OPTIMIZATION OF FEROPROBE FOR RELAX-TYPE MAGNETOMETERS

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The article deals with construction of an optimal feroprobe of relax-type magnetometer. The article is divided into three parts. The first chapter discusses about feroprobe, its specific parts and construction of feroprobe. The second chapter is dedicated to measuring transmission characteristics which define the main metrological properties realized feroprobes. The third chapter discusses the measurement of the axial anisotropy of feroprobes, which defines the quality of design of realized feroprobes. The added value of the thesis is summarization of metrological properties of feroprobes considering the different constructive view and material of feroprobe core.

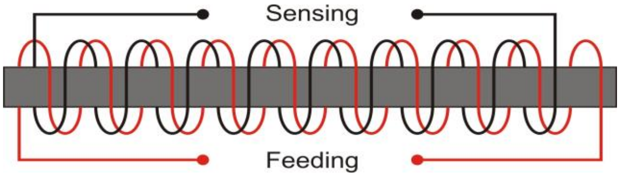
K e y w o r d s: Relax-type magnetometer, feroprobe, measurement, characteristic.

1 Introduction

In these days, the magnetometer usage is wide spread in large scale of technological applications. We may find utilization of these components mainly in steel works and mining industry, where there are very tough operating conditions, and also in medicine, navigation and psychotronics, where the main requirement is high accuracy of these devices. Developement of magnetometers is advancing very rappidly and requirements for these devices are still more strict. Modern magnetometers based on magnetic resitivity and magnetic impedance are, with their parameters, in metrological sphere competitive to relax-type magnetometers. But on the other hand the measurement proces and its means are always a bit of a compromise, which the relax type magnetometers still offer. Measurement proceses described in this thesis, create a picture of measurement cahrateristics of relax type magnetometers. Gathering of multiple complex measurements, which determined the most adequate structure design of sensors (feroprobes) of relax type magnetometers, is the main contribution of this article.

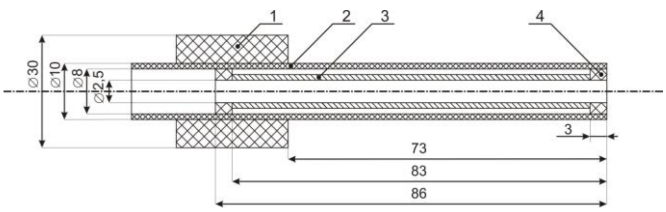
2 Feroprobe.

The term feroprobe defines that part of the magnetometer which is directly affected by the measured quality and which transforms this quality to a proportional electrical signal.



Pic. 1 *Feroprobe*

Feroprobe as the sensing part of magnetometer consists of three basic parts: case, coil and core. Case of feroprobe can be realized in different versions, but basically it must not consists of ferromagnetic parts. Case made for the purposes of measuring is described on Picture 2. Whereas measurement was realized with the possibility of different angle values of feroprobe, the spool (3) placed in a plastic tube (2). The proper position of the coil in the tube we use some capsule (4). Extended part (1) is used to facilitate handling. Dimensions of measuring feroprobe were chosen depending on the research already made on KLTP and coil dimensions.



Pic. 2: *Construction of feroprobe realized on purpose of measurement*

The coil is made of copper wire of diameter 0.17 mm. Is actually made up of a pair of coaxially imposed tight selenoids with length of 80 mm, with circular cavity of diameter 2.5 mm. The first coil is made off 880 turns and the other has 1760 turns. The numbers of turns are in the range ± 10 from the nominal number of turns, caused of limitations associated with production. Initial production included production of several coils, from which we determined the most appropriate considering certain qualitative parameters. Because the design of all coils was almost the same, as a best coefficient about the appropriate coil we selected the quality of coil. To determine this parameter, it was necessary to know the DC resistance of windings and inductance. We used measuring instrument (Instek LCR meter – 816th) for measuring the parameters. Measurement of inductance coils was realized at a frequency of 500 Hz.

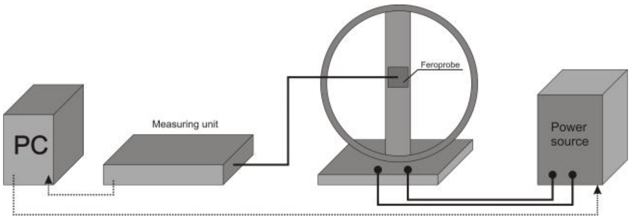
To improve the coil quality we used the copper wire of diameter 0.11 mm. This approach was useless because of winding resistance increased twice and it was not suitable for usage.

To create feroprobe core we used magnetically soft amorphous metal glases. Nowadays they are commercially available in the forms of strips, wires and micro wires. These materials have excellent magnetic properties and the absence of magnetocrystalic anisotropy. The wide usage is predetermined by favorable price. The magnetically soft amorphous metal glasses are actually alloys of ferromagnetic metals (Fe, Co, Ni) with the glass-forming additives (Si, B, C, P) and other impurities. In our measurements we used materials from the company Vacuumschmelze GmbH (VAC) called

Vitrovac (VAC 6030) and experimental materials from the Institute of Experimental Physics Kosice named 8116 and 8116 – 309. These materials were available in the form of strips with thickness of 35 microns. The measurement was realized with stripes length of 80 mm. 6030 VAC material was available in three widths (2, 1.5 and 1 mm). Materials 8116 and 8116 - 309 were investigated only as a strip of width 2 mm.

3 Measurement of transfer characteristics of feroprobe.

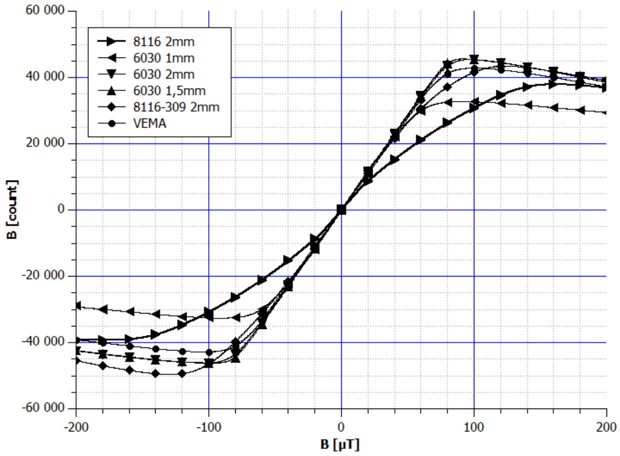
Measurement of transfer characteristics of feroprobe defines relationship between the external field and relaxation time of the feroprobe. To generate a magnetic field we used coil of large diameter which conversion constant 1 μT/mA . Power supply is provided by digitally controlled current source, which has worked in a range of ± 200 mA in steps of 0.5 mA or up to ± 100 mA in steps of 0.25 mA. The principal scheme of the measuring facility is shown on Picture 3. The measurement was performed by feroprobe, which had the opportunity to exchange the core and was placed in the axis of the circular coil. Cores of feroprobe were created from strips, which properties was listed in the previous chapter. Quantity of strips for each measurement varies from one to eight. We tried to determine the impact of the number of stripes on the range, sensitivity and linearity of feroprobe. By defining these parameters we determined the main metrological properties.



Pic. 3: *The principle of measuring workplace of the transfer characteristics feroprobe.*

Measurement of the sample characteristics was executed automatically. The results of measurements of the samples were graphically and statistically adjusted in Microsoft Exel and QtiPlot. The main goal of performing this measurement was to determine the quality parameters of the samples and determine the best quantity of stripes using different materials and designs.

Comparing different measurement approach of feroprobe characteristics, with different cores, different quantity of stripes and design of stripes we were able to define the best samples considering the measured range, linearity and sensitivity of each feroprobe. Picture 4 describes the different transfer characteristics of feroprobe which cores was selected from the best samples of each set of measurements.



Pic. 4: *Transfer characteristics of feroprobe*

Material VAC 6030 for all geometric designs provides the same result. Linearity and sensitivity of the samples was almost constant. Measuring range depends on the quantity of stripes, thus the volume of the core feroprobe.

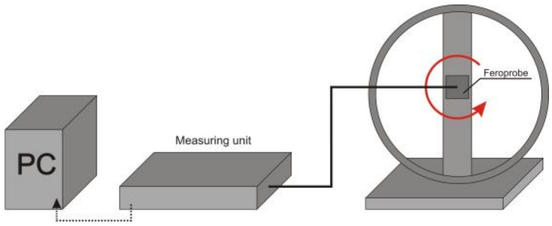
Using material 8116 we can observe the greatest range, but at the same time decrease of sensitivity and linearity degradation, resulting in the introduction of larger errors.

By adjusting the material 8116 we achieved a reduction of measuring range, but on the other side the improvement of sensitivity and linearity.

Value of the measurement range has been defined as part of the range, in which the initial sensitivity of the samples decreased by 10%, 30% and 50%. Distance between values of measuring range for these boundary values determines vigor transition zone linearity and saturation. Parameter Error / FS determines maximum linearity error of the transfer characteristics of its linear model. The correlation coefficient is a parameter determining the degree of similarity of the transfer characteristics for its linear model.

4 Measurement of axial anisotropy of feroprobe.

Measurement of axial anisotropy of feroprobe should determine the dependence of the output value of relax-type magnetometer for angular rotation in external magnetic field. Measurement was executed in the Earth's magnetic field. The measurement took place in ten turns with increments of 5 degrees. Setting the desired angle of rotation was executed manually. The principal scheme of the measuring facility is shown on Picture 5.



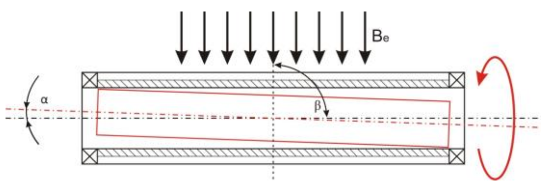
Pic. 5: *The measuring workplace for axial anisotropy of feroprobe.*

For more accurate measurement procedure and for determining the approximate shape of axial anisotropy of feroprobe we used feroprobe KLTP. The shape of measured values was of sinusoidal character superposed by interference. To determine the source and nature of the signals contained in the signal measured by the described approach, we applied spectral analysis to describe the signal.

The resulting spectrum reaches its maximum on the tenth component. This fact is clear from the sinusoidal waveform. The fact that it occurred on the tenth sample is due to the situation that the measure was executed in the ten rotations and for calculation we considered periodicity of signal as a periodicity of whole measurement and not as one rotation only.

DC offset signal does not carry information. Occurrence in the measurement was due to the wrong initial setup of magnetic zero. In the beginning of the measurement the probe was set up to the position that its output has detected a zero value. But the angular displacement of the core of feroprobe against the indicator fixed to the case of feroprobe was not accurate and more over it not defined the angular position which will determine the minimum. DC offset and even leaps in the field had no significant effect on the shape of the spectrum.

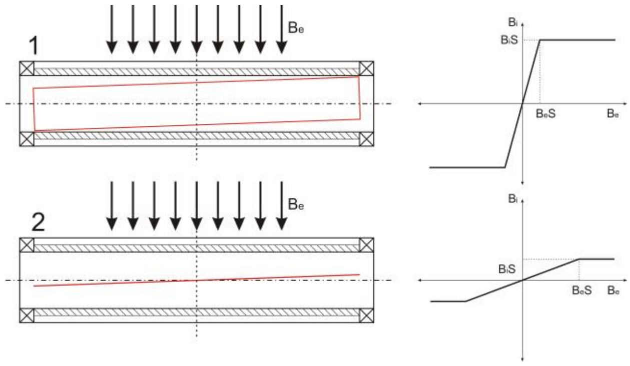
The dominant component of the spectrum it self determines the sinusoidal waveform. Closer analysis pointing to the conclusion that if our core of feroprobe was perfectly accurate and precisely placed on the axis of feroprobe, the axial anisotropy measurements acquired by the shape of the DC signal affected only by noise. Sinusoidal waveform caused uncertainty structures and the associated precession movement of the core feroprobe. Precession movement of the core of feroprobe caused the change of angle applied on the core of feroprobe and changed the effects of an external magnetic field on the core of feroprobe. Precession movement the core of feroprobe is shown on the Picture 6.



Pic. 6: *Precession movement of the core of feroprobe.*

The absolute error of axial anisotropy caused by uncertainty of construction acquired in each sample maximum value of about 130 count. When the error is applied to the transfer characteristics of the samples we get an error, which we introduced into the measurement by uncertainty of construction.

Twenty component of the spectrum is due to the fact that the core shape of feroprobe is not homogeneous. So that it is a strip and not a rod. When we perform the rotation of one strip in the magnetic field we get per rotation strip two times into the axis of easy magnetization and two times into the axis of heavy magnetization. The approach causes into superimposition signal by output signal of the half period. The change of ability of magnetization strip is caused by a change of parameter of demagnetization, causing the transfer change of characteristics of feroprobe when exposed to a magnetic field in the direction of the easy and heavy direction of magnetization of the core of feroprobe. The principle of shape anisotropy of core of feroprobe is shown on Picture 7. Since there is a change of the transfer characteristics of feroprobe, the output value magnetometer is also changing.



Pic. 8: *Shape anisotropy of the core of ferosondy.*

4 Conclusion

By accomplishing of these measurements I have determined properties of feroprobe core for modern materials used for its construction. Gathered values will serve as an instrument for choosing of propper feroprobe design, as it is not possible to design optimal solution for all of the applications. Mainly because the process of choosing the optimal solution is a rather sensitive compromise. Correct choice of the feroprobe core is a very large-scale problem and only a fraction of possible construction design is mentioned in this article.

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