3-D Structure Characterisation of the Nonwoven Fabrics by means of an Optical Method

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Abstract: The characterisation of fabric structure by means of quantified parameters is essential for the control of the fabrication processes and the resulting properties of the nonwoven materials. Important parameters of the structure are the porosity, the mean pore size and the pore size distribution, the specific area of the texture, the fibres orientation the last one needing to be characterised in the three dimension of the fabric web. In this research work we intend to evaluate the porous fibres orientation in geotextiles nonwovens using a procedure based on the fibres light conducting and their associated scattering. The interpretation of the phenomena is made through a modelisation concept of the pore fibre interfaces

Keywords: Structure, nonwoven, fibres orientation, optical analysis.

1. Introduction

The physical properties of the nonwovens depend of the nature of the filament or the fibres: their chemical composition, their morphological properties and of the organisation of the fabric structure. This structure depends of the manufacturing processes i.e.: spuned, carded, air or water laid processes either consolidated by polymer latex, thermofusing or needling. The characterisation of the fabric structure by means of quantified parameters is therefore essential for the control of the fabrication processes and the resulting properties of the nonwoven materials.

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In this research work we intend essentially to evaluate the fibres orientation in some geotextiles nonwovens using a procedure based on the nonwoven fibres light conducting and their associated scattering. The interpretation of the phenomena is made on a modelisation concept for the pore fibre interfaces, the Equivalent Conformal Surface. The physical parameters monitoring the light conducting in the nonwoven texture are analysed and the effect of needling intensity and compression of the nonwoven geotextile texture are observed.

2. The Optical Analysis Method

2.1 Principle

Laser beams are utilised for the control of the fibres orientation in planar webs structure and of yarns characteristics in: paper industry [1], [2], textile industry [3], [4], and polymer composite materials [5],[6]. In this research we present the application of the method for three dimensional networks characterisation as nonwoven geotextiles, funding the analysis of the phenomena on a geometrical modelling: the equivalent pore concept [7].

In this process a laser beam is focused on a small area, about 0.3 mm^2, embracing only few fibres at the laser impact point. These fibres act as guides conducting the light. The result of this phenomena is a lateral spreading of the incident light in the different directions, the process been controlled by the jumping of the light rays from fibre to fibre contacts through their crossing areas in the structure. A part of the incident light is transmitted in the web thickness in the direction of the incident light beam from fibre to fibre. These phenomena gives a macroscopic lateral dispersion as well an transmission of the light in the structure (see figure 1).

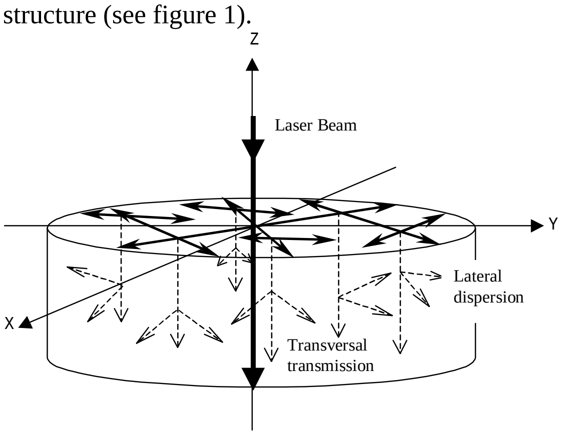

Figure 1. Dispersion and transmission of the light in the Nonwoven structure.

Note that in the case of structure made with fibres the spreading of the light is privileged along the fibres axis making possible to reveal the anisotropic distribution of the fibres in the different directions of the space. The shape pattern of the illuminated area at the impact plane of the laser beam can be observed by the light transmitted through the texture: it is interpreted to give the fibre distribution in this plane.

By the stereometry properties of polyphasic structures [8] we know that the mean number of interfaces between pores and particles intercepted per unit of length in any direction of a porous media is equal to the specific surface area projected on the plane perpendicular to the choosen direction. This property, as it has been advanced by one of us [9], can be used to identify an Equivalent Conformal Surface able to represent the fibre orientation distribution for the porous texture. An ellipsoidal surface fits most of the fibre distributions encountered in practice making easiest the recognition of the anisotropy parameters of the texture by an analysis along the mains axis, i.e., the maximum, medium and minimum fibre orientation of the fabric. As an example of these properties we show the light shape patterns as they appear at the verso of an illuminated geotextile fabric when the laser is impinging along the thickness (a), the machine direction (b) and the cross direction (c) of the fabric.

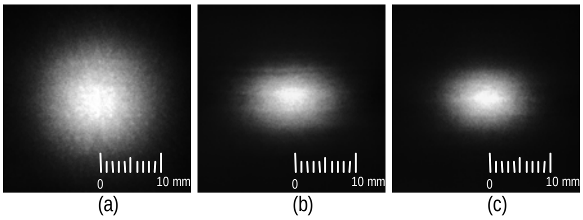

Figure 2. Light patterns for a laser impinging a) along the thickness, b) along the machine direction, c) along the cross direction (N3-400-150 geotextile fabric).

2.2 Hardware and analysis process

We use an experimental optical bench with a collimated He-Ne laser beam of 10 mW and a microscope objective (*L*) to focus the laser beam on the sample surface using micrometers devices (see figure 3).

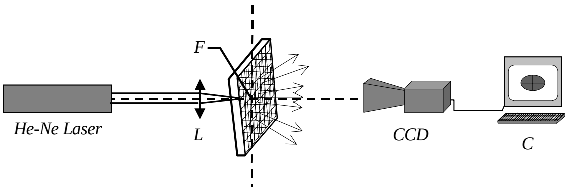

Figure3. Experimental apparatus for light transmission analysis.

A solid state detector (*CCD*) captures the image on the other side of the sample. The image is acquired and stored on a computer (*C*) in order to perform the analysis.

The method of analysis [10], comprises the following steps:

- Location of the investigated area of the sample at the focus (*F*) of the laser beam.
- Find the best of an equi-intensity curve contour, for computing the shape of the transmission pattern.

2.3 Influence of the sample thickness on the size of the optical pattern

The size of the optical pattern depends of the volume intercepted by the light for the scattering. In the case of thinner samples the extension of the pattern is lesser than for the largest one. The figure 6 shows this effect for two thicknesses of geotextiles with the same needling density but basis weights in a ratio of 2:1.

If the thickness is large the attenuation of the light intensity in the direction of the observation increases, inhibiting the detection of the phenomena. An optimum thickness exists therefore for the light pattern detection.

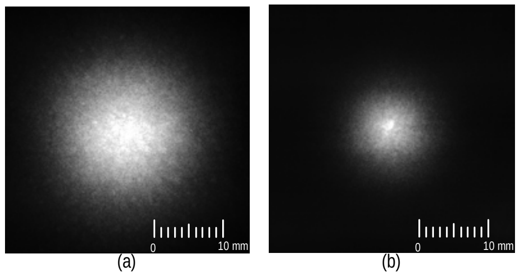

Figure 6. Influence of the sample thickness on the size of the optical pattern (a) N3-400(g/m^2)-150, (b) N3-200(g/m^2)-150 geotextile fabric.

2.4 Influence of the fibre diameter on the light intensity pattern

The intensity of the light dispersion in the fabric depends of the probability of the fibres intercepted by the light guide fibre and the probability for the light to be refracted inside the light guide (see figure 4).

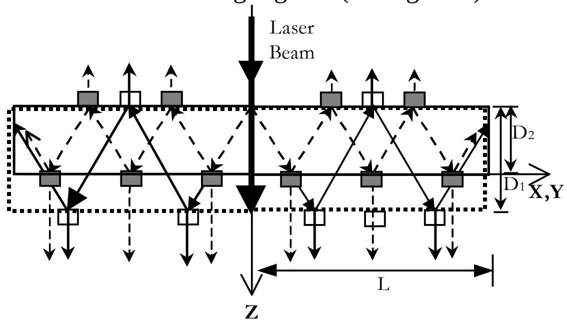

Figure 4. Probability of the lateral and transversal light dispersion for fibres of different diameters: example, if $D_1 > D_2$ $\left(P_{LD_1} / P_{LD_2} \right)_{lateral} = 3/5$.

Both probabilities are inversely related to the fibre diameter. In that conditions the dispersion of the light is favoured for the fabrics with small fibre diameters. We can control this effect observing the optical patterns in the case of geotextiles N3dtex-400-150 and N6dtex-400-150 (see figure 5).

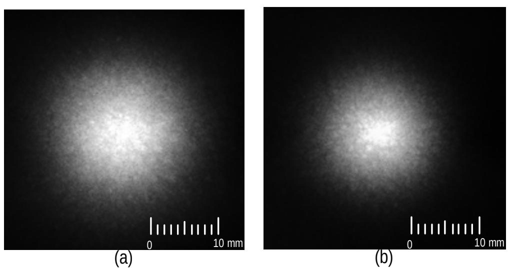

Figure5. The influence of fibres diameter on the size of the optical pattern for a) N3dtex-400-150, and b) N6dtex-400-150 samples.

3. Analysis of geotextile samples

3.1 Presentation of the samples

In figure 7 we present the in plane view of a needlepunched geotextile (N3-400-150) with the corresponding light scattered pattern superposed and in figure 8 an enlarged in plane view of the same geotextile. For the lateral and longitudinal analysis, the samples were cutted in small ribbons of 4-mm thickness and piled in stack.

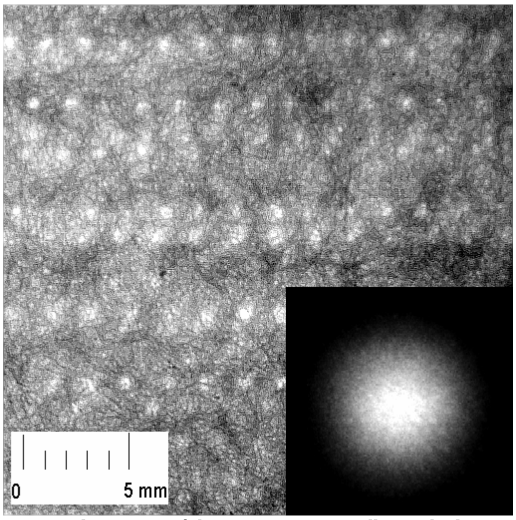

Figure 7. In plane view of the N3-400-150 needlepunched geotextile with the corresponding light scattered pattern superposed.

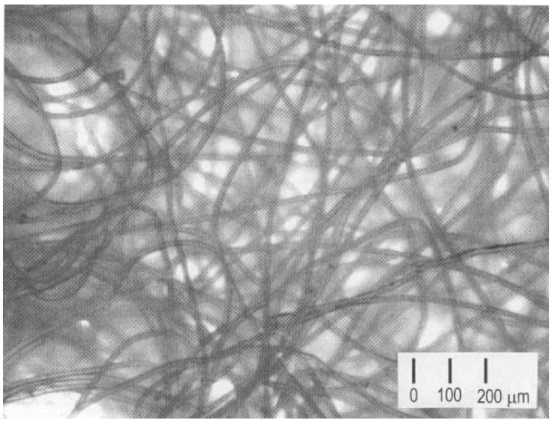

Figure 8. Enlarged in plane view of the N3-400-150 needlepunched geotextile.

4. Discussion of the results

We have summarised the textural characterisation of the samples for different compressure sates, see table I. The determination of the parameters of ellipticity which characterise the fibre orientation in the three dimensional space are listed in table II.

Due to the laser beam diameter, it is possible to avoid the direct show through the needlepunched holes.

As it can be observed these geotextiles have a light anisotropy of the fibres distribution in the plane, as it is revealed by the value of the ellipticity: a/b ≅ 1.075. The cross direction of the webs looks the more orientated. The transversal direction of the web texture is more anisotropic a/c ≅ 1.48, and b/c ≅ 1.39 in the machine direction. The combining of these two values gives a computed ellipticity in the plane of a/b ≅ 1.07, which is close to the directly measured one. This proves the validity of our concept of modelling for this optical analysis.

The level of compressure has an effect on the transversal anisotropy. In most of the cases the ellipticities a/c and b/c increases with the level of compaction.

Sample	Basis Weight (g/m2)	Transversal compressure (%)	Thickness (µm)	Porosity	Mean pore medium chord (µm)
		0	4950	0.926	305
N6-400-150	387	59	2100	0.829	114
		64	1670	0.781	84
		71	1430	0.746	69
		0	3500	0.922	278
N6-400-500	291	59	1500	0.818	106
		64	1250	0.780	83
		71	1000	0.724	62
		0	6250	0.949	309
N3-400-150	336	59	2700	0.888	125
		64	2331	0.864	106
		71	1857	0.829	81
		0	3480	0.944	280
N3-400-500	209	59	1450	0.865	106
		64	1250	0.843	88
		71	1000	0.804	68
		0	3380	0.96	348
N3-200-150	144	59	1430	0.905	158
		64	1225	0.889	133
		71	975	0.862	104
		0	2950	0.948	303
N3-200-500	164	59	1280	0.880	122
		64	1094	0.860	102
		71	875	0.823	77

Table I. Textural characterisation of the samples. Reference code: N6 dtex, 400 g/m^2, 150 needling density (p/cm^2).

Sample	Transversal compressure (%)	Anisotropy		a/b Computed MD / CD	a/b Measured
		MD a/c	CD b/c		
	59	1.35	1.27	1.07	
N6-400-150	64	1.41	1.31	1.08	1.07
	71	1.48	1.39	1.07	
	59	1.38	1.28	1.08	
N6-400-500	64	1.45	1.32	1.10	1.08
	71	1.51	1.40	1.08	
	59	1.55	1.51	1.03	
N3-400-150	64	1.51	1.45	1.05	1.06
	71	1.52	1.47	1.04	
	59	1.50	1.47	1.02	
N3-400-500	64	1.53	1.42	1.08	1.08
	71	1.56	1.43	1.09	
	59	1.45	1.42	1.01	
N3-200-150	64	1.44	1.36	1.05	1.08
	71	1.47	1.40	1.05	
	59	1.46	1.42	1.03	
N3-200-500	64	1.40	1.35	1.04	1.09
	71	1.42	1.35	1.05	

Table II. Geotextiles anisotropy parameters: a/c, b/c, a/b, respectively measured along the MD, CD and fabric thickness (mean value for 6 determination each).

The needling density, from 150 to 500 p/cm^2, affects slightly the transversal anisotropy. The fibres anisotropy looks a little bit lesser with the increase of the punching as it can be observed in the CD measurements for the 3 dtex fibres geotextiles. The high basis weight, 400 g/m^2, is more affected than the light one (200 g/m^2).

5. Conclusions

The characterisation of the fibres orientation of geotextiles nonwovens fabrics is possible in a three dimensional analysis by optical methods using a laser light beam dispersed by the web.

The anisotropy of the structure is defined by the parameters of ellipticity in reference to an Equivalent Conformal Surface of the web texture.

By this method we have observed the effect of the web compressure and the needling density. Correlation of the textural characterisation of the nonwoven fabric with their processes of manufacturing and end-uses are very promising and it will be explored in our futures researches.

Acknowledgement

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