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The Effects of Perlite Concentration and Coating Thickness of the Polyester Nonwoven Structures on Thermal and Acoustic Insulation and Also Electromagnetic Radiation Properties

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In this study, the improvement of the thermal and acoustic insulation and also electromagnetic radiation properties of polyester (PET) nonwoven fabric (NWF) with 180 g/m^2 weight was investigated. For this purpose, PET NWF was coated with perlite stone powder having 210 – 590 µm particle size using polyurethane (PU) based coating. Five different concentrations from 1 to 5 % of perlite stone powder were applied to the surface of PET NWF having five different thicknesses. And then the effect of perlite concentration and its thickness to thermal, acoustic and electromagnetic radiation properties were studied. It was found that the addition of perlite stone powder increased the thermal and acoustic insulation properties of PET NWF. Furthermore, the addition of perlite stone powder does not affect the electromagnetic radiation properties of samples.

Keywords: polyester nonwoven, thermal insulation, acoustic insulation, electromagnetic radiation.

1. INTRODUCTION

The technical textile term was first time used at around 1980 and it primarily means functional textiles rather than aesthetic and decorative textiles. Nowadays, the nonwovens have the major widespread application among the other types of technical textiles. The nonwovens can be described as the combination of not the yarns but the fibers attached together by mechanical, chemical, thermal and solvent application resulted as a surface area [1]. NWFs have various functional properties, such as, extension, bending rigidity, air permeability, absorbency, abrasion resistance, liquid repellency, filtration, porosity, light and compression properties etc., according to their application areas [2].

The cost of the heating and cooling depending on seasons increases. It became major important to use thermal insulation material in order to reduce the energy consumption on habitants [3]. A variety of the thermal insulation material was undertaken; namely waste wool [4], recycled polyester fibers [5], natural fibers [6], cotton, kenaf and bagasse nonwoven [7], composites consists of kenaf, jute, flax, waste cotton, polyester and substandard polypropylene [8] was tremendously increased on use of this area.

The modern life brings together with another problem such as the sound pollution. As the technology develops, in the habitants and the equipment on the working offices causes sound pollution. The sound pollution causes on human the annoyance, sleep disturbance, heart attacks, learning disabilities and tinnitus. There are tremendous studies in order to prevent the sound pollution on the habitants, cars, factories, hospitals, schools and other areas by use of sound absorbing materials [9]. For sound control application porous materials, polyurethane foams, mineral fibers and composites fortified with different fibers are widely used [10].

Developing technology increased welfare and terms of modern life caused increasing the electrical and electronic equipment. Electronic device, electrical kitchen tools, office equipment and communication tools used at habitats radiate electromagnetic energy within different frequency ranges. The radiation with different frequency ranges creates immortal effects on where the electronic equipment used, as well as causes negative effect on plants, animals and human.

The aim of this study is to produce materials having thermal and sound insulation, as well as electromagnetic shield properties. In order to improve the thermal and sound insulation and also electromagnetic shield properties, PET NWF was coated with porous perlite stone powder with different concentration and thickness. Finally, the sound absorption and thermal transmission coefficient and also electromagnetic shield properties was analyzed.

2. EXPERIMENTAL DETAILS

2.1. Fabric

In this study, 100 % PET NWF (produced by needle punch technique with FEILONG FL-ZM-200 nonwoven machine by using 200 µm fiber) with 180 g/m^2 was used.

2.2. Perlite stone

The expanded perlite stone used on this study, was first grinded by using ball mill and then by using a sieve, particle size between 210 – 590 µm was taken.

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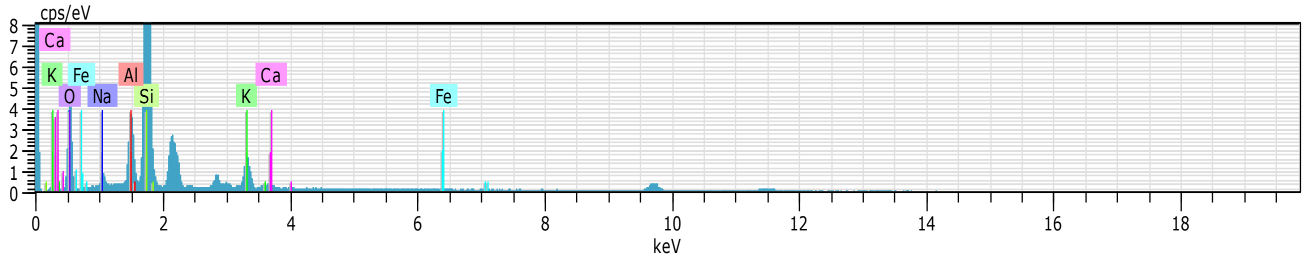

Fig. 1. Element composition of perlite stone

El	AN	Series	unn., wt.%	C norm., wt.%	C Atom., at.%	C Error, %
O	8	K-series	86.85	86.85	92.17	2.1
Si	14		9.15	9.15	5.53	0.4
Al	13		2.12	2.12	1.34	0.1
K	19		1.03	1.03	0.45	0.1
Na	11		0.60	0.60	0.44	0.1
Fe	26		0.23	0.23	0.07	0.0
Ca	20		0.01	0.01	0.00	0.0
		Total:	100.00	100.00	100.00	

The composition of the perlite was analyzed by using ZEISS/EVO 40 scanning electron microscope and Energy Disperse X-Ray Spectroscopy (EDX). The chemical composition is shown in Fig. 1.

2.3. Coated paste

In order to apply the perlite stone powder onto the NWF, PU based coating paste was used. Coating paste was prepared by using RUCO-COAT PU 1110 (Rudolf Duraner), RUCO-COAT FX 8011 (Rudolf Duraner) and RUCO-COAT TH821 (Rudolf Duraner).

Perlite stone was grinded by using a bead mill and then sieved to get a pore size between 210 – 590 µm. After this procedure, the perlite stone powder was blended with the polyurethane coating material by mechanic propeller mixer for 1 hour at 60 rpm. The perlite stone powder was added to the coating paste with 1, 2, 3, 4 and 5 % concentration of coating paste, respectively.

2.4. Sample preparation

In this study, NWF was coated with coating paste together with perlite stone powder having 210 – 590 µm particle size to improve the insulation and electromagnetic shield properties of PET NWF. The concentration of perlite was taken 1, 2, 3, 4, 5 % respectively, based on PU weight, for 1.25 mm PU coating thickness. And by using 1% perlite concentration, the PU coating thickness was taken 1.25, 1.40, 1.55, 1.70 and 1.85 mm respectively. The properties of samples are given in Table 1.

2.5. Water repellency procedure

Before coating paste applied to the samples, water repellency treatment was undertaken in order to improve the efficiency of coating. The water repellency treatment was carried out by using RUCO-DRY DFY fluorocarbon based auxiliaries by exhaust method and then the treated samples were dried at 100 °C for 10 min.

2.6. Coating procedure

The paste consisting perlite stone powder and polyurethane based coating material was applied to the PET NWF samples by using absorbing type coating apparatus (ATAC Lab. Machines RK 40). The coated thickness was 1.25 mm, 1.40 mm, 1.55 mm, 1.70 mm and 1.85 mm respectively. After coating procedure, the samples were dried at 100 °C for 10 min by using laboratory type drying instrument (ATAC Lab. Machines GK 40).

Table 1. The properties of samples

Sample Code	Properties
PET + PU	PET NWF+ PU
PET + PU + 1 % Perlite	PET NWF+1% perlite in PU
PET + PU + 2 % Perlite	PET NWF+2% perlite in PU
PET + PU + 3 % Perlite	PET NWF+3% perlite in PU
PET + PU + 4 % Perlite	PET NWF+4% perlite in PU
PET + PU + 5 % Perlite	PET NWF+5% perlite in PU
PET + 1.25	PET NWF+1% perlite in PU with the thickness of coating is 1.25 mm
PET + 1.40	PET NWF+1% perlite in PU with the thickness of coating is 1.40 mm
PET + 1.55	PET NWF+1% perlite in PU with the thickness of coating is 1.55 mm.
PET + 1.70	PET NWF + 1 % perlite in PU with the thickness of coating is 1.70 mm
PET + 1.85	PET NWF + 1 % perlite in PU with the thickness of coating is 1.85 mm

2.7. Measurements of thermal conductivity coefficient

The measurements of the thermal conductivity coefficient of the samples were carried out by using P.A.HİLTON LTD. H940 heat transfer measuring device. The samples having Δx thickness and 25 mm diameter was placed between two brass panel with different temperature. As a result, the temperature of the two faces of the samples will be different. There will be heat transfer between two faces from hot face to cold face according to Fourier heat transfer law. The sample between two mediums will have heat transfer coefficient according to the law. The thermal conductivity coefficient can be calculated by using Fourier Law as giving below [11].

$$Q = -k.A.\frac{dT}{dx}, \quad (1)$$

where Q is the heat flow (Watt), A is the surface field (m^2), ΔT is the temperature difference, x is the thickness of sample, k is the thermal conductivity coefficient (W/m.K). The measurements of thermal conductivity coefficient were iterated three times.

2.8. Measurements of sound absorption coefficient

The sound absorption coefficient of samples was measured by two functional transfer microphone method of impedance tube according to TS EN ISO 10534-2 [12] standard.

2.9. Measurements of electromagnetic shield properties

The electromagnetic shield effect of the fabric was measured by using Network Analyzer (ROHDE@SCHWARZ) instrument. The efficiency of electromagnetic shield was measured in accordance with ASTM D 4935-10 standard between 15 – 3.000 MHz frequency.

3. DISCUSSION

3.1. Results of thermal conductivity coefficient

In this study, thermal conductivity coefficient of samples was measured by using P.A.HILTON LTD.H940 instrument and the thermal conductivity coefficient of samples was calculated using Fourier Equation. The heat flow (Q) was taken 10 W, the surface field 4.91 x 10^{-4} m^2. The coated samples thicknesses were measured with James Heal Thickness Gauge. The thickness of samples is taken 0.140 ± 0.005 mm for PET + PU, PET + PU + 1 % Perlite, PET + PU + 2 % Perlite, PET + PU + 3 % Perlite, PET + PU + 4 % Perlite, PET + PU + 5 % Perlite, PET + 1.25; 0.155 ± 0.005 mm for PET + 1.40; 0.170 ± 0.005 mm for PET + 1.55; 0.195 ± 0.005 mm for PET + 1.70 and for 0.210 ± 0.005 mm respectively. Thermal conductivity coefficient of samples is given in Fig. 2 and Fig. 3.

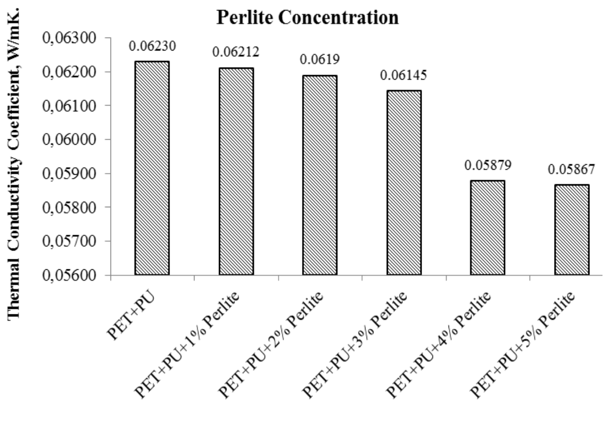

Fig. 2. Thermal conductivity coefficient of samples coated with perlite stone powder at different concentration

It is seen from the results that, the thermal conductivity coefficient of PET NWFs decreased by the addition of perlite stone powder. It is attributed, the silicon dioxide within the perlite caused reduction on thermal conductivity coefficient.

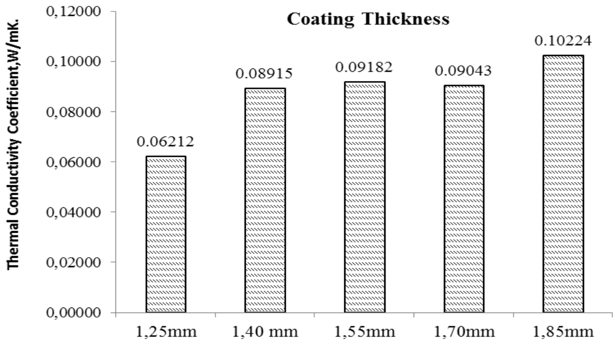

Fig. 3. Thermal conductivity coefficient (W/m.K) of samples coated with perlite stone powder at 1 % concentration

Increased perlite stone powder concentration decreased the thermal conductivity coefficient of the samples. Naturally, the increased perlite concentration causes increasing the amounts of aluminum oxide (alumina), calcium oxide, and iron oxide. It is concluded that, the increased amounts of such oxides leads to increase the thermal conductivity coefficient. Besides, the micro porous structure of perlite stone powder also leads to increase the thermal conductivity coefficient.

Increased coated thickness increased the thermal conductivity coefficient. According to Fourier Law, the thermal insulation is inversely proportional with thickness, and increased sample thickness increased the thermal conductivity coefficient.

3.2. Results of electromagnetic shield

The electromagnetic shield effect of the samples was measured by using Network Analyzer (ROHDE@SCHWARZ) instrument. It was though, the perlite stone powder might have free metals resulting sufficient electrical conductivity and magnetic permeability. Therefore, the electromagnetic shield effect was measured. But there was no considerable shield effect. The reason of these results was deemed that the amount of metal in perlite stone powder do not qualify to provide electromagnetic shielding effect [13].

3.3. Measurements of sound absorption coefficients

The sound absorption coefficient of samples was analysed using impedance tube and the results were recorded as shown in Fig. 4 and Fig. 5.

According to results, the increased amount of perlite stone powder increased the sound absorption coefficient. This can be explained by the porous structure of perlite stone powder. As known, when the sound waves contact with a porous material, some of the sound energy converts to heat energy by the air present within the void, and by rubbing on the voids wall [14].

By the evaluation of the sound absorption confident based on the coating thickness, it is seen that the increased sample thickness increased the sound insulation coefficient. This can be explained as the increased sample thickness increases the distance for the sound waves to pass to the other side of the sample.

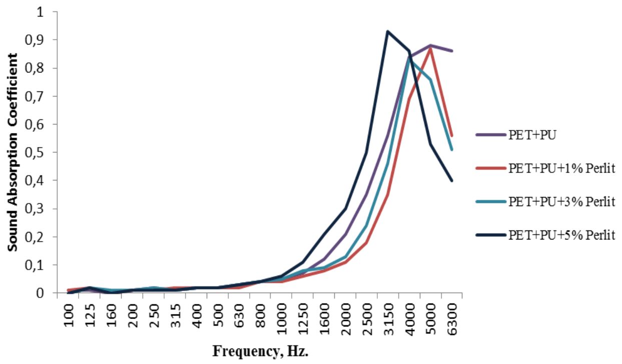

Fig. 4. Sound absorption coefficient of samples coated with perlite stone powder at different concentration

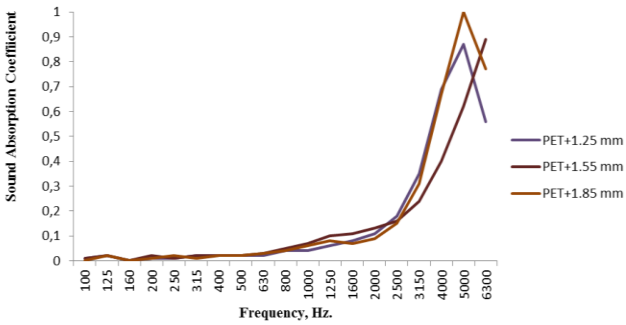

Fig. 5. Sound absorption coefficient of samples coated with perlite stone powder at different thickness

Thus, the increased distance between the sound waves and the sample causes more friction. In this way, the amount of sound energy converted into thermal energy increases due to the friction.

4. CONCLUSION

In this study, the thermal insulation behavior increased with increased perlite stone powder concentration Besides, the increased coating thickness also increased the thermal transmission coefficient of the samples. It is seen from the sound absorption coefficient results that, the increased perlite concentration and its thickness caused increase in sound absorption coefficient of the samples. The electromagnetic shield results showed that, there was no improved behavior on this aspect. As a result of this study, it is recommended to use the perlite stone powder coated PET nonwoven samples on thermal and sound insulation applications.

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