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Tests of materials shielding electromagnetic field of low and medium frequencies dedicated for screens or protective clothing

Abstract. *In the paper electromagnetic field shielding properties of different materials that may be dedicated for different purposes like screening of field source, work place or protection of the worker were tested and compared. The tests were conducted in the scope of frequencies: 50 Hz - 30MHz.*

Streszczenie*. W artykule przedstawiono wyniki pomiarów wybranych materiałów, które mogą być wykorzystane jako ekran elektromagnetyczny w odzieży ochronnej. Porównanie przeprowadzono w zakresie częstotliwości do 50Hz do 30MHz. (****Badania materiałów ekranujących pole elektromagnetyczne niskich i średnich częstotliwości przeznaczonych na ekrany lub odzież ochronną****).*

Keywords: electromagnetic field, shielding, protective clothes
Słowa kluczowe: pole elektromagnetyczne, ekranowanie, odzież ochronna

Introduction

With the development of technology, rapid growth in the number of sources of electromagnetic fields (EMFs) including sources of small and medium-frequency (50 Hz - 30 MHz) results in increase of the number of workers exposed to these fields. Studies show that in Poland exposure to electromagnetic fields of small and medium frequencies can affect tens of thousands of workers employed in the service including service of devices and installations that are used to distribute electric power, electrothermal devices (furnaces for melting scrap steel, induction furnaces and heaters for thermal processing of steel elements), dielectric heaters, resistance welders, medical equipment (electrosurgery devices, physiotherapy diathermies, MRI scanners, NMR spectrometers, magnetic therapy devices) [1, 2, 8].

Effect of influence of electromagnetic fields (EFM) on human body can be direct or indirect. Direct effects include :

- Inducing of electric currents and voltages,
- stimulation of electrically sensitive tissues such as muscles or nerves – result of the flow of currents directly induced in the human body (in frequencies below hundreds of kHz)
- thermal effects - heating of tissues by absorbed energy, including serious burns (frequencies exceeding 1 MHz)
- induced or contact currents in human body can also disturb work of medical implants (heart stimulators) such as screens or posts [1, 2]

Indirect effects of EMF are result of field energy absorption by objects that are exposed to it and influence on human body [1,2, 3].

Research continues and effects of EMFs on human body, especially if the exposure to EMFs is extended over many years are not yet fully established. Besides health consequences of humans EMFs may cause damages of electrical devices. Therefore protection against EMFs both workers and equipment is required.

For protection against electromagnetic fields in work environment, according to Directive 89/656/EEC [4], personal protective equipment including protective clothing must be used when the risk cannot be avoided or sufficiently limited by procedures of work organization, technical means or collective protective measures. Collective protection measures against EMFs constitute shielding of source (localizing) or shielding of work place (protective) [1]. This is usually metal mesh or sheet. Personal protective equipment is usually clothing that constitutes Faraday cage. Such clothing should be made of electroconductive textile material.

However it needs textile that is electroconductive, with good shielding effectiveness, preferably made of metal like metal sheet, mechanically resistant (resistant to abrasion, tear) but flexible, light, with good hand.

Currently on the market there are no protective clothing and solutions shielding electromagnetic fields of small and medium frequencies. In this paper the analysis of materials containing conductive elements of its structure, which potentially should shield the electromagnetic field were conducted. Their selection was based on the review of available materials and technologies that can be used to construct materials for clothing or screens used to protect workers from exposure to electromagnetic fields [9]. The shielding efficiency of textiles compared with those conventionally used for shielding - metal nets.

Experiments

Materials

Materials selected for tests can be divided into three groups:

- with chrome-nickel or stainless steel wire
- with conductive yarn (in the form of a thin steel or silver wire or carbon yarn)
- nonwoven with active carbon.

Table 1 Characteristic of tested materials

No	Sample	Surface mass [g/m^2]	Thickness [mm]
1	Chromium/nickel net Wire diameter: 0,035 mm Width of mesh: 0,05 mm	237 ± 11	0,09
2	Stainless steel net Wire diameter: 0,25 mm Width of mesh: 0,9 mm	2513 ± 15	0,50
3	Nonwoven with active carbon	157 ± 8	0,56
4	Fabric made of Polyester, and Copper / Silver yarn	105 ± 5	0,31
5	Fabric made of Polyester and Stainless Steel yarn	128 ± 6	0,38

Samples: 1 and 2 are the meshes that could be used for the purpose of electromagnetic shielding as collective protective measures due to their rigidity and mass. The samples: 3, 4, 5 are the textile materials that could be used for protective clothing. Samples 4 and 5 were developed within the research project conducted in CIOP-PIB.

Testing Methodology

For described (table 1) structures of materials measurements of the electromagnetic field shielding effectiveness of small and medium frequencies (50 Hz - 30 MHz) were conducted.

The tests of EMF shielding effectiveness were conducted with regard to its two components: the electric field E [V/m] and the magnetic field H [A/m]. Materials properties were characterized by **shielding effectiveness (K),** ratio calculated according to the following formulas:

-for electric field $$K(E) = \frac{|\mathbf{E}_0(\mathbf{r})|}{|\mathbf{E}_1(\mathbf{r})|} \quad (1)$$

- for magnetic field $$K(H) = \frac{|\mathbf{H}_0(\mathbf{r})|}{|\mathbf{H}_1(\mathbf{r})|} \quad (2)$$

where: E_0, H_0 - the field level of frequency f in the location of electromagnetic field sensor, measured by isotropic sensor of RMS, E_1, H_1 - the field level of frequency f in the location of electromagnetic field sensor, measured by isotropic sensor of RMS value covered by the sample of tested material

Laboratory setup for shielding efficiency measurements were designed on the basis of accredited reference sources of EMF (e.g. Helmholtz coils, air capacitors and GTEM cell operating in the frequency range 10 Hz – 5.5 GHz (Fig. 1) [6].

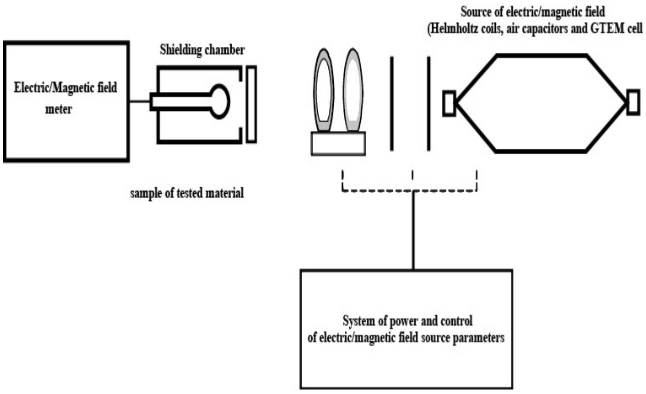

Fig 1. The scheme of the structure of laboratory setup for EMF shielding efficiencies measurements [6]

Results and discussion

The examples of measurement results obtained in the scope of shielding electromagnetic fields of small and medium frequencies by tested materials with an expanded uncertainty (for coverage factor k = 2 and confidence p = 95%) (table 1) are presented on the figures 2-5.

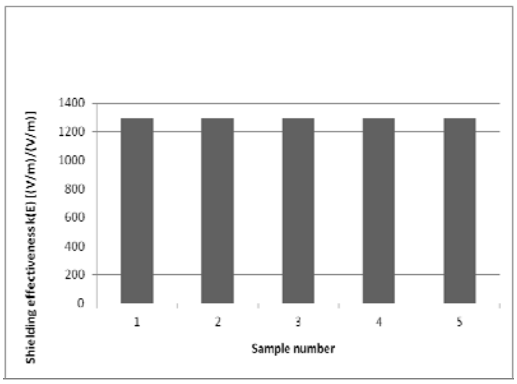

Fig. 2 Shielding effectiveness of electric field E[V/m] for tested materials in frequency range (10-200 000) Hz.

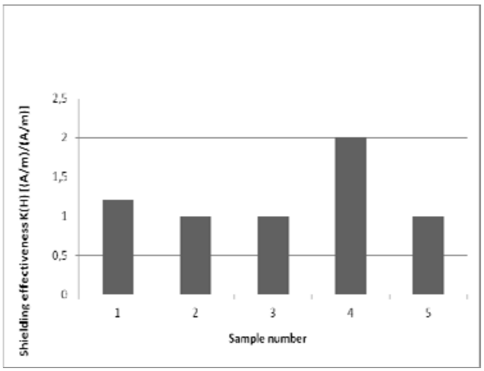

Fig. 3 Shielding effectiveness of magnetic field H[A/m] for tested materials in frequency range (10-200 000) Hz.

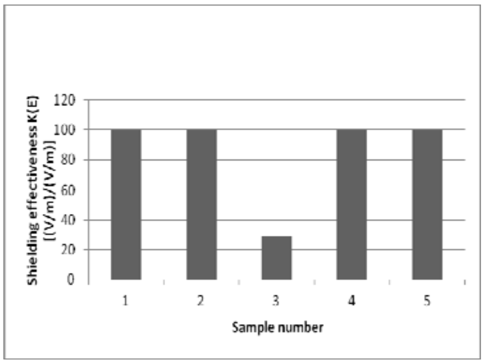

Fig. 4 Shielding effectiveness of electric field E[V/m] for tested materials in frequency range 50MHz

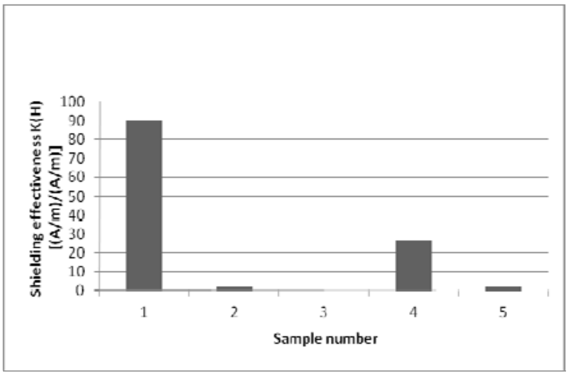

Fig. 5 Shielding effectiveness of magnetic field H [A/m] for tested materials in frequency 50MHz

As follows from the test results:

- **for electric field** E[V/m] all the selected materials shielded 1300 times in frequency range (10-200 000) Hz. In frequency 50 MHz samples 1, 2, 4, 5 shielded electric component close to 100 times. Sample no 3 shielded electric field 30 times.
- **for magnetic field** H[A/m] shielding effectiveness of samples 2, 3, 5 was not observed. The shielding effectiveness of sample no 1 was 1,2 times and for sample no 2 was 2 times. In case of shielding effectiveness of magnetic field H [A/m] in frequency 50MHz every sample except no 3 shielded at least 2 times. Shielding effectiveness of sample no 1 was 90 times and sample no 4 was 27 times. Additionally it was observed that sample 4 reduces magnetic field two times from the frequency of 200 kHz.

Conclusions

As the effect of carried out measurement in the scope of shielding effectiveness in small and medium frequencies comparison of metal meshes and developed in CIOP-PIB textile materials was performed. Materials were evaluated in respect to their utility for construction of protective clothing. Even though metal meshes may be considered as better electromagnetic fields screens especially for law and medium frequencies fabrics showed comparable properties. Textile samples 4 and 5 were characterized by good usability parameters (low mass, high flexibility, breathability, good hand) and high enough EMFs shielding effectiveness in frequencies (50 Hz - 30 MHz). In occupational safety and health engineering (OSH) the minimum value of K ration is recommended at the level of 10 for material to be used for PPE construction.

Both samples no 4 and 5 may be applied in construction of clothing protecting against EMFs of small and medium frequencies. However the better shielding effectiveness has sample no 4. The material may be used for clothing protecting against electric field in the frequencies range of 10 Hz – 50 MHz and against magnetic field in the frequency of 50 MHz and higher.

The decision to use protective clothing as a control measure should be based on a risk assessment. Depending on risk present it should be possible to decide how efficient protective clothing is needed and its relevant selection. Protective clothing including protection against electromagnetic fields should meet the requirements of Directive89/686/EEC [5].

However in case of clothing protecting against electromagnetic fields confirmation of its compliance with this document is difficult because there is no European standard harmonized with, this Directive which would define the requirements and test methods for this group of products. The only normative document developed in Europe on clothing to protect against electromagnetic fields is the German standard DIN 32780-100:2002 [7], which formulates requirements for protective clothing against high frequency electromagnetic fields. According to this document information on protective clothing shielding effectiveness should be included in manufacturer instruction.

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