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Application of Metallic Powder Materials for Pulsed Electromagnetic Field Shielding

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ABSTRACT

Pollution by pulsed electromagnetic field (EMF or PEMF) is a collateral effect of many technological operations, where pulsed electromagnetic processes are employed. For instance, in case of direct current and impulse welding systems, magnetic-pulsed processing (metal sheets and powders fast forming), and various electric discharge equipment (e.g. thyristors) a frequency range of such fields is between 0.5 to 100 kHz with impulse duration from milliseconds to microseconds. Energy of such impulses may reach 200.0 kJ and even more. In order to protect personnel and equipment against interference of pulsed electromagnetic fields various materials with shielding effectiveness are used. In this work, the EMF shielding element made of iron powder is compared to solid metal shielding materials.

Keywords: pulse electromagnetic fields, EMF pollution, shielding effectiveness, screens.

1. INTRODUCTION AND THEORY

Electromagnetic fields (EMF) as non-ionising radiation are recognized as a significant concern of modern life [1][2]. Intensive EMF of ultra-low frequencies are created by industrial machinery and various industrial processing equipment [3]. Electric and magnetic fields of industrial frequency are created also by transmission lines, panel board and cabins, including those incorporated in civil engineering structures [4], interacting with electronic and electrical equipment in workplaces and living spaces [5].

The issue of damping of magnetic fields produced by laboratory and industrial equipment for materials processing by means of electromagnetic field had already been addressed in previous article [6]

Shielding is the most effective way of protection against EMF influence. EMF damping or shielding effectiveness (SE) depends on depth of penetration of current in a shield wall, and can be expressed in form of simple relationship (1).

$$SE=\frac{H_0}{H} \quad (1)$$

Where H_0 is an EMF strength in the absence of the shield, and H is an EMF strength when the shield is applied. The theory of Schelkunoff [7] describes the shielding effectiveness as a combination of following effects as shown in equation (2) [8]:

$$SE_{dB}=A_{dB}+R_{dB}+B_{dB} \quad (2)$$

Where A is a shield material's absorption, R is a reflection loss, and B is a component of multiple reflection loss inside the shield expressed in decibels (Figure 1)

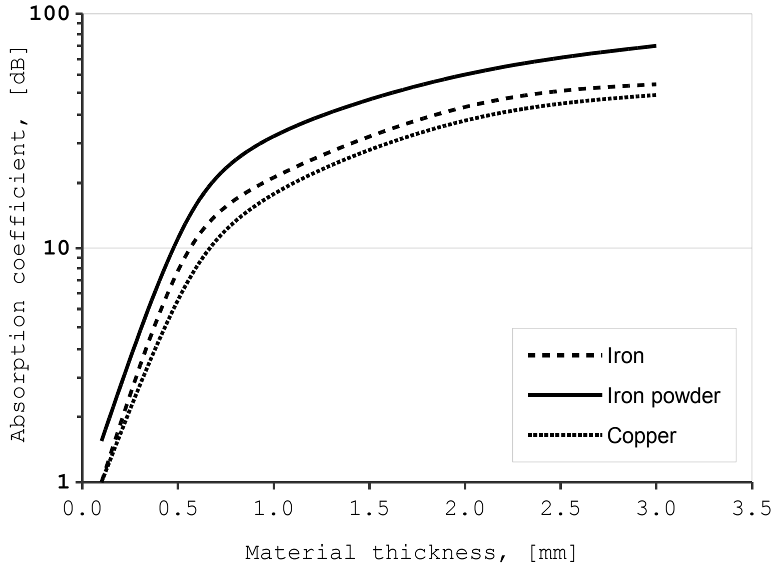

Fig. 1. EMF absorption coefficient vs. thickness of shielding material.

Up-to-date research on EMF shielding materials covers many specialist electric, magnetic and electromagnetic radiation protection measures. Amongst them is a development of new polymers, fabrics, paints which possess EMF shielding properties [9]–[11].

The Laboratory of Powder Materials of Riga Technical University is conducting research activities on iron powder materials applications for EMF shielding. This paper outlines the research of ferromagnetic powder materials application for reduction of low-frequency electromagnetic fields in industrial environment, where electromagnetic processing of materials is taking place. Interested range of frequencies lies between 0.5 kHz and 100 kHz that corresponds to technological processes of welding and magnetic-pulsed processing equipment [12], including electro-hydraulic cleaning systems [13].

2. EXPERIMENTAL PART

Ferromagnetic powder materials, particularly powder wastes produced by powder metallurgy processes may be considered as an inexpensive media for EMF shielding of electromagnetic installations. Thus, an EMF shielding capability of solid metallic materials and iron powder filling was estimated. Properties of used materials, including magnetic permeability and electrical resistivity are presented in Table 1.

Table 1. Properties of materials used for experimental measurements.

Material	Shielding material form and thickness	Fe (Cu*) contents, weight %	Electrical resistivity, [Ohm cm]	Initial permeability
Iron powder (Höganäs M20/80-19)	loose filling of 10 and 30 mm	> 99%	10^{4}	80
Mild steel S235	Plates of 8 and 15 mm	> 98%	$10x10^{-6}$	250
Copper (Cu)	Plate of 0.5 mm	> 99%*	10^{-8}	1

An experimental set-up for EMF shielding measurements comprises of pulsed magnetic field emitter-coil coupled with generator of impulse currents, shielding element made of powder filling or solid metals, and the Hall probe connected to gauss-meter (Figure 2). For the measurement of magnetic field emitted from coil a symmetry point has been chosen. All tests For 200 V and maximum discharge current 0.38 kA and maximum EMF strength measured without a shield 1.07 kA/m.

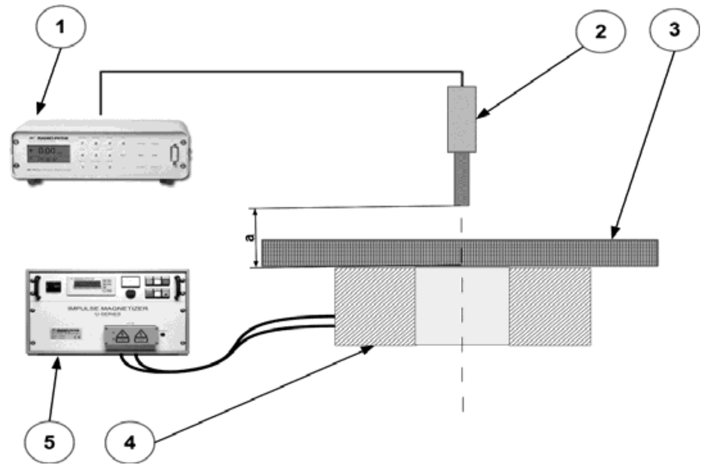

Fig. 2. Schematics of experimental set-up used for local EMF strength measurements.
1 - Gauss-/teslameter FH-55, 2 - Hall probe, 3 – EMF shielding material, 4 – Coil, 5 – Source of impulse currents (2800 J, Impulse currents up to 60000 A)

3. RESULTS AND DISCUSSION

Figure 3 shows the indicative trend of EMF shielding capability of powder filling comparing to solid mild steel plates and copper foil. Mild steel plates of 8 mm and 15 mm are equally shielding EMF field , while powder filling performs slightly better only at distances of more than 40 mm from the coil.

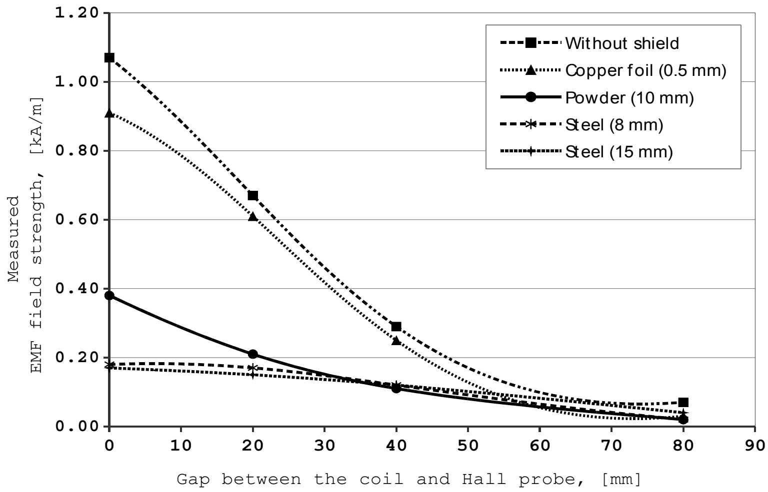

Fig. 3. Transmitted EMF strength measurements for powder fillings 10 mm comparing to solid steel and copper plates.

Meanwhile, M20/80-19 powder fillings in shape of cylinders (filling diameter 60 mm, thickness 10 and 30 mm) have been tested. Transmitted EMF strength measurements for 10 and 30 mm powder fillings are shown in Figure 4. 30 mm thick powder filling demonstrates better shielding capacity than 10 mm layer. However, it does not have any significant influence on EMF shielding on distances of more than 40 mm from the powder filling.

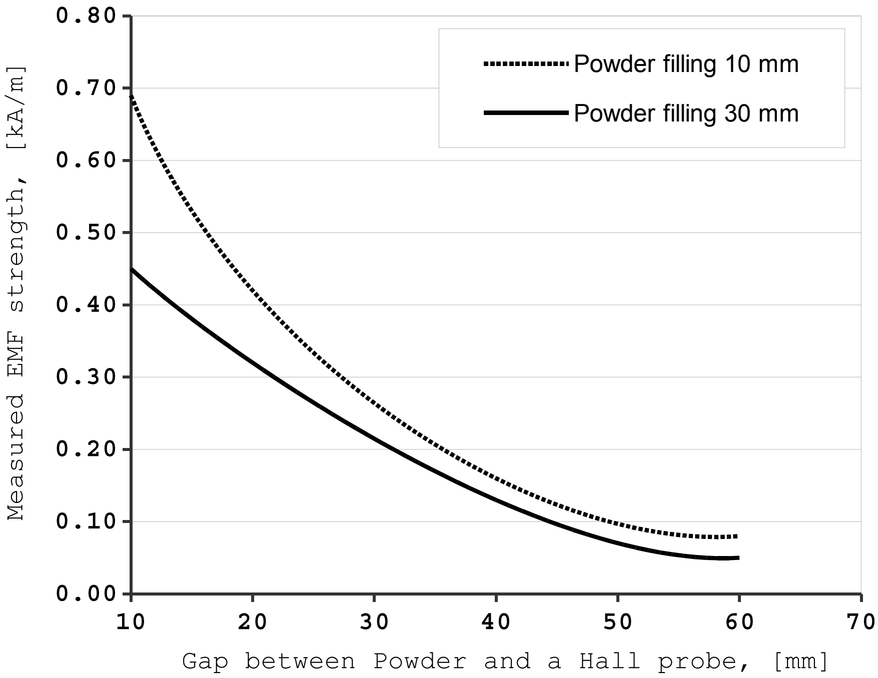

Fig. 4. Transmitted EMF strength measurements for cylindrical M20/80-19 powder fillings (thickness: 10 and 30 mm).

4. CONCLUSIONS AND FURTHER WORK

An EMF shielding capacity of iron powder fillings in comparison to solid mild steel plates and copper foil have been demonstrated. In particular case of experimental set-up, it was found that powder filling may act as an effective EMF shield on distances below 40 mm from the EMF emitter (coil).

Iron powder filling can be used for EMF shielding screen (or matts) manufacturing for protection against impulse magnetic fields generated by electromagnetic coils and equipment.

Additional advantage of iron powder EMF shields is in that for manufacturing of iron powder EMF shielding a waste iron powder (sediments of filters) can be used.

Shielding properties of iron powder filling open great opportunity for further shielding improvement and new iron composite EMF shielding material design.

5. AKNOWLEDGEMENTS

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