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DEVELOPMENT OF THE CAPACITIVE SENSOR FOR MONITORING THE QUALITY OF INDUSTRIAL OILS FOR TEXTILE MACHINES

РАЗРАБОТКА ЕМКОСТНОГО СЕНСОРА МОНИТОРИНГА КАЧЕСТВА ПРОМЫШЛЕННЫХ МАСЕЛ ДЛЯ ТЕКСТИЛЬНЫХ СТАНКОВ

Jezhora A.[1], Navumenka A.[2], Zhiznevsky V.[3], Leonov V.[4]
Vitebsk State Technological University, Belarus
e-мail: jezhora@mail.ru[1], andrew.navumenka@gmail.com[2],
isap@vstu.by[3], leonov203509@gmail.com[4]
Джежора А.А.[1], Науменко А.М.[2], Жизневский В.А.[3], Леонов В.В.[4]
Витебский государственный технологический университет, Республика Беларусь

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Ключевые слова: диэлькометрия, неразрушающий контроль, IDS-сенсор, деградация, промышленные масла.

Abstract. The article discusses the design and characteristics of the interdigitated dielectrometry sensors (IDS). Investigation of the effect of interelectrode gaps on the deviations of the dielectric constant, sensitivity, and working capacity of the sensor. It is established that sensors must be shielded to reduce the level of interference. A sensor design with high metrological characteristics is proposed. The developed design of the IDS sensor is advisable to be used in quality monitoring systems for industrial oils for textile machines.

Аннотация. В статье рассмотрена конструкция и характеристики IDS-сенсора. Исследование влияния межэлектродных зазоров на отклонения диэлектрической проницаемости, чувствительности, рабочей емкости сенсора. Установлено, для снижения уровня помех сенсоры должны быть экранированы. Предложена конструкция сенсора с высокими метрологическими характеристиками. Разработанную конструкцию IDS-сенсора целесообразно использовать в системах мониторинга качества промышленных масел для текстильных станков.

Oils perform an important role in the textile industry. They determine the reliability and durability of machines, mechanisms, and power plants. The theoretical forecast of the shelf life of industrial oils is complex and depends on many factors. A more reasonable approach is to screen the condition of oils online using quality sensors at the control points. To date, it has not been possible to create a reliable and cost-effective sensor system for determining the condition of industrial oils according to standards.

The purpose of the work is to determine the parameters of the IDS sensor for remote monitoring of industrial oil.

The design of the IDS sensor is shown in Figure 1. The sensor contains a system of parallel tape electrodes (high-potential 1 and low-potential 3). The electrodes lie in the same plane on the surface of the flat substrate 4. Power lines 5, 6 pass from high-potential electrode 1 to low-potential electrode 3 and create a useful capacitance. Security electrode 2 shields part of power lines 7 passing through substrate 4 and reduces the parasitic capacitance.

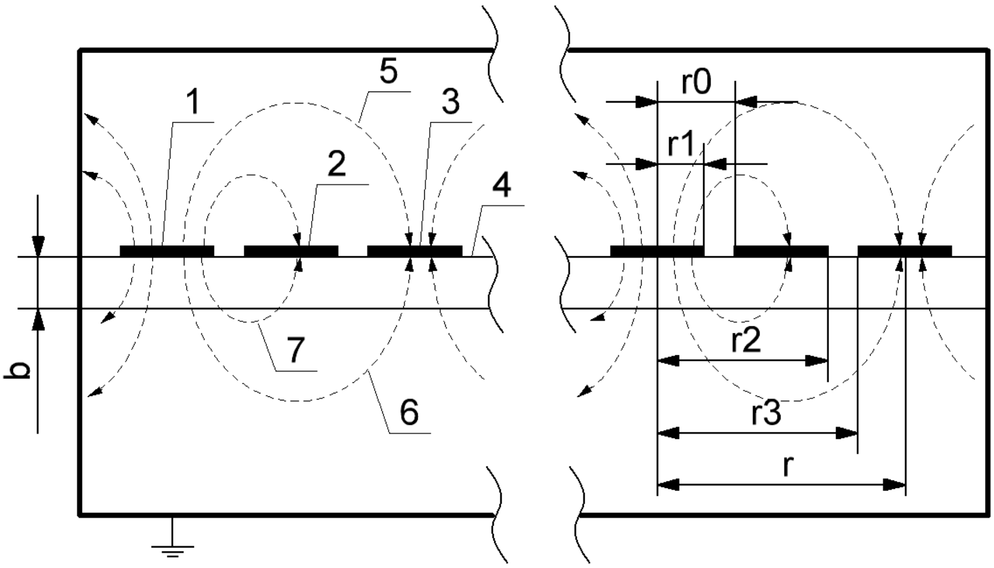

Figure 1 – IDS sensor cross section

The design of the IDS sensor of an open space surrounded by a Faraday screen has a number of advantages. Firstly, the IDS sensor does not have a grounded shield on the substrate and has a large working capacity. Secondly, the security electrode minimizes parasitic capacitances in the substrate. Thirdly, the Faraday screen eliminates the influence of external electromagnetic fields. Due to this, the signal-to-noise ratio is used as much as possible.

The capacity of IDS sensors cannot be calculated analytically. Analytical models are based on simplified configurations and idealized assumptions, which limits their calculation accuracy for real structures [1].

The mathematical model of capacitive sensors described in [2] is used for the research. Design parameters of the IDS sensor: section dimensions **r**, metallization **w** of the sensor varied in order to see their influence normalized capacity $\mathbf{C_{IDS}}$ and accuracy **D**:

$$D = (\varepsilon_r - \varepsilon_{r,IDS})/\varepsilon_r*100\%, \tag{1}$$

$$w = (r - r0 + r1 - r3 + r2)/r, \tag{2}$$

where ε_r – reference value of the dielectric constant; $\varepsilon_{r,IDS}$ – the value of the dielectric constant measured by the IDS sensor.

The simulation is carried out for a structure of 10 electrodes (10 r) and the thickness of the substrate b = 0.3 mm. The model is constructed taking into account the actual thickness of the electrodes **b**, which is important when designing sensors on thin substrates. Sensor fields are considered in electrostatics since the frequency of the electromagnetic field $v \leq 10^6$ Hz and the design dimensions of the sensor are much smaller than the length of the electromagnetic wave. In addition, the electrical conductivity of the oil at low frequencies is disregarded [3].

The simulation results are shown in Figure 2, 3. It is established that a decrease in metallization leads to a decrease in accuracy and working capacity. High accuracy is achieved when the section size is **r** = 3 - 5 mm. The size of the section does not significantly affect the normalized capacity of the sensor.

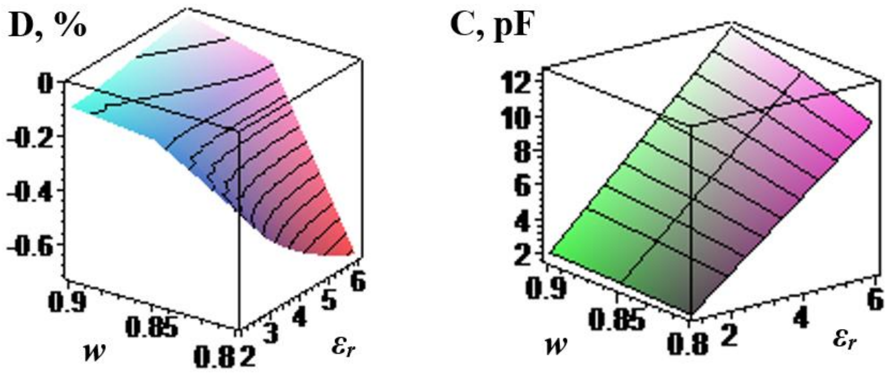

Figure 2 – Dependence of accuracy **D** and capacitance **C** on metallization of the sensor **w** and reference dielectric constant ε_r

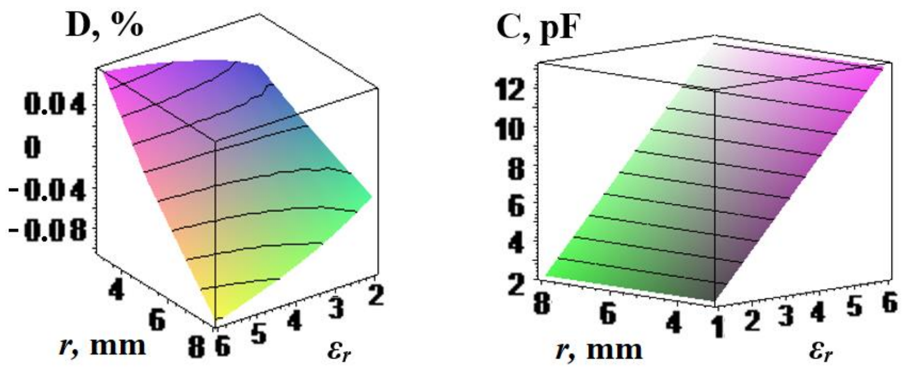

Figure 3 – Dependence of accuracy **D** and capacitance **C** on the size of the section **r** and reference dielectric constant ε_r

As a result of the simulation, the sensor dimensions were selected: the length of the electrode **l** = 50.0 mm, the size of the section **r** = 4.40 mm, the size of the electrode 2*r0 = 2.18 mm, the size of the security electrode r2 - r0 = r3 - r2 = 1.42 mm, the distance between the electrodes r0 - r1 = 0.4 mm, metallization w = 0.82. Further reduction of the distance between the electrodes is limited by the manufacturing technology. The measurement error of the dielectric constant is no more than 0.25 %, the normalized capacitance is 1.025 pF for 6 sections. The developed design of the IDS sensor is advisable to use in quality monitoring systems for industrial oils for textile machines.

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