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Comparative Analyses of UV Radiation Transmission through Virtual and Real Woven Fabrics for Selected Weaves

Abstract
This article presents comparative research involving the assessment of the transmission of UV radiation through virtual and real woven fabrics. Woven fabrics of different geometrical structure were selected for both of the cases of assessment of UV radiation transmission through virtual and real fabric presented here. The tests of radiation transmission for virtual and real fabrics were performed using the method of askew radiation. The analysis confirmed the possibility of using the virtual method for determining the UV radiation barrier properties of woven fabrics.

Key words: *UV radiation, transmission, woven fabrics, virtual fabrics, real fabrics, askew radiation, luxography method.*

Introduction

This article is a continuation of an article published in Fibres and Textiles in Eastern Europe concerning UV radiation transmission through woven fabrics in dependence on its inter-thread channels [1]. The present article describes the comparative investigation of UV radiation transmission through virtual and real fabrics. The aim of this article was to compare the assessment of UV radiation through woven fabric by calculating the radiation transmission as well as measuring it using real fabrics. Furthermore, the research was aimed at confirming that the possibility of determining UV radiation barrier properties by the virtual method exists. Woven fabrics of different geometrical structure were selected for testing. Tests of radiation transmission for virtual as well as real fabrics were carried out using the askew transmission method. The radiation transmission was evaluated at different angles of irradiation. The designing of a virtual fabric composed of structural modules, as well as their composition, is described in [1], in which the method of UV transmission assessment is discussed in detail. A brief presentation of the methods is described below.

Materials and methods

Materials

Three types of weaves, twill, rep and panama, were selected for the analysis. The real woven fabrics used for the test were manufactured from cotton yarns without sizing, being of an equal linear density of 2 × 25 tex for both systems: the warp and weft. The warp and weft densities were accepted as equal to the thread diameter. The virtual fabrics were design based on real ones by using appropriate structure modules.

Virtual method

This method takes into account the geometrical shape of inter-thread channels.

The light source and recording camera were in an unmovable position while the fabric rotated. Recording of the woven fabric image was performed in seventeen angle steps, each of 12°, beginning from 0° to 180°, with an additional image for the angle of 90°. The particular angles were related to the askew of the fabric in relation to the light source and recording camera. The results obtained presented the light transmission, which means that the values calculated were proportional to the transmission. An assumption was made that in these conditions light propagates from the channel walls without diffractionand with no absorption of the fabric by the material of the fibres. Details of this method are given in [1].

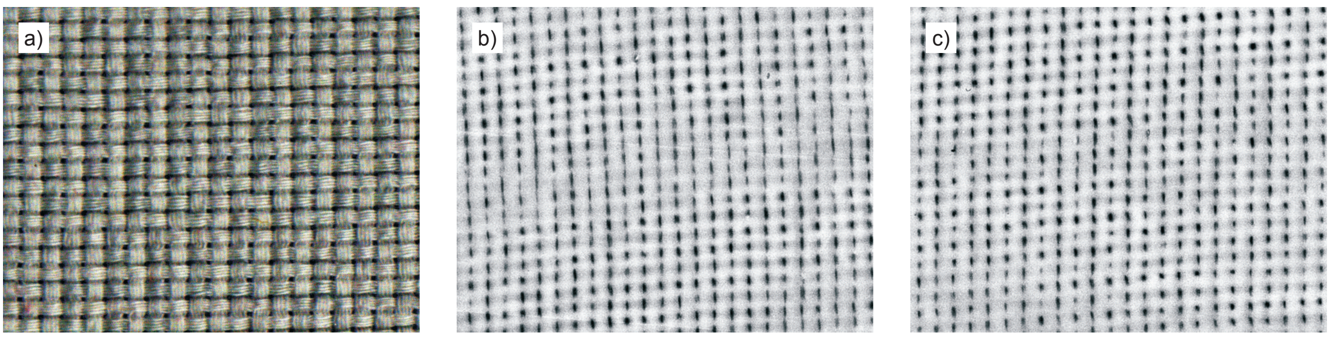

Figure 1. *Fabric selected for the comparative test; a - view of the fabric in reflected light, b - photogram of paper irradiated by visual radiation, c - photogram of paper irradiated by UV radiation.*

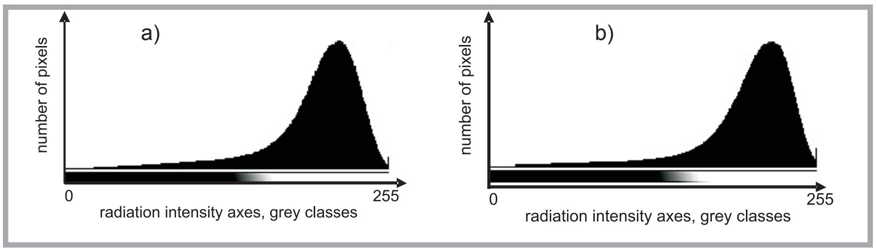

***Figure 2.** Histograms of radiation transmission for a - visual radiation, and b - UV radiation. The following average values and standard deviation were obtained: a) an average value of 195.42 for grey classes, standard deviation – 43.34 b) an average value of 196.53 for grey classes, standard deviation - 44.90 [4, 7]*

Tests of radiation transmission through real woven fabrics

The luxography method was chosen for determination of the light transmission through the real fabrics. This method involves directly obtaining photograms on light sensitive paper without using any optical devices [2 - 4]. In order to simplify this method, we accepted the use of visible radiation. According to our considerations and the assumption that UV radiation in the range taken into account is not absorbed by the fabric material, the acceptation should be valid. However, a confirmation was carried out. Two tests were performed: one using the visual radiation characteristic for the full spectrum of white light, and the second using UV radiation of 320 - 400 nm wavelength. The light source used for visual radiation was a 20 W mat light bulb of 3000 K radiation temperature. The source of UV radiation used was a bulb made by PHILIPS. The distance between the radiation sources, samples and papers was the same. Appropriate photographic papers with a spectral sensitivity related to those of the light sources were applied. The papers irradiated, developed and fixed were characterised by grey levels proportional to the light transmission, which meant that we obtained results opposite to those of the virtual method. A single layer fabric of panama weave and basic configuration of warp and weft was used for this test. ***Figure 1*** presents a view of the selected fabric in reflected light, as well as photograms of papers irradiated by visual and UV radiation.

Comparative analysis was performed by analysing histograms of the grey levels of both irradiated papers. The results are presented in ***Figure 2***.

On the basis of these results, it is clearly visible that practically no differences exist between the transmission of visible light and UV radiation. As for manufacturing the fabric, a material was used which is not transparent for visible light, it is also evident that it is not transparent for UV radiation for the length applied. This also means that for the barrier properties of the fabric used, the inter-thread channels and, at the same time, the structure selected are responsible. All further investigations were carried out using visible radiation and the skew method, with irradiation of the samples by a parallel light beam at different angles. During the tests performed, the angles were changed every 12° and additionally at 90° and 180°.

Such tests were carried out for twill, panama and rep weaves. Examples of histograms from the test with a fabric of panama weave taken at different angles are presented in ***Figure 3***.

Table 1 (see page 54) presents the summarised results of the tests described above for all three weaves. The data presented is for 17 angles and grey level classes of 0, 50, 100 and 150. Based on these results, a bar diagram was constructed for panama weave, presented in ***Figure 4*** (see page 54).

In order to compare the results obtained by measuring radiation through real fabric, values from the first column for the given weaves (i.e. for the 0 grey level classes) were taken into account. The results presented show that fabrics with panama and rep weaves have better barrier properties against irradiation in comparison with fabric of twill weave.

Comparative analysis of radiation transmitted through woven fabrics measured by the virtual and real fabric method

The results determined by the measurements described in the preceding section were compared with results obtained by analysing radiation transmission through virtual fabric composed of appropriate structural elements. Average values

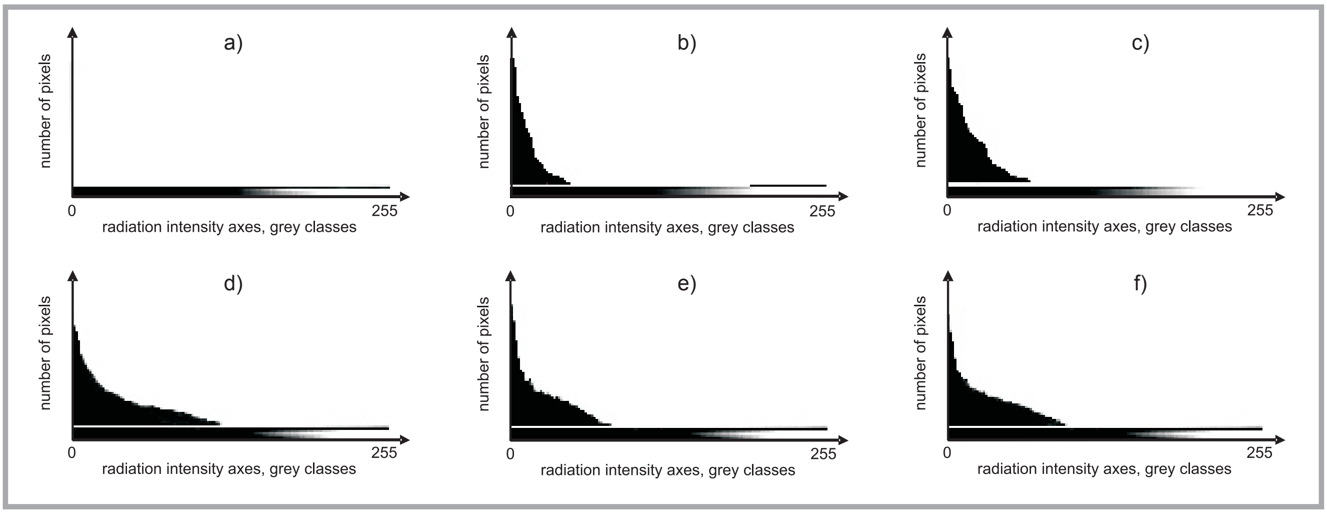

***Figure 3.** Histograms of radiation transmission for a fabric of panama weave for the following angles: a) 0°, b) 12°, c) 24°, d) 72°, e) 84° and f) 90°., as an example.*

Table 1. *Summarised results of radiation transmitted by fabrics of twill, panama and rep weaves measured by the luxography method.*

Angle of irradiation, deg	Number of pixels at the following grey angle classis: 0, 50, 100, 150											
	panama				rep				twill			
	0	50	100	150	0	50	100	150	0	50	100	150
0	60279	0	0	0	60279	0	0	0	60025	0	0	0
12	35698	50	0	0	36958	97	0	0	10795	1978	519	9
24	29059	231	19	0	30057	298	15	0	3107	923	493	15
36	15824	395	28	0	16579	436	25	0	1012	743	254	42
48	6328	367	30	5	7896	536	34	0	747	678	382	36
60	18235	360	8	0	19846	586	26	0	917	846	567	21
72	6092	473	39	0	7934	697	24	0	875	776	457	20
84	11089	307	23	0	12789	699	21	0	987	982	475	45
90	20065	586	42	0	21567	726	43	0	2727	1723	635	67
96	15047	350	25	0	16349	689	23	0	865	824	545	34
108	5584	480	37	0	6941	615	28	0	776	937	499	17
120	19056	390	7	0	20438	526	13	0	658	774	337	20
132	5394	382	6	0	6891	548	17	0	827	686	463	23
144	12023	301	27	0	13861	468	38	0	768	623	586	21
156	27179	256	21	0	28604	268	15	0	2998	977	517	15
168	35159	57	0	0	36468	95	0	0	11497	1653	674	7
180	60279	0	0	0	60279	0	0	0	60025	0	0	0

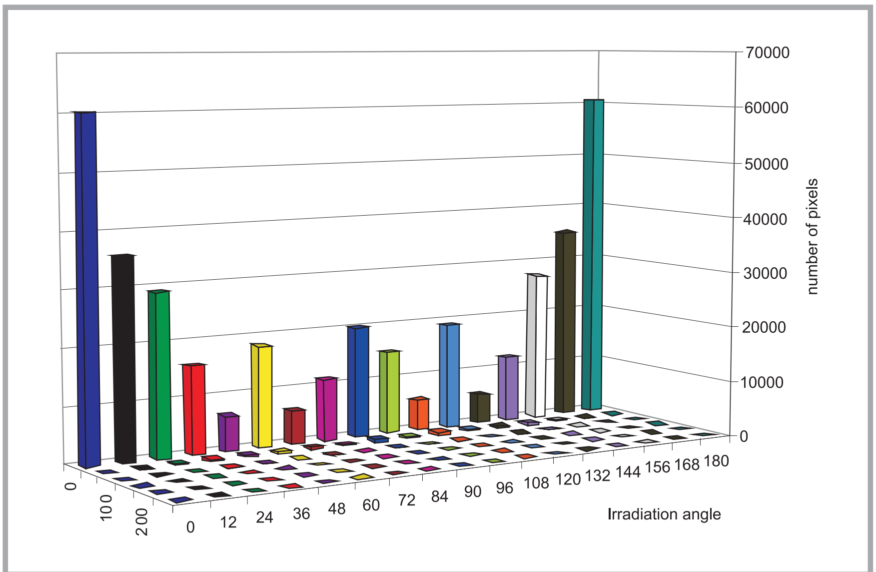

Figure 4. Bar diagram of the radiation intensity of fabric with a panama weave constructed on the basis of Table 1 [5].

of the percentage of light transmitted at different angles for panama, rep and twill weaves is presented in ***Table 2***. As was mentioned earlier, the angular light transmission dependence of virtual fabric is a negative of the angular dependence for real fabrics, expressed in the number of pixels in the 0 grey level class. The percentage transmitted through virtual fabrics of panama, rep and twill weave at different angles is presented in ***Table 2***.

The results of both methods are compared using the diagrams presented in ***Figure 5***. From the analysis obtained by both methods, the importance of inter-thread channels for radiation transmission is evident. It is already known that air permeability also depends on the structure of the fabric, which means on the value and configuration of the inter-thread channels, which can be recognised as pores. But it should be emphasised that air permeability is connected to the fabric's modular structure other relations than the transmission of radiation. An interesting experiment, consisting in measurement of the air permeability of all three fabrics tested, was additionally carried out. The test was conducted in accordance with Standard PN-EN ISO 9237-1998, the results of which are also included in Figure 5. In order to facilitate the comparison of the results, expressed in different units and ranges, they were recalculated into relative units. The data indicate that in order to achieve quick results, the possibility of using the virtual method for determining the barrier properties of woven fabrics against UV radiation exists and can be recommended. On the other hand, the measurements of air permeability showed that no direct relation exists between radiation transmission and air permeability. However, it is curious that fabrics with better barrier properties, namely panama and rep fabrics, are also characterised by greater air permeability. This means that the arrangement of inter-thread channels impacts UV radiation and air permeability in a different way, and that when designing a fabric correct interrelations should be considered.

Conclusions

The investigation carried out enabled the following statements to be made:

- The possibility of determining the barrier properties of woven fabrics against UV radiation by calculation of the radiation transmission through a virtual fabric exists and is recommended.
- The results obtained by measuring the light transmission through a real fabric, expressed in the number of pixels in a given class of grey scale and given angle of irradiation, are compatible with the results of the percentage of radiation transmission through a virtual fabric at the same angle of irradiation, but are mutually opposed.
- The configuration of the internal structure of woven fabrics has a great influence on radiation transmission and air permeability, but the impact of the structure is different.

Editorial note

The article includes essential fragments of the Ph.D. thesis 'Influence of the woven fabric structure on its UV transmission' by Małgorzata Dulęba-Majek under the promotership of Prof. Jerzy Słodowy Ph.D.,D.Sc.,Technical University of Łodz, 2005

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Table 2. Percentage of radiation transmitted through panama, rep and twill weaves at different angles.

Angle of irradiation, deg	Percentage of transmitted radiation for:		
	PANAMA	REP	TWILL
0	0.00	0.00	0.00
12	0.00	0.00	0.00
24	0.00	0.00	0.00
36	1.27	0.74	2.48
48	5.68	4.41	7.71
60	11.27	8.62	14.28
72	19.26	15.56	23.01
84	26.35	24.13	28.53
90	33.33	33.33	33.33
96	26.55	24.08	28.61
108	19.57	14.98	23.13
120	11.01	8.78	14.53
132	5.02	3.06	7.73
144	1.36	1.74	2.19
156	0.00	0.00	0.00
168	0.00	0.00	0.00
180	0.00	0.00	0.00

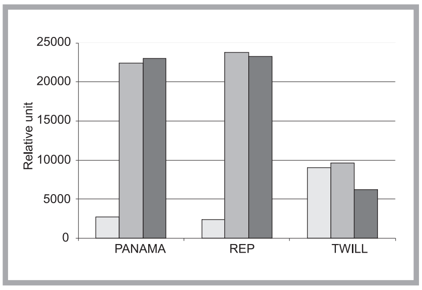

***Figure 5.** Comparison of average measurement results expressed in relative units of radiation transmission and air permeability through woven fabrics of panama, rep and twill weaves. □ - average value of the percentage of radiation transmitted through the virtual woven fabric (percent recalculated into the relative unit), ■ - average value of barrier properties of real woven fabric (number of pixels recalculated into the relative unit), ■ - air permeability of the woven fabrics (mm/s according to Standard PN-EN ISO 9237-1998 recalculated into relative units).*

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