Journal of Achievements in Materials and Manufacturing Engineering

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Fabrication of screens for electromagnetic fields shielding with threats analysis at the position

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Received 30.10.2013; published in revised form 01.01.2014

ABSTRACT

Purpose: The aim of this article is to pay attention on the necessary of protection of the people and devices from the harmful electromagnetic radiation. The special role play the screens (materials or systems) for shielding which have a very diversified construction depending on the frequency of electromagnetic fields.

Design/methodology/approach: In the paper a problem of electromagnetic fields shielding was presented. Moreover, the occupational risk assessment at the vacuum sublimation position was showed.

Findings: The screening methods and materials used for screens were discussed. The threats occurring at the vacuum sublimation position and the preventive actions decreasing the risk level were presented.

Research limitations/implications: The paper presents the one of the methods for screens fabrication – vacuum sublimation in a simple laboratory vacuum sublimation equipment. The structure testing and investigation of thickness of fabricated screen (constructed from four layers: aluminum – polypropylene – aluminum – metallic glass of Metglas type) were carried out. The occupational risk assessment was made by three-stage scale method according to PN-N-18002 standard.

Practical implications: The results of microscopic observation of fabricated material system unequivocally reject the vacuum sublimation method using a laboratory vacuum sublimation equipment for the screens fabrication.

Originality/value: In the article the different kinds of threats occurring at the vacuum sublimation position were presented. The various preventive actions were proposed.

Keywords: Materials; Electromagnetic fields shielding; Structure testing; Occupational risk assessment

Reference to this paper should be given in the following way:

M. Spilka, A. Kania, S. Griner, Fabrication of screens for electromagnetic fields shielding with threats analysis at the position, Journal of Achievements in Materials and Manufacturing Engineering 62/1 (2014) 38-44.

INDUSTRIAL MANAGEMENT AND ORGANISATION

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1. Introduction

Independently of the size intensity of electromagnetic fields occurring in both the professional and extraprofessional environment, there should be always used so-called ALARA principle (As Low As Reasonably Achievable), according to which exposure on electromagnetic field fabricated artificially, and influencing on the human body should be limited maximally. Necessary actions, limiting exposure for electromagnetic fields do not have to depend on disconnection of the field source from exploitation. Reduction of exposure can be often achieved by technical and organizational methods [1,2].

One from the ways of protection before the harmful effects of influence of the electromagnetic fields is shielding. The idea of shielding is to limit and eliminate the undesirable source radiation outside the specified area. It can be also limited to protection of direct environment of the same objects that are protected before the influence of an external electromagnetic field. Important in both cases is the effectiveness of the screen working, as well as the costs of such protection [3].

In this article an identification of threats and a risk assessment at the vacuum sublimation position are also presented. That is very important from the worker who works at this position point of view.

2. Shielding of electromagnetic fields

The physical basis of electromagnetic fields shielding are based on Maxwell's theory which is the description of the macroscopic wave events occurring in the homogeneous material and in the field about specific characteristics [3,4]. The theory of electromagnetic waves propagation in the matter is based on the solutions of Maxwell's equations and it is general especially in the confrontation with the detailed requirements of practice. This is connected with the fact that Maxwell's equations defined algebraically can not solved exactly for the real field, and in case of practical applications the results usually require of verification and correction. All the solutions of equations are approximation and they are for the simplest systems. In case of complex, composite materials there are more problems. Also for problems of electromagnetic wave propagation solving there are used approximate numerical methods, but they are not always give a satisfactory solution. For these reasons, the most often, problems of electromagnetic waves shielding are resolved experimentally.

The intensity of a field passing through the screen is shield as a result of reflection, dissipation and absorption of energy [2].

The reflective shielding depends on frequency, type of a field, material properties of screen and distance of the screen from the source of the field.

In theory of wave phenomena the reflection effect is explained by incompatibility of wave impedances and the environment surrounding the screen. In the practical considerations generally ignored, as a small, shielding effect resulting from reflection of energy inside the screen material [2,4].

The absorptive shielding depends on the electrical and magnetic properties of screen material, thickness and frequency, however practically does not depend on the kind of field incident on the screen. In respect of the applications, there are three types of shielding [2]: locating shielding, covering shielding and masking shielding.

There is division of shielding way due to the kind of field on shielding of the electrical field, magnetic field and electromagnetic field, also [4].

During shielding of the electric component of the field there are used phenomenon of the accumulating loads in the condition of equilibrium only on conductor surface, independently of that how they are created.

The shielding of the magnetic component of the field is used when the harmful field is static or it is changing extremely low.

For shielding of the electromagnetic fields with higher frequencies there are used ferromagnetic metals with high electrical conductivity.

From the theoretical point of view, the effectiveness of shielding depends on set of the physical properties, screen geometry and characteristics of radiation source – in this first of all, on the kind of material used for screen making, its thickness and shape of the screen, size of the shielded object, field frequency, distance from the source, intensity of the incidence of electromagnetic wave on the screen.

From the practical point of view, to shielding of the electrical component of the fields should be applied materials about high electrical conductivity, whereas to shielding of the magnetic component of the fields should be applied materials about high magnetic permeability. With increasing the electromagnetic field frequency decreases the significance of permeability in the shielding effects, and increases the impact of electrical permeability. At the high frequencies magnetic properties of material have a secondary importance; it is exhibited a conductivity of the material. At the high fields intensities and for medium frequencies should be applied laminated screens made of materials about decreasing permeability and increasing conductivity in direction of interior of the screen.

According to theoretical and practical knowledge, it is stated that the most difficult problem is to shield the magnetic and electromagnetic fields about low frequency, because in this case are necessary materials about high magnetic permeability, low remanence, coercive force and low magnetostriction. The large thickness of the screen is also required. For shielding of the electro-magnetic fields about an average frequency are necessary the ferromagnetic materials about high conductivity. For high frequencies and the electric fields it is sufficient that the material on the screen was an electrical conductor [2,4].

On the basis of research carried out and the literature knowledge, there was assumed, that materials fulfilling the requirements in the shielding area depending on the frequency of field, should be characterized by advantageous soft magnetic properties and a good electrical conductivity. Because of that multilayer systems about nano- and micrometric thickness of the layers should more effectively shield the electromagnetic field [1-8].

Fabrication of such screens is also difficult. These materials or, more precisely, such material systems are fabricated during many processes: PVD, CVD techniques and electrochemical methods.

3. Research methodology and results

For vacuum sublimation the samples of polypropylene foil on both sides sublimated aluminum with 50 mm x 50 mm and a thickness of 50 μm were used. On the foil metallic glass layer of Metglas type □ $Fe_{78}Si_9B_{13}$ (in the form of a ribbon having a thickness of 0.027 mm and a width of 4 mm) was applied.

Before the sublimation process of metallic glass, the polypropylene foil samples with acetone were degreased. The sublimation process in a vacuum sublimation equipment was carried out. Then the metallic glass ribbon of Metglas type in the evaporator made of tungsten was placed. The samples in the laboratory vacuum sublimation equipment were placed, in such way the metallic glass can deposit on the surface of the samples.

In the vacuum sublimation equipment was the vacuum about 0.0002 Tr. The tungsten evaporator was heated to the 1200-1300°C. At the time of 60 s there was an intense evaporation of the metallic glass. The current of evaporation was approximately 25 A.

The investigation of thickness of the applied metallic glass layer on the scanning electron microscope SUPRA 25 by ZEISS company was carried out. The magnification range was 3480 x □ 100 000 x and the acceleration voltage 25 kV.

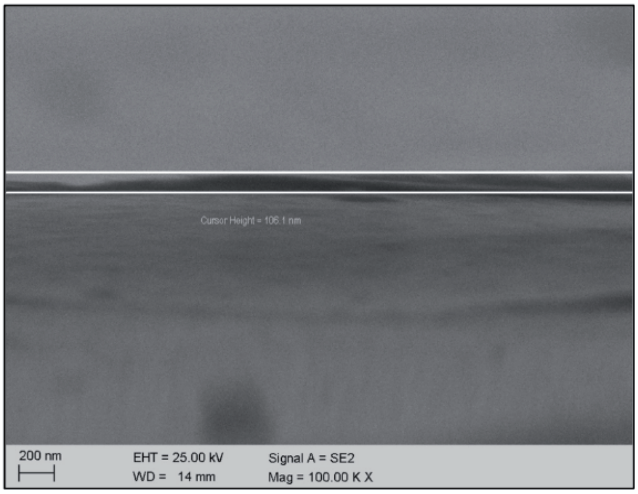

Fig. 1. The cross section of the surface of polypropylene foil with deposited aluminum and metallic glass (Metglas) layer, 100 000 x

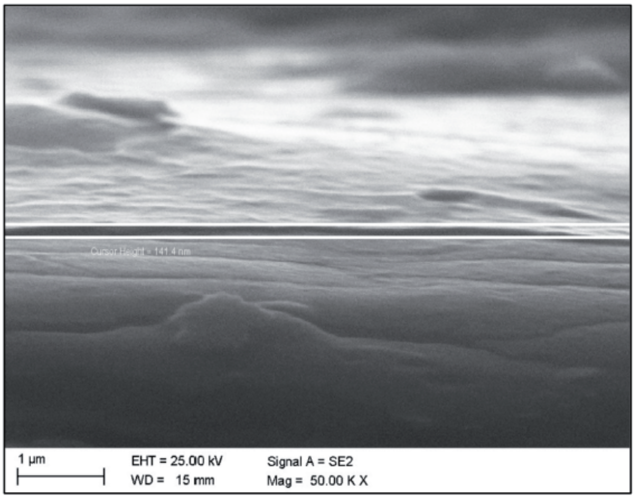

Fig. 2. The edge of polypropylene foil with deposited aluminum and Metglas layer, 50 000 x

On the basis of research the difference in thickness of Metglas layer was observed. This difference is due to the non-uniform vacuum sublimation of the samples in the laboratory vacuum sublimation equipment. The thickness of sublimated metallic glass layer of Metglas type was in the range from 106.1 nm (Fig. 1) to 141.4 nm (Fig. 2). The figures show the homogeneous structure of sublimated aluminum layer and smooth surface of Metglas with slight uplifts of metallic glass on the aluminum surface.

As a result of the microanalysis of aluminum area, iron which is from the scattered X-ray at Metglas layer was identified (Fig. 3).

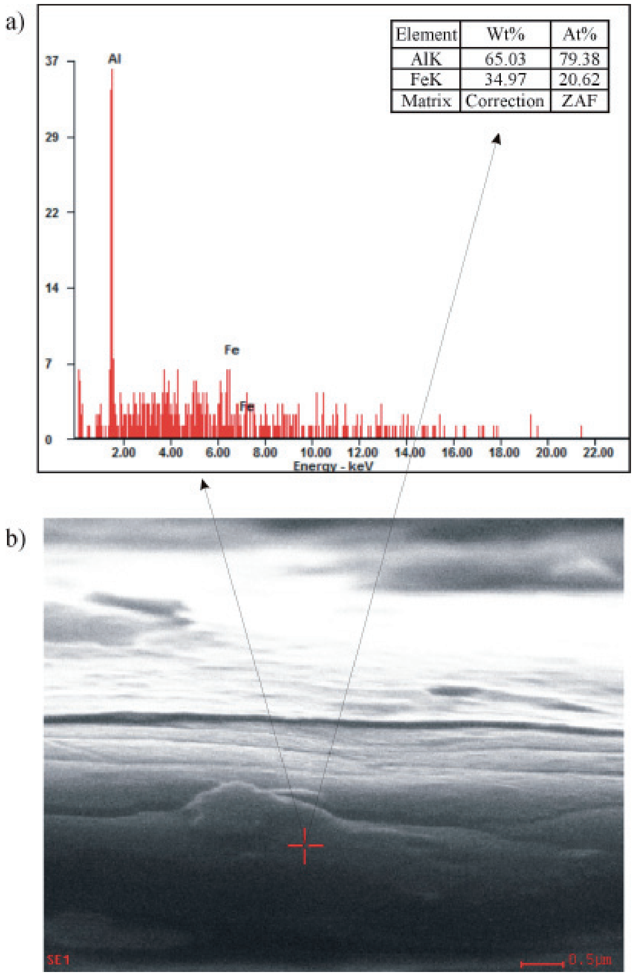

Fig. 3. Result of chemical analysis of polypropylene foil with deposited aluminum and metallic glass - Metglas layer a) microanalysis of aluminum area, b) microstructure of polypropylene foil with deposited aluminum and Metglas layer

4. Occupational risk assessment at the vacuum sublimation position

According to the occupational risk assessment methodology based on PN-N-18002 standard threats occurring at the vacuum sublimation position and possible effects of threats were identified [9-11]. In order to determination of the occupational risk acceptability frequency of effects and probability of event causing threat were determined (Table 1).

In Table 2 the card of the occupational risk estimation after preventive means for the risk reduction usage was presented. It was made by three-stage scale method [9].

5. Conclusions

The phenomenon of electromagnetic radiation is connected with emission and transfer of energy for a distance in a form of: light, electromagnetic waves or heat particles. The electromagnetic radiation source can be different systems (equipments) which are daily use in our life or in industries.

The electromagnetic radiation can be reduced by introducing denotation and areas signs where a strong electromagnetic field is recognized. The second way which can minimize the effect of radiation is shielded rooms with devices, and shielding of the people who work at this places.

The article raises a problem of electromagnetic fields shielding. The screening methods and materials used for this purpose are presented. The one of the methods of shielding materials fabrication was discussed □ vacuum sublimation.

The paper presents the results of microscopic observation of fabricated material system: aluminum-polypropylene-aluminum-Metglas ($Fe_{78}Si_{13}B_9$) for electromagnetic fields shielding. The results of the analysis unequivocally reject the vacuum sublimation method using a laboratory vacuum sublimation equipment. Metglas layer deposited on the surface of aluminum-polypropylene-aluminum is non-uniform with visible uplift of Metglas layer, resulting in a significant way for the shielding effectiveness of this material.

At the vacuum sublimation position the occupational risk assessment was also carried out. The threats occurring there were identified, the risk level was estimated, and possible protective actions were also suggested.

Table 1.
Card of the occupational risk estimation

Threats	Threat source	Effect	Frequency of effects	Probability	Risk estimation	Preventive means
Chemical individuals	solvents, glues	poisonings, allergic effects, diseases of upper respiration paths	high	low-probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Observe the procedures handling dangerous substances; ensure the effective ventilation of position
Inadequate lighting at the position	lack or bad light sources	eyesight damage	medium	probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Use of the light sources about light frequency compatible with the standards
Electric shock	damage of conductor insulation, contact with metal casings, which are under voltage	death	high	low-probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Use of differential current switch and technical condition control
Object's stroke	worked objects, hand tools, assembled or disassembled constructions	break limbs, concussion, injuries, palm injuries	medium	probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Use of protective gloves, use of the efficient hand tools
Noise	machinery and devices	deseases of audition organ	medium	probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Use only technically efficient machinery, use of the ear protectors
Fire, explosion	usage of fire near inflammable materials, electrical system out of order	skin burn, death	high	low-probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Observe the fire safety requirements, systematic control of a wiring system efficiency

Threats	Threat source	Effect	Frequency of effects	Probability	Risk estimation	Preventive means
Ionizing radiation	apparatus	malignant tumour, death	high	low-probably	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Keep large distance, use of the lead shields
Electromagnetic radiation	induction furnace, welding machine, energy systems, transformers	immune and nervous system disturbances, headache, tiredness	medium	probably	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Use of the shielding clothing, shielding conduits, thin shielding grids
Forced body position	long term works connected with hand and mechanical treatment	bone and articular degeneration	low	high-probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Adapt the position to ergonomic requirements, keep break works, changes in doing actions
Fall at the same level	uneven and slippery areas at the position	break limbs, concussion, dislocation and internal injuries	medium	probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Use of the protective and anti slip shoes, eliminate oil and water stains
Excessive physical effort	lifting of heavy objects	rupture, bone and articular defect, heart failure	high	low-probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Use of an auxiliary equipment, preventive medical examination carry out, observe of the individual transport principles
Harmful gases	ineffective or lack of ventilation	sultriness, headache, diseases of respiration paths	high	low-probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary	Use of the respiratory means protection, ensure the effective ventilation of position

Table 2.
Card of the risk estimation after use of preventive means

Threat	Frequency of effects	Probability	Risk estimation
Chemical individuals	medium	low-probable	**Low** – assurance, that occupational risk will remain at the same level is necessary
Inadequate lighting at the position	low	low-probable	**Low** – assurance, that occupational risk will remain at the same level is necessary
Electric shock	medium	low-probable	**Low** – assurance, that occupational risk will remain at the same level is necessary
Object's stroke	medium	low-probable	**Low** – assurance, that occupational risk will remain at the same level is necessary
Noise	medium	low-probable	**Low** – assurance, that occupational risk will remain at the same level is necessary
Fire, explosion	high	low-probable	**Low** – assurance, that occupational risk will remain at the same level is necessary
Ionizing radiation	medium	low-probable	**Low** – assurance, that occupational risk will remain at the same level is necessary
Electromagnetic radiation	low	low-probable	**Low** – assurance, that occupational risk will remain at the same level is necessary
Forced body position	low	probable	**Low** – assurance, that occupational risk will remain at the same level is necessary
Fall at the same level	medium	low-probable	**Low** – assurance, that occupational risk will remain at the same level is necessary
Excessive physical effort	high	low-probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary
Harmful gases	high	low-probable	**Medium** – acceptable, but planning and realization of actions directed on its decrease are necessary

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