The effect of eddy currents on the temperature of pickup coils when measuring paramagnetic materials at high frequencies

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During the measurement of the magnetic properties of diluted paramagnetic gels at high-frequencies, a significant increase in the sample's temperature was observed. The detailed analysis showed that the temperature rise was caused by an undesired heat released in the pickup coils due to the induced eddy currents. In order to relate the coil's dimensions to the observed effect, the mathematical model of the eddy current losses in the coil's wire was developed and verified experimentally. The numerical results obtained by the proposed model show an excellent agreement with the measured values and could be adopted for the improved pickup coil design.

Keywords: FEM; coil temperature; magnetic measurements; high frequency; eddy currents

1. Introduction

The magnetic properties of substances containing magnetic nanoparticles, such as magnetic liquids, magnetic powders, or magnetic gels, are usually determined by the induction principle [1]. For this reason, a measurement system comprised of a water-cooled excitation coil and a set of tiny measuring coils (pickup coils) placed in the center of the excitation coil is used, as shown in Figure 1. The pickup coils are devoted to measuring magnetic field intensity (*H*) and magnetic polarisation (*J*) [2]. While the pickup coils are placed in the center of the excitation coil, they experience a homogeneous, vertically oriented magnetic field. By the law of magnetic induction, eddy currents occur in the coil's conductors, generating undesired heat. Consequently, the measured sample is additionally heated, and its temperature increases to some extent. In order to evaluate the mentioned effect, the mathematical model of the eddy currents in circular wire was developed, and thermal calculations were carried out.

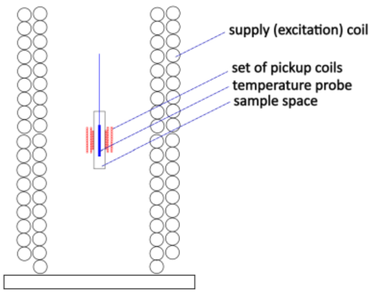
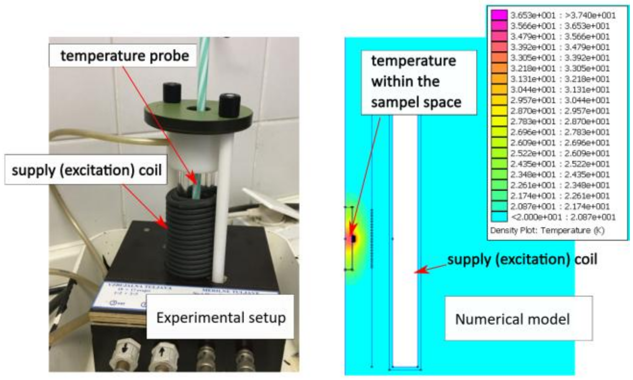


Figure 1: The principal setup of the measuring system in question. The field intensity produced by this system could go as high as 30 kA/m, and the frequency could be adopted from 90 kHz to 500 kHz. A detailed approach to the coil design and the system's performance can be found in the reference [2].

2. Results and discussion

The proposed model was verified by comparing the calculated steady-state temperature values in the measuring chamber with those in the real experimental system. The calculations were conducted using the FEM-based software FEMM 4.2 and Matlab. The results are shown in Figure 2, where the steady-state temperature difference between the sample chamber and the ambient temperature (d*T*) is provided for two excitation current values.



a) b)

Measured temp. difference		Calculated temp. difference	
dT=2,56 °C	at 40 A	dT=2,56 °C	at 40 A
dT=5,77 °C	at 60 A	dT=5,76 °C	at 60 A

Figure 2: The experimental setup (a) and the FEM model (b). The temperature difference between the average temperature in the empty sample chamber and the environment temperature d*T* was measured at two excitation current values, 40A and 60A, respectively.

References

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