The need for a more accurate and stable measurement of the technological parameters of the movement of objects of control and management systems puts forward the problem of developing new traffic control systems with improved information and technical characteristics, which explains the relevance of the research problem.

Biparametric chains are called here chains in which two parameters of the chain are variables at the same time. Most often, the variables are the parameters of the reactive elements of the inductive coil and capacitor.

Some electromagnetic sensors (for example, sensors of motion parameters) - primary transducers contain biparametric circuits. The advantage of these so-called biparametric sensors is that they combine the advantages of electromagnetic (high output power, stability of characteristics) and capacitive (linear static characteristics, high sensitivity) sensors [4,5]. If at the same time the reactive elements form a resonant circuit, the sensitivity of such sensors increases dramatically.

Chains of biparametric resonant sensors are chains with electrical and magnetic parameters distributed along the coordinate of the moving part [8,9]. The distribution of parameters leads to the fact that in the operating range of the input value x, the circuit leaves the resonant mode, while sharply reducing the sensitivity of the sensors.

2. Materials and Method

An important requirement for biparametric resonant sensors with distributed parameters is the fulfillment of resonance conditions over the entire range of changes in the values of the parameters of their reactive elements. The resonance mode can be saved in the following three ways.

By satisfying the condition (Eq. 1):

$$L(x)C(x) = const \quad [6] \tag{1}$$

*Corresponding author: absaid.sulliev@mail.ru

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what is achieved if the parameters of the reactive elements are changed according to $L(x)=\kappa_1 x$ $C(x)=\kappa_1/x$ or $L(x)=\kappa_1/x$, $C(x)=\kappa_2 x$, where

κ_1, κ_2 - coefficients of proportionality.

The advantage of this method of maintaining the resonant mode is that, with a known law of change of $C(x)$ or $L(x)$, it is always possible to find a function $L(x)$or $C(x)$that satisfies the condition (1).

2. By fulfilling the condition $[L_1(x)+L_2(x)]C=const$ or $[C_1(x)+C_2(x)]L=const$ [7], where $L_1(x)$, $L_2(x)$ и $C_1(x)$, $C_2(x)$ - respectively inductance and capacitance of differential circuits of biparametric resonant motion sensors.

3. By satisfying the condition

$\omega(x)=1/\sqrt{L(x)C}$ or $\omega(x)=1/\sqrt{LC(x)}$ [7], where $\omega(x)$ - angular frequency of the power supply voltage.

According to this method, the change in the resonant frequency of the circuit when changing $L(x)$ or $C(x)$ automatically "tracked" by the frequency generator with changing frequency [8].

3. Results and Discussions

Based on biparametric resonant circuits with distributed parameters, it is possible to create sensors for displacement, speed, and other motion parameters.

Although the influence of the distributed magnetic resistance of steel and the magnetic capacitance of the gap between the rods can be taken into account when finding the law of gap change $\delta_2(x)$ between the plates of a capacitor of variable capacitance and thus ensure the condition (1.3), but the complexity of the design, due to the manufacture of a variable capacitor with an LCD according to a non-linear law, significantly reduces the advantages of the BRMS.

If we analyze the operation of the motion control unit in inductive and transformer modes, then it is not difficult to make sure that voltage and current resonance can form in inductive sensors, and only voltage resonance can form in the measuring winding of transformer sensors.

Figure 1 shows the design of the linear displacement BRMS. In this sensor, the resonance in the measuring circuit is ensured by the fulfillment of the condition (Eq. 2):

$$[L_{2л}(x)+L_{2п}(x)]C=const \quad (2)$$

those. a capacitor of constant capacitance is connected to the differential measuring circuit of the transformer sensor and the circuit is tuned to voltage resonance [50]. Due to resonance, the sensor has a high and almost constant sensitivity when converting small linear displacements. With the expansion of the conversion range, the distribution of the magnetic resistance of the long rods of the magnetic circuit begins to affect and the measuring circuit of the sensor is detuned, as a result of which its sensitivity sharply decreases. Figure 2 shows the experimental curves of the change in the inductance of the measuring winding from the coordinate of the moving part of the sensor [9, 10]. Curve analysis $L_{2л}(x), L_{2п}(x)$ and $L_2(x)=L_{2л}(x)+L_{2п}(x)$ indicates that the resonance condition (2) is practically not satisfied for large ranges of convertible displacements.

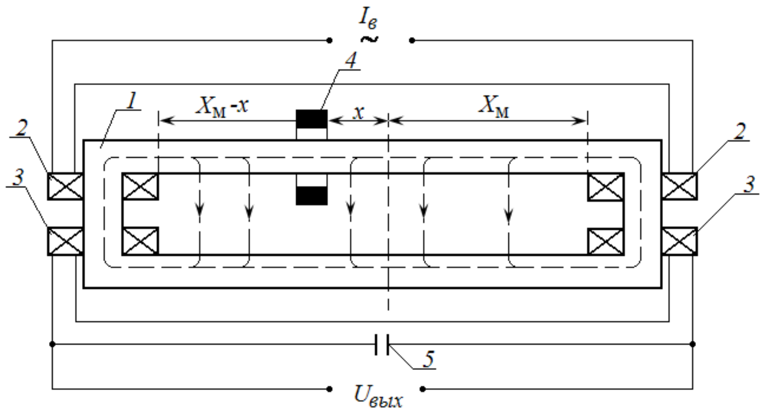

Fig. 1. The design of the transformer differential BRMS: shaped magnetic circuit 1, back-to-back sections of the excitation winding 2, measuring winding 3, capacitor 4, screen 5

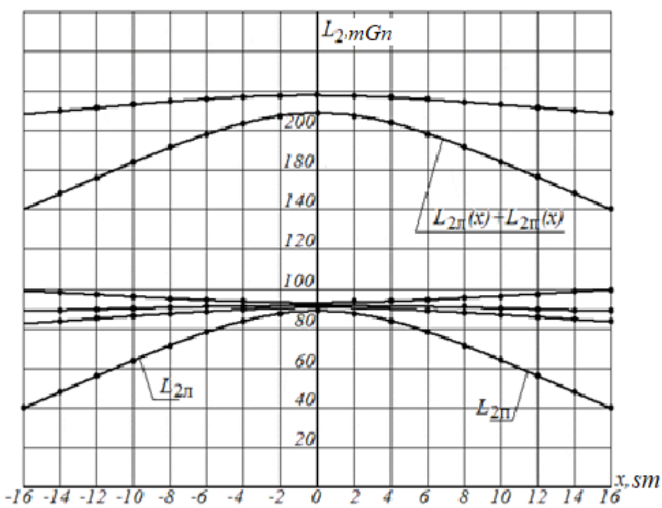

Fig. 2. Experimental curves of change in the inductance of the measuring winding from the coordinates of the moving part of the BRMS

4. Conclusions

Thus, the methods of maintaining the resonant mode in biparametric circuits with distributed parameters are investigated and the influence of changing the parameters circuit and the power source on the resonant mode is studied. New designs of the BRMS movement have been developed. It is shown that the use of the developed magnetic systems makes it possible to create a motion BRMS with high and constant sensitivity and linearity of the transformation.

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