Production Technology and Shielding Properties of the Needle-Punched Non-Vowen Fabrics with Carbon Additives

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***Abstract*—The goal of this work was to develop needle-punched non-vowen fabrics with radio protective properties. The article describes the investigation of the effect of carbon additives on the shielding properties of the needle-punched non-vowen fabrics for creation of materials to protect human organisms from electromagnetic radiation. The samples were prepared using polyester, polypropylene, wool and cellulose-hydrate filaments. The needle-punched non-vowen fabric was made with the textile apparatus AIN-1800 M. The transmission and reflection coefficients of the experimental samples were studied in the range of 0.3…17 GHz using scalar network analyzer. The electromagnetic radiation transmission coefficient provided by the samples varies in the range of 6.0÷12.6 dB and the reflection characteristics vary in the range of –2÷–29 dB.**

Keywords—*electromagnetic radiation; materials; needle-punched non-vowen fabrics; carbon additives; transmission and reflection characteristics*

I. INTRODUCTION

Brisk advancement and implementation of new information technologies and tools of information transmission and processing (desktop computers, laptops, tablet PCs, communicator, etc.) led to the development of new type of environment — the electromagnetic smog which consists of electromagnetic radiation in the wide range of frequencies, mostly microwaves and radiowaves. Due to that we have a need of new types of electromagnetic radiation absorbers.

The materials on the basis of vowen or non-vowen textile to ensure shielding properties in a wide range of frequencies are promiseful if they are characterized by a high level of protection from the effects of external electromagnetic fields, biological compatibility with biological objects [1–3].

Today there is a strong demand for the materials that can be used to make protective shields from the electromagnetic radiation produced by various electronic devices. The most actual problem is to produce flexible, air-penetrable and cheap materials to ensure a sufficient degree of suppression of electromagnetic radiation in the wide range of frequencies [4, 5].

The article depicts the research of the outcomes of carbon additives and their percentage on the shielding properties of the non-vowen textiles for development of materials to protect of human creatures from electromagnetic radiation. The samples were prepared using natural, synthetic and artificial fibers and filaments.

II. EXPERIMENT

A. Material Preparation

As fibers and filaments we used polyester with linear mass density 0.33 tex and 0.44 tex, polypropylene with linear mass density 0.33 tex, and wool with linear mass density 76 tex.

As carbon additives we used carbon cellulose-hydrate filaments UVG-22-C made by Svetlogorsk Khimvolokno Co. The carbon cellulose-hydrate filaments were 65 mm long, with diameter of the fiber of 7–10 μm, with linear electrical resistance less than 20 Ohm·cm and electrical resistance about 0.024 Ohm·cm (Table 1).

TABLE I. CELLULOSE-HYDRATE FILAMENTS CHARACTERISTICS

Nominal linear density, ktex		7; 10
Deviation of actual linear density from nominal, ktex		± 2
Specific linear electrical resistance, Ohm·cm		< 20
Specific volume electrical resistance, Ohm·cm		0.024±0.004
Carbon content, %		98
Tensile strength, MPa		450[a]
Breaking load, N	tow 7 ktex	100
	tow 10 ktex	150
Actual humidity, %		1.0
Ash content, %		1.0
Filaments per tow		100 000 – 150 000
Fiber diameter, μm		7 – 10
Linear density of elementary fiber, tex		0.08 – 0.09

[a] For one fiber

Fig. 1. The overall appearance of the cellulose-hydrate filaments UVG-22-C

The needle-punched non-vowen fabric was made with the textile apparatus AIN-1800 M which consisted of carding machine, cross lapping machine and needle-punched machine. Some samples of the needle-punched non-vowen fabrics were produced with weight of fabrics from 160 g/m^2 to 250 g/m^2, with width of fabrics from 40 cm to 150 cm, and with thickness from 4.7 mm to 6 mm. The number of strokes was from 450 to 600. The frequency of the needle breakage was from 70 to 120 per 1 cm^2 surface area and the needle punch depth was from 4 to 7 mm.

B. Measurement Techniques and Tools

The effectiveness of the electromagnetic radiation shielding by the non-vowen fabric was measured by the ratio of the electric field strength at the point of space in the absence of this material to the electric field strength at the same point in the presence of the material and was characterized by the transmission and reflection coefficients.

To study the shielding characteristics, we used a scalar network analyzer SNA 0.01–18 to measure transmission and reflection coefficients. The analyzer works on the principle of separate isolation and direct detection of the levels of the incident and reflected waves. The measurements were done with averaging the result three times and included three stages.

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At the first stage, a calibration was carried out, during which the optimum power level was established for the operation of the detector detectors. In this modification of the meter, the calibration was performed automatically.

The second stage consisted in measuring the transmission coefficients according to the scheme shown in Fig. 1. In this case, the sweep generator of the network analyzer forms signals in the certain frequency range and sends them through the A/R unit to the transmitting antenna. The signal processing unit registers the electromagnetic radiation that passed through the experimental sample.

The third stage consisted in measuring the reflection coefficients. In this case, a short-circuit was installed at the output, the sweep generator of the meter formed a signal in a given frequency band and fed it to the transmitting antenna through the A/R unit. The processing unit for measuring signals recorded the electromagnetic radiation reflected from the sample under study. The relative error in the measurements was ± 1%.

Measurements of the power levels of the electromagnetic radiation passed through the sample were carried out with the help of an installation, the circuit of which is shown in Fig. 2.

The measurements were carried out in two stages. At the first stage, calibration was performed, during which the power levels of the electromagnetic radiation generator were determined in the frequency range 0.7…17 GHz, corresponding to the electromagnetic radiation power levels at the receiving antenna of 1 mW, 2 mW, 3 mW, 4 mW and 5 mW. In this case, the sample was not installed between the transmitting and receiving antennas. In order to increase the accuracy of further measurements, calibration at each frequency was performed tenfold.

At the second stage, the sample was placed between the antennas, and at each frequency, electromagnetic radiation with power levels of 1 mW, 2 mW, 3 mW, 4 mW and 5 mW was alternately generated using a generator on the transmitting antenna, and the readings of the PM 0.01-39.5. The relative error in the measurements was ±5%.

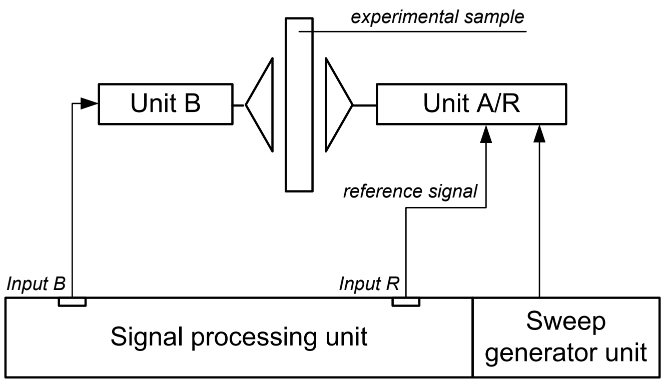

Fig. 2. Block schematic diagram of the SNA 0,01-18

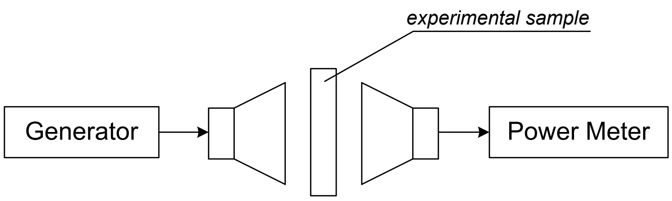

Fig. 3. Block schematic diagram of the electromagnetic power measurement

III. RESULTS AND DISCUSSION

The electromagnetic radiation transmission and reflection coefficients of the samples were measured using scalar network analyzer in the range of 0.7...17 GHz.

The transmission and reflection characteristics of the non-vowen fabrics with carbon additives in the range 0.7–3 GHz are shown in Fig. 4 and 5 respectively. The transmission and reflection characteristics of the non-vowen fabrics with carbon additives in the range 3–17 GHz are shown in Fig. 6 and 7 respectively.

The electromagnetic radiation transmission S_{12} provided by the samples of needle-punched non-vowen fabrics is in the range of 6.0÷12.6 dB and the reflection characteristics S_{11} vary in the range of –2÷–29 dB depending on the percentage of components.

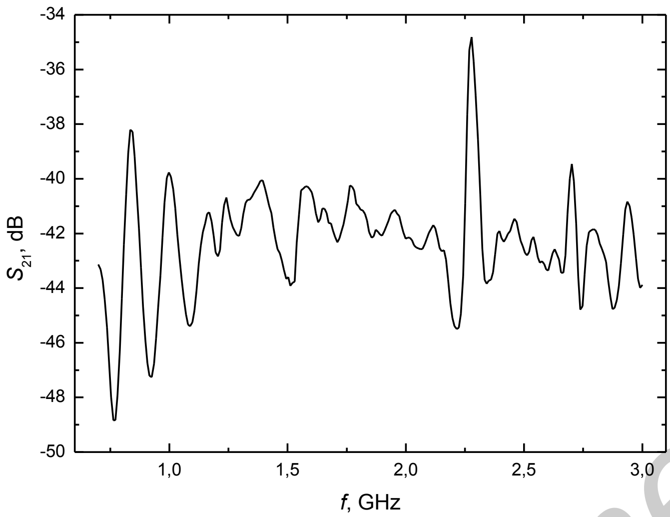

Fig. 4. The transmission properties of the non-vowen fabrics with carbon additives in the range 0.7–3 GHz

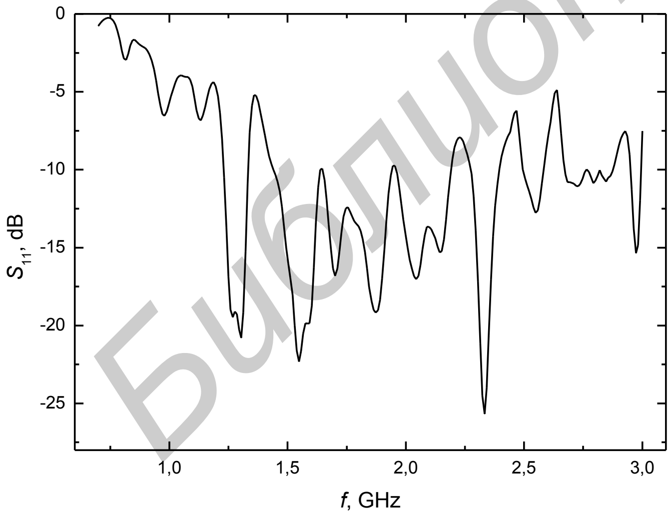

Fig. 5. The reflective properties of the non-vowen fabrics with carbon additives in the range 0.7–3 GHz

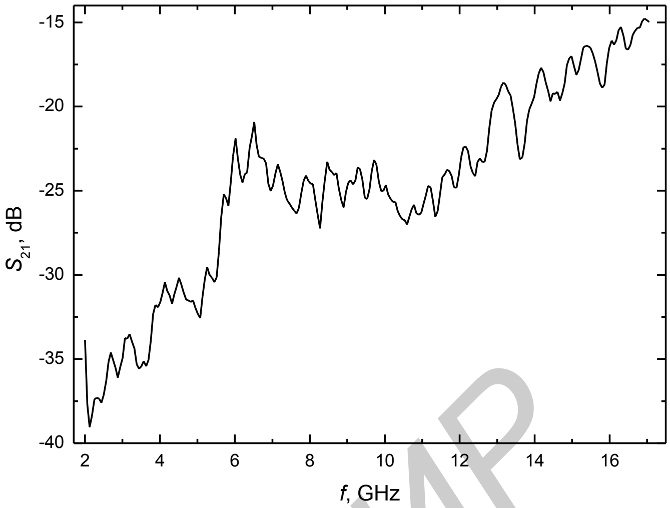

Fig. 6. The transmission properties of the non-vowen fabrics with carbon additives in the range 3–17 GHz

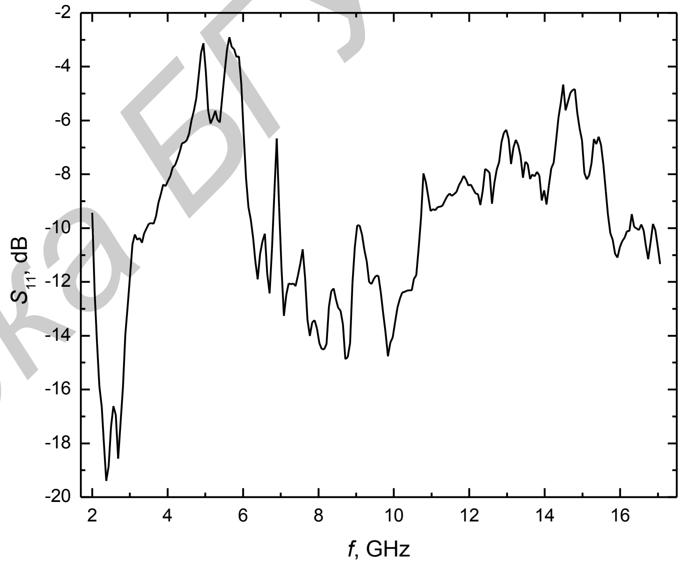

Fig. 7. The reflective properties of the non-vowen fabrics with carbon additives in the range 3–17 GHz

IV. CONCLUSIONS

Studies have shown that the development of the flexible electromagnetic shields and absorbers of electromagnetic radiation based on the non-vowen fabrics with carbon additives is perspective and their efficiency in the microwave range of microwave frequencies from 0.7 up to 17 GHz.

The main advantages of non-vowen fabrics with carbon additives are as follows: high values of the transmission and reflection coefficients, its lightweight and possibility to add it as a protective layer for the protective enclosures and clothing.

Fig. 8. The overall appearance of the needle-punched non-vowen fabrics with carbon additives (thin black lines represents carbon fibers)

It can be used to create a light, strong, durable and attractive decorative shielding materials, as well as radar absorbing materials with masking capabilities in microwave range.

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