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Effects of Topographic Structure on Wettability of Woven Fabrics

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1. Introduction

Each surface is characterised by its chemical composition, a certain surface geometry and roughness. The interaction of liquids with textile fabrics may involve one or several physical phenomena such as fibre wettability, depending on the intermolecular interaction between the liquid and fibre surface, their surface geometry, the capillary geometry of the fibrous assembly (Hasan et al., 2008), the amount and chemical nature of the liquid as well as on external forces. A rough textile surface possesses pores, crevices, capillaries or other typical structures with their own characteristic wetting and penetration properties. As a consequence, the apparent contact angle on these surfaces will be affected by thermodynamics and kinetics associated with such intrinsic structures.

Fabric texture affects the porosity and strongly influences the textile characteristics such as fabric mass, thickness, draping ability, stress-strain behaviour, or air permeability (Potluri et al., 2006; Milašius et al., 2003; Kumpikaité, 2007). The surface topography of fabrics is responsible for their functionality – appearance and handle, wettability, soiling behavior and cleanability (Calvimontes et al., 2005), abrasion resistance and wear (Dutschk et al., 2007). However, there are very few systematic investigations of quantitative relations between construction parameters, topography of fabrics and their wettability.

One technique that has been extensively used for studying the wetting properties of solid surfaces, is dynamic wetting measurements. Calvimontes et al. (2005), demonstrated its utility in characterizing both textile materials and interactions between them and aqueous solutions of soil release polymers. Differences between the soiling behaviour and cleanability of three polyester textile materials with various topographical structures were determined despite the similarity of their chemical nature. In other studies (Calvimontes et al., 2005; Hasan et al., 2009), the usefulness of the application of a relatively new imaging technique based on the principle of chromatic aberration was shown in characterizing the surface of textile materials before and after impregnation with soil release polymers.

2. Textile topography

In almost all the studies cited above, a large number of roughness and waviness parameters were obtained that did not take into account the scales-morphologic periodicity of each surface studied and its influence on the whole topography. All textile materials having periodic surfaces show some horizontal and vertical repeating units; therefore, different length scales have to be taken into account for a proper interpretation of the topographic data measured (Hasan et al., 2009; Calvimontes et al., 2009).

2.1 Topography measurements

Depending on fabric characteristics, and the structure and size of repeating units, several non-contact measurement methods such as chromatic with-light sensor (CWL) - also called chromatic confocal imaging-, high-resolution scandisk confocal microscopy (SDCM), scanning electron microscopy (SEM), confocal laser canning microscopy (CSOM), conoscopic holography (CSL), etc. can be used.

In Calvimontes et al. (2009) CWL was used and recommended for the optical topographic analysis of textile materials. This instrument allows a lateral and a vertical measure range up to 100 mm and 380 µm, respectively, and a lateral and vertical resolution up to 1 µm and 3 nm, respectively. In Lukesch (2009) and Calvimontes (2009), the use of CWL to measure topography of textile surfaces was compared with the use of SDCM. According to these studies, wider cut-off lengths and larger z-ranges make CWL more appropriate than SDCM to measure topographic characteristics of polyester and cotton fabrics.

It is important to note, that the selection of a method due to its high resolution could be inadequate if the cut-off length available or z-range is too small. On the other hand, the use of a very high resolution and larger cut-off lengths (scan areas) results in data whose excessive size could demand extremely long calculation times and special or non-existent hardware and software.

2.2 Optimal sampling conditions

Cut-off length (L_m), defined as the length of one side of the square sampling area, and resolution (distance between measured points Δ_x, assuming that $\Delta_x = \Delta_y$) are the most important sampling parameters, which apart from particular instrumental dependent parameters, such as light intensity, measuring frequency, etc., have to be optimally defined before characterising topography.

Tsukada & Sasajima (1982) and Yim & Kim (1991), discussed the problem of an optimum sampling interval (L_m) by checking the variance of the root mean square roughness (R_q) for a surface under different sampling intervals. According to Stout et al. (1993), recommendation mentioned above for the choice of sampling interval is doubtful because of the fact that the optimum L_m seems to influence the amplitude parameters (wave height W_t and waviness W_z).

The use of tables that relate foreseen the mean rough height (R_z), root mean square roughness (R_q) and arithmetic mean roughness (R_a) with L_m is frequently recommended to set the optimal value of L_m for periodic as well as non-periodic surfaces. As optimal sampling conditions are strongly dependent on the type of material to be characterized, researcher experience is usually required. A systematic procedure to define optimal cut-off length and resolution values was proposed and probed in Calvimontes (2009).

2.3 Topographic characterization using different length scales concept

The use of a scale concept to characterize and study textile surfaces is a new skill that helps to correlate textile parameters, topography and topographical changes with interface phenomena such as spreading, wetting, capillary penetration, and soil release (Calvimontes et al., 2007).

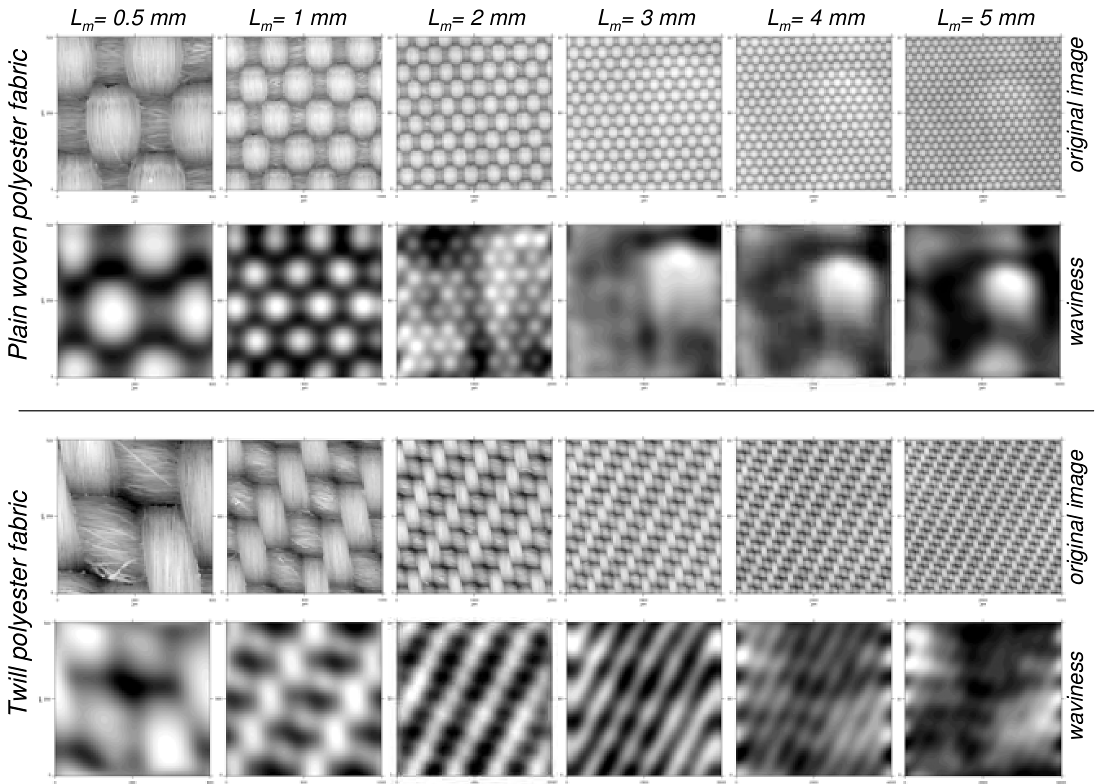


Fig. 1. Original and waviness images of polyester fabric surfaces as a function of L_m

As shown in Figure 1, waviness images obtained by Fast Fourier Transformation-filtering (FFT) (Raja & Radhakrishnan, 1979) provide different type of information depending on cut-off length used. Due to the structural diversity of textile materials, their classification by unit size and morphology on different length scales is necessary. A suggestion to find general range values of L_m in order to identify different measurable length scales is not reasonable. However, the specification of at least three different length scales (macro-, meso- and microscale) is absolutely necessary to describe morphologically homogeneous textile groups. From a conceptual point of view, each one of the length scales proposed for a textile structure has to provide specific information about the surface morphology and topometry of the materials.

Macro-morphological irregularities of textile surfaces such as folds and wrinkles can be studied using FFT-filtering of topographical data measured by large values of L_m. A cut-off length value larger than 3 mm was suggested by Calvimontes et al. (2009) to quantify plane irregularities (waves and wrinkles) of polyester fabrics.

Dimensional changes (relaxation/shrinkage) of fabrics at macro scale influence their meso- and micro-topography due to the modification of repeating unit dimensions and, therefore, distances between yarns, filaments and fibres.

In Figure 2 macro-waviness diagram alone for woven plain does not show any morphological influence of repetitive units (r.u.) morphology, in this case r.u. > 13^2. For macro-topographical characterization of twill and Panama types of weave, optimal L_m values have to be larger than 5 mm.

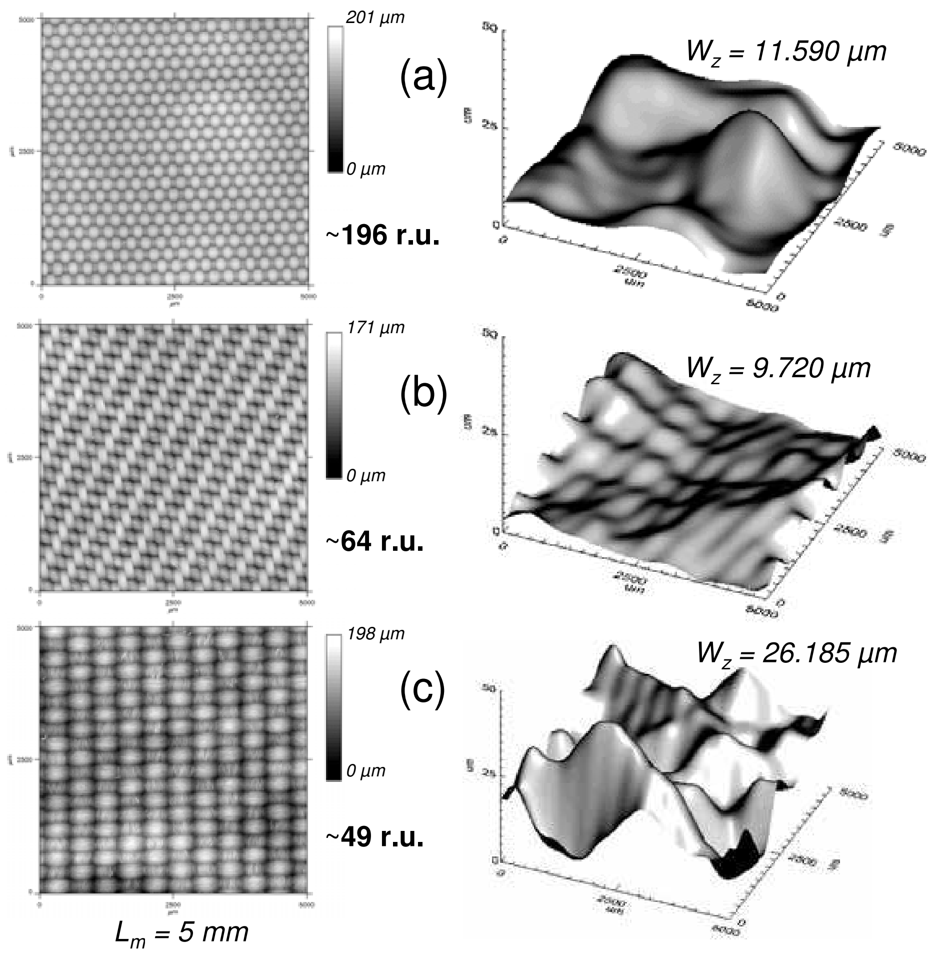


Fig. 2. 2D images (left) and 3D waviness diagrams (right) with W_z values for: (a) woven plain; (b) twill and (c) panama polyester fabrics.

Meso-scale of textile materials should be used to describe the surface topography produced by the type of weave and yarn used, without attending previous defined macro-topographic irregularities and details corresponding to fibres or filaments. A study of fabric surface topography at a mesoscopic scale using FFT-filtering starts with the selection of a new optimal L_m value, which basically depends on the size of fabric repeating unit. From a large amount of experimental data for polyester fabrics studied, it was revealed that a sample area (L_m x L_m) has to cover about 8 repetitive units (Calvimontes et al. 2009).

Another way to construct meso-topographic diagrams is the use of digital surface filtering, which calculates the arithmetical mean of each data point with its neighbourhood (Stout et al., 1993). Filter density used depends on fabric characteristics and has to be able to produce a surface without topographical details of fibres or filaments. Figure 3 shows the construction of meso-topographic surfaces by using FFT-filtering and Smooth filtering. In order to compare morphologies and W_z values obtained, L_m and filtering method used should be remained the same during the characterisation process.

An application of the study on meso- scales claims to know relative z-distances between warps and wefts for woven fabrics and the amplitude of their wave (sinoidal) trace. As shown in Figure 3, wefts describe almost a linear trace (their amplitudes are small). As a consequence, the first contact of any solid with the fabric surface takes place by the warps ("hills") and the final penetration of fluids into the fabric surface takes place principally on

wefts (“valleys”). This finding plays a crucial role in understanding the wetting behaviour of textile materials (Calvimontes et al. 2007).
Unlike macro- and meso-scales, characterisation at a micro-length scale reveals the influence of filaments and fibres characteristics on the resulting topography. Profile, fineness, as well as natural or machined texture of these elements or distances between them are only some of possible characteristics which define the resulting morphology and topometry at this length scale.
The selection of an optimal cut-off length in this case no longer depends on some statistical or mathematical criteria as seen at macro and meso length scales, rather on the size and location of the set of filaments or fibres by type and orientation.

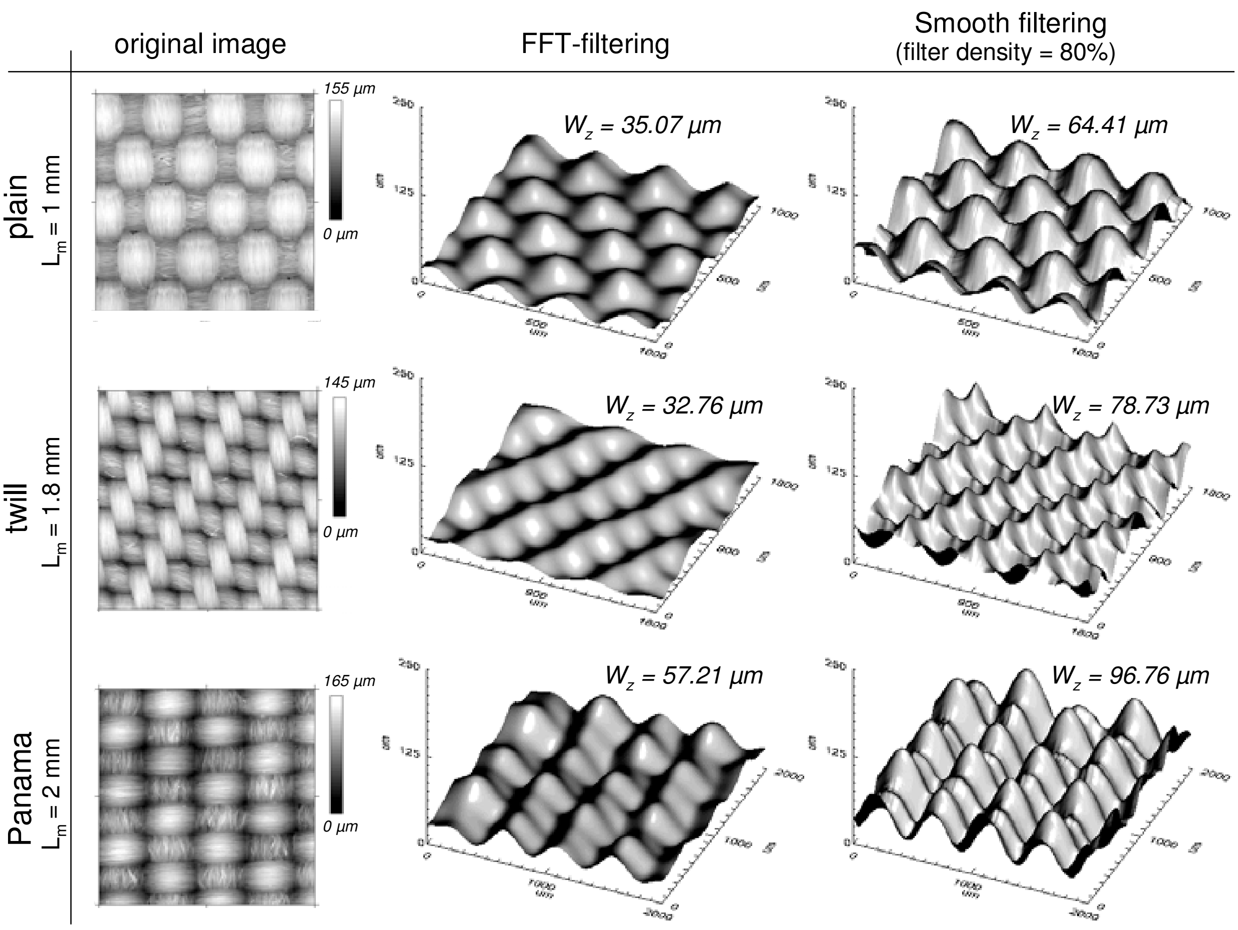


Fig. 3. Meso-topography of different polyester fabrics by FFT filtering and smooth filtering

To study the micro-topography of woven plain fabrics, warps and wefts should be zoomed separately. Optimal L_m values of warps and wefts depend on the type of weave and construction parameters such as yarn types, their diameters, warp densities, weft densities, etc. Depending on the textile structure, more than one L_m value could be necessary for a complete micro-topographical characterisation, as shown in Figure 4.
The number of sub-areas to be isolated depends on topographical parameters studied and on standard deviations of their mean values. Usually, five different zooms should be enough to characterise polyester monofilament fabrics. Depending on the characterization criteria, the elimination of micro-waviness, a consequence of yarn profile and fabric meso-topography, is possible by FFT-filtering, as shown in Figure 5.

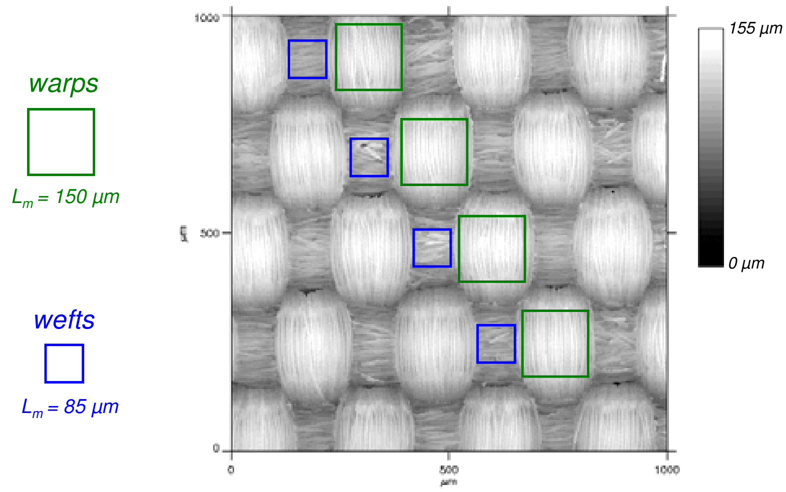


Fig. 4. Optimal L_m values for the characterisation of warps and wefts micro-topography separately at the surface of woven plain polyester fabric.

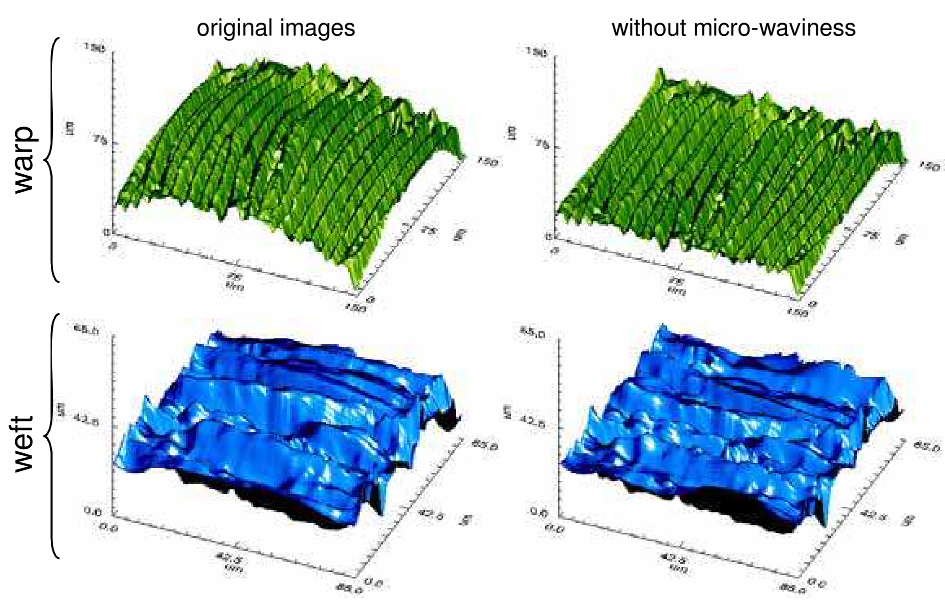


Fig. 5. Micro-topographical images of a warp and a weft. The elimination of micro-waviness was possible by FFT-filtering

Using the new topographical data generated, it is possible to calculate any micro-topographical parameter by profiling or by using the whole surface. The volumetrical characterization is a good tool to measure textile surfaces through evaluating of porosity or filling quantities at different deep heights. Fractal dimension or Wenzel roughness factor could be of interest to characterize micro-topographical modifications of natural fibres, e.g. changes caused by plasma or enzymatic action.

3. Influence of topography on wettability of textile structures

One technique that has found extensive use in studying the wetting properties of solid surfaces is dynamic wetting measurements. Seven different cases of connection between topography and wetting of textiles will be described in following pages. In all of them, dynamic wetting measurements were carried out by a FibroDAT 1122 HS dynamic contact angle tester (Fibro System, Sweden). Some advantages of this equipment over other contact angle measuring systems as well as the measuring procedure have been detailed by Dutschk et al. (2003).

3.1 Type of weave and construction parameters

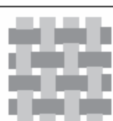
Hasan et al. (2008) studied the influence of the type of weave on topography and wettability of polyester fabrics produced using multi-microfilament yarn with different filament structures with filament diameter being between 6 and 7.5 µm. The characteristics of yarns used are summarised in Table 1. Two basic types of weaves - plain (1/1) and twill (2/2 Z) - were produced by variation yarn combinations and the weft density without changing the warp density. After the manufacturing, the fabrics were desized under laboratory conditions raising the primary fabric density. The composition of each sample are detailed in previous studies (Calvimontes et al., 2006).

Yarn	Number of filaments	Structure	Filament fineness, dtex[1]	Filament diameter, µm	Yarn fineness, dtex[1]
A	128	flat	0.78	6.0	9.9
B	128	textured, tangled	0.92	7.5[2]	11.5
C	256	false-twist textured	0.78	6.5[2]	16.3
D	384	textured, tangled	0.67	6.5[2]	24.6

[1] Measured according to DIN EN ISO 1973:1996; [2] before texturing.

Table 1. Characteristics of the multi-microfilament yarns used by Hasan et al. (2008)

Relevant topographic characteristics obtained from the fabrics are given in Table 2. Comparing the macroscopic roughness parameters for different types of weave, it was ascertained that a decrease occurs for the plain weave and an increase for the twill weave if the weft density increases. Fabric density calculated according to Walz & Luibrand (1947), is inversely proportional to air permeability (for the same weft yarn) measured, as expected, and the results are summarized in Table 3. This nearly linear relationship is independent of the fabric texture, contrary to the macroscopic roughness parameters as shown in Figure 6. An increase in weft density smoothes the surface waviness independently of the type of weave, as illustrated in Figure 7. The values of waviness are higher for the twill weave than for the plain weave with the same weft density.

Type of weave		Yarn variations					
		A–B		A–C		A–D	
		weft/cm*		weft/cm*		weft/cm*	
Plain		39 / 43	40 / 46	32 / 36	36 / 40	26 / 30	29 / 32
Twill		50 / 56	54 / 57	42 / 45	47 / 53	35 / 39	38 / 44

* Weft density is given for each sample before (above) and after desizing (below), respectively.

Table 2. Composition of polyester fabrics woven varying construction parameters (68 warps (cm)

Type of weave	Yarn composition/ weft density	Sample specification	Root mean square roughness, R_q, µm	Mean peak to valley height R_z, µm	Porosity, $\mu m^3/\mu m^2$	Waviness, µm
Plain 1/1	A–B / 39	pB39	9.7	95.5	1.189	48.7
	A–B / 40	pB40	9.5	90.1	0.942	47.5
	A–C / 32	pC32	10.9	115.8	2.528	52.8
	A–C / 36	pC36	9.7	87.3	1.325	50.3
	A–D / 26	pD26	11.1	93.7	1.574	67.9
	A–D / 29	pD29	10.6	83.7	0.760	60.2
Twill 2/2 Z	A–B / 50	tB50	9.4	48.8	0.552	47.5
	A–B / 54	tB54	9.3	88.5	0.916	40.5
	A–C / 42	tC42	9.4	70.9	0.583	59.8
	A–C / 47	tC47	9.8	79.6	0.628	48.9
	A–D / 35	tD35	11.2	111.6	1.221	76.8
	A–D / 38	tD38	11.6	114.9	1.438	65.3

Table 3. Topographic characteristics obtained by means of CWL (chromatic white light sensor

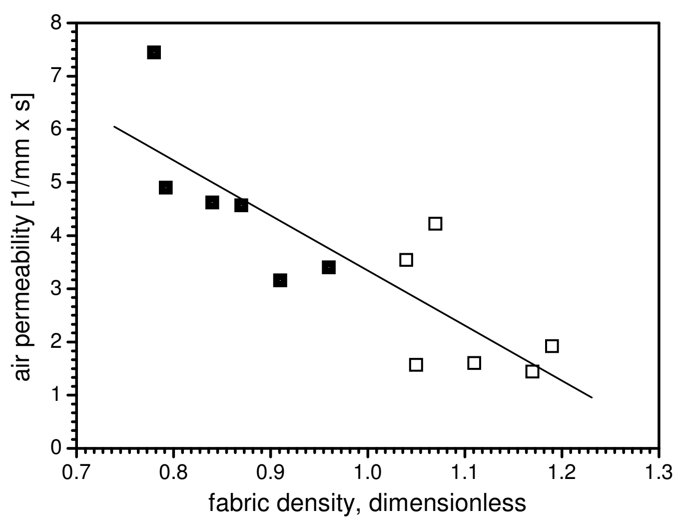


Fig. 6. Nearly linear relationship between fabric density calculated and air permeability measured: (□) plain and (■) twill weave

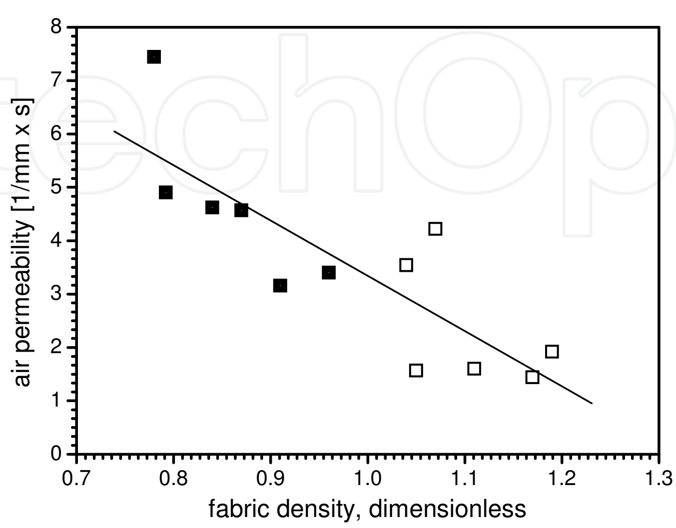


Fig. 7. Dependency of the waviness on the weft density for (□) plain and (■) twill weave

Variations in interlacing are also reflected in the fabric wettability considered in terms of the spreading rate as shown earlier (Calvimontes et al., 2006). The spreading rate decreased with increasing waviness for the plain weave, whereas it increased in the case of twill. It was concluded that the fabric wettability could be adjusted (in certain limits) by variation of density and interlacing, keeping in mind the same chemical nature of microfilaments.

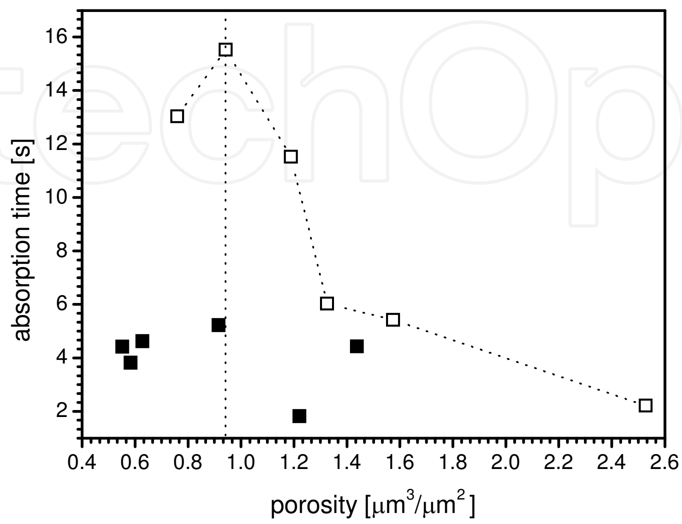


Fig. 8. Absorption time vs. surface porosity calculated as the ratio between the real pore volume and the corresponding geometric surface for (□) plain and (■) twill structures

Noticeable differences in the wetting behaviour of water were seen between the two types of weave, if changes in porosity are considered. In the case of the plain weave, higher weft density leads to lower porosity and, as a consequence, to higher water absorption time, as shown in Figure 8. Moreover, water penetration into the plain texture is slightly slowed down with increasing porosity, reaches a maximum value of the absorption time (about 16 s) in the porosity range of approximately 1 $\mu m^3/\mu m^2$, and then accelerates towards the higher porosity values. It can be speculated about a "critical" value of the fabric's porosity. Presumably, below this value water percolates with low velocity and above this with a high value. In contrast, the higher weft density of the twill weave results in higher porosity (cf. Table 2). The values of absorption time obtained for the twill texture are generally very low of about 2 – 5 s and are almost independent of the porosity, as illustrated in Figure 7.

The differences in the penetration behaviour of water observed on two predetermined patterns of interlacing are caused by the different topographical structure, since the chemical nature of filaments used was kept constant. It is noted, that the lateral distance between the threads is about 120 and 300 µm for the twill and plain weaves, respectively. The vertical dimension of the surface features is measured up to 20 µm for the plain topography and 40 µm for the twill topography. It is well known, that in the case of moderately hydrophobic surfaces the complex internal geometry of real porous systems could enhance liquid penetration (Bico et al., 2001). As reported earlier (Matsui, 1994), polyester is moderately hydrophobic with a water contact angle of 77° on its flat surface. The results obtained in the present study would suggest that water advanced in a stable flood (wicking regime) is observed (Kissa, 1996). The difference in the penetration behaviour (lower for the plain weave and faster for the twill weave) arises from the difference in the shape and size of the pores.

The same comments were applied in the relationship between air permeability and the absorption time in an earlier work (Calvimontes et al., 2006), where it was found that water penetration strongly depends on air permeability for the plain topography. It seems to be absolutely independent of this textile parameter for the twill structure, although no correlations between both characteristics air permeability and porosity were found.

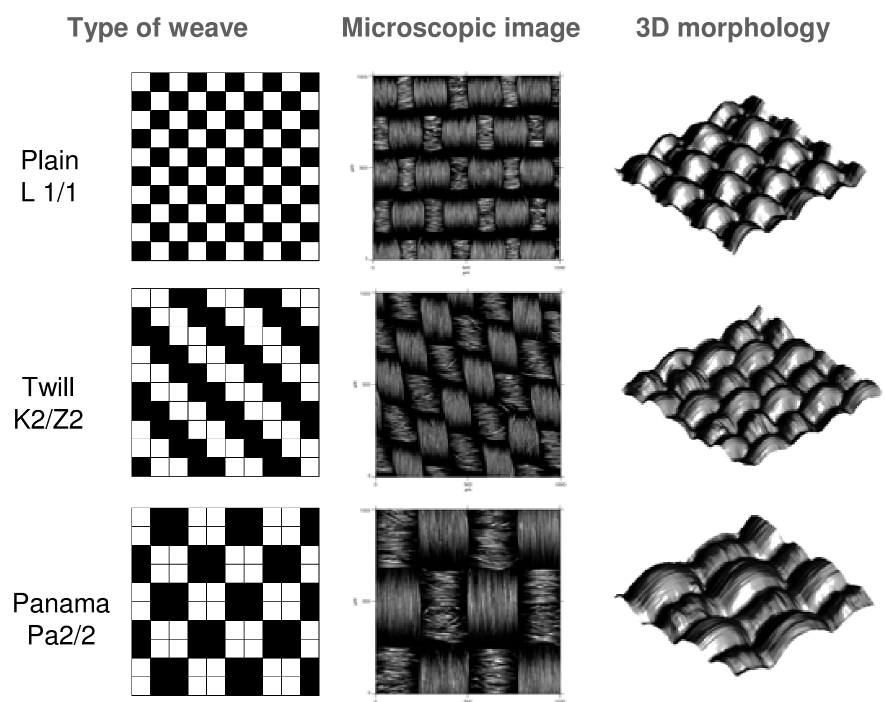


Fig. 9. Polyester fabrics used to study the influence of the type on weave on water spreading

In essence, to achieve a more hydrophobic fabric texture, the technological parameters should be changed as follows: for both plain and twill structure, the weft density and filament fineness should be increased, and the yarn fineness should be reduced. In general, the plain weave with the yarn combination A-B and density of 46 wefts/cm (desized) shows the "best" wetting properties with the longest delay of penetration.

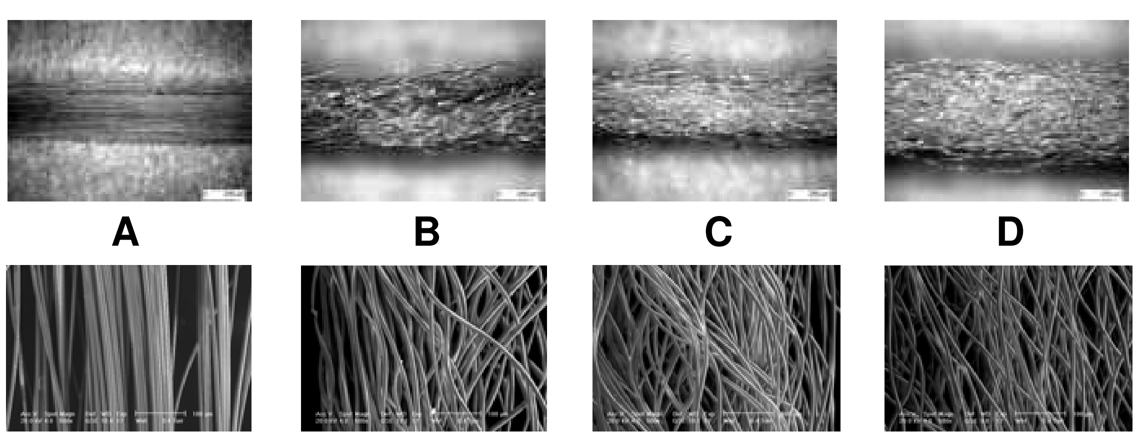


Fig. 10. Microscopic images of warp yarns (above) and filaments (below), according to parameters detailed in Table 1

Calvimontes et al. (2007) used 14 different polyester fabrics, having plain, twill and panama structures to show how the use of topographic characterisation at different scales can provide important information of the spreading behaviour.
Polyester fabrics of three different types of weave (Figure 9) were manufactured using filaments produced by spinning of the same polymer material (polyethylene therephthalate). Warp yarns were formed from flat filaments, while wefts were textured by three different processes (Table 1 and Figure 10).

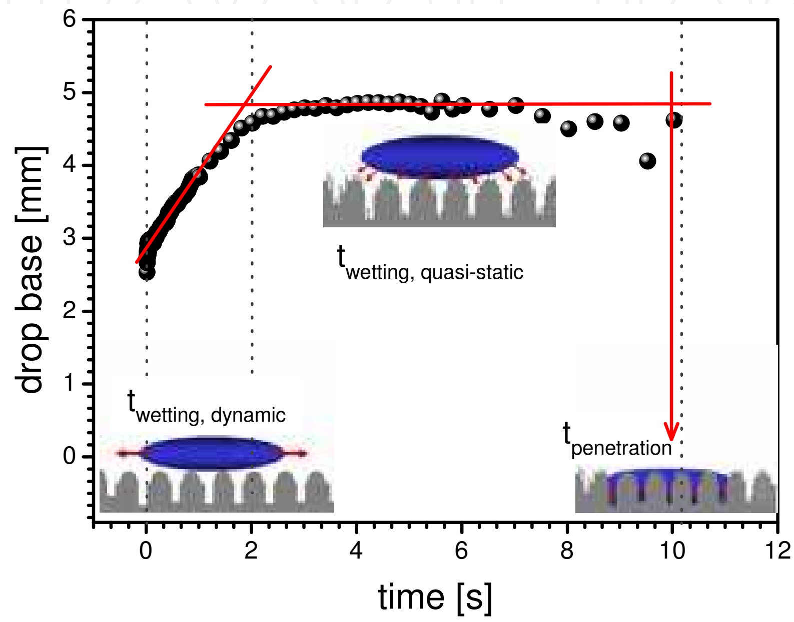


Fig. 11. Three different wetting regimes for a textile surface

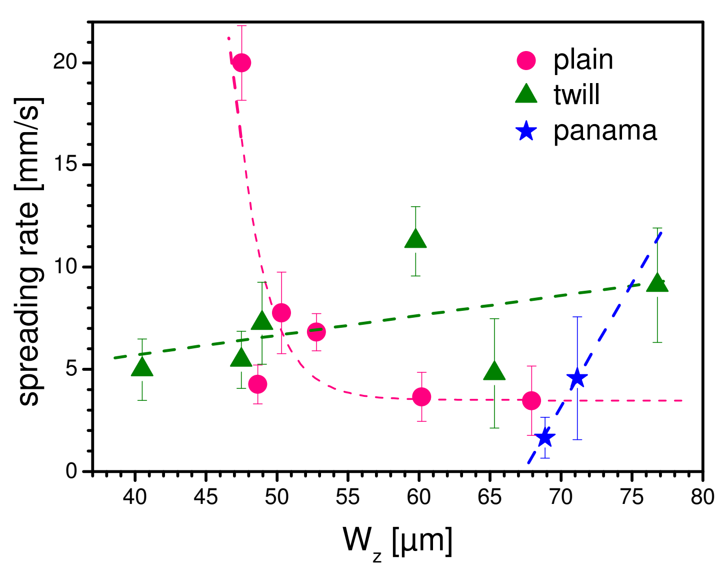


Fig. 12. Dynamic wetting: meso-morphology controls the spreading rate of a liquid drop on a textile structure

On the basis of macroscopic water drop base changes measured with a dynamic contact angle tester (Fibro DAT 1122, Fibro System, Sweden), the wetting behaviour of a water drop can be divided into three regimes (Figure 11): dynamic wetting, defined as growing of the drop diameter depending on time (also known as spreading), the quasi-static wetting, where the drop diameter remains approximately constant, and penetration, which is marked by liquid drop absorption into fabrics depending on time.
By using the waviness as a meso-topographical parameter, it is evident that the meso-topography of the fabrics controls the spreading rate of a liquid drop (Figure 12). For the plain weave, an increase of the waviness depth causes a decrease of the spreading rate; warp yarns ("hills") slow down the liquid motion (Figure 13). For twill weave, an increase of the waviness depth causes formation of deep and long domains of weft yarns ("canals") with small "islands". As a consequence, an increase of the spreading rate is observed. Finally, for the panama weave, an increase of the waviness depth causes formation of long and quasi-endless (without "islands") deep domains ("canals"). Consequently, the waviness depth and spreading rate are proportional to each other.

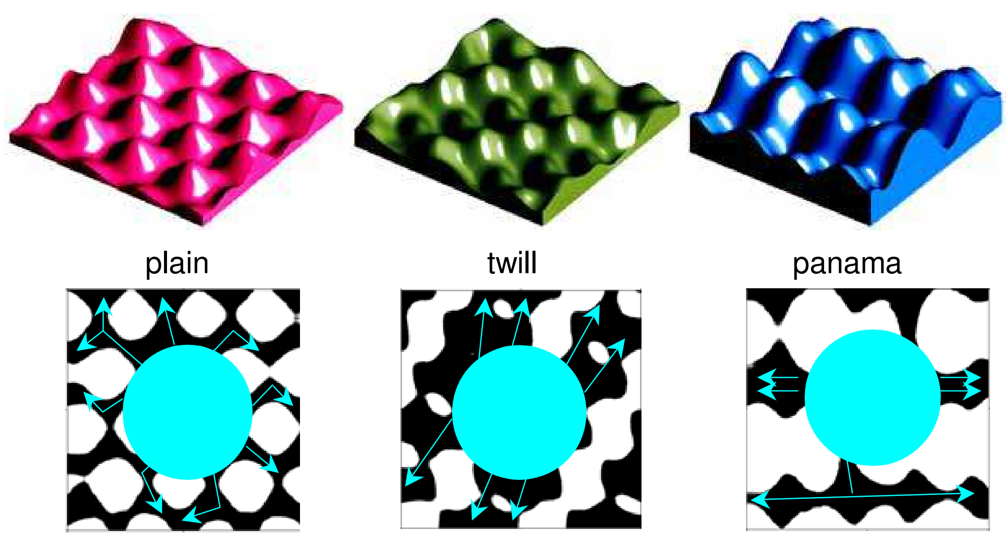


Fig. 13. Respective textile morphology at a meso-length scale controls the spreading rate. Above: morphology; below: spreading directions of a liquid drop

A thorough comparison between topographic parameters for 14 fabrics, having three different types of weaves, reveals that the respective morphology at meso length scale controls the spreading rate.

3.3 Yarns texture

By zooming of warps and wefts separately at a smaller scale, topography measurements and the characterisation concept at different length scales provide important information about changes in textile microstructures. Using this information, the behaviour of a liquid drop on fabrics, detailed in Tables 1 and 2, while wetting can be explained. On the basis of experimental results (Calvimontes, 2009), revealing differences for two basic types of woven fabrics – plain and twill – in respect to capillarity and water penetration (Figure 14), the concept of a novel wicking model was developed. This conceptual model was verified in respect to the cleanability behaviour of fabrics using paraffin oil and acetylene black soils.

Results illustrated in Figure 14 show: (i) warp yarns topography hardly affect the cleanability of fabrics; (ii) spaces between fibres make the plain weave surface oleophil (the larger they are, the more stain penetrate); (iii) spaces between fibres make the twill weave surface oleophob. The larger and deeper they are, the more stain penetrates and the worse their cleanability and (iv) the weft yarn roughness controls the hydrophobicity or hydrophilicity of fabrics and, as a consequence, their cleanability (cf. Figure 15).

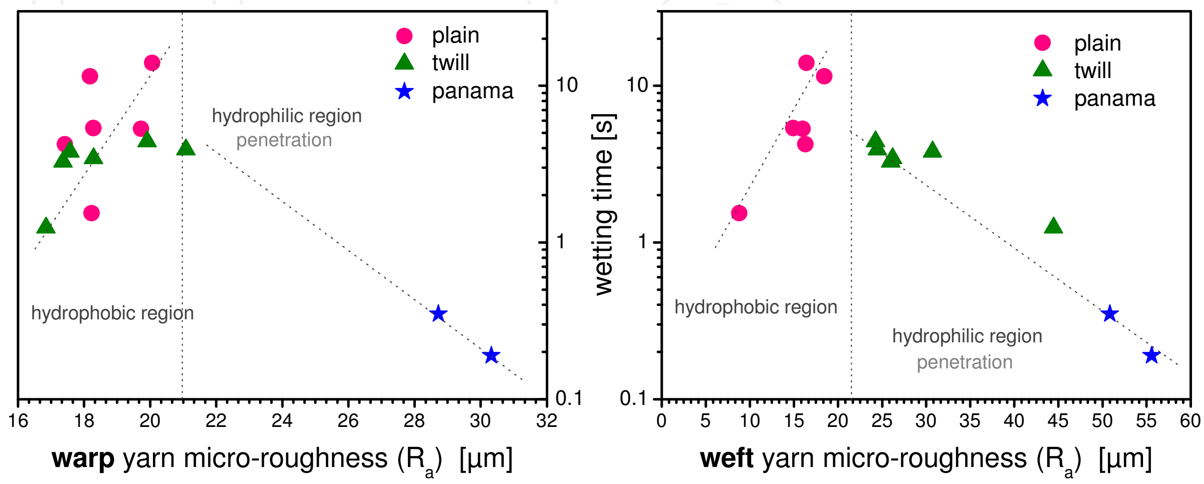


Fig. 14. Liquid flow in warp and weft directions occurs in two different regimes, depending on the micro-topography

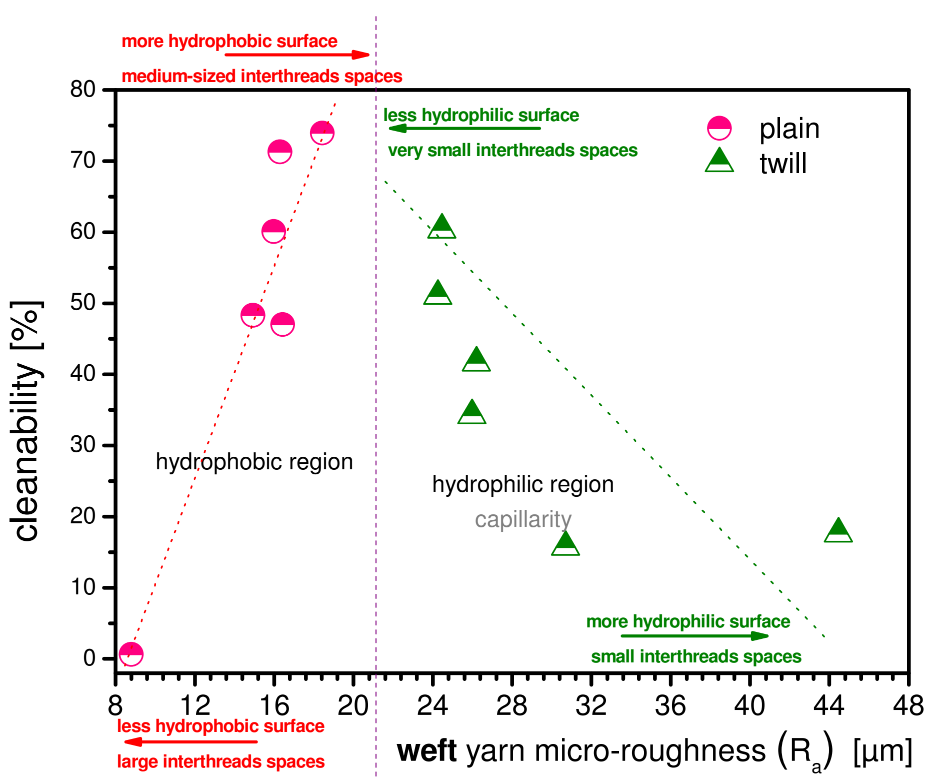


Fig. 15. The conceptual model proposed allows a better understanding of the cleanability phenomenon of polyester fabrics by using a different length scale concept for their characterisation. Soil material: paraffin oil and acetylene black in the ratio 97.98:2.02

3.4 Fibre cross sectional shape and the effect of heat-setting

Hasan et al. (2008), studied warp rib (2/2) fabrics (a derivative of the plain weave) produced using differently profiled polyester filaments – round and cruciform – in a melt-spinning process. The general manufacturing procedure is detailed by Hasan (2007).

Microscopic images of different cross sectional shapes of the fibre manufactured are shown in Figure 16. The fabrics were desized and treated by heat-setting at 190 °C for 10 s after being manufactured. Both modifications – desized with and without heat-setting – were discussed. Figure 17 illustrates different basic weaves used in this study.

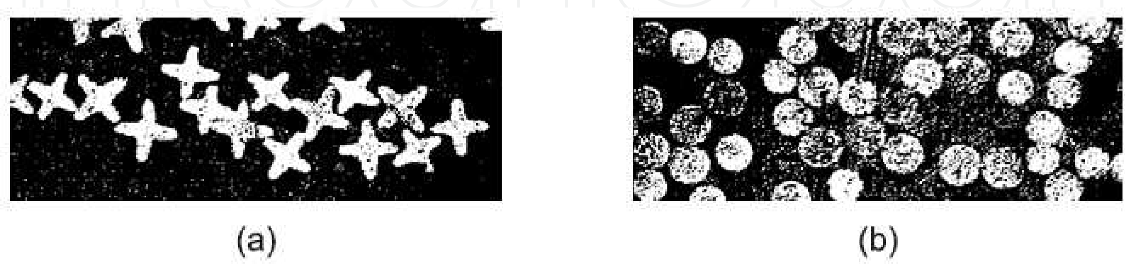


Fig. 16. Microscopic images showing different cross-sectional shapes of the polyester fiber manufactured: (a) cruciform; (b) circle-shaped

Geometric cover factor of the fabrics was calculated using their microscopic images as the ratio of the projected fabric surface area covered by yarns to the total fabric surface area given using the following equation (Sabit, A., 2001).

$$cf = c_w + c_f - c_w c_f$$

where c_w and c_f are the warp and weft cover factor, respectively. The warp cover factor is a product of the warp count and the diameter of warp yarn. Following the same logics, the weft cover factor is a product of the weft count and the diameter of weft yarn. In our calculations, the yarn diameter was replaced by the major axis length of yarn having an ellipsoid form. The relevant topographic characteristics obtained for the fabrics manufactured using differently profiled fibre as well as water contact angle for the fabrics are given in Table 4. For convenience, the fabrics analyzed are specified by identification codes, detailed in Table 5.

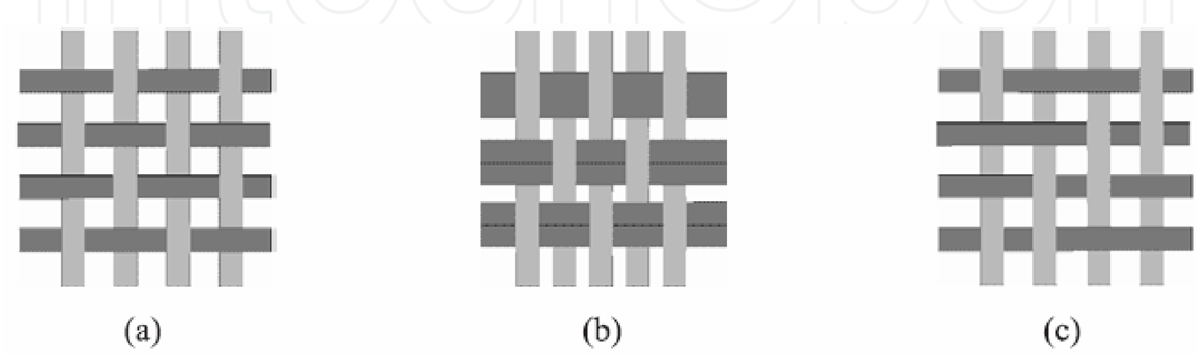


Fig. 17. Basic weaves used: (a) plain weave; (b) warp rip weave; (c) twill

Fabrics identification code	Cover factor	Water contact angle, deg
R-20-D	1.084	113 ± 5
R-30-D	1.017	106 ± 6
R-20-H	1.110	118 ± 6
R-30-H	1.029	117 ± 6
X-20-D	1.032	109 ± 5
X-30-D	0.974	114 ± 4
X-20-H	1.043	119 ± 5
X-30-H	0.998	124 ± 5

Table 4. Geometric factor and water contact angle data

Fibre cross-section	Weft density	Treatment	Fabrics identification code
Round	20/cm	desized heat-setted	R-20-D R-20-H
	30/cm	desized heat-setted	R-30-D R-30-H
Cruciform	20/cm	desized heat-setted	X-20-D X-20-H
	30/cm	desized heat-setted	X-30-D X-30-H

Table 5. Identification code of fabrics.

In contrast to wetting measurements on plain and twill fabrics, woven using commercial multi-microfilament yarn, water drops do not penetrate into the textile surface. No statistically significant changes were found in the wetting behaviour of the fabrics containing round and cruciform shaped fibres (Figure 18). The wettability of fabrics changes

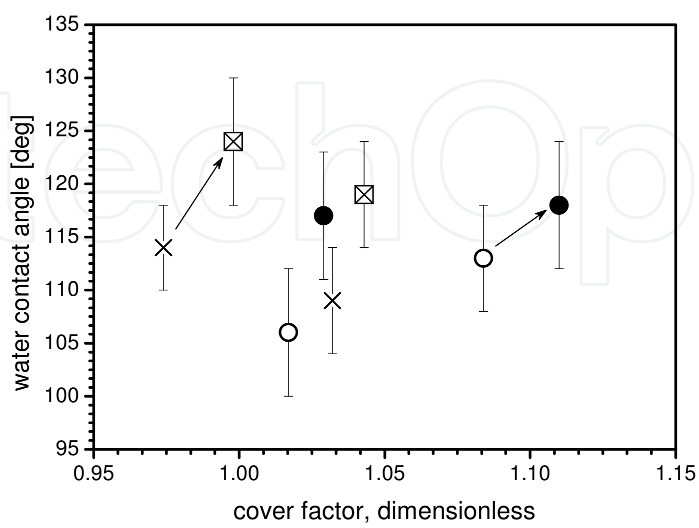


Fig. 18. Water contact angle as a function of the geometric cover factor: (○) round desized without heat-setting (●) round desized with heat-setting; (×) cruciform without heat-setting; (⊠) cruciform with heat-setting.

after their heat-setting. The largest water contact angle of 124° was observed for fabrics containing cruciform fibres with a cover factor that is smaller than that for fabrics with round fibres.

However, no relationship was found between the geometric cover factor and water contact angle. It therefore seems worth pointing out that the geometric cover factor is an idealized effective parameter, which cannot precisely describe the topography of fabrics. On the contrary, surface roughness and waviness can be used to understand the wetting behaviour of liquids on fabrics with a complex structure. A clear linear tendency was found for the water contact angle and surface roughness, as shown in Figure 19, independent of the modification applied.

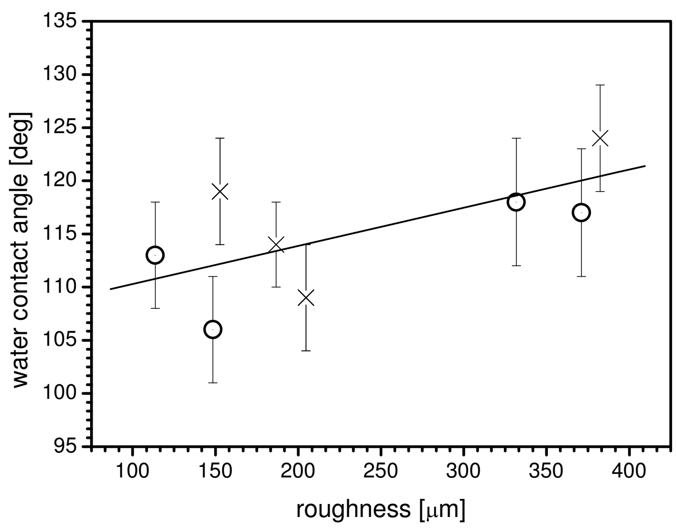


Fig. 19. Water contact angle as a function or roughness (○) round; (×) cruciform

The topography analysis allows filtering measured total profiles of a surface to split them into two analytical representations for displaying surface features: roughness and waviness. The first information represents the shorter spatial wavelengths, whereas the second one represents the longer wavelength features of the surface. Both filtered profiles as well as the schematic of a complex fabric structure are illustrated in Figure 20. Interestingly, surface waviness measured is a function of the geometric cover factor calculated, shown in Figure 21. The fabrics with cruciform fibres have smaller cover factors than those of round fibres. Generally, the maximum cover factor is 1, whereby idealised yarns touch each other. The factor can be larger than 1 if the yarns pile up on top of each other (Sabit, 2001). Real yarns, usually consisting of several single filaments, are flexible and can take different shapes from elliptic to round depending on warp and weft densities. By these means, the appearance of a minimum in the cover factor versus the porosity curve, as shown in Figure 22a, can be explained. A sketch in Figure 22b illustrates possible fabric structures depending on the warp and weft density.

Summarising, by the use of profiled fibres, e.g. the cruciform, the fabric manufacture could lead to a more hydrophobic fabric texture on the basis of different roughness length scales.

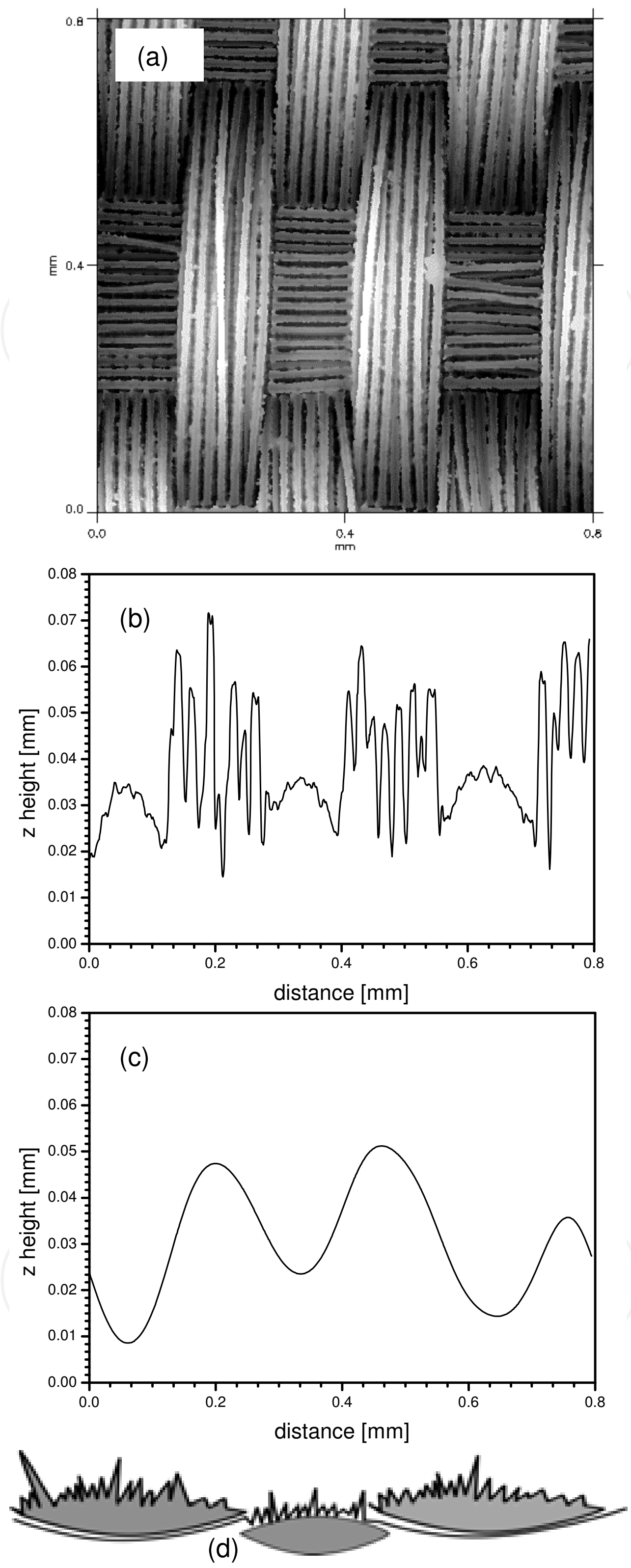


Fig. 20. (a) 2D image of a fabric scanned with chromatic confocal sensor; (b) filtered roughness profile of a plain fabric surface as an example; (c) filtered waviness profile of a plain fabric surface as an example; (d) schematic of a complex fabric structure: the total profile contains both roughness and waviness information

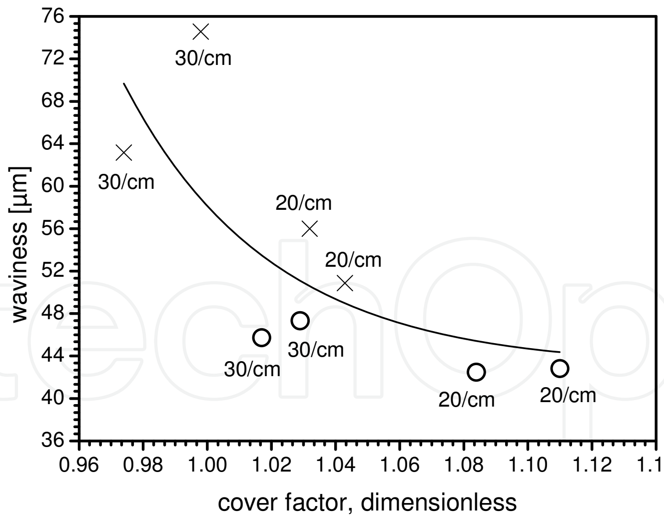
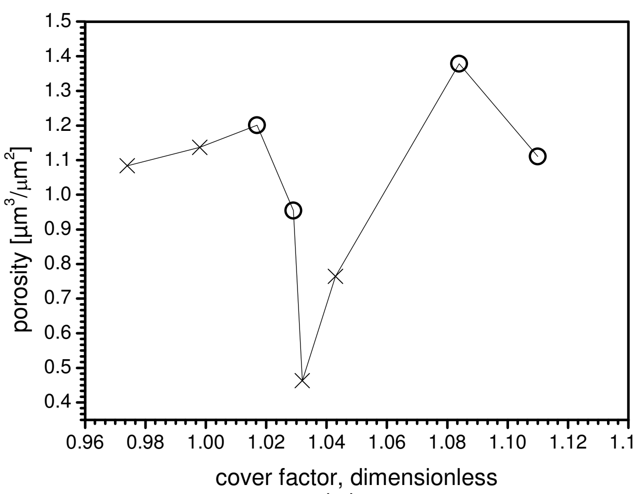
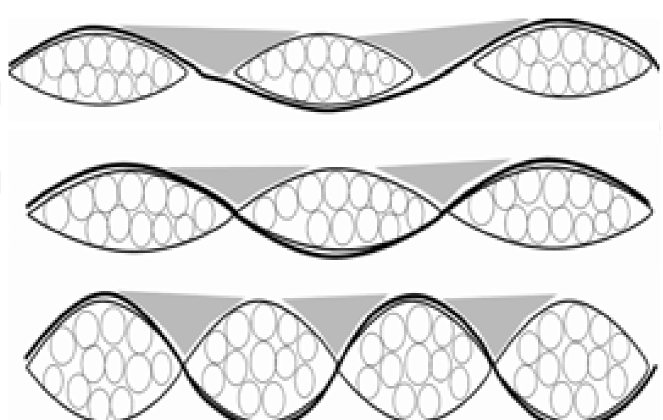


Fig. 21. Relationship between waviness measured and the cover factor calculated: (○) round; (×) cruciform



(a)



(b)

Fig. 22. (a) Fabrics surface porosity measured versus the cover factor calculated: (○) round; (×) cruciform; (b) schematic of differently shaped yarns within a fabric resulting in different surface porosity

Saha (2010) reported the effect of heat setting on the improvement of hydrophobicity of an hydrophobic polyester plain woven fabric, which was heat-setted at 170°C, 180°C, 190°C, 200°C, 210°C, 220°C and 240°C for 60 seconds. According to these results, the effect of thermosetting increased the water contact angle for fabrics thermofixed at 170°C from 113° up to 122° for the thermofixed ones at 200°C (Figure 23). Pilling factor, calculated using mean roughness variations according to Calvimontes (2009), shows a minimum value precisely at 200°C (Figure 24). At this temperature a relative maximum of micro-porosity of warps surface was also found (Figure 25a).

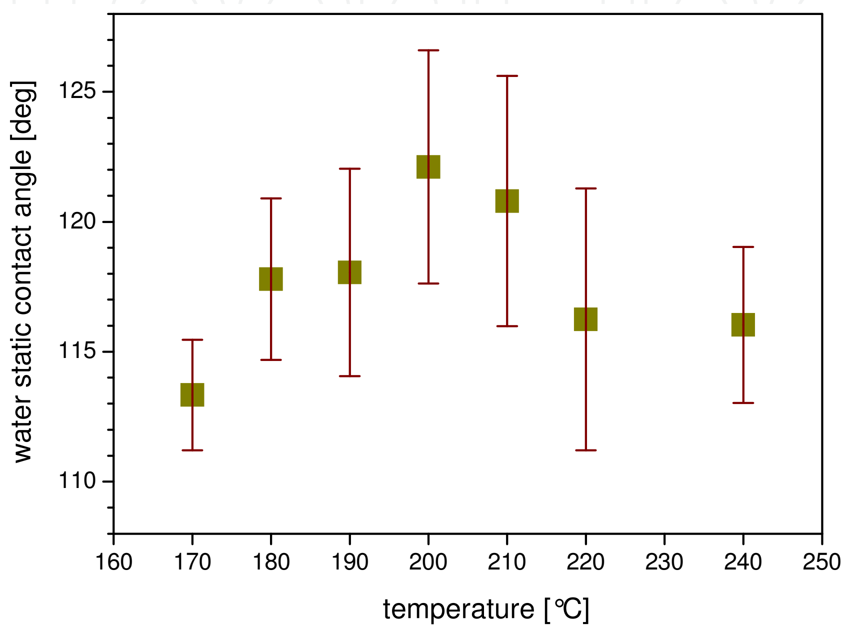


Fig. 23. Water contact angle on thermofixed polyester fabrics

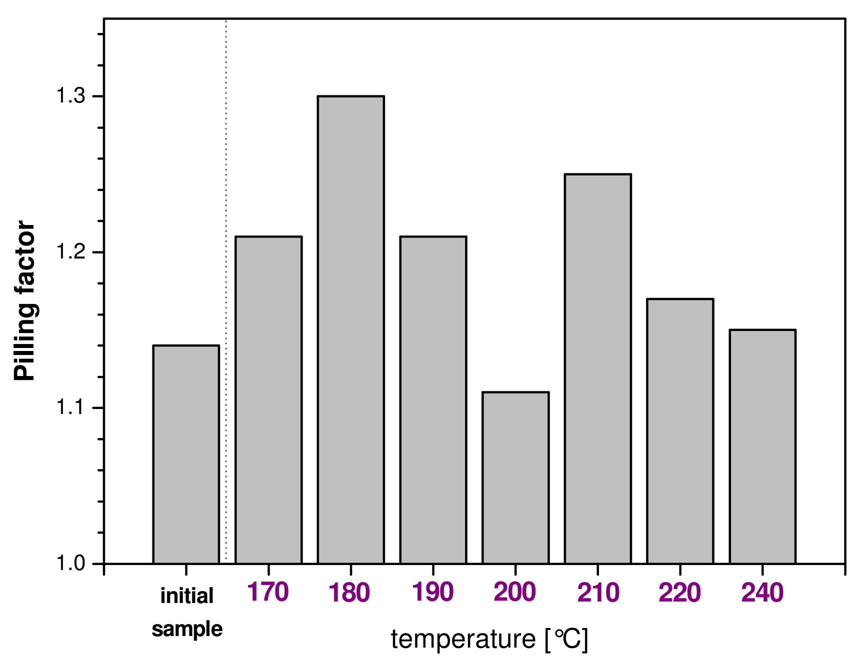


Fig. 24. Pilling factor for thermofixed polyester fabrics

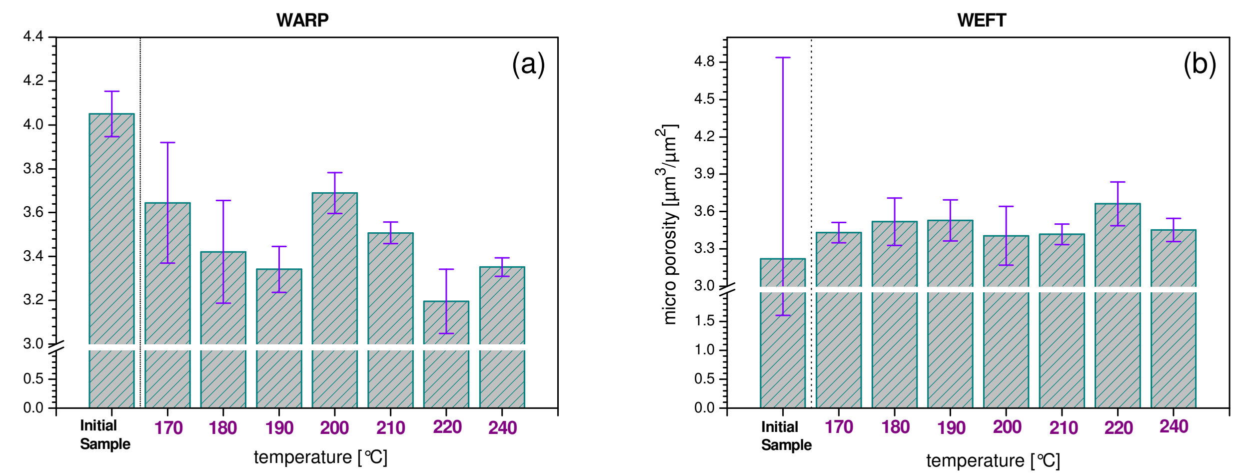


Fig. 25. Micro-porosity of thermofixed polyester fabrics: (a) warps; (b) wefts

On the contrary, the porosity of wefts surface is stabilized by thermosetting (Figure 25b). However, according to that explained previously (Section 2.3), the first contact of any liquid with the fabric surface takes place by the warps, because their higher wave amplitude.

This information allows to conclude that heat-setting smoothes the fabric surface on mesoscopic scale by decreasing pilling, but at the same time, it increases the spaces between warp filaments. The effect is a decrease of the solid fraction –contact area- between polyester fibres surface and water, which, according to Cassie & Baxter (1944), improves hydrophobicity of hydrophobic surfaces.

It was shown in this Chapter, that topographical characteristics of the fabrics strongly depend on their construction parameters such as the type and fineness of filaments, yarn fineness, yarn density, and the type of weave. This characteristics have strong influence on, and in many cases, control the wetting properties.

The topographical study of textile materials using a length scale concept allows to effectively characterize surfaces separately by considering and analyzing their specific morphologies caused by their construction parameters and to successfully find correlations between topography and wettability.

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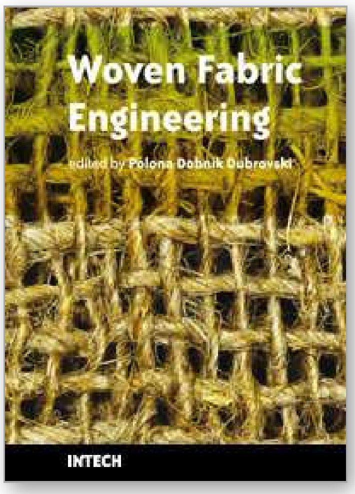
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