IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE)
e-ISSN: 2348-019X, p-ISSN: 2348-0181, Volume 6, Issue 6 (Nov. - Dec. 2019), PP 14-19
www.iosrjournals.org

The effect of image segmentation on the determination of porosity of woven textiles through image processing

Radostina A. Angelova
Department of Textiles, Technical University of Sofia, Bulgaria

Abstract: *The processing of grayscale images of woven macrostructures is a fast way for determination of their porosity. The method is suitable for complex macrostructures and textiles with uneven distribution and size of the pores. The study aims to assess the effect of the image segmentation threshold on the porosity determination. The experimental results from the image processing are compared with results from the theoretical determination of the porosity, based on geometrical models. The analysis allows determining some recommended values of the threshold for different types of woven macrostructures.*

Date of Submission: 02-11-2019 Date of Acceptance: 18-12-2019

I. Introduction

The porosity of a woven textile macrostructure depends on its inherent characteristics: linear density and material of yarns, yarn structure, number of threads in warp and weft directions, number of warp and weft sets (if more than two). The porosity determines the permeability and penetration abilities of the textiles, as well as the heat transfer through them. In this sense, the porosity is very important for the thermophysiological comfort of textiles and clothing (i.e. bedding, protective clothing), for application of technical textiles (i.e. airbags, sails), medical textiles (i.e. filters, implants) and quality of processes (i.e. inkjet printing).

The theoretical approach for determination of the porosity of a woven textile requires the determination of warp and weft cover factors, based on the known (measured or calculated) warp and weft densities and linear density of the warp and weft sets of threads [1]. However, this approach is used for single-layer woven macrostructures only. The determination of the porosity of complex macrostructures requires other methods to be applied. They could be based on the direct measurements of the pore area, which is tedious work and can be applied for modelling of a particular woven structure [2]. Another method is the sorption method, based on the determination of the vapours of a liquid (with low-molecular-weight), absorbed at different vapour pressures [3]. The mercury porosimetry is also used [4]: a method, based on the principle that a nonwetting liquid, which does not react with the textile surface cannot penetrate its pores without application of sufficient pressure. The air-permeability of the textiles can also be measured, and the porosity is defined as the proportion between the flow through the textile and the flow through a vacuum [5].

The processing of grayscale images of woven textiles is another way of determination of the porosity [6, 7]. The method is fast, it doesn't require sophisticated equipment and software, and it is very suitable for complex macrostructures and textiles with uneven distribution and uneven size of the pores. However, the conversion of the microscopic image into a binary image requires different settings, which can influence the output result.

The aim of the present paper is to study the effect of the image segmentation threshold on the porosity determination of woven macrostructures by image analysis. The porosity results from the image processing are compared with results from the theoretical determination of the porosity, based on geometrical models. The analysis allows assessing and recommending values of the threshold for different woven macrostructures.

II. Theoretical Background

The image segmentation or thresholding of a grayscale image leads to conversion to a binary image. There are different ways of image segmentation [8]:

- based on the shape of the histogram of the grayscale image;
- clustering into two parts of the grayscale image: object and background;
- algorithms that use the entropy of the object and the foreground;
- based on the similarity of the grayscale image and the binary image;
- the spatial method;
- local adaptation of each pixel to the characteristics of the image.

The threshold determines the number of both black and white pixels. Its value T is often selected to be the mean value of the grayscale image. Then the pixel is converted into a black one if the image intensity I<T or the pixel is converted into a white one if I>T.

III. Materials and Methods

Table 1 summarizes the basic characteristics of the woven samples. The yarns linear density was experimentally measured, following ISO 7211-2:1984 [9]. The fabric weight was determined, applying BDS EN 12127:2000 [10].ISO 2060:2019 international standard was used for experimental measurement of the fabric density (warp and weft density) [11].

Table 1: Structural Data of the Studied Samples

Sample No	Material	Fabric weight, g/m^2	Fabric density, threads/dm		Linear density, tex		Weave pattern
			Warp, D_{wa}	Weft, D_{wf}	Warp, Tt_{wa}	Weft, Tt_{wa}	
1	CO 100%	89	176	124	28	28	Plain
2	CO 100%	138	270	266	25	25	Plain
3	CO 100%	201	258	238	36	36	Plain
4	CO 100%	184	383	338	28	28	Twill 2/1
5	CO 100%	202	386	226	30	36	Twill 3/1

A digitalmicroscopeOptika DM-15 with a built-in camera was used to make the pictures.Fivepictures were takenfor eachsample. The image resolution was set to 300 dpi with 256 greyscale level.

The conversion from grayscale to a binary image was applied using boundary extraction from 40 to 200 with the step of 20. Two values were determined for each threshold: the total number of pixels and the number of pixels in the pores (black pixels). For each threshold the average values were calculated, based on the measurement of the five images for every sample.

The porosity P was calculated as:

(1) $$P = \frac{n_p}{N}100, \%$$

where n_p is the number of black pixels, and N is the total number of pixels.

The porosity values, determined by the pictures, were compared with the theoretical porosity P_t of a woven macrostructure, calculated in the basis of geometrical dependences:

(2) $$P_t = 100 - (E_{wa} + E_{wf} - 0.01\mathrm{E}_{wa}\mathrm{E}_{wf})$$

where E_{wa} and E_{wf} are the warp and weft cover factors of the woven macrostructure, respectively.

The cover factors were calculated through warp D_{wa} and weft density D_{wf} of the samples and the linear density of the warp Tt_{wa} and weft threads Tt_{wf}, namely:

(3) $$E_{\mathrm{wa}} = k_f D_{wa}\sqrt{\frac{Tt_{wa}}{1000}}, \%$$

$$E_{\mathrm{wf}} = k_f D_{wf}\sqrt{\frac{Tt_{wf}}{1000}}, \%,$$

where k_f is a coefficient that depends on the material.

IV. Results and discussion

Figure1 presents the microscopic images of Sample 1 (the most porous and light fabric) and Sample 5 (the less porous and tightly woven fabric).

Figure 2 shows the results from the image processing of the microscopic picture of Sample 1, using different threshold levels. As the sample is very porous, the visible changes appear after threshold T>120 (Fig. 2e). Certainly, the number of black pixels change with every change of the threshold.

Figure 3 summarizes the differences in the image segmentation of the B&W picture of Sample 5. The same threshold levels were applied, but due to the minimal porosity of Sample 5, the visible changes appear faster. The binary image on Fig. 3d (T=100) already differs from the binary images with a lower threshold (T<100).

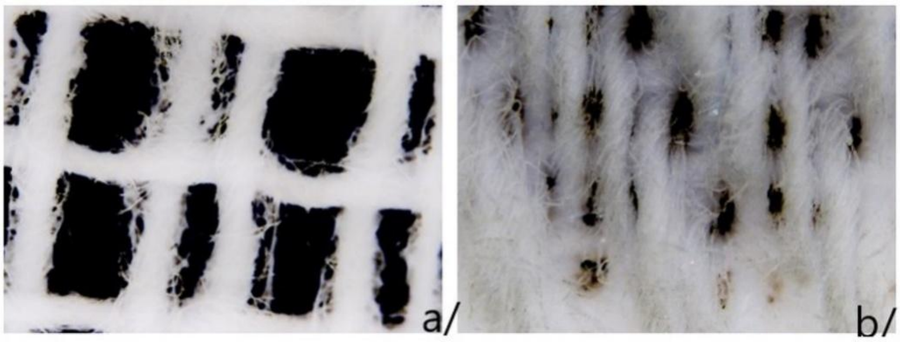

Figure 1: Microscopic images of a/ Sample 1; b/ Sample 5

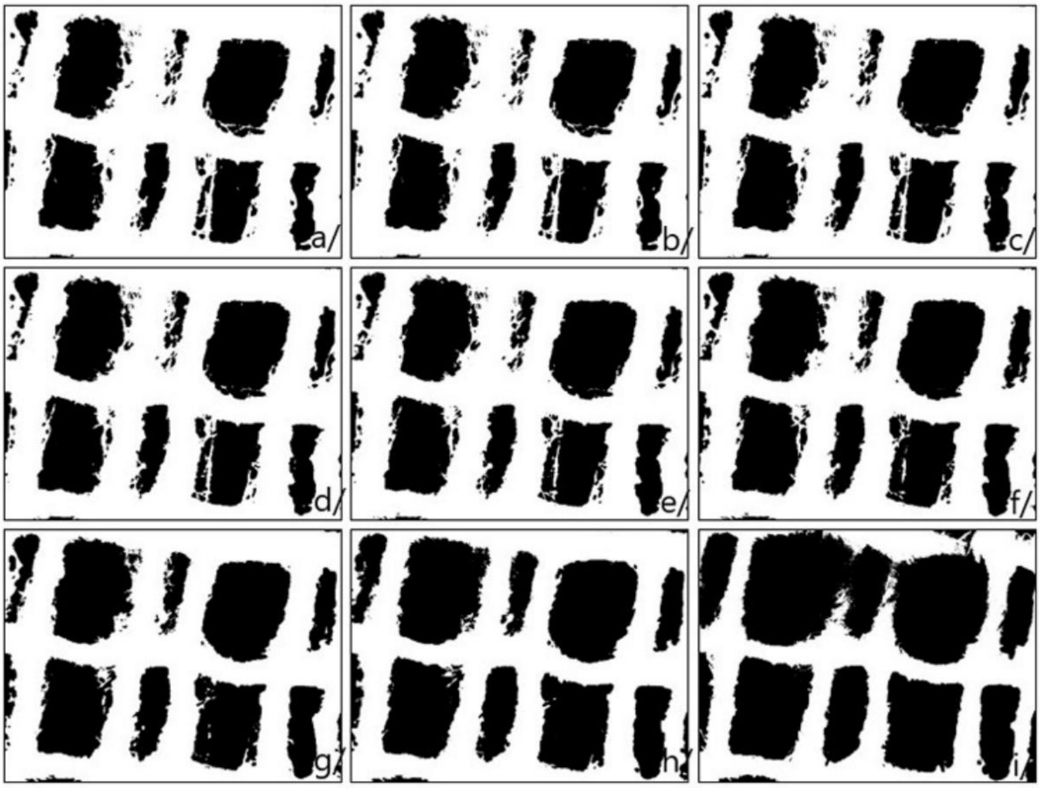

Figure 2: Image segmentation of Sample 1, using different threshold levels T: a/ T=40, b/ T=60, c/ T=80, d/ T=100, e/ T=120, f/ T=140, g/ T=160, h/ T=180, i/ T=200.

The porosity was calculated for each sample and threshold. With the increment of the threshold for the image segmentation the porosity of all samples increased as well, as the number of black pixels on an image raised (Fig. 4). The results showed that the porosity increment was smooth to the threshold level of about 80-100, then changed faster, especially for the samples with higher fabric weight and fabric density (Samples 3-5).

Figure 5 shows the comparison between the theoretical values of the porosity of the samples P_t, calculated by eq. (2), and the measured porosity values, using different threshold. The analysis shows that for the most porous Sample 1 (P_t=48%), the measured and theoretical values coincide at a threshold T=180. For Sample 2 (P_t=24%), the measured and theoretical porosity have closest values for threshold T=120. For Sample 3 (P_t=17%), the measured and theoretical porosity coincide at a threshold of approx. T=100. For Sample 4 (P_t=13%) and Sample 5 (P_t=8.9%), the same threshold of approx. T=100 gives the best results.

The conclusion is that for very porous and light fabrics, the threshold for the image segmentation has to be much higher than the used by default (T=128). Values of T=160-180 are recommended. For macrostructures with fabric weight above 100 g/m^2, a threshold of T=100-120 can be used. For tightly woven macrostructures with fabric weight above 150 g/m^2, a threshold of T=100 is recommended.

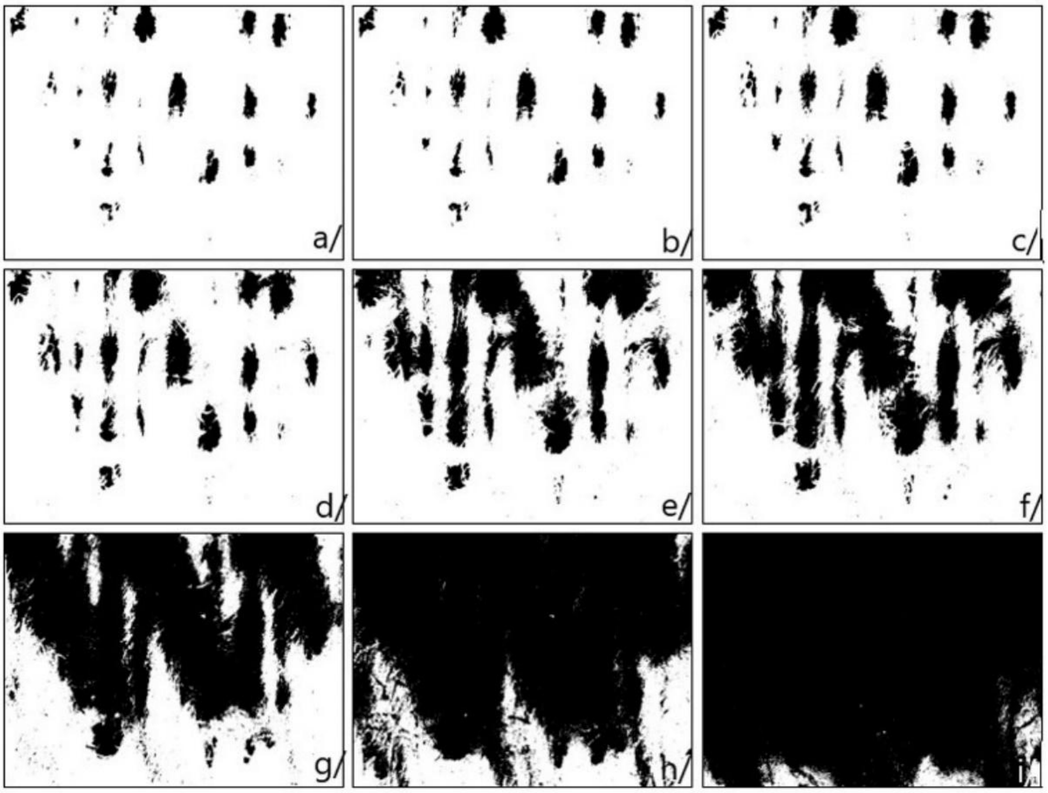

Figure 3: Image segmentation of Sample 5, using different threshold levels T: a/ T=40, b/ T=60, c/ T=80, d/ T=100, e/ T=120, f/ T=140, g/ T=160, h/ T=180, i/ T=200.

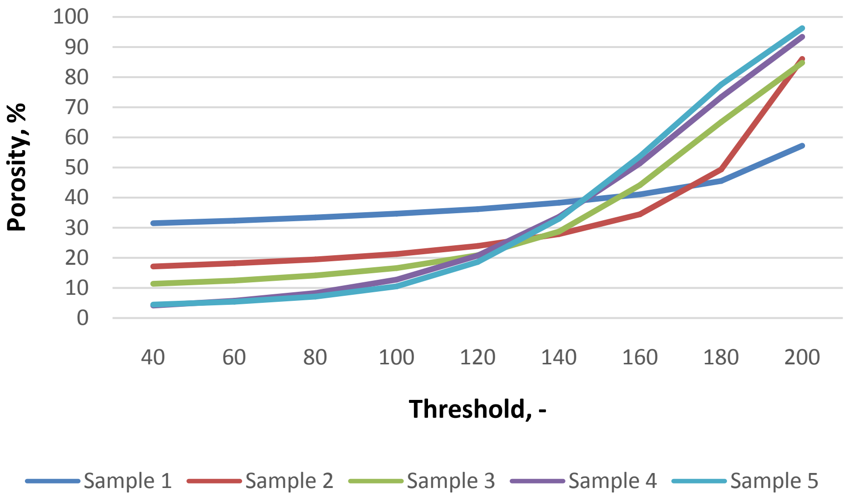

Figure 4: Porosity change as a function of the image segmentation threshold

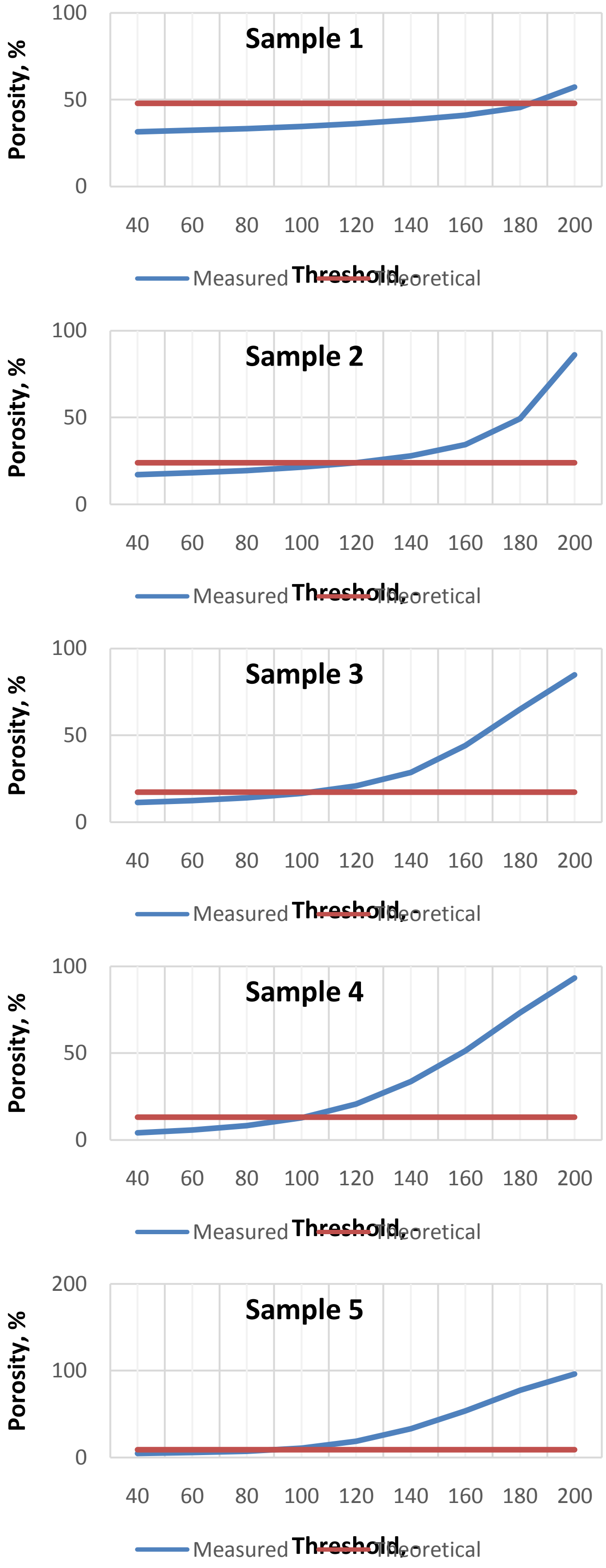

Figure 5: Comparison between the measured and theoretical porosity

V. Conclusion

The processing of grayscale images of woven textiles is a fast and reliable method to determine the porosity of a woven macrostructure. The settings, used for the image segmentation and conversion of the microscopic image into a binary image, influence the output result. The comparison between the measured and theoretical values of porosity showed that the following values of the threshold T could be suggested:

- T=160-180 for porous light fabrics (fabric weight up to 100 g/m^2)
- T=100-120 for fabric weight above 100 g/m^2
- T=100 for fabric weight above 150 g/m^2.

References

[1]. Angelova, R. A. (2015). Textiles and human thermophysiological comfort in the indoor environment. Crc Press. Boca Raton, USA.

[2]. Angelova, R. A. (2012). Determination of the pore size of woven structures through image analysis. *Open Engineering*, *2*(1), 129-135.

[3]. Vílchez, S., Manich, A. M., Miras, J., Molina, R., Erra, P., &Esquena, J. (2016). Dynamic vapour sorption and thermoporometry of polyamide fabrics coated with chitosan hydrogels. *Thermochimica Acta*, *639*, 47-52.

[4]. Nagy, V., & Vas, L. M. (2005). Pore characteristic determination with mercury porosimetry in polyester staple yarns. *Fibres and Textiles in Eastern Europe*, *13*(3), 21.

[5]. Benltoufa, S., Fayala, F., Cheikhrouhou, M., & Nasrallah, S. B. (2019). Porosity determination of jersey structure. *Laboratoired'Etudes des SystèmesThermiques et Energétiques, ENIM, Monastir*, *5019*.

[6]. Aydilek, A. H., Oguz, S. H., &Edil, T. B. (2002). Digital image analysis to determine pore opening size distribution of nonwoven geotextiles. *Journal of Computing in Civil Engineering*, *16*(4), 280-290.

[7]. Turker E. (2014). Determination of Structural Parameters of Single-Colored Woven Fabrics by Using Image Processing Method. *TekstilveKonfeksiyon*, *24*(4), 339-348.

[8]. Sezgin, M., &Sankur, B. (2004). Survey over image thresholding techniques and quantitative performance evaluation. *Journal of Electronic imaging*, *13*(1), 146-166.

[9]. ISO 2060:2019 Textiles — Yarn from packages — Determination of linear density (mass per unit length) by the skein method.

[10]. BDS EN 12127:2000 Textiles. Fabrics. Determination of mass per unit area using small samples.

[11]. ISO 7211-2:1984 Textiles — Woven fabrics — Construction — Methods of analysis — Part 2: Determination of number of threads per unit length.

Radostina A. Angelova. "The effect of image segmentation on the determination of porosity of woven textiles through image processing." IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE) , vol. 6, no. 6, 2019, pp. 14-19