

ANALYSIS OF REFERENCE MAGNETIC FIELDS HOMOGENEITY GENERATED BY A HELMHOLTZ-LIKE COIL MEASUREMENT SYSTEM FOR MAGNETIC FIELD SENSORS TESTING

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1. Introduction

Magnetic field sensors are widely used in various industrial fields. The correctness of their work is of great importance for the validity of many processes. For this reason the elaboration of a measurement station allowing precise calibration of magnetic field sensors used in the field of industry was necessary.

The paper presents the analysis of magnetic field generated by a automated measurement system using Helmholtz-like coils for magnetic field sensors calibration, and its comparison to a simulation of the system using proper Helmholtz coils and Helmholtz-like coils used in the system.

Helmholtz coils are used to generate highly homogenous field in an area between them, but as opposed to long solenoids, which generate the most homogenous magnetic field, they have more room between the coils to maneuver. In order for them to generate a field of a substantial value, they have to be heavy and increased in size. For the coils to generate the most homogenous field, the ratio of the coil's height to its width should be $\sqrt{\frac{31}{36}}$ [1-4]. The impact of a modification of this value, which would assure lighter and smaller coils, on the homogeneity of generated magnetic field was researched.

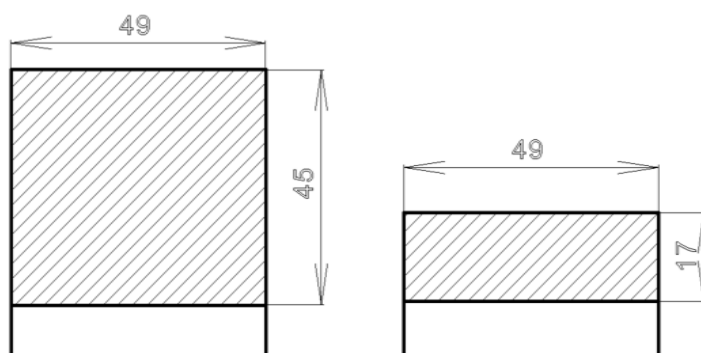


Fig.1: *Dimensions of a proper Helmholtz coil (left) and modified coil (right)*

2. Experimental details

The system consisted of three pairs of Helmholtz coils, which compensated the Earth's magnetic field, and one pair of Helmholtz-like coils, which generated magnetic field with flux density of up to 10 mT. The generating coils dimensions were as follows:

- Mean diameter – 270 mm,
- Distance between the middles of the windings – 135 mm,
- Windings lengths – 49 mm,
- Windings heights – 17 mm,

The distribution of the magnetic field generated by the existing system was measured using LakeShore 455 magnetometer with HMMA-2504-VR Hall-effect probe. Measurements were taken only for the axial component of the field, every 10 mm in an area of 140x140 mm. The magnetic field flux density was set to a constant value of 8 mT in the centre of the coils.

3. Simulation details

A mesh grid was done for both normal Helmholtz coil pair and the modified one using Netgen software. The mesh was simulated in Elmer FEM software for generated magnetic field, which enabled the display of its distribution inside both of the pairs. The Elmer FEM software proved correct in magnetic field simulations. [5,6]

The data from simulations, as well as from measurements, was exported to Octave software, in which it was processed and from which the plots were drawn. Then it was normalised to a value of 1 in the centre of the measurement area and analysed for 0,5%, 1% and 2% deviation, from which the area of homogeneity was determined.

4. Results

The research resulted in very little differences between Helmholtz and modified Helmholtz coil pairs, with the former generating magnetic field more of a square-shape, and the latter generating field consisting of a more two-rectangular shape, one in the direction parallel to axis and one perpendicular to it. The simulated plots are shown in Fig.2. and Fig.3. Figure 4 represents data measured directly from the system.

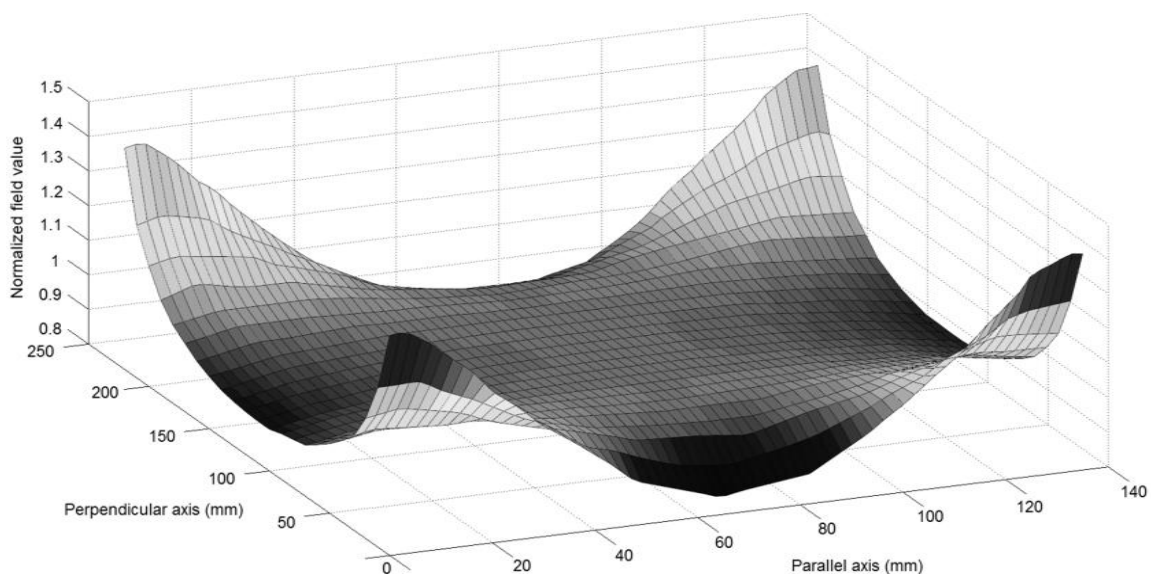


Fig.2: *Distribution of magnetic field in a Helmholtz coil pair (simulation)*

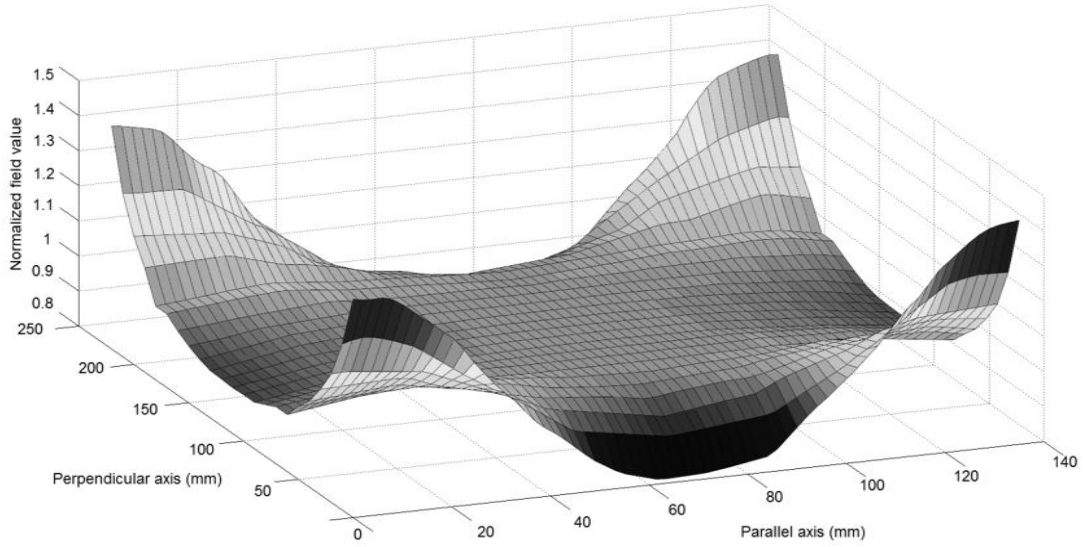


Fig.3: *Distribution of magnetic field in a modified Helmholtz coil pair (simulation)*

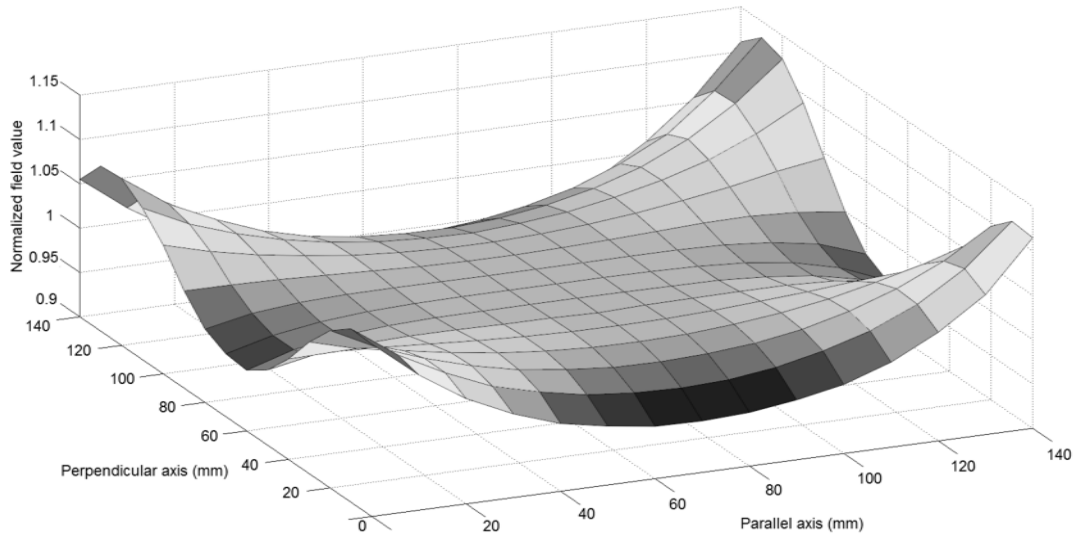


Fig.4. *Distribution of magnetic field in the existing system (measured)*

The simulated differences between proper and modified Helmholtz coils are negligible and cover each other in the area of homogeneous field. Largest differences occur near the coils, in the area not used in the measurement system. Experimental results verify simulation results within the resolution and uncertainty of the measurements. Table 1. presents obtained homogeneous field areas.

Tab. 1. *Results of simulations and experiment.*

Level of homogeneity in comparison to the centre	Area of homogeneity		
	Helmholtz coils – simulation	Modified coils – simulation	Modified coils – experiment
0,5%	45x70 mm	49x70 mm 35x90 mm	50x80 mm 40x90 mm
1%	61x90 mm	63x100 mm	60x100 mm
2%	80x110 mm	82x110 mm	80x110 mm

5. Conclusion

The results were satisfying, the simulated and measured data overlaid each other and appeared as genuine. Magnetic field generated by modified coils was sufficiently homogeneous within the measurement area. The coils were a good substitute of proper Helmholtz coils and the whole measurement system generated magnetic field which could be used as reference.

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