Subjective Interpretation and Objective Evaluation of Blackout Fabric’s Barrier Properties

DOI: 10.5604/12303666.1215526

Abstract
This work presents an experimental approach and the results of preliminary measurements of the light barrier properties of shading fabrics (blackouts). Based on literature it can be stated that there is a lack of requirements for fabrics with barrier features against sunlight. Woven blackouts which obtain shading properties through their structure need the development of objective methods, measurement indicators, and assessment criteria. Research was conducted on six woven blackouts, commonly used in public buildings as curtains. According to the conventional method, the level of transmittance evaluated was confirmed. All samples feature very good protection against visual radiation (VIS). However the subjective interpretation contributed to the discovery of differences between the samples. The questions raised are as follows: What differences are acceptable? How to qualify blackout features properly? To demonstrate the ineffectiveness of the standard method, computer image analysis was used.

Key words: light barrier properties, visible radiation (VIS), shading fabrics, blackouts, public buildings, digital image analysis.

Thus far no one cared to check whether this methodology could be applied to blackout fabrics.

It can be stated, that research on the shading systems only focused on the heating load reduction of draperies [3, 4]. Another paper was related to the performance of shadings depending on their daylight characteristics [5 - 7]. None of the literature reviewed defined the acceptable level of light barrier properties nor the methods of qualifying the blackouts. There have been cases where the investor defined a satisfactory level of barrier properties (based on feelings when the fabric was put on window glazing). The process of identifying the optical barrier features of blackouts is a significant problem for manufacturers and users. The subject of the main special requirements for curtains like shading (above fire resistance) should be defined clearly and precisely.

It is worth emphasising that the fabrics presented in the article owe their barrier properties to the special construction. Regarding the assortment of curtains, the anti-sunlight protective properties result from a proper combination of the parameters of the material, weave, and weaving process, and not from the finishing treatment. The coated blackout fabrics used in buildings as curtains have been replaced by woven blackout fabrics. The mechanism of darkening by coated fabrics is not a combination of so many parameters as for woven blackouts. Therefore deviations are expected from the standards that have been defined so far by coated blackout fabrics. The woven blackout fabrics have not yet been analysed in terms of the impact of their structure on the level of barrier properties. The structural analysis proved that such materials are ostensibly homogeneous and require individual evaluation criteria.

This study presents a method for qualifying woven blackout fabrics to be used for barriers against visible light. The aim of the work was to identify experimentally blackout fabrics proposed as curtains, their structures, basic parameters and the level of barrier properties. First of all the methodology commonly used was applied. The results allowed to conclude that the testing conditions were insufficient for blackout type fabrics with a complex structure. Consequently the image analysis technique was proposed as a widely available tool. The method was useful as an objective way of evaluating the fabric appearance and features. Many interesting studies have been conducted recently to evaluate fabric geometry. This research was based on reports about the identification of channels in woven fabrics influencing barrier features [8, 9]. Wilbik-Hałgas, for example, examined the surface porosity and structural channels of knitted fabrics using computer image analysis. The effectiveness of darkening in the case of woven blackouts is associated with their...
geometry and structural parameters, which create a tendency to form clearances. Determining the size and amount of clearances on the fabric surface tested will be an introduction to guidelines for designing woven blackout fabrics. Based on the literature consideration of this problem, it seems that the digital image analysis technique has not been applied for estimation of the VIS-barrier properties of curtains. This work confirms that method presented can be useful and adequate for blackout fabrics.

## Experimental

### Materials

There are two techniques for obtaining blackout fabrics: laminating and weaving. Woven blackouts, also known as a blackout with black weft, are commonly used for curtains in the design of window spaces.

Six of the woven blackout fabrics often used as curtains in hotels were tested. Images of the samples are presented in Figure 1.

Fabrics of this type have a smooth, homogeneous structure without any pattern. As we can see in Figure 1, the blackout effects designed are accomplished by:
- printing (fabrics 1 and 5)
- monochromatic dyeing (fabrics 2, 3, 6)
- using decorative threads (fabric 4)

Due to the fundamental feature of blackout fabrics - darkening the spaces, developing an adequate fabric structure is mandatory. Comparing the appropriate parameters of yarns, weaves and the cover factor can lead to the obtaining of optical barrier properties [10, 11].

First structural parameters of the fabrics tested were described. Some of the basic ones are shown in Table 1.

Furthermore, constructional analysis of samples was conducted. It can be stated that blackout fabrics have complex structures with a build-up warp or weft yarns system (samples 1, 2, 3, 5, 6) as well as a multilayer design (sample 4). Constructions of woven blackouts are designed on the basis of sateen weaves in accordance with the criteria of structural correctness [10, 12]. Applying textured polyester threads of multifilament fibres and increased density of threads in the fabric structure intensifies the darkening effect (the parameters are presented in Table 1).

In addition, the mechanism of darkening is supported by the appearance of one internal arrangement of black coloured threads.

The sunlight-barrier properties of curtains arise from a proper combination of the parameters of the material, weave and weaving process. The structures of blackout fabrics presented vary from one another and they are only apparently homogeneous.

### Methods

#### Measurements of light barrier properties with the standard method

In the next stage of the research, the level of light barrier properties of the blackout fabrics was evaluated. Tests were carried out using a 550 Jasco UV/VIS spectrophotometer equipped with an integrating sphere in accordance with the test procedure (The Lodz Textile Research Institute’s own procedure no. PR/17/2007 Flat Textiles, Examination of the light transmission within the range of 400 nm to 700 nm) [13], based on PN-EN ISO 13758-1 [2]. In order to verify the level of optical barrier properties, the light transmittance was determined within the wavelength range of 400 - 700 nm. The results are presented in Figure 2.

Based on the experimental results, the transmittance level evaluated was 0 - 1%. The presence of a higher peak in sample no. 2 (above 2%) should be explained by the effect of absorption within the red band - the colour of sample no. 2. That observation could be neglected because it occurred almost outside the visible area analysed. In the UPF/SPF classification system, according to AS/NZS and BS EN standards [14, 15], a level of transmission less than 2.5% (UPF in
of light sources were tested that had to satisfy the requirements regarding surface homogeneity, stability in time and size of the lighting area. The illumination intensities were adjusted experimentally. Accordingly filters were used for intensity control. It is important to eliminate additional excitation manifested by the lighting of yarns. Figure 3 presents images of the samples.

Figure 2. Spectral transmittance $T$ of fabrics tested at wavelength $\lambda$.

It can be concluded that there is very good protection against visible light (VIS) by each sample, regardless of different constructions. Differences in transmitted light could be observed with the naked eye. However, another conclusion arises that the method is ineffective. Due to the complicated structure, the black-outs require special measuring conditions which should be developed exclusively for such fabrics.

A simple test stand was constructed for analyzing the mechanism of light passage through the fabric. The samples were put on an LED light source (panel) and images were recorded by an Optical Digital Microscope at 50$\times$ magnification (Delta Optical Smart, Poland). First many kinds of light sources were tested that had to satisfy the requirements regarding surface homogeneity, stability in time and size of the lighting area. The illumination intensities were adjusted experimentally. Accordingly filters were used for intensity control. It is important to eliminate additional excitation manifested by the lighting of yarns. Figure 3 presents images of the samples.

Figure 3. Images of blackout fabrics and transmitted light. a) Sample no. 1, b) Sample no. 2, c) Sample no. 3, d) Sample no. 4, e) Sample no. 5, f) Sample no. 6.
Detailed microscopic analysis of the woven structures confirmed the initial subjective evaluation of the fabrics. The light transmitted through the area observed revealed the interstices. All fabrics had dissimilar internal structures, and the analysis of yarn and weaving parameters confirmed it (Figure 2). Consequently their barrier properties were expected to be different, but could not be concluded based on the results of transmittance tests obtained. Such a discrepancy proved that the research method was inadequate for blackout fabrics. Searching for an appropriate objective methodology is the aim of the further part of the research.

**Measurements of light barrier properties of blackouts**

As stated before, the images of fabric structures allowed for observation of irregularity disclosing the inner clearances. There are applications of image analysis techniques widely known for identification of fabric structures. For the authors, studies related to the recognition of faults and the determination of their causes were of significance [17, 18]. Some researchers focused on channels or spacing between thread formation in woven fabric structures like Polipowski et al. [8]. They identified and determined the channel spacing surface in real products and proposed the use of 3D computer image analysis as opposed to 2D analysis. In recent years Ruru Pan et al. [19] used image analysis in order to identify the parameters of high-tightness woven fabrics. An important discovery was the significance of what was the way of illumination, leading to the conclusion that the structure details of samples are better examined with transmitted rather than with reflected light. The kind of light source also impacts the quality of the images. In our research a LED panel source was chosen which illuminated uniformly the whole area of the fabrics analysed. There are known studies on the influence of the structural parameters of woven fabric on barrier properties against UV [20,21]. The subjects are similar, but the researches did not use image analysis methods.

Image recording was done as the first step of computer image analysis. Afterwards research on typical digital images was conducted with ImageJ software [22]. All samples were imaged at a resolution of 640 × 480 pixels at the 8-bit gray level. Processing based on simple functions was applied [23]. The following operations were carried out: variation of the gray scale, contrast improvement and the threshold procedure [24 - 26].

On the grey scale the images varied from 0 to 255. The number of brightness levels (which facilitated clearance detection) was chosen in the range of 0 - 127. The pores were determined by the grey level value, where black had a grey level of 0, and white 255. The threshold level of 127 means the maximum grey level accepted as a clearance. The images were only analysed in selected colour channels. Pixels with values higher than the threshold value were projected as white. Scaling the brightness accurately allowed to distinguish between the clearances (meaning the places not covered by threads) and the effect of gloss or light conduction through the yarns. Results of the image processing are shown in Table 2.

We conducted preliminary image processing with the analysis of particular object thresholds, which allowed to identify the image areas which exhibited structural irregularity. This research involved recognising objects that differ from the fabric background - namely the clearances.

The next stage was measurement and morphological analysis. The following feature extractions were selected: pixel

| Number of sample | Grey scale images 640 × 480 pixels 8-bit, 300 K | Images after processing |
|------------------|-----------------------------------------------|-------------------------|
|                  | Inversion and contrast enhancement  | Brightening balance     |
| 1                | ![Image 1](image1.png)                    | ![Image 2](image2.png)   |
| 2                | ![Image 3](image3.png)                    | ![Image 4](image4.png)   |
| 3                | ![Image 5](image5.png)                    | ![Image 6](image6.png)   |
| 4                | ![Image 7](image7.png)                    | ![Image 8](image8.png)   |
| 5                | ![Image 9](image9.png)                    | ![Image 10](image10.png) |
| 6                | ![Image 11](image11.png)                  | ![Image 12](image12.png) |

*Table 2. Images of samples after processing.*
Results and discussion

The investigation was aimed at measuring the area of pores and to compare the samples. Therefore the number of pixels which belonged to clearance areas and the number of pixels in pores related to the total pixels are the most important indicators of blackout quality. Comparison of these parameters leads to establishing an acceptable level of their barrier properties.

Results of the analysis of the distribution, amount, and quality of clearances are presented in Figure 4 and Table 3.

The above histograms describe the distribution and occurrence frequency of clearances on the samples’ surface. Histograms of the distribution of gray values in the active image or selection were calculated and displayed. The horizontal axis represents the possible gray values and the vertical axis shows the number of pixels found for each gray value. A characteristic distant from the value of 255 means the appearance of a clearance. The histogram of sample No. 2 should be considered as a model characteristic in relation to the blackout fabrics. The results of detailed surface analysis (quantitative interpretation) of each sample are shown in Table 3.

First of all we observed that the method presented disclosed the differences between samples, which meant the method was sensitive enough. The results showed that the differences among the fabrics tested were in the range from 3 to 339 pixels in the pore area. Sample No. 5 showed the worst barrier properties. It had the biggest number of clearances, which was confirmed by the subjective assessment of its disrupted barrier properties. Samples 2 and 3 had the characteristics close to perfection, as we can see in Figure 4 and Table 3. Than we could conclude that the acceptable level of light transmission between the values 10 - 15 expressed in pixels should be adopted for blackouts. Blackouts should have a percentage of the pore area less for sample No. 2 evaluated in the range of about 0.001%. The acceptable size of pores should be about 1 - 2 pixels.

It was stated that the ratio of the total surface area of the pores to that accompanying the average size and amount of pores are the most important indicators for blackouts. However, attention should be paid to the distribution of clearances, because of their great importance due to visual perception. They should not stand out, as it is most adverse when arranged in a repetitive sequence, which is particu-
larly discernible to the human eye, as in fabrics No. 4 and 5.

### Summary and conclusions

Blackout fabrics should block the sunlight. Such a capability is necessary to satisfy the need of shading public interiors. These features are achievable by a complex construction (multilayer or built-up structures) and comparison of threads and weaving structural parameters presented in Table 1. Those differences are the consequences of the irregularity and diversity of the structure, as determined.

To evaluate the barrier properties of fabrics, a standard spectroscopy procedure based on the European Standard was applied. According to the standard method, the fabrics proved to have very good barrier properties. However, concerning transmitted light, the samples of blackout behaved in a dissimilar manner.

Detailed microscopic analysis of blackout structures disclosed that the conventional spectrophotometric spot measurement method presents an inaccurate level of light barrier properties. The method is not sensitive enough to local interference of the fabric structure. The clearances are formed in different ways, as a cluster of several individual ones (samples 5, 6) or distributed over the whole surface (sample 4). The distribution of clearances denies the suitability of the spectrophotometric method proposed in the Standard [2].

Digital image analysis was indicated as the simplest, cheapest and most available diagnostic tool for evaluating the light barrier properties of blackout fabrics. The key advantage of this method is the analysis of a bigger surface of samples, which reveals the heterogeneity of fabrics. The results achieved with the method match the subjective assessment of a receiver. The method can be applied for preliminary classification of woven blackout fabrics. Based on the results of the research presented, we can state initially that the estimation factors of the darkening performance and further classification of blackout fabrics must rely on the testing methods specially dedicated for darkening fabrics. Such activity may be first carried out on the basis of assessment of the ratio of the average size and percentage of pore area.

The analysis above and proposals defined are an inspiration for further research in order to search for optimal solutions for darkening systems with the use of weaving technology as well as for new methodology of assessing them.

Nowadays blackouts have homogeneous structures that exhibit differences in light barrier properties. The question for the future is how to objectively obtain such properties in non homogeneous structures?

Works on the innovative design of blackout fabrics are being conducted at the Institute of Textile Architecture of Lodz University of Technology.

### References

1. Manual for Fabrics for hotels. Specification for Fabrics Hilton Europe and UK & Ireland, 2009, available: http://cedar rapid.org/government/departments/purchasing/Documents/2012/3rd%20Quarter%2007_08/09/712-022%20Convention%20Complex%20Hotel%20Guest%20Room%20Tables/712-022%20Attachment%20.pdf
2. EN ISO 13758-1:2001 – Textiles. Solar UV protective properties, Part 1.
3. Cukierski G, Buchanan D R. Effectiveness of Conventional Modified and New Interior Window Treatments in Reducing Heat Transfer Losses. Proc. Fourth National Passive Solar Energy Society, University of Delaware, 1979; p 402-406.
4. Grasso M M and Hunn B D. Windows Shades in Energy Conservation. Family and Consumer Sciences Research Journal 1982; ISSN: 1562-9394, 11, 1: 89-97.
5. Hunn B D, Grasso M M, Rewerts A M, Beaudry M A. Evaluation of Directional Shading Fabric Composites with Application to Improved Daylighting. HVAC&R Research 1996; 2, 4: 354-374.
6. Grasso M M, and Hunn B D. Effect of Textile Properties on the Bidirectional Solar-Optical Properties of Shading Fabrics. Textile Research Journal 1992; 62, 5: 247-257.
7. Grasso M M, Hunn B D, Rewert A M. Effect of Textile Properties in Evaluating a Directional Shading Fabric. Textile Research Journal 1997; ISSN: 0040-5175, 67, 4: 233-247.
8. Poliowski M et al. Study on Woven Fabric Structure Using 3D Computer Image Analysis for In-Depth Identification of Thread Channels. Fibres and Textiles in Eastern Europe 2015; 23, 2(110): 33-39.
9. Wilbik-Halgas B et al. Air and water vapour permeability in double-layered knitted fabrics with different raw materials. Fibres and Textiles in Eastern Europe 2006; 14, 3(57): 77-80.
10. Nycz E, Owczarz R, Średnicka L, Budowa tkanín 1990, ISBN 83-02-03229-8, WSIP.
11. Szosland J. Struktury tkaninowe 2007, ISBN 83-86492-42-2.
12. Żajkiewicz H., 1975, Budowa tkanín, WSIP.
13. Hemka L. Opracowanie metodyki badań oraz kryteriów oceny właściwości barierowych dla UV materiałów wyposażenia wnętrz i do budownictwa. Prace Instytutu Elektrotechniki, zeszty 245, 2010, p. 301-317.
14. AS/NZS 4399:1996 - Sun protective clothing. Evaluation and classification.
15. AS/NZS 6260:2012 Sunscreen products. Evaluation and classification.
16. BS EN 13758-2:2006 – Textiles – Solar UV protective properties- Part 2: Classification and making of apparel.
17. Akio Sakaguchi, Guang HuwWen, Yo-Ichi Matsumoto, Koichiro Toriumi, Hyungsup Kim, Image Analysis of Woven Fabric Surface Irregularity. Textile Research Journal 2001; 71: 666-671.
18. Wu Y, Pourdeyhimi B, Spivak M. Texture Evaluation of Carpets Using Image Analysis. Textile Research Journal 1991; 61: 407-419.
19. Ruru Pan et al. Applying Image Analysis for Automatic Density Measurement of High-lightness Woven Fabrics. Fibres and Textiles in Eastern Europe 2015; 24, 2(110): 66-72.
20. Dulęba-Majek M. Transmission of UV Radiation through Woven Fabrics In Dependence on the Inter-Thread Spacing. Fibres and Textiles in Eastern Europe 2009; 17, 2(73): 34-35.
21. Gabrielić H et al. Influence of Fabric Constructional Parameters and Thread Colour on UV Radiation Protection. Fibres and Textiles in Eastern Europe 2009; 17, 1(72): 46-54.
22. Image J, available: http://rsb.info.nih.gov/IJ/download.html
23. Drobina R, Machnio M S. Application of the Image Analysis Technique for Textile Identification. Austex Research Journal 2006, ISSN 1470-9589, 6, 1.
24. Cybulskia M. Assessing Yarn Structure with Image Analysis Methods. Textile Research Journal 1999; 69: 369-373.
25. Perzyna M. Evaluating the geometry of the structural elements in knitted fabrics in a computer image analysis system. Przegląd Włókienniczy 2000; ISSN:17318645, 5: 24-26.
26. Krucifika I, Gracycz M, Przegląd wybranych metod analizy obrazu stosowanych do oceny jakości włókien i tekstyliów. II Konferencja Naukowa Wydziału Włókienniczego, Łódź 1999, J-22, p. 5-8.

Received 04.12.2015  Reviewed 06.05.2016

FIBRES & TEXTILES in Eastern Europe, 2016, Vol. 24, 5(110)