HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

RESEARCH ON THE OPERATING PRINCIPLES AND CHARACTERISTICS OF STRAIN GAUGE SENSORS

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Abstract: This article analyzes the structure of strain gauge sensors, their operating mechanisms, and main technical characteristics. The study examines the phenomenon of the piezoresistive (strain) effect, the properties of materials used in sensors, and the factors affecting measurement accuracy.

Keywords: strain gauge, piezoresistive effect, manganin, electrical resistance, deformation, pressure, strain sensitivity coefficient, strain manometer, Wheatstone bridge circuit.

Annotatsiya: Mazkur maqolada tenzodatchiklarning strukturasi, ishlash mexanizmlari va ularning asosiy texnik tavsiflari tahlil qilinadi. Tadqiqot davomida tenzoeffekt hodisasi, datchiklarda qo‘llaniladigan materiallarning xususiyatlari va o‘lchash aniqligiga ta’sir etuvchi omillar ko‘rib chiqilgan.

Kalit so‘zlar: tenzodatchik, tenzoeffekt, manganin, elektr qarshilik, deformatsiya, bosim, tenzosezgirlik koeffitsiyenti, tenzomanometr, elektr ko‘prik sxemasi.

Аннотация: В данной статье анализируются структура тензодатчиков, механизмы их работы и основные технические характеристики. В ходе исследования рассмотрены явление тензоэффекта, свойства материалов, применяемых в датчиках, а также факторы, влияющие на точность измерений.

Ключевые слова: тензодатчик, тензоэффект, манганин, электрическое сопротивление, деформация, давление, коэффициент тензочувствительности, тензоманометр, мостовая электрическая схема.

Introduction: In modern measurement technology, strain gauges (strain gauges) are widely used to detect mechanical stress, small deformations, and vibrations.

The principle of operation of strain gauges is based on the strain effect, which is a change in the electrical resistance of a conductor or semiconductor as a result of a change in its geometric shape.

These sensors enable high-precision control of pressure, weight, and deformation in industrial devices.

Methods: The principle of operation **of resistance manometers** is based on the change in the resistance of the sensing element under the influence of external pressure. The range of sensing elements includes manganese, platinum, constantan, tungsten, semiconductors, etc. Manganese is the most convenient for use in resistance manometers. Manganese has a linear relationship between the increase in electrical resistance ΔR *and the pressure* R *:*

$$\Delta R = K_p R P, \quad (1)$$

where: K_r is the coefficient of variation of manganese resistance 1/Pa. R is the resistance, Ohm.

The linearity of the resistance of manganese is confirmed by experimental data up to a pressure of 3000 mPa. In addition, the temperature coefficient of electrical resistance of manganese is very small. The small sensitivity of the transducer does not allow using these manometers to measure very high (more than 100 mPa) pressures. For manganese, $K_r = 22.95 \cdot 10^{-2}$ to $K_r = 24.61 \cdot 10^{-2}$ 1/Pa.

HSR (LONDON),
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ISSN: 2058-5519|Impact factor-15.9
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Figure 1 shows a diagram of a sensor with a manganese wire transducer. Its housing 3 has two hermetic metal rods *4 with a manganese resistance 2 installed. The connector 1 serves to connect the transducer to the object.* The transducer is connected to the measuring instrument using clamps *5* on the upper part of the rods . To measure the resistance of the manganese coil in the transformer, bridges are usually used, and for more precise measurements, potentiometers . The basic error allowed by manganese resistance sensors does not exceed ±1%.

Manganese manometers MM-2500, produced in our country, are capable of measuring pressures up to 2500 MPa. The piezoelectric coefficient of semiconductor sensors is a thousand times higher than that of manganese, but the dependence of the resistance of the sensors on pressure is nonlinear. In addition, there is a large amount of hysteresis, and temperature also has an effect. Semiconductor resistance sensors are mechanically fragile and are not suitable for measuring pressures above 10 MPa.

Strain gauges are used as sensing elements in the electrical resistance method. The principle of operation of a strain gauge is to convert a force or a deformation proportional to it into a change in the resistance of a wire attached to a deformed object.

Figure 2 shows a diagram of a strain gauge. The sensing element of the strain gauge consists of a manganese wire 1 with a diameter of 0.02 ... 0.05 mm. This wire is placed in a sandwich between thin sheets of paper 2. Output terminals are connected to the ends of the wire. The sensing element of the strain gauge is glued to the surface of the elastic element. When the elastic element is deformed under pressure, the strain gauge wire stretches, its cross-section decreases, and its resistance changes.

Strain gauges attached to the sensing element detect the measured pressure R as a change in electrical resistance. This is measured by the strain-sensitivity coefficient K *:*

$$K = \frac{\Delta R / R}{\Delta l / l}., \qquad (2)$$

Where: $\Delta R/R$ is the relative change in the resistance of the strain gauge; $\Delta l/l$ is the relative deformation of the wire; The value of the coefficient K is in the range of 0.5-4.0 for metals. A strain gauge is connected to an electrical bridge circuit to measure resistance. The bridge scale is graduated in units of pressure.

Advantages of strain gauges: the relationship between electrical resistance and pressure is linear, the degree of inertia is small, the instruments can be placed in places where it is difficult to measure, the error does not exceed ±2%. Disadvantages: very low sensitivity, dependence on temperature changes. Resistance manometers are rarely used in industrial technological devices for measuring pressure. The EDD-22 strain gauge, operating according to the above principle, is designed to measure pressures from 0.1 to 0.6 MPa.

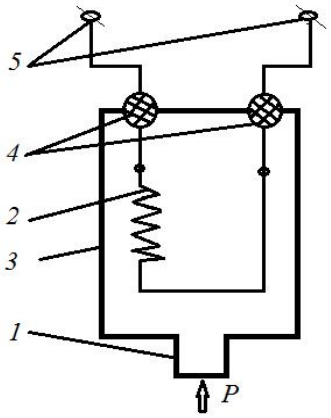


Figure 1. Manganin sensor circuit

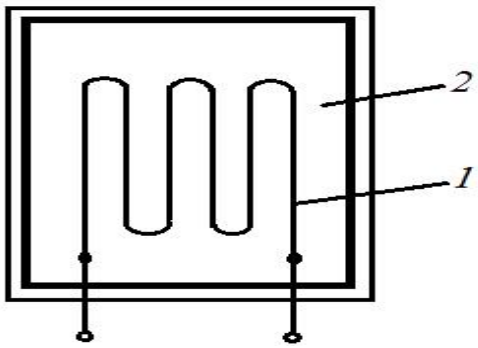


Figure 2. Strain gauge circuit diagram

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ISSN: 2058-5519|Impact factor-15.9
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diagram

Results: The appearance of the strain gauge-based device is shown in Figure 3.

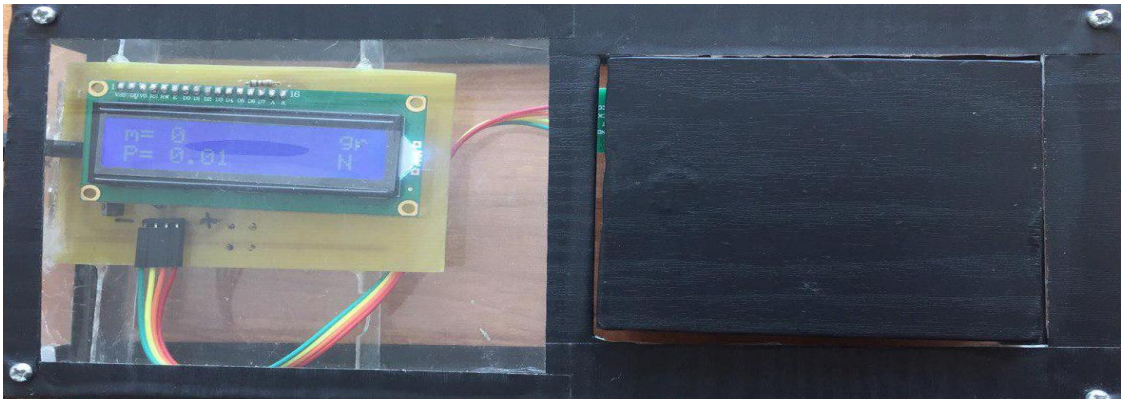


Figure 3a. Appearance of a strain gauge-based device

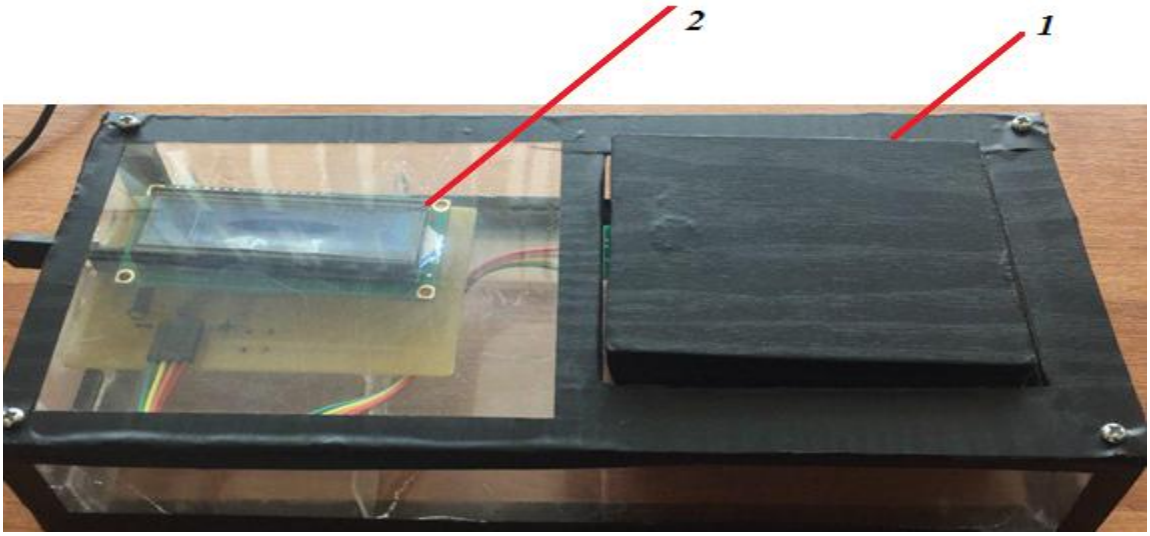


Figure 3b. Measuring parts of a strain gauge-based instrument (1-sensitive element, 2-electronic display).

Research results this It shows that manganin sensors pressure to change relatively high to linearity The electrical resistance of manganin wire varies linearly up to a pressure of 3000 MPa .

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Sensitivity: The strain-sensitivity coefficient for metals lies in the range of 0.5 to 4.0.

Accuracy: The basic error of manganin resistance sensors does not exceed a limit of ±1% to ±2%.

Range: EDD-22 strain gauges are capable of measuring pressures from 0.1 to 0.6 MPa, while MM-2500 manganin manometers are capable of measuring high pressures up to 2500 MPa.

Discussion:

In the process of analyzing strain gauges, it was found that the choice of material is of great importance. Although semiconductor sensors are thousands of times more sensitive than metal sensors, their dependence is nonlinear and they have a large hysteresis. Also, semiconductor elements are less mechanically robust and can fail at pressures above 10 MPa.

The main advantage of manganin sensors is their low inertia and the possibility of using them in difficult-to-measure areas. However, their main disadvantages are their dependence on temperature changes and low sensitivity. However, due to the very small temperature coefficient of manganin, it is more effective than platinum, copper and nickel in high-precision measurements.

Conclusion: Strain gauges are reliable and linear elements in measurement systems. Studies confirm that manganin sensors remain the most suitable solution in areas where high pressure and accuracy are required.

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