Секція: **Механічна інженерія**

УДК 531.374

Дубиняк Т. - к.т.н., доцент, Цюпа С., Микулик П.
Тернопільський національний технічний університет імені Івана Пулюя

ЗАЛЕЖНІСТЬ ІНДУКТИВНОСТІ КОТУШКИ ВІД ВЕЛИЧИНИ ПОВІТРЯНОГО ЗАЗОРУ ПРИ КОНТРОЛІ ШОРСТКОСТІ

Науковий керівник: к.т.н., доцент Тарас Дубиняк

Dubynyak T., Tsiupa S., Mykulyk P.
Ternopil Ivan Puluj National Technical University

DEPENDENCE OF COIL INDUCTANCE ON AIR GAP SIZE IN ROUGHNESS CONTROL

Ключові слова: Шорсткість поверхні, параметри шорсткості, пристрій, профілометр.
Keywords: Surface roughness, roughness parameters, device, profilometer.

The objective of this study is to enhance the accuracy of surface roughness measurement for flat-surfaced parts. The device, illustrated in the figures, operates by measuring the surface using support points 2 and 3. When the drive 5 is activated, the carriage 4 first moves the contact needle 10 and the base support 11 along the reference surface 17, ensuring proper calibration. Afterward, the needle 10 and support 11 leave the reference surface 17 and proceed to measure the target surface.

The signals from sensors 6 and 7, after conversion through circuits 18 and 19 and amplification by amplifiers 20 and 21, are sent to the summing unit 22. The output from this unit provides a signal characterizing surface roughness, while the output from amplifier 21 indicates surface waviness. Data recording and reading are handled by unit 24. Due to the use of balancers 12 and 13 and springs 14 and 15, measurements can be conducted on arbitrarily oriented surfaces. Figure 1 shows the device schematic, while Figure 2 illustrates the structure of the base support and contact needle.

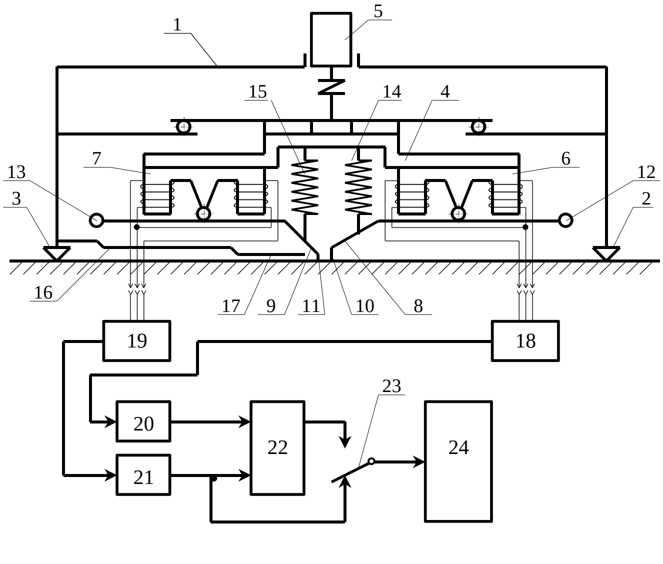

Figure 1. - Scheme of the device

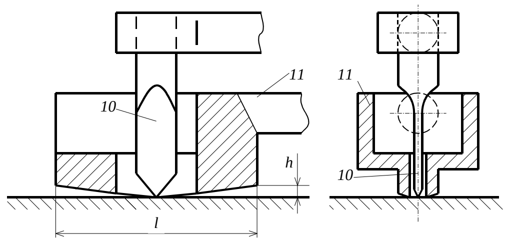

Figure 2. - Scheme of the base support and contact needle

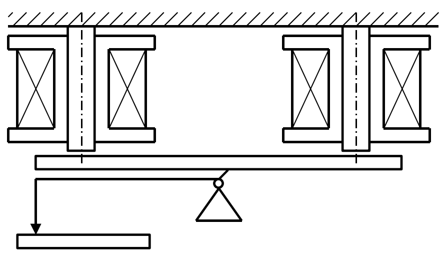

Figure 3. - Scheme of profilometer operation

Inductive transducers are widely used to convert mechanical quantities that are initially transformed into displacement. In this case, a small-displacement inductive transducer with a variable air gap δ is used. This transducer is highly sensitive to input values, as even a slight displacement causes a significant change in inductance. It has low susceptibility to external magnetic fields and a compact design, as the required inductance is achieved with a minimal number of coil turns. The inductance coils in profilometers are arranged so that changes in air gaps within their magnetic circuits double the sensitivity. This also helps mitigate temperature errors. The coils are connected to a power circuit, and as sensor tips move, the voltage generated at the support loads is proportional to this displacement. The operating principle of the inductive sensor is based on changes in system inductance due to variations in the air gap. The key informative parameter of the inductive transducer with a variable air gap is the total electrical impedance Z of the magnetized segment, which is a function of the complex impedance Zm of the transducer's magnetic circuit [1,2].

$$Z = R_0 + \omega \frac{\omega^2 \cdot X_м}{\left(R_м + R_\delta\right)^2 + X_м^2} + j \cdot \omega \frac{\omega^2\left(R_м + R_\delta\right)}{\left(R_м + R_\delta\right)^2 + X_м^2}$$

The inductance L of the electromagnetic system is determined by the ratio of the magnetic flux linkage to the current I that generates it. When the magnetic core is unsaturated, the inductance of the choke can be expressed using the following formula:

$$L = \frac{\Sigma \Phi_i \cdot \omega_i}{I} \cdot \Phi, \quad L_x = \frac{w^2}{R_м + 2\cdot\left(\frac{\delta_b}{\mu_0 \cdot S_b}\right)} = \frac{w^2}{R_м + 2\cdot\left[\left(\frac{\delta_b}{S_b \cdot 4 \cdot 3.14 \cdot 10^{-7}}\right)\right]} = k \cdot \frac{S_b}{\delta_b},$$

where: L_x - is the sensor inductance (which varies with air gap size), w - is the number of coil turns, $R_м$ - is the magnetic resistance of the core and armature, δ_b - is the air gap length, S_b - is the cross-sectional area of the air gap. To derive the dependence of sensor inductance on the air gap size, the following expression can be used: $L_1 = \mu_0 \cdot \dfrac{\omega^2}{2 \cdot \dfrac{\delta_b}{S_b}}$

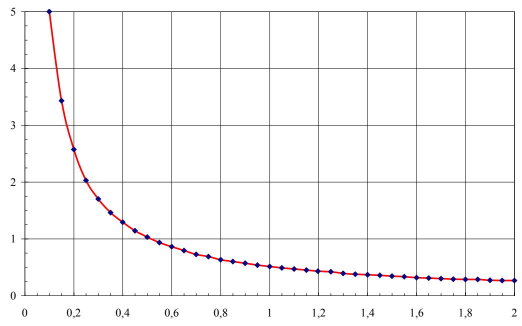

Figure 4 - Graph of the dependence of inductance L on the air gap size δ

By analyzing the graph in Figure 4, it can be concluded that this inductive transducer is highly sensitive only to small displacements. At larger displacements, a significant increase in the air gap size results in only a minor change in coil inductance, leading to low sensitivity. To address this issue, the device design incorporates two inductance coils arranged so that when the air gap increases in one coil, it decreases in the other. Using a microcomputer, both coil readings are analyzed, and when one reaches its limit, the system processes data from the other, ensuring continuous measurement accuracy.

Reference

1. Buchynskyi, M. Ya. Machine-Building Technology: Textbook / M. Ya. Buchynskyi, O. V. Horyniak, V. I. Skopa. – Lviv: Lviv Polytechnic Publishing House, 2020. – 512 p.
2. Ivanov, V. O. Technological Foundations of Surface Processing of Parts: Monograph / V. O. Ivanov, L. M. Kravchuk. – Dnipro: DNU, 2021. – 196 p.