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Mathematical model of precision sensor for an automatic weapons stabilizer system

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ABSTRACT

The mathematical model of the weapons stabilizer for mobile objects is presented, an equation of motion was obtained, and the schematic of the major components of the automated weapons stabilizer system was determined. The block diagram of the acceleration signal conversion in the sensor piezoelectric element was presented, and the method of compensating the input voltage by introduction of negative feedback based on the reverse piezoelectric effect was suggested. A technique for high-precision sensitivity axis of the piezoelectric sensor was presented.

1. Introduction

The military security of each country depends heavily on the accuracy of means and methods of measuring the basic parameters of the weapons stabilization system at the modern mobile objects, in particular, the armored personnel carriers (APCs). These objects are affected by considerably large overloading and uncontrolled mechanical disturbances (shock, vibration). Therefore, the requirements for accuracy of means and methods of measuring the parameters of the weapons stabilization system are much higher. This primarily concerns the measurement of mobile objects acceleration.

Providing the accuracy improvement of measuring the mobile objects acceleration, such as used in weapons stabilization system (WSS), is a great challenge. WSS effectiveness is mostly dependent on the accuracy and performance of the stabilizer sensitive elements and accelerometers. The modern stabilization systems, using the spring, string, quartz, magnetic, and gyroscopic accelerometers cannot provide the required speed of response and accuracy [1,2]. Therefore, the urgent scientific and technical challenge is to improve the accuracy and speed of response when measuring the acceleration values by creation of a new piezoelectric sensor (PS) for the automatic weapons stabilization system.

The recent literature concerning this subject [3–26] contain no information on analysis of a mathematical model of precision sensor of an automated weapons stabilizer system and research of its main characteristics [27,17].

2. Piezoelectric acceleration sensor principle

2.1. Piezoelectric sensor for weapons stabilizer

The summarized shortcomings of the existing accelerometers for the weapons stabilizing system are eliminated completely or partially due to the use of a piezoelectric element as the WSS accelerometer. Fig. 1 shows a proposed piezoelectric element in the WSS system [28].

WSS contains piezoelectric element 1, sensors for object speed 2 and location coordinates and current height sensors 3, the outputs of which are connected to mobile objects microcontroller 4.

Piezoelectric accelerometer 1 is located on the double-axis platform 12, stabilizing its sensitivity axis vertically. The sensor of the WSS piezoelectric sensing element (PSE) consists of a piezoelectric element (PE) 5, working on the compression-stretching strain, with insulators 7 on the ends and inertial mass (IM) 6. In order to improve the reliability and durability of the structure, the sensor is pressed elastically to the basis 8 with screw 10. PSE is connected to the operational amplifier via cable 11.

Piezoelectric element 5 is a multi-layer structure (piezopack) consisting of crystal lithium niobate layers with antiparallel polarization and electrodes separated by connecting layers. It can be welded seams, adhesive layers or other contact connection.

Linear accelerometers 13, 14 are located on the two-axis platform 12 and connected to microcontroller inputs 4. Motors inputs 15, 16 are connected to microcontroller outputs 4 (Fig. 2).

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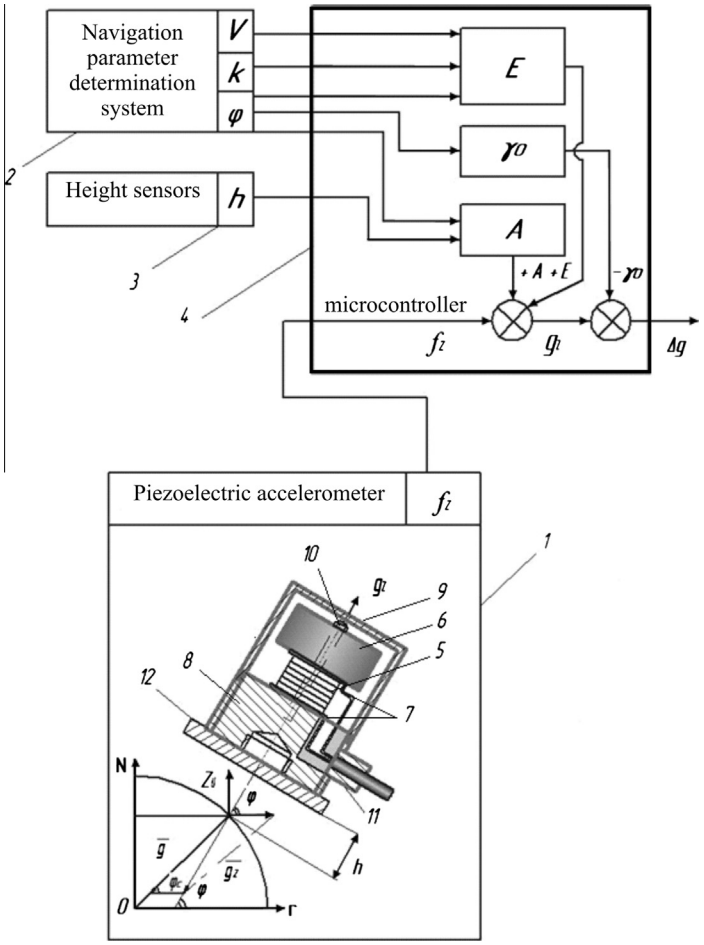

Fig. 1. Piezoelectric accelerometer as a part of WSS: 1 - PSE; 2 – navigation parameter determination system; 3 – height sensors; 4 – microcontroller; 5 – PE; 6 – IM; 7 – insulator; 8 – basis; 9 – sealed enclosure; 10 – screw; 11 – cable; 12 – two-axis platform.

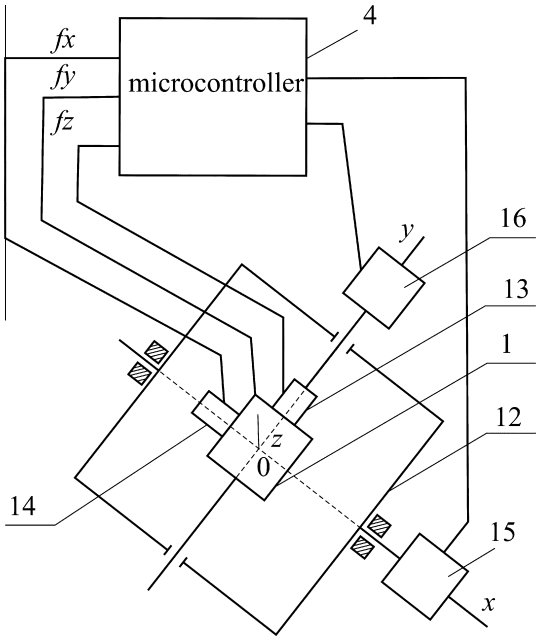

Fig. 2. PSE sensitivity axis stabilization system. 1 – PSE; 4 – microcontroller; 12 – two-axis platform; 13, 14 – linear accelerometers; 15, 16 – DC motors.

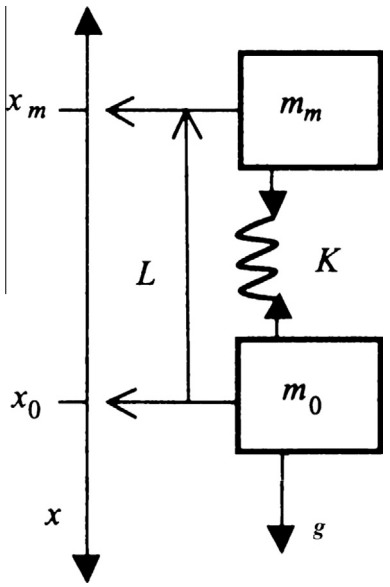

Fig. 3. PSE sensing element operating principle.