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METHOD OF ELECTROMAGNETIC SCREEN SHIELDING PROPERTIES DETERMINATION

The estimation of existing approaches to shielding of electromagnetic fields has been made. The fact of the unsatisfactory metrological base has been established. The new approach for problem solving has been offered.
Key words: an electromagnetic field, the sensor, measurement.

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МЕТОД ОПРЕДЕЛЕНИЯ ЗАЩИТНЫХ СВОЙСТВ ЭЛЕКТРОМАГНИТНОГО ЭКРАНА

Проведена оценка существующих подходов экранирования электромагнитных полей. Установлено: метрологическая база неудовлетворительна. Предложен новый поход к этой проблематике.
Ключевые слова: электромагнитное поле, датчик, измерение.

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Problem formulation. Negative influence of anthropogenic electromagnetic fields and radiation on human is beyond doubt [1]. Methods of human protection from this physical factor are known and applied [2]. Nevertheless specific instructions concerning control of materials shielding properties are absent in sanitary code. Experimental investigations aimed at the assessment of screening materials shielding properties are given in the paper [3]. However, given measurement methods, on our opinion, are imperfect.

Application of ferrous resonant sensor, which has great capacity, can distort measurement results, and this is unacceptable for low strength electromagnetic field control. Beside that calculation methods of estimation of electromagnetic shields efficiency [4] have complicated mathematical apparatus, which is not adapted for application by experts in occupational safety and electromagnetic ecology. Therefore it is necessary to develop new methods for acquisition of valid data on electromagnetic screen shielding properties.

The aim of investigation is to develop the methodological base for electromagnetic screen shielding properties determination.

Results and discussion. Investigation of electromagnetic screen shielding properties has features, which are caused by wide electromagnetic field spectrum. At low intensities the sensor characteristics have significant influence and distort the measurement results. Besides, it is necessary to take into account the errors caused by measurement device. In our case this problem is solved with direct connection of the sensor with the sound card of personal computer.

To obtain the valid data of electromagnetic screen shielding properties we have applied the specially developed modulation sensor of magnetic field amplitude registration (the level of electric component is obtained with translation based on fundamental physical relations). The sensor is the coil with two galvanically isolated circuits. The excitation signal current 15-20 *mA* is delivered to one of the circuits. Modulation excitation frequency – 750-1000 *kHz*. Measurement reading is performed from another circuit. Circuits are coiled on the magnetic core of amorphous alloy MM-11N, which is annealed at the temperature 520 *°C*. Advantages of the sensor are small size (10×5×5 *mm*) and linear dependence of sensitivity on measured field frequency (fig. 1).

Given frequency dependence of sensor sensitivity is linear till 100 *kHz*. There is a little deviation from linearity at the higher frequencies (till 400 *kHz*), but it's taken into account at measurement. Such sensor parameters are quite acceptable for experiment conditions.

Graduation of sensor has been performed with generator Г-36А and gaussmeter Ш1-8. During experiment the signal registration has been carried out with application of broadband voltage amplifier В9-2, which allows selection of received signals frequencies, that is important for detection of extraneous sources contribution in total electromagnetic field.

Statistical treatment of experimental data has been performed with regression analysis procedure with application of Excel and Approximator 1.21. Analytic function indices have been determined with 95 % reliability.

For measurement of electromagnetic fields with powerline frequency 50 *Hz* and its harmonics the meter П3 50В has been applied, which allows measuring the electric field strength from 10 *V*/*m* and the magnetic induction from 10 *nT*. Relative error of measurement is lower than 15 %, that is quite acceptable for control of high intensity fields caused by powerful sources of electricity consumption, which cause background electromagnetic fields in offices and rooms.

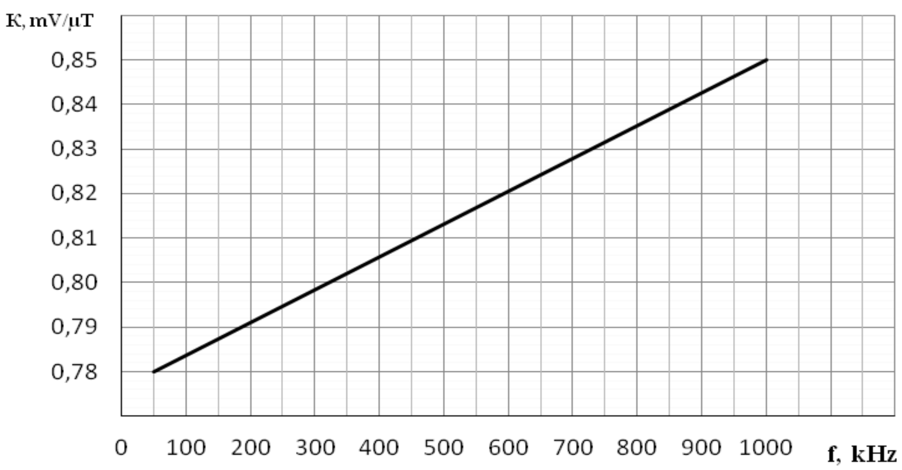

Figure 1. Dependence of modulation sensor sensitivity on measured field frequency

As a result of electromagnetic screen shielding properties investigations the frequency dependence of magnetic conductivity of soft magnetic amorphous alloy has been received (fig. 2).

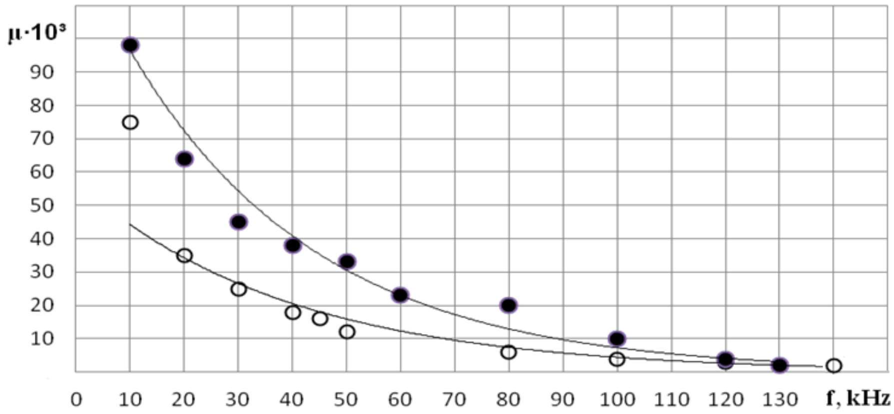

Figure 2. The frequency dependence of magnetic conductivity of soft magnetic amorphous alloy (cobalt content – 84 %):
○ – initial state; ● – heat-treated state

Excel statistical processing has shown the curves described with functions (fig. 3).

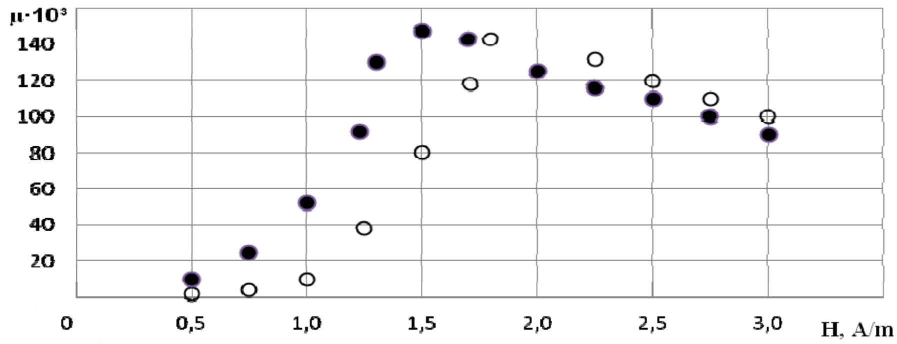

Figure 3. Dependence of magnetic conductivity of high-cobalt amorphous alloy (cobalt content – 84 %) on 5kHz magnetic field amplitude:
○ – initial state – $\mu = 2932{,}7 f^{1{,}25}$;
● – heat-treated state – $\mu = 1634{,}1 f^{1{,}25}$.

Received data give possibility to determine shielding properties of the chosen material according to already known parameters and frequencies of external magnetic field.

Initial specimens have been subjected to burning in 1000 *A/m* permanent magnetic field at 300 *°C*. Results analysis show significant changes in alloy shielding characteristics in initial and heat-treated state. In addition the marked shift of curves allows choosing material state according to levels of external fields.

Given curves have homogenous form for this class of materials. It gives possibility to determine shielding characteristics of the chosen material with graph methods without preliminary test, and that is technically and economically rational.

A common drawback of metallic electromagnetic shields is that significant part of protective properties (especially in the ***UHF (Ultra High Frequency)*** – area and above)) is realized due to the reflection of electromagnetic radiation.

In this case, it is possible that the direction of this radiation to an undesirable point (defending one room or building, we deteriorate the electromagnetic environment in other places) In addition, the control range of protective properties of amorphous magnetic alloys are not entirely satisfactory.

Thus, there exists a need for materials with low coefficient of reflection and with acceptable manageability of protective properties.

Based on theoretical considerations, especially on the basic equations of electrodynamics of continuous media, changes in the levels of absorption and reflection of electromagnetic waves caused by varying the dielectric constant of the medium (or its conductivity).

Accordingly, it is necessary to develop a protective material whose main component is an insulator, wherein drive elements (metal balls, powder, etc.) are evenly distributed.Changing the concentration of metallic inclusions also allows changing the necessary parameters. To find such material polypropylene is taken for base (matrix) and petals of aluminum used as an excipient. The average thickness of the petals was 0,250-0,50 *microns*, and the average size – 20-50 *microns*. Thickness of the protective material 2-3 *mm*.

The uniform distribution of the metallic substance in the matrix was controlled by X-ray topography method using the URS-2 apparatus. Experimental studies have shown that the maximum efficiency of screening is achieved with a metal content of 15-16 % (of weight). In this case reflection coefficient amounts 0,14-0,16, which is quite satisfactory, Since for the metal electromagnetic shielding it amounts to 0,6-0,9 (depending on the frequency of the screened field.) The advantage of the resulting protective material is its flexibility, ie inability to manufacture a desired shape of the electromagnetic screen. Fo these results to exclude experimental error, it is necessary to give a reasonable theoretical interpretation. To do this, it is advisable to use the fundamental relation of electrodynamics of continuous media, which examines electroconductivity of the metal-insulator systems at the percolation threshold of electricity. So the attenuation factor of the electromagnetic wave *Ke* (by capacity) is defined as:

$$Ke = \frac{(n+1)+\chi^z}{4n}\exp\left(\frac{z\chi\omega x}{c}\right).$$

The reflection coefficient $K_в$ in the case of a normal incident wave is defined as:

$$K_в = \frac{(n-1)^2+\chi^z}{(n+1)^2+\chi^z},$$

where n – refractive index of the material;

x – the thickness of the sample;

ω – angular frequency of the radiation;

χ – the coefficient of extinction of the material, which determines the speed of the wave damping.

In a reasonable approximation, we can assume that

$$Z = \frac{\sigma_\partial}{\sigma_m},$$

where σ_d and σ_m – the conductivity of the dielectric (the matrix) and metal.

The coefficients n and χ easily determined from the relations of real and imaginary parts of the complex dielectric permittivity

$$n = \sqrt{\frac{\varepsilon_1 + \sqrt{\varepsilon_1^2 + \varepsilon_2^2}}{2}};$$

$$\chi = \sqrt{\frac{\varepsilon_1 - \sqrt{\varepsilon_1^2 + \varepsilon_2^2}}{2}},$$

where ε_1 and ε_2 – the real and imaginary parts of complex dielectric permittivity $\hat{\varepsilon}$:

$$\hat{\varepsilon} = \varepsilon + i\frac{4\pi\sigma}{\omega}.$$

Calculations of screening and reflection coefficients for the different concentrations of the metal filling is quite time consuming, so for their execution a software application was developed ,which enables reducing time and improving their accuracy. Analysis of the obtained results shows that the differences in the results of experiments and calculations are 8-11 %. This percentage can be considered acceptable, given the uncertainty of natural measurements and a number of assumptions when determining the analytic functions, This opens the possibility of developing flexible covering materials with controllable protective qualities, which not only protect the premises from external electromagnetic influences, but also absorbs radiation generated by equipment indoors. Testing of the composite material in the range of 3-300 *MHz* showed no significant changes in the protective properties of a change in the frequency of electromagnetic radiation shielded.

Conclusions.

Investigations of frequency-amplitude dependencies of screening properties of soft magnetic amorphous alloys have proved the applicability of developed method for managing this parameter.

Such approach excludes sensor influence on measurement results.

Today the most perspective materials for protection from electromagnetic fields and radiation are soft magnetic amorphous alloys.

To prevent an increase in the levels of electromagnetic fields in undesired areas due to the reflection of electromagnetic waves from the shields is expedient to use composite metal-polymer screens with small reflection coefficients. The advantage of these screens is controllability of the protective properties over a wide amplitude and frequency range.

According to significant dependence of these materials screening properties on frequency and amplitude of external electromagnetic fields it is necessary to investigate the possibility of development of multilayer screens, and that is the field for perspective investigations.

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