Characterization on pore size of honeycomb-patterned micro-porous PET fibers using image processing techniques

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REZUMAT – ABSTRACT – INHALTSANGABE

Caracterizarea mărimii porilor la fibrele PET microporoase cu structură tip fagure, prin utilizarea tehnicilor de prelucrare a imaginii

Lucrarea prezintă o metodă de caracterizare a structurii porilor de suprafață ai fibrelor PET cu structură tip fagure, prin utilizarea microscopiei electronice cu scanare (SEM) și a tehnicilor de prelucrare a imaginii. Ei se constituie în pori cu caneluri lineare și pori tip elipsă. Distribuția porilor de suprafață și numărul de micropori variază de la o fibră la alta, ceea ce poate determina diferențe semnificative ale proprietăților firelor filate. Se propune o clătire suficientă, cu apă curată, a fibrelor, anterior proceselor de deshidratare și fixare, în vederea eliminării efectului de supraîncărcare/înfundare a porilor.

Cuvinte-cheie: morfologie de suprafață, pori cu canelură lineară, pori tip elipsă, tehnică de prelucrare a imaginii

Characterization on pore size of honeycomb-patterned micro-porous PET fibers using image processing techniques

This paper presents a method to characterize the pore structure of the fibre surface for the honeycomb-patterned PET fibers, by using a scanning electron microscopy (SEM) and image processing techniques. They consist of linear channel pores (LCP) and ellipse pores (EP). The surface pore distribution and micropore numbers varied from each fiber to another, which can make significant differences on the property of the spun yarns. It is proposed that the fiber should be sufficiently rinsed with clean water before dewatering and setting processes, to eliminate the pore-clogging effect.

Key-words: surface morphology, linear channel pore, ellipse pore, image processing technique

Die Charakterisierung der Porengrösse bei den mikroporösen PET-Faser mit Wabenstruktur, durch Benutzung von Bildbearbeitungstechniken

Die Arbeit stellt vor eine Charakterisierungsmethode der Struktur der Oberflächenporen der PET -Faser mit Wabenstruktur, durch Benutzung von elektronischen Mikroskopie mit Bildaufnahme (SEM) und Bildbearbeitungstechniken. Sie sind Poren mit linearen Rillen (LCP) und ellypsenartige Poren (EP) bestehen. Die Verteilung der Oberflächenporen und die Anzahl der Mikroporen schwankt in Abhängigkeit der Faser, was zu wesentlichen Unterschiede der Spinnfaseregenschaften führen kann. In diesem Sinne wird vor den Prozessen für Entfeuchtung (Trocknung) und Fixierung, eine ausreichende Spülung mit reinem Wasser der Faser für die Absonderung des überporositätefektes (Porenanhäufung), vorgeschlagen.

Schlüsselwörter: Oberflächenmorphologie, Porengrösse, Poren mit linearen Rille, ellypsenartige Poren, Bildbearbeitungstechniken

Sportswear, in particular, needs to absorb water and moisture after intense exercise. Synthetic fiber without such function is not suitable for sportswear because of stuffiness and stickiness. For this reason, the development of a functional synthetic fiber with water transport and quick dry properties was a major objective over a long period. At present, two approaches can be used to make these functional fabrics. One method to produce such fabrics is using profiled fibers, which can be achieved by using spinning boards with specially designed nozzles. The profiled fibers, such as tetra-channel fiber *Coolmax*, by DuPont (Kajiwara et al., 2000), are mainly used in the market worldwide to produce moisture absorption and quick dry fabrics. The air trapped inside the hollow channel fiber is deemed as a kind of thermal insulating material, which reduces the weight of textiles and keeps the human body warm (Jackson et al., 1994; Dave et al., 1987; Hu et al., 2005). The second approach is using the micro-porous fibre, such as porous hollow fiber *Wellkey*, by Teijin (Wang et al., 2009). Hundreds of thousands of micro pores run through both inside of the fiber and on the surface, which can be treated as a major way to transport water and transfer the moisture vapor.

Previous studies devoted to developing methods of measuring pore characteristics can be found in many porous media fields. The pore structure analysis was reported by using various micro porous techniques, such as the scanning tunneling microscopy – *STM* (Vignal et al., 1999), scanning electron microscopy – *SEM* (Oshida et al., 1995), transmission electron microscopy – *TEM* (Oshida et al., 1995; Yoshizawa et al., 1998) and other normal optical microscopy (Oshida et al., 1996). Fatt introduced the model of porous media in the rock science (Fatt, 1996). Lot of works were down also in the same rock field (Bakke et al., 1996; Blunt et al., 1991; Delerue et al., 2002, 1999; Hidajat et al., 2002). The pore size distribution and modeling were studied also in nonwoven and membrane fields by using image processing techniques (Zeng et al., 2000; Dimassi et al., 2008). However, the image processing technique applied to such a honeycomb-patterned micro-porous fiber has not yet been reported.

The objective of this study is to use the SEM and image processing technique to measure the pore size of the honeycomb-patterned micro-porous polyester fiber. Four parameters are proposed in this paper to characterize the fiber pore size property. Furthermore, the frequency histogram pictures for the four parameters are also presented and analyzed. Finally, some conclusions and suggestions are projected.

METHODOLOGY

The fibers were observed under a JSM-5610 scanning electron microscopy (JEOL, Japan). It was observed

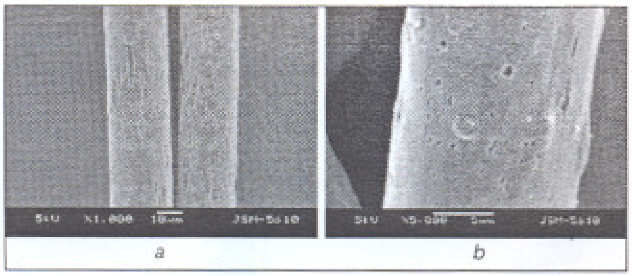

Fig. 1. Linear channel pores (LCP) and ellipse pores (EP):
a – LCPs on the fiber surface; *b* – EPs on the fiber surface

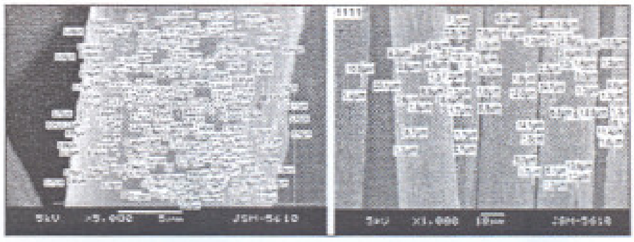

Fig. 2. The pore sizes on the fiber surface measured by JEOL SmileView software

that there are mainly two kinds of pores on the fiber surface. One type of pores have long channels, which are so called linear channel pores (LCP); another type of pores have an ellipse shape, which are called ellipse pores (EP), as seen in figure 1. These two types of pores greatly increased the fiber specific area, so the water transport property of fiber assembles is highly enhanced.

It was assumed that each pore on the fiber surface is flat and has a certain depth. Hence, the external shape of these two types of pores can be marked in yellow color by the Paint drawing tool (Microsoft). The JEOL SmileView software (JEOL, Japan) was then used to measure the size of the yellow marked pores. The major diameter D_m, minor diameter D_{mi} of the pore, the ratio of the major and minor pore diameter R, and the pore surface area S_p were used to characterize the size properties of pores on the fiber surface. For LCP, the shape is deemed as diamond-patterned, and then the pore surface area can be calculated by:

$$S_{LCP} = ab \tag{1}$$

where:

S_{LCP} is the pore surface area, μm^2;

a – the major diameter of the pore, μm;

b – the minor diameter of the pore, μm.

For the EP, the surface area *SEP* of a pore on the fiber surface can be expressed as

$$S_{LCP} = \pi ab/4 \tag{2}$$

The SEM images after the size measurements are presented in figure 2.

RESULTS AND DISCUSSION

The results of maximum, average, and minimum values for the four parameters of the LCP and EP are listed in table 1. It was found that the ratio R for LCP is about 3 times higher than that of the EP. For the pore surface area, the averaged value for the LCP is about 62 times that of the EP. Hence, EP on the fiber surface should be amplified to 5,000 times, under a SEM, in order to get an enough clear image.

Three hundred and four measurements were obtained for the LCPs. The frequency histogram pictures were drawn by using the SPSS software, as shown in figure 3. It was found that the major diameter of the LCP has a large distribution, i.e. varied from 1 to 24.70 μm. However, most of the values of the D_m are ranged from 1.67 to 6.67 μm. The minor diameter D_{mi} has a good centralization, about 85% of values ranged from 0.5 to 1.3 μm. For the pore area S_p, it has a standard deviation of 8.093, which showed that values varied a lot. This was mainly due to the larger distribution of the D_m values. The major/minor diameter ratio R was found above 1.67, which proved that the LCPs have long and narrow channels on the fiber surface.

Similarly, three hundred and ten measurements were obtained for the EPs on the fiber surface.

The frequency histogram pictures for the major diameter, minor diameter, ratio of major/minor diameter and the surface area were also drawn, as seen in figure 4.

It can be easily found that the standard deviations of D_m, D_{mi}, R, S_p for EP were 0.335, 0.260, 1.046 and 0.144 respectively, which are much smaller than the values of the LCPs. Hence, EPs have good centralization on those four parameters compared with the LCPs. The majority of D_m values for the EP were ranged from 0.25 to 0.67 μm. For the minor diameter D_{mi}, the main averaged range was from 0.10 to 0.37 μm. Comparing the pore size areas of the EPs with those of the LCPs, EPs have only 1/80 to 1/58 of the LCPs pore area. Thus, EPs are much smaller than the LCPs, which have close to circular shapes on the fiber surface, other than the linear channels for the LCPs.

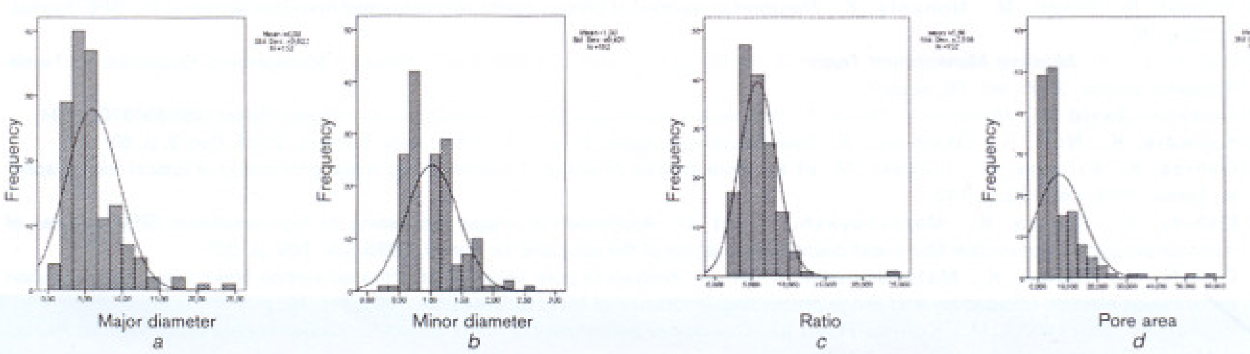

Fig. 3. The frequency histogram pictures of D_m, D_{mi}, R, S_p of LCPs:
a – the major diameter; *b* – the minor diameter; *c* – the ratio of major/minor diameter; *d* – the pore surface area

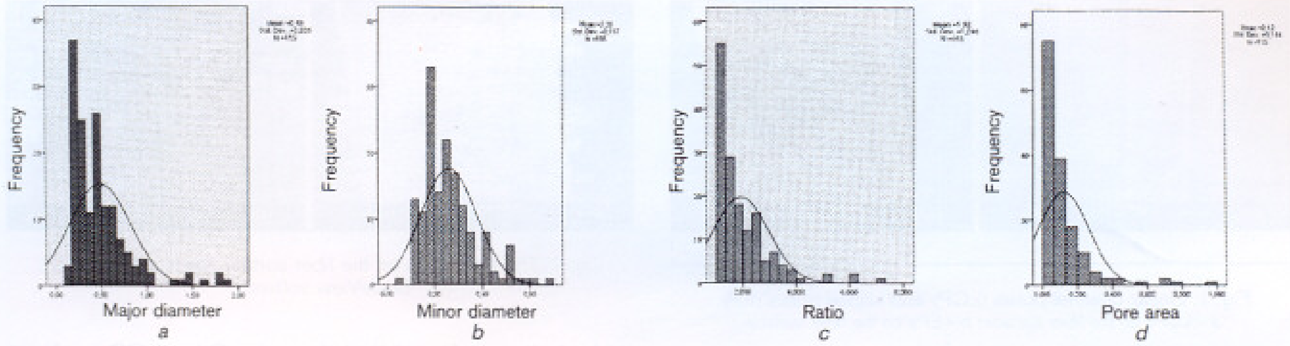

Fig. 4. The histogram pictures of D_m, D_{mi}, R, S_p of ECPs:
a – the major diameter; *b* – the minor diameter; *c* – the ratio of major/minor diameter; *d* – the pore surface area

Table 1

Parameters	Values for LCP			Values for EP		
	Max.	Mean	Min.	Max.	Mean	Min.
D_m, μm	24.70	5.99	1.00	1.84	0.49	0.14
D_{mi}, μm	2.60	1.03	0.20	0.68	0.26	0.04
R	24.50	5.82	1.67	7.25	1.88	1.00
S_p, μm²	56.81	6.18	0.60	0.98	0.099	0.0075

Since the pore size of the EP was relatively small, it is suggested that the fibers should be rinsed sufficiently to prevent the pore clogging during the whole further finishing process.

CONCLUSIONS

This paper presents a method for the pore size measuring of the honeycomb-patterned microporous PET fiber. The pore size was measured and analyzed by a JEOL 5610 SEM and the SmileView image processing software. It was found that the micro pores could be classified into two types, LCP and EP. For the LCP, the averaged major and minor diameters were 5.99 μm and 1.03 μm, respectively. EPs have a good centralization on the fiber surface, as compared to the LCPs, of which the averaged major and minor diameters were 0.49 μm and, respectively, 0.26 μm. It was also found that the pore size distribution varied a lot for each fiber, which may cause the yarn strength varied from each other. Further studies should be paying more attention to the effect of the pore distribution on the yarn strength.

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NOTE ECONOMICE

CREȘTERI PE PIAȚA TEXTILELOR TEHNICE DIN S.U.A.

În anul 2009, din cauza recesiunii globale, vânzările de textile, din S.U.A., au scăzut cu 6,3%, iar exporturile cu 23%. Acest domeniu cuprinde cca 7 000 de companii, cu 1 500 de furnizori de fibre, fire și materiale și distribuitori de echipamente și servicii și 5 500 de fabricanți de produse finite. Valoarea acestor produse textile a fost în 2009 de 27,8 miliarde de dolari, iar în 2010 se estimează a fi de 26,8 miliarde de dolari. Datorită faptului că cererile armatei se mențin considerabile, din cauza conflictelor din Afganistan și Irak, acest sector a înregistrat o creștere de 10% – în anii 2008–2009, prin cele 190 000 de corturi necesare anual și cele 575 000 de seturi de echipamente individuale de protecție, destinate atât armatei, cât și forțelor de aplicare a legii. Prin amendamentul Berry se solicită fabricarea, în S.U.A., a 100 de produse pentru acest sector. Recenta rectificare Kissell a extins această solicitare și în cadrul sectorului de securitate internă și de pază a coastei.

În industria geosinteticelor din S.U.A., în care activează peste 50 de companii și care se ridică la o producție anuală de 800 de milioane m^2 de material, s-a înregistrat o creștere de 5–6%, în 2008, rămânând constantă și în 2009. Pentru piața structurilor tehnice textile, IFAI prognozează o scădere cu 5–10%.

Piața materialelor destinate industriei constructoare de mașini a scăzut cu 35%, în ultimii doi ani, fiind afectată în mod direct de scăderea vânzărilor la mașini. Piața articolelor pentru timp liber și recreere înregistrează un declin de 40% în sectorul construcțiilor de ambarcațiuni și de 15–20% în cel al umbrarelor și baldachinelor rezidențiale.

Potrivit previziunilor IFAI, materialele geosintetice, militare și de protecție, dar și cele medicale, de grafică digitală, textilele inteligente și cele ecologice din S.U.A. vor înregistra, în următorii ani, procente de piață în creștere, prin intermediul a trei materiale de bază – tricoturi din urzeală, materiale compozite și textile nețesute.

Smarttextiles and nanotechnology, decembrie 2009, p. 12