Study of some Nonwoven Parameters Influence on the Absorption Kinetics of Liquid

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Abstract: Absorbent products, incontinence pads and baby diapers are among the nonwoven end-use applications that are influenced by the structural characteristics of nonwoven materials. These characteristics include porosity, pore-size distribution and contact angle. This paper discusses the influence of these parameters on absorption kinetics, which is considered as a functional property when nonwovens are used as cover stock in hygienic products. The impact of these parameters on the kinetics of absorption has revealed that the behaviour of this functionality is driven by the contact angle, which reflects the hydrophilic state of the structure and also depends on pore size dimension. Moreover, a good performance can be accomplished if we combine and optimise these parameters.

Keywords: Nonwovens, kinetic of absorption, porosity, pore size distribution, contact angle.

INTRODUCTION

About 33% of nonwoven products are used in hygienic applications [1]. Disposables articles for hygienic care should offer excellent absorbency as well as comfort. There are many requirements facing the producers of nonwoven fabrics. The final product must combine all necessary functions, i.e. fluid acquisition, distribution and retention. Fig. (**1**) shows the anatomy of a diaper where the key requirement for nonwovens at the cover sheet is its ability to imbibe rapidly and hold large amount of fluid under a pressure. Absorbency rate and absorbent capacity have been regarded as the most important features desired by consumers in a disposable diaper. The absorbency rate is governed by the structure of the fabric (i.e., the pores size and the orientation of fibres). In addition to those factors, the wetting surface characteristics (contact angle) of fibres in the web and the structure are the most important [2-4].

Research in absorbency has focused on examination of the effect of various factors and the development of structural models to predict the values of the absorbency rate and the absorbent capacity [5].

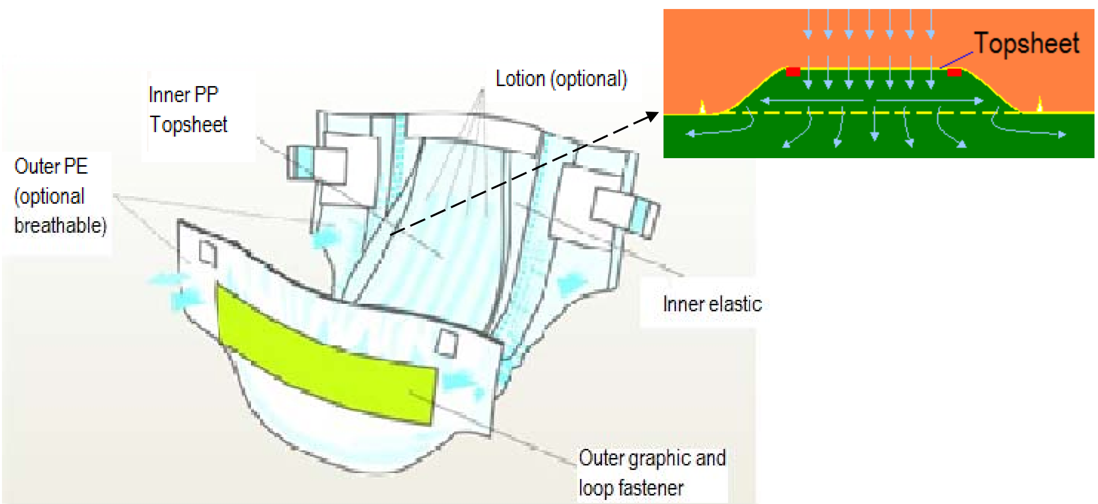

Fig. (1). Schematic overview of a modern disposable diaper.

Fryer and Gupta tried in their study to determine the pore size distribution, the pore property changes and the impact of pore structure on absorption [6]. Konopka and Pourdeyhimi planned to explore the manner in which fluids flow through nonwovens and developed a framework for the prediction of wicking by considering the fibre orientation and the anisotropy of the nonwoven webs [7].

In order to understand more about the structure influence on nonwoven performance, it is essential to optimise the nonwoven structure (fibre, porosity, pore size distribution) [8, 9]. Thus, some relationships between structure and

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nonwoven functional properties (absorbency rate, strike through time, kinetics of absorption) can be established [10, 11]. In this regard, this paper explores the relationships between the structural parameters and the absorption kinetics measurements of nonwoven fabrics. First we were essentially interested in characterising the nonwovens by determining their porosity and pore size distribution. Also, we took into account the measurement of their contact angle to estimate the hydrophilic character of nonwoven webs.

MATERIALS AND METHODS

Nonwoven Characteristics

We investigated three different kinds of nonwoven fabrics, commonly used in baby diapers. The first is a carded (C) thermobonded polypropylene web. The second is a point bondedspunbonded-meltblown-spunbonded (SMS) polypropylene nonwoven and the third a point spunbonded (S) polypropylene nonwoven. The webs have a weight ranging from 15 g/m² to 23 g/m² and a thickness ranging from 0.1 to 0.2 mm. All these fabrics were subject to hydrophilic treatment.

For these webs, we will adopt these notations which refer to weight/nonwoven type/producer, respectively.

Table 1. Notations Adopted for Nonwovens

Parameters	Notations
Weight (g/m²)	15
	16
	17
	22
	23
Nonwoven type	C
	SMS
	S
Producers	Dounor: P1
	Fiber web: P2
	Sâaf: P3
	Saudi German: P4
	Pegas: P5

EXPERIMENTAL

Nonwoven Characterisation

The Image Analyses and Processing

Porosity (ε) is simply the fraction of the volume occupied by pores.

$$\varepsilon = \frac{V_p}{V}$$

where V_p is the total pore volume and V is the volume of the structure. Image analyses are applied to determine porosity and pore size distribution. The device used to capture images consisted in a Motic digital microscope DM-143 used to magnify the web structure (magnification: 40 times) and a computer to conduct image analyses. The sample was illuminated to improve the resolution. As the nonwoven used were too thin (between 0.1 and 0.2 mm), the web structure can be regarded as being two dimensional.

The captured images possess 256 shades of gray. A grey scale image needs to be transformed into various forms to meet the requirements of applying different techniques. Fig. (**2**) shows the major procedures of image transformation. Some of image filtering processes were performed. Both median and morphological filter were used to reduce noise. The image sharpening process was conducted to distinguish the surface fibres from the background one (Fig. **2b**). The resulting images were divided into two parts such as surface fibre and the rest. The obtained fibre images were converted to binary image by comparing intensities with its mean intensity pixel by pixel (Fig. **2c**). The porosity as well as pore size distribution were measured and recorded with a programmed software.

Fig. (2). Image transformation process to nonwoven image: (**a**) original image, (**b**) filtered image and (**c**) binary image.

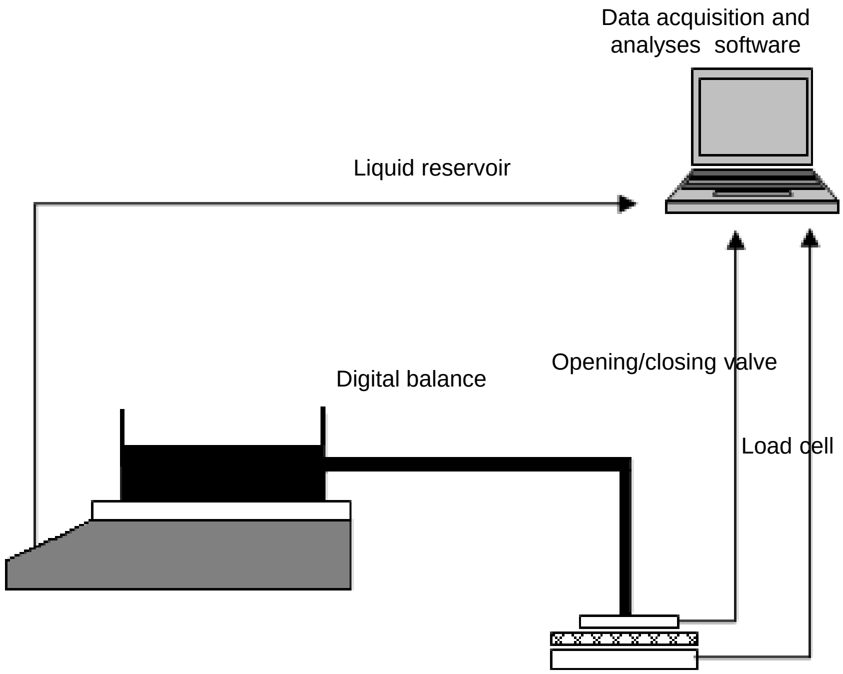

Fig. (3). Schematic diagram of absorption kinetics measurement.

Contact Angle Measurement

When water is used as a liquid to measure contact angle, we can evaluate the hydrophilic state of the fabric. The experimental device is a DIGIDROP Contact Angle Meter from GBXotog Scientific Instrument.

Absorption Kinetics

The principle of absorption kinetics measurement is based on mass variation of the absorbed solution by the sample as a function of time. In fact, the tested sample is placed automatically under a pressure of 0.7 psi when we start off the system (rise of the load cell). Then a fixed volume of 20 mL is absorbed and absorbed quantity evolution as a function of time is recorded (Fig. **3**).

Absorption kinetics for different webs was achieved on samples that had the same absorbent core in order to limit the factors which can affect the absorption kinetics behaviour. Tests were performed at ambient temperature.

RESULTS AND DISCUSSION

Absorption kinetics was measured to evaluate the capacity of the surface layer of nonwoven to transfer the liquid through the effective storage layer (absorbent core).

For each sample of nonwoven, the measurements of absorption kinetics were conducted three times; different values recorded a standard deviation about 3%.

Fig. (**4**) presents the results. Various factors affected the values for absorption kinetics. Fig. (**5**) shows the values of

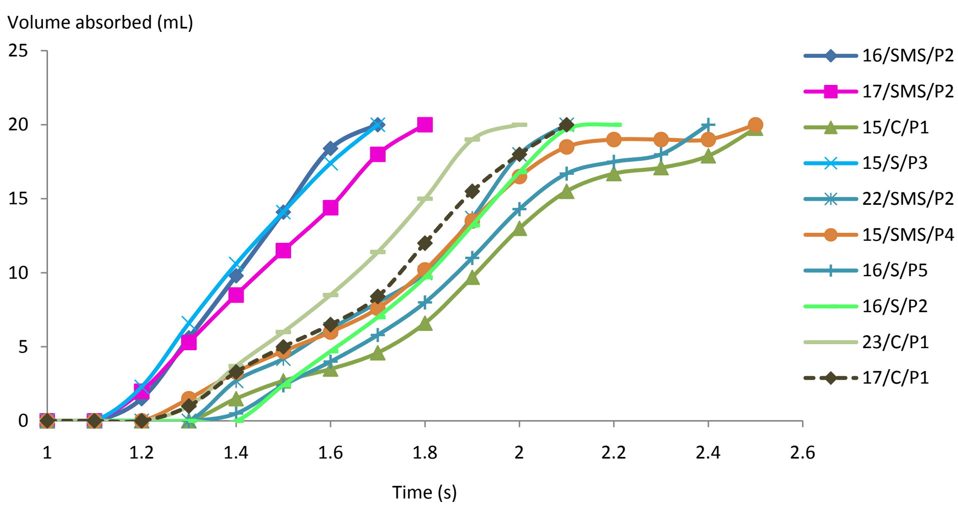

Fig. (4). The absorption kinetics performance for different nonwoven fabrics.

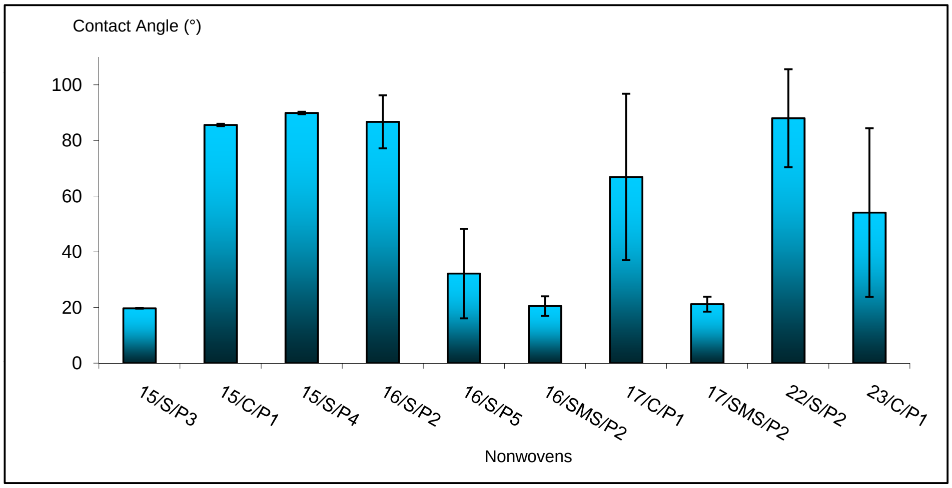

Fig. (5). The contact angle for different nonwoven fabrics.

the contact angle for different nonwoven fabrics. Table **2** shows the nonwoven pore size distribution.

As the contact angle is lower, the nonwovens absorb rapidly the injected volume, in fact the webs which recorded the best performance were: 16/SMS/P2, 15/S/P3 and 17/SMS/P2.

However, from the analyses of the obtained results for the last two webs (15/S/P3 and 17/SMS/P2), one would expect that the hydrophilic character is more decisive in the determination of the absorption kinetics than the pore size dimension. Comparing the % of pores that have a size superior to 500 pixels of 17/SMS/P2 fabric with those of 15/S/P3 indicates such assumption. This behaviour is also confirmed when comparing between pore size distribution and contact angle of the web 17/SMS/P2 and 23/C/P1 (1.37% and 2.8%). Such interesting result can be explained by the fact that hydrophilic treatment intervenes in the first contact with liquid, pores are basically responsible for the diffusion and the propagation through the webs [12].

The rest of the fabrics (22/S/P2, 17/C/P1, 15/S/P4, 16/S/P5 and 16/S/P2) show less performance due to their high contact angle recorded. Such results concerning the contact angle can reflect the non uniformity of the hydrophilic treatment and can explain some leakage problems observed in some baby diapers.

Concerning the nonwoven type, we can notice that spunbonded (S) and spunbonded-meltblown-spunbonded (SMS) recorded better performances than the carded ones. Indeed, for S and SMS fabrics, fibres are isotropically distributed, while carded fabrics show an anisotropic repartition which leads to a lower liquid spreading through the structure [7]. If we compare between the performances of carded fabrics, we can note as expected that higher basis weights allow a rapid absorption of the liquid.

CONCLUSION

This work investigated the absorbent behaviour of some nonwoven webs used as a cover sheet in absorbent products. It also examined the following structural characteristics: porosity, pore-size distribution and contact angle. The parameter used in characterising the behaviour was the absorption of kinetics. The tests used image analyses to determine porosity and pore size distribution parameters. The contact angle was measured to appreciate the nonwoven hydrophilic state. It was confirmed that the last parameter produced significant effects on the absorption kinetic performance. The paper shows the role of the structure on liquid spreading as well. We conclude that obtaining well performing products and achieving the desired result need a compromise between all structure characteristics.

Table 2. Nonwoven Pore Size Distribution

NW / Pore Size (pixel)	15/S/P3	15/C/P1	15/S/P4	16/S/P2	16/S/P5	16/SMS/P2	17/C/P1	17/SMS/P2	23/C/P1	22/S/P2
<100	85.61%	83.22%	81.27%	83.81%	83.91%	83.97%	82.39%	82.82%	84.27%	75.18%
(100-200)	8.86%	9.87%	10.25%	6.88%	6.05%	9.41%	9.63%	8.93%	8.39%	10.64%
(200-300)	3.42%	2.96%	5.3%	4.86%	2.87%	4.18%	2.99%	3.78%	2.45%	5.67%
(300-500)	1.11%	2.3%	2.12%	1.21%	2.23%	1.39%	2.66%	3.44%	2.8%	4.61%
> 500	1.01% (530-678)	1.97% (500-741)	1.41% (516 -638)	3.64% (536-1679)	0.64% (500-784)	1.05% (535-570)	2.33% (511-2011)	1.37% (760-930)	2.8% (527-1484)	4.94% (558-1483)

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