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«Metrological Support of Innovative Technologies» ICMSIT-II 2021

«Metrological analysis of a magnetometer to measure the magnetization of magnetic nanofluids in strong magnetic fields»

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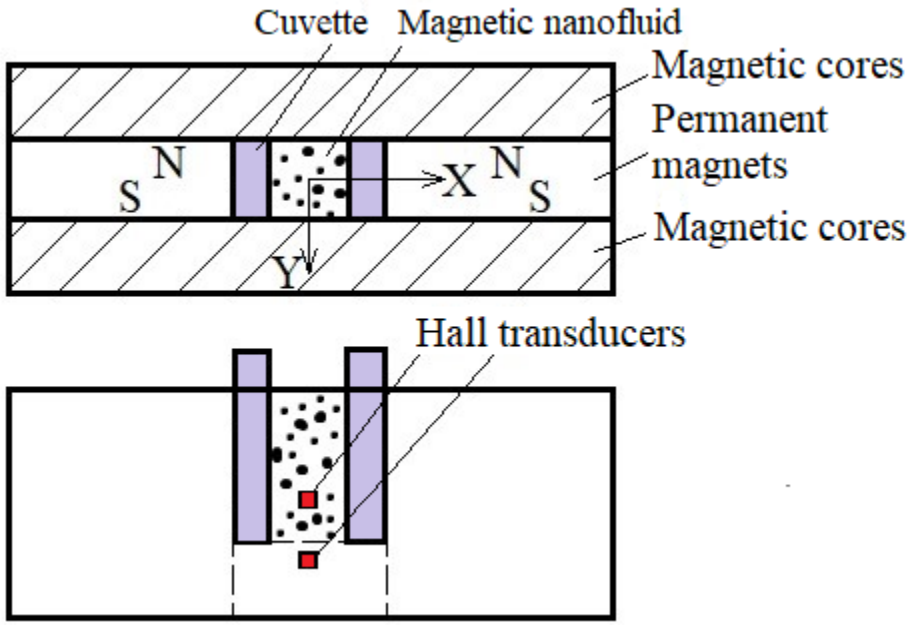
Problem statement

- There is a need for reliable test systems that enable the express analysis of saturation magnetization of magnetic nanofluids. A distinctive feature of multifunctional magnetic nanofluids as compared to other colloidal materials is their relatively high magnetization. We propose a design of a mobile magnetometer with Hall sensors for studying the saturation magnetization of magnetic dispersed materials. A preliminary theoretical analysis of the magnetometer methodological error, which had been caused by the imperfection of the methods for measuring magnetic fields in the device, has revealed the need for additional research aimed at clarifying it.
- **The purpose of the work** was to research the metrological analysis of a mobile magnetometer to determine the magnetization of the technical saturation of magnetic nanofluids and to assess the compliance of the device with international standards for magnetic measurements.

A device description



- Permanent magnets made of $SmCo_5$ alloy and magnetic cores made of soft magnetic steel form the device magnetic circuit. Magnetic fluxes add up in a magnetic fluid area and create a uniform field with an intensity up to $(2 \div 4) \cdot 10^5$ A/m. The magnetizing magnetic field intensity and the value of the magnetic field induction in a nanofluid are measured using Hall effect transducers, which are connected oppositely in a single measuring electrical circuit to determine the Hall EMF of the proportional magnetization of the material under study. A circuit method for correcting the non-equipotentiality EMF is used to improve the measurement accuracy. A comparative estimate of the relative error in measuring the magnetization of magnetic nanofluids was less than 2 % (for magnetic nanofluids with magnetization in the range from 10 kA/m to 50 kA/m).

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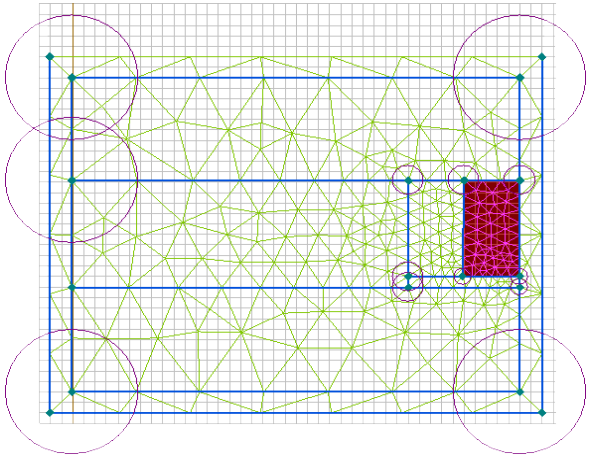
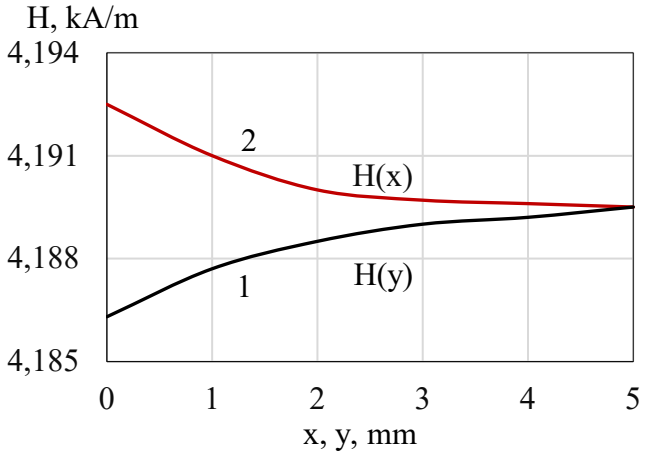
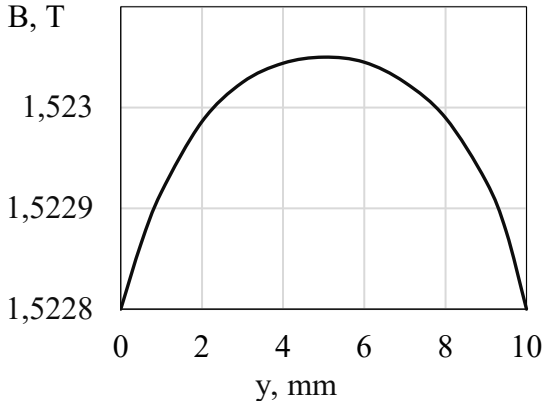
Solution methods



- **Estimation of the device methodical error using numerical simulation.** It has been established that the magnetometer methodological error is due to the fact that Hall effect transducers do not reflect the field in the substance correctly due to non-magnetic gaps. The device methodical error was estimated by numerical simulation of the magnetic field parameters in a real magnetic system of the device using the Elcut computer program. The results of a numerical analysis of the device magnetic system model give the dependences of the methodological error in measuring the magnetic field induction in the substance and the magnetizing field intensity on the size of non-magnetic cavities in the device magnetic circuit and the magnetic properties of the materials under study.



The change in the magnetic field strength in the working gap of the device magnetic system (counting from the working gap center): 1 – along the lines of force, 2 – across the lines of force.



The change in the magnetic field induction in the cast iron sample (along the lines of force).

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Conclusions

Results, implementation

- Based on the results of a numerical analysis of the device magnetic system model, we have found the dependences of the methodological error in measuring the induction of the magnetic field in the substance and the magnetizing field intensity on the size of non-magnetic cavities in the device magnetic circuit and the magnetic properties of the materials under study. It is shown that the relative methodological error in determining the magnetization of magnetic nanofluids on the device does not exceed 1 %.
- It was found that the device has high metrological indicators, which enables accurate measurements of magnetization with low costs of the material under study.
- It is confirmed that the magnetic field affecting the material samples under study has a high degree of uniformity.
- The magnetometer can be used to study a wide range of materials including new promising magnetorheological fluids with magnetization up to 600 kA/m.
- It is shown that the described magnetometer might become a good basis for developing sufficiently accurate instruments to measure the magnetization of strongly magnetic materials.

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