Agronomy Research **12**(1), 279–284, 2014

Cellular structures from perforated metallic tape and its application for electromagnetic shielding solutions

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Abstract. The current study is devoted to the manufacturing of cellular structures from perforated steel tapes, which are obtained as a waste during stamping of fine-sized details. Obtained cellular structures can be used for electromagnetic shielding solutions. The relevance of the current study can be characterized as in modern working and living environments there is an increasing need for electromagnetic shielding solutions. This need can be based on several points of view: 1) a need to protect workers from electromagnetic fields (EMFs) generated by working machinery, 2) a need to protect sensitive electronic devices from the surrounding EMFs, 3) minimizing health risk from EMFs in the living areas (high tension power lines, power transformers etc), 4) counter-espionage applications (preventing electronic surveillance). Besides, the recycling of metal wastes is one of the significant modern tasks of the industry.
The different methods of manufacturing of protective shield from perforated materials by profiling and welding are studied. The methodology for manufacturing of lightweight and reliable (including strength and corrosion resistance) protective shield is elaborated and offered. The main directions for using of such protective shield are the following: protection from electromagnetic fields, solar radiation and noise.
This study undertook shielding efficiency measurements in a controlled environment. Test materials were irradiated with various electromagnetic fields: 1) low frequency magnetic field, 2) low frequency electric field and 3) high frequency electromagnetic field. The results showed great differences in between different test samples. The best shielding factor was obtained with the samples where the electromagnetic absorbing material was thickest.

Key words: perforated metallic waste, cellular structures, profiling, welding, electromagnetic fields, shielding.

INTRODUCTION

World Health Organization electromagnetic fields (EMF) are recognized as one of the most widespread adverse factors of environment (Bonner, 2002). In industrial production and construction the various industrial processing equipment and devices for the scientific purposes, creating EMF of average frequencies is used (Borner et al., 2011). In environment intensive EMF of ultralow frequencies are created electrified vehicles and by railway transports (Muc, 2001). Electric and magnetic fields of industrial frequency are created also by electricity transmission air-lines, panel board to substations, including built in buildings (Coll et al., 2010). Sources of electromagnetic fields are also personal computers and various household devices. Electromagnetic fields may interact with electronic and electrical equipment, magnetic systems and also living spaces and workplaces (Koppel et al., 2013).

It should be mentioned that in a context with our research activities the range of frequencies of electromagnetic radiation of the magnetic-pulsed technological processes is of importance due to powerful EMF sources used (Table. 1).

Table 1. Range of frequencies of EMF of some technological processes and operations

Maximum energy of EMF, kJ	Frequency range, kHz	Technological processes and operations
0.5–10	0.5–3	DC welding, application of tiristors, and impulse welding.
1.0–200	5–100	Magnetic-pulse processing, electro-hydraulic cleaning, electric discharge equipment.
30–3,000	0.1–50	High-frequency processes of magnetic-pulse processing, plasma physics equipment, electric discharge systems etc.

There are several approaches for weakening of EMF influence:

- passive, active, collective, or individual shielding,
- control to exposure to EMF by reduction of time of contact with EMF sources,
- distance control between EMF source and protected objects,
- structural improvement of the equipment decreasing a level of the EMF influence.

Shielding is the most effective way of protection against EMF influence. EMF damping or shielding effectiveness (SE) depends on depth of penetration of high-frequency current in a shield wall, and can be expressed in form of simple relationship (1) or in decibels. It can be characterized the relationship of EMF strength in the absence of the shield (H_0) and in the presence of the shield (H).

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

Magnetic permeability influences on shielding effectiveness of steel sheet materials (Fujita et al., 2005). High magnetic permeability of shield material along with high frequency of a shielded field decrease depth of penetration and therefore minimising a thickness of shielding screens. Moreover, the shielding screens not only weakens, but also distort and dissipate magnetic field influence for the protected area. Schelkunoff's theory (Schelkunoff, 1943) characterize the shielding effectiveness as a combination of following effects (2):

$$SE = A + R + B \quad (2)$$

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 (Morari et al., 2011).

The shielding effectiveness determined by varies for electric and magnetic fields and depends on coordinates of a point of measurement. This circumstance complicates its quantitative assessment. It is possible to shield both a source of radiations, and a workplace of the operator.

There are plenty of EMF shielding materials for commercial applications (Chomerics Inc., 2013). Special attention is paid to metallized fabrics, protective paints or films or other special materials (Dixon & Masi, 1998) which can be used as shielding materials. The Laboratory of Powder Materials of Riga Technical University is carrying out a research on possible application of sputtered iron powder materials for EMF shielding design is suggested (Mironovs & Polakovs, 2011).

This paper covers an inexpensive solution for electromagnetic processing equipment shielding against EMF. For protection against pulsed electromagnetic fields (PMF) shielding screens fabricated from perforated sheet metal materials, grids, or ferromagnetic plates located outside of the cylindrical coil or the casing closing a working zone can be applied.

MATERIALS AND METHODS

Laboratory of powder materials of Riga Technical University is carrying out research activities on development of cellular structures made of punched metal tapes (Fig. 1) (Mironovs et al., 2012; Mironovs et al., 2013).

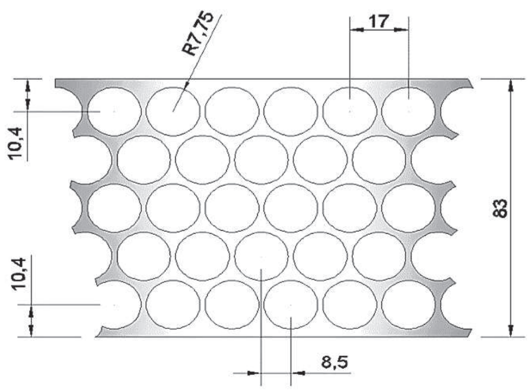


Figure 1. Punched steel tape (sheet thickness 1.2 mm) as a source material for shielding screens.

EMF shielding capability of screens made of the steel punched tape by welding (Fig. 2a) and an interlacing (Fig. 2b) was estimated.

Investigation presented in current paper was conducted with use of a permanent magnet (Fig. 3). Evaluation of magnetif field strength was carried out by means of laboratory gauss-meter FH-55.

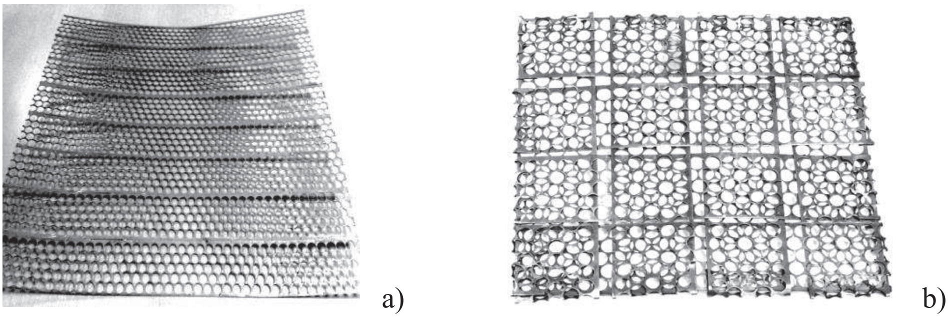
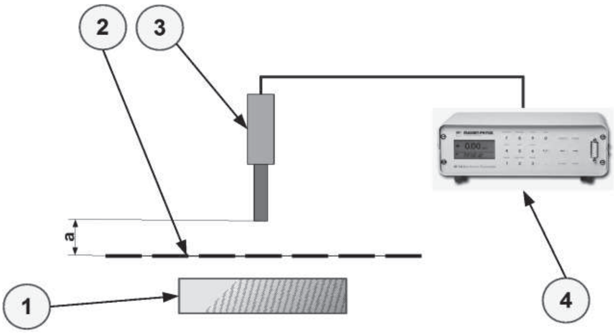


Figure 2. Shilding screens of 500 x 500 mm made of punched steel tape (Fig. 1.) thickness 1.2 mm. a) welded, b) interlaced.



Figuer 3. Installation schematics for determination of intensity of EMF of permanent magnet, where: 1 – permanent magnet Fe-Nd-B, 2 – perforated steel shield, 3 – hall probe, 4 – Gauss-/teslameter FH-55).

For evaluating shielding effectiveness for the EMF the electromagnetic coil installation has been used (Figs 4, 5).

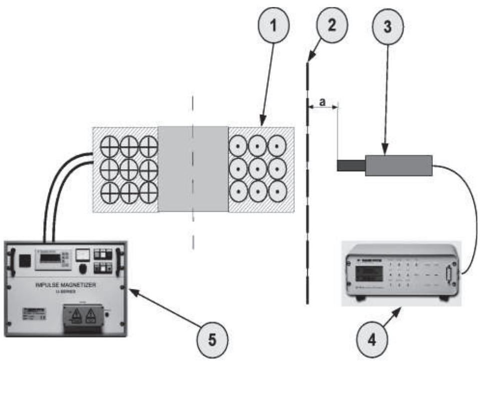


Figure 4. Measurement of EMF on a lateral coil surface (transversally to magnetic flux).

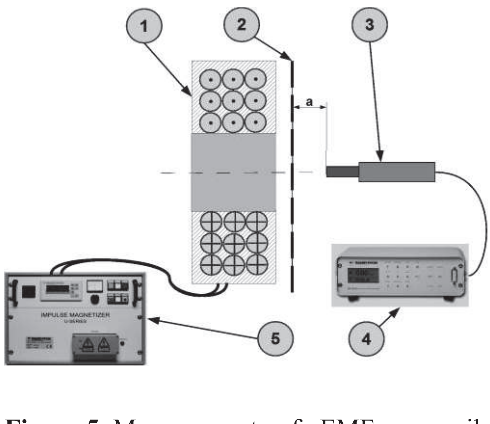


Figure 5. Measurement of EMF on coil axially to magnetic flux.

where: 1 – coil; 2 – perforated steel shield; 3 – hall probe; 4 – Gauss-/teslameter FH-55; 5 – Impulse currents source (2,800 J, Impulse currents up to 60,000 A).

RESULTS AND DISCUSSION

Change of magnetic field strength of a permanent magnet depending on distance to the measuring instrument probe without screen and with application of two types of screens (Fig. 7) was investigated. The maximum field intensity on the magnet's surface was measured (2.4 MA m^{-1}). Relationship between distance *a* and magnetic field strength of a permanent magnet (according to the scheme in Fig. 3) is shown in Fig. 6.

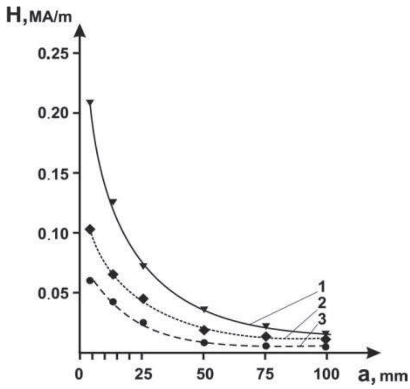


Figure 6. Damping curve of magnetic field strength with distance *a:* 1 – without shielding screen; 2 – with single layer welded shield; 3 – with dual layer interlaced shield.

Results of measurement of pulse EMF at various arrangement of the coil and mesh screens from the shielding screens made of steel punched tapes is presented in Fig. 7.

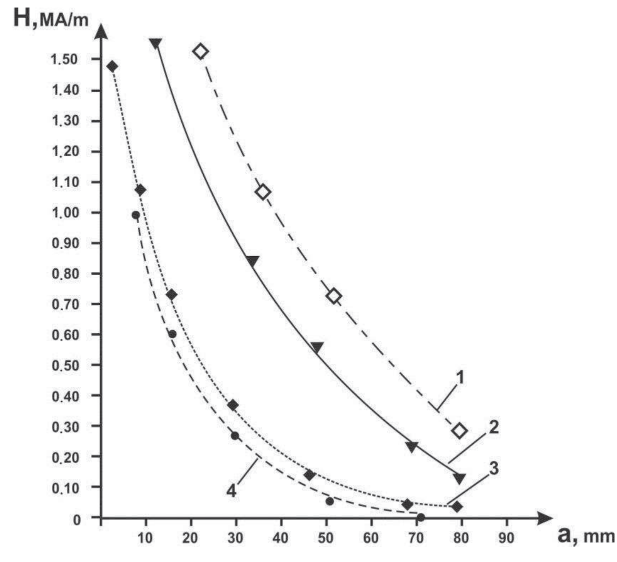


Figure 7. Damping of pulsed EMF in axial and transversal position of the screen shielding: 1 –axially to magnetic flux without shielding screen; 2 – axially to magnetic flux shielding screen; 3 – transversally to magnetic flux without shielding screen, 4 – transversally to magnetic flux shielding screen.

CONCLUSIONS

1) An experimental analysis of shielding effectiveness of shielding screens made of perforated (punched) steel tapes is done. It was found that perforated shielding screens may decrease magnetic field strength in both cases: a static magnetic field of the permanent magnet and in case of electromagnetic field generated by coil.

2) The shielding effectiveness of presented shielding materials depends on variety of parameters and have to be evaluated for each specific application e.g. interlaced shielding screen has demonstrated a better performance for electromagnetic field damping.

ACKNOWLEDGEMENTS. This work has been supported by the Latvian Council of Science within the Project Nr. 110/2012 'Titanium compound wear-resistant nano-coatings in mechanical engineering'.

We would like to thank students M. Lisicins and K. Zitans (Riga Technical University) for active participation.

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