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Multilayer material for electromagnetic field shielding and EMI pollution prevention

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Abstract. A significant growth of scientific activities related to electromagnetic fields interaction with equipment and living organisms have turned into an up-to-date research trend in recent decades. Power transmission lines, electric devices, and portable electronics have become a source of electromagnetic pollution. Therefore, a question of electromagnetic shielding is a substantial criterion for workplace safety. Current paper suggests a possible solution based on loose materials and rubber compounds for essential protection of people and equipment against electromagnetic influence.

Key words: crumb rubber, iron powder, electromagnetic shielding, perforated steel, multilayer structures.

INTRODUCTION

The European countries recognise non-ionising electromagnetic fields (EMF) as a significant concern of modern life (Health Protection Agency 2012). Meanwhile, ultra-low electromagnetic frequencies (50–60 Hz) are of importance in case of industrial and residential electrical installations and wirings (European_Commission, 2015b). According to research activities carried out by international scientific groups, low-frequency range (Jain & Tyagi, 1999) can be considered as an electromagnetic hazard (European_Commission, 2015a), especially for industrial (Mild & Sandström, 2015) (machinery) and transportation (Muc, 2001) environments. Non-ionising electromagnetic fields can be isolated by providing a conductive barrier enveloping an electrical equipment or sources of electromagnetic fields. Moreover, shielding is needed for protection against interferences between electrical and electronics equipment at industrial and household levels (Chung, 2000).

Shielding effectiveness (SE) is characterised by ratio of the electromagnetic field energy on one side of the shield to the electromagnetic field energy on the other side of the shield (Nichols, 2013). At the same time, the theory describes the shielding effectiveness as a combination of following effects: shield material's absorption, reflection loss, and multiple reflection loss inside the shield (Morari et al., 2011).

Applications of steel materials for damping of magnetic fields produced in lab-scale equipment along with electromagnetic fields in contemporary workplaces have been outlined in several *Agronomy research* papers (Koppel et al. 2013; Mironovs et al., 2014). In previous work (Mironovs et al., 2016) a method for obtaining a new material by transformation of end-of-life crumb rubber wastes (Rubber. Products, 2016) to crumb rubber-iron powder mixture has been introduced. Meanwhile, in current paper an application of crumb rubber-iron powder mixture (CRIP) for electromagnetic shielding is investigated.

MATERIALS AND METHODS

Bulk CRIP was used as a perspective raw material for electromagnetic shielding tests (Figs 1, 2). Iron powder M20/80-19 was used as a reference material. For experimental trials, loose powders were packed in rectangular multilayer blocks approximately 100 x 100 mm with respected thickness of 20, 40, and 35 mm (Table 1.).

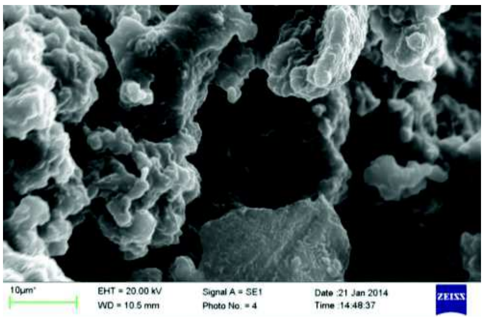

Figure 1. Developed devulcanised crumb rubber (NGR) surface structure enables high strength interaction with non-rubber particles (Rubber.Products 2016).

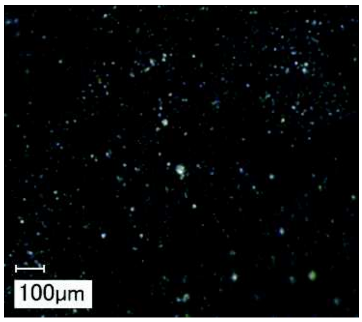

Figure 2. Crumb rubber – iron powder mixture (Mironovs et al. 2016).

Table 1. Shielding materials used in experimental trials

Shielding material	Block dimensions, mm	Iron (Fe) contents, %
Multilayer CRIP blocks	100 x 100 x 20 and 100 x 100 x 40	~ 30%
Multilayer iron powder (Höganäs M20/80-19) block	100 x 100 x 35	> 99%

An experimental rig (Fig. 3) for measurements of electromagnetic fields shielding consisted of electromagnetic field (EMF) source (300W desktop computer power source), shielding block made multilayer CRIP blocks, or iron powder M20/80-19 filling, and the portable electromagnetic radiation tester (teslameter GM3120) has been designed. Magnetic fields were measured in microteslas (μT) (Energy Networks Association 2013).

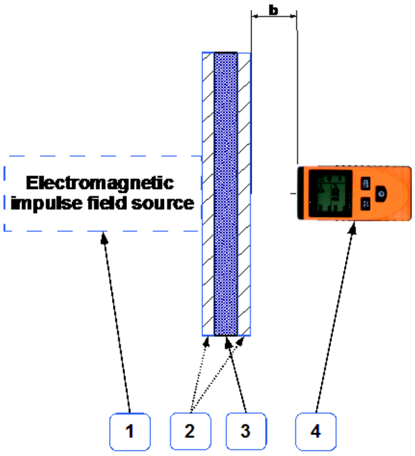

Figure 3. Schematics of experimental rig used for local EMF strength measurements: 1 – Source of electromagnetic impulse fields; 2 – Layer made of crumb rubber; 3 – Layer made of crumb rubber – iron powder mixture (CRIP); 4 – Electromagnetic radiation tester-teslameter GM3120.

RESULTS AND DISCUSSION

Experimental trials have demonstrated a feasibility of suggested shielding materials based on CRIP. 20 mm CRIP block have resulted a reduction of magnetic field strength for about 1.5–2.0 times (13.00 μT vs. 8.50 μT) comparing to unshielded measurements (Fig. 4). Investigated CRIP shielding elements have shown an effectiveness up to 60 mm distance from EMF source (with background electromagnetic field strength 0.70–0.80 μT).

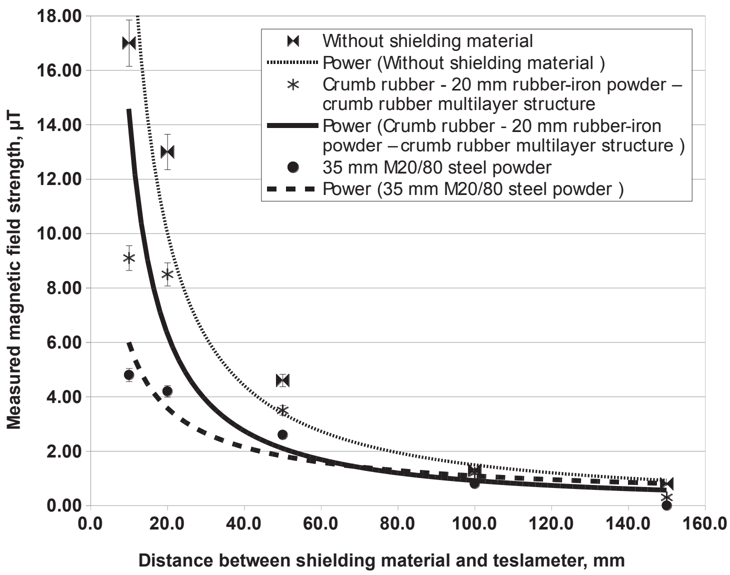

Figure 4. Measured magnetic field strength vs. distance between shielding materials and teslameter (*b* in Fig. 3).

A suggested material was investigated in multilayer elastomeric compositions, which can be used for applications requiring EMI shielding (Morari et al., 2011) in combination with shock and sound absorption features.

FURTHER DEVELOPMENTS

Further research activities will cover multilayer structures containing CRIP, rubber mat, and reinforcment with perforated steel bands. One of multilayer realisations is shown in (Fig. 5). Specifications of reinforcement material are listed in Table 2.

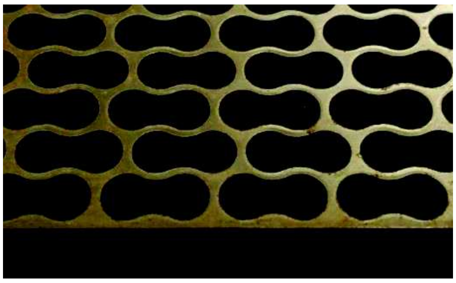

Figure 5. Preparation of multilayer structure composed of crumb rubber / CRIP reinforced by perforated steel tapes.

Table 2. Perforated steel tape specifications

Steel Standard	50-T-C-H, GOST 2284-79
Thickness, mm	1.2
Width, mm	80
Permeable area, %	72.25
Effective cross-sectional area, mm^2	18.12
Tensile load bearing capacity, N	9,314
Strain, %	1.35

Suggested multilayer structure is characterised by its multifunctional performance: electromagnetic field shielding with shock and sound absorption features. Further modification of rubber substrate with copper or aluminium containing components may be considered for shielding of radio-frequency (Weibler, 1993), as well as for shielding of microwave sources (Micheli et al., 2011).

CONCLUSIONS

An experimental investigations of materials based on crumb rubber (devulcanised crumb rubber (NGR)) have proved that crumb rubber – iron powder mixture can be used for shielding of electromagnetic field of ultra-low frequency, thus minimising an electromagnetic pollution.

Multilayer materials made of crumb rubber – iron powder mixture filling can be considered as a shielding media for low-frequency EMF emitting sources (household and industrial equipment).

Further development of low-cost shielding materials based on crumb rubber fully supports the European Union trend to the circular economy (European_Commission 2015a) by introduction of materials re-use and recycling and, therefore, industrial wastes minimisation (European_Commission 2016).

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