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Modelling Absorbent Phenomena of Absorbent Structure

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Abstract: Absorption, retention and strike through time, as evaluating criteria of absorbent structures quality were studied. Determination of influent parameters on these criteria were realized by using the design method of experimental sets. In this study, the studied parameters are: Super absorbent polymer (SAP)/fluff ratio, compression and the porosity of the non woven used as a cover stock. Absorption capacity and retention are mostly influenced by SAP/fluff ratio. However, strike through time is affected by compression. Thus, a modelling of these characteristics in function of the important parameter was established.

Key words: Absorbent structure, modelling, strike through time, absorption capacity and retention

INTRODUCTION

Hygienic product and specially baby diapers have to meet certain requirements: absorption, retention and more over comfort and aesthetics in order to satisfy the user (Alternative Absorbents 2003). Hygienic product must combine between acquisition, distribution and liquid retention inside one structure (Dutkiewicz, 2003). Baby diapers were generally constituted of fluff, Super Absorbent Polymer (SAP) powder and a cover stock. Fibres are able to absorb liquid instantly and partially and imprison it in the inter fibre space. However in wet state and under pressure, the networks fibres tend to collapse thus entrain a change in capillary volume and block liquid flow (Rosinskaya *et al*., 2002; Darry *et al*., 2003; Aliouch *et al*., 2001). SAP particles have a high absorption capacity and are able to imprison liquid for a long period of time.

But the velocity of swelling is, in the beginning, too slow and presents the possibility of gel blocking (Aliouch *et al*., 2001; Kevin *et al*., 1991). In this survey, we propose to study some parameters variation effect such: SAP/fluff ratio, compression and the porosity of the non woven cover stock to determine their influence on baby diaper absorption parameters: absorption capacity and retention. We establish therefore descriptive equation of these phenomena in order to set up a modelling.

MATERIALS AND METHODS

Materials characteristics: We used the following materials:

- SAP particles: HySorb B7160 polymer type based on sodium acrylate, the properties of the polymer are: Grannulometry: 106-500 μm = 50%, 500-850 μm = 50%, Density: 0.7 g cm^{-3}, Absorption capacity: 35 g g^{-1}, Absorption under a charge of 50 g cm^{-2}: 23 g g^{-1} (g of water by g of Polymer).
- The fibre used is a cellulose fluff LKC type

Aspect: White brilliant short fibre, Population: 2 millions fibre/g of fluff, Conventional water content: 8%.

Different tests were carried out on laboratory samples whose absorbent structure general model consists of a layer of SAP polymer inserted between two layers of wood pulp. The whole structure is overcome by a first non woven (the High Loft) and a second one (the cover stock). The samples model is shown in Fig. 1. The liquid test used is a 0.9% NaCl solution at ambient temperature.

- The high loft: this non woven allows acquisition, distribution and liquid transport. This acquisition layer is designed to take up liquid and transport it across the top of the core structure below. It also transports the fluid in a lateral direction across the surface of the absorbent core and transfers it at multiple positions, making more efficient use of the SAP.
- The cover stock: it is a non woven generally constituted of spunbonded polypropylene, with its porous structure must transmit liquid into the absorbent core in a rapid and effective manner and keep a high degree of surface dryness, the dry feel effect.

In this research, we studied the influence of the following parameters on absorbents structure properties.

1: Represent the SAP/fluff ratio varied throw the different tests. The variation of this ratio is realized on six levels varying from 5 to 30%.

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Table 1: Levels parameter

Parameter	SAP/fluff ratio						Cover stock porosity			Structure compression		
Level parameter	1	2	3	4	5	6	1	2	3	1	2	3
Value	5%	10%	15%	20%	25%	30%	0.78	0.81	0.84	7.9	5.9	4.2

Table 2: Orthogonal table used for tests

Test	SAP/fluff ratio	Cover stock porosity	Structure compression
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	1
5	2	2	2
6	2	3	3
7	3	1	2
8	3	2	3
9	3	3	1
10	4	1	3
11	4	2	1
12	4	3	2
13	5	1	2
14	5	2	3
15	5	3	1
16	6	1	3
17	6	2	1
18	6	3	2

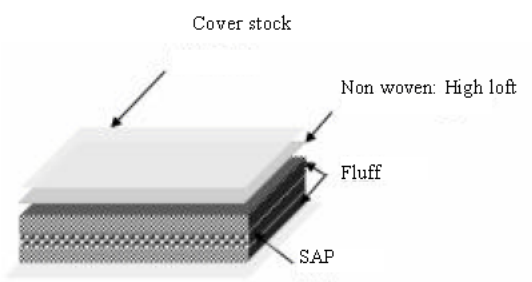

Fig. 1: Model of laboratory samples

2: Represent the non woven variety, expressed in term of cover stock porosity.

3: Represent the structure compression; this parameter is expressed in term of structure thickness and later in term of porosity.

The cover stock and the structure porosity (ε) are derived from the following Eq. 1 (Hsiech, 1995):

$$\varepsilon = 1 - \frac{\rho_{\text{structure}}}{\rho_{\text{fibers filaments}}}$$
$$\varepsilon = 1 - \frac{\text{Surface mass}}{\text{Thikness} \times \rho_{\text{fibers/filaments}}} \quad (1)$$

For the last 2 parameters, 3 levels were tested. Different parameters levels are given in Table 1. For tests, as seen in Table 2 we established an orthogonal table.

For the structures we tested fundamental properties permitting to characterize baby diaper performance such as:

- Total absorbency which measures the liquid quantity remained associated to the material after a time of impregnation and draining.
- The retention which measure the liquid quantity after sample centrifugation. The sample was previously impregnated and drained.
- The strike through time which is the time taking by a structure to absorb totally, a defined liquid quantity These tests were realized according to
- STN2: 117/87 standards for total absorbency and retention measurement.
- STN2: 138/90 standards for strike through measurement.

RESULTS AND DISCUSSION

Results analysis reveals the effect of each parameter on different measured performances (Table 3).

Results analysis: Concerning absorption capacity, the most influent parameter on absorption capacity is SAP/fluff ratio. In fact an SAP/fluff ratio increase improves absorption capacity (Aliouch *et al*., 2000). Moreover, we can note that absorption capacity variation is about 5.43% for a ratio variation from 5 to 10% and is about 7.09% for a ratio variation from 10 to 15% (Fig. 2).

However this variation do not exceeds 2% for a ratio variation from 15 to 20% and from 25 to 30%. This might suggest that beyond a certain threshold the addition of the SAP, by keeping fluff quantity constant, becomes without effect (Aliouch *et al*., 2001; Dutkiewicz, 2003). After SAP particles swelling, we assist to a gel blocking phenomenon, which block the liquid diffusion through the SAP. Consequently we observe a structure saturation and therefore absorption capacity record little variation.

Concerning retention, we obtained that the only parameter which have a remarkable influence is the SAP/fluff ratio. In fact SAP particles are responsible of retention (Darry *et al*., 2003; Kevin *et al*., 1991). After centrifugation, the liquid located in pore structure is eliminated. Only bounded liquid to fibre structure is

Table 3: Parameter effects

Parameters	SAP/fluff ratio	Cover stock porosity	Structure compression
Absorption capacity (g g^{-1})	16.09	2.75	3.66
Retention (g g^{-1})	107.30	2.68	0.41
Strike through time (sec)	20.93	10.23	70.60

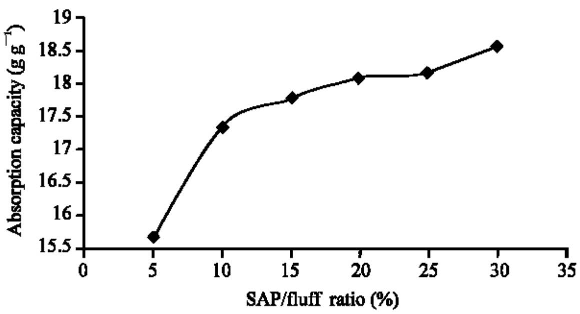

Fig. 2: SAP/fluff ratio influence on absorption capacity

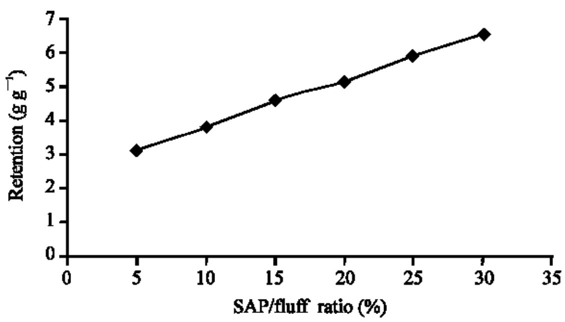

Fig. 3: SAP/fluff ratio influence on retention

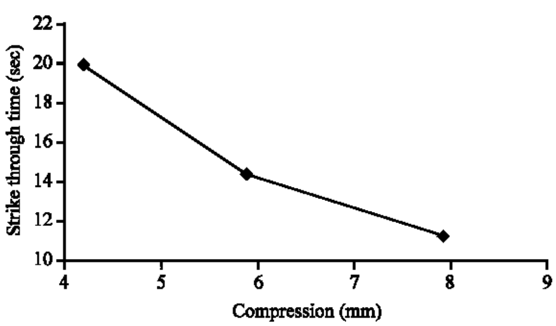

Fig. 4: Compression influence on strike through time

retained. SPA polymer has a retention capacity higher than fibres, consequently it will be responsible of retention since even after centrifugation; liquid will be retained. A variation of the average retention value varies from 22.3% for a variation from 5 to 10%, then decrease to 9.78% for a variation from 25 to 30% (Fig. 3).

Regarding strike through time, results proved that the most influent parameter is compression. We found an increase of strike trough time mean value corresponding to 79.65% for compression related to 4.2 mm et 7.9 mm (Fig. 4). In fact compression affects porous web structure and since absorption rate is governed by liquid absorption through the structure, it will be changed. As pores configuration and distribution have an impact on absorption rate, strike trough time will be affected too. Admittedly, it was proved that compression allows liquid propagation (Dutkiewicz, 2003), but it decease absorption rate.

Modelling absorbent phenomena: Gupta *et al*. (1994) proposed a model Eq. 2 which allows absorption capacity prediction of absorbents fibrous structures not containing a SAP. Model validation was conducted by means of GATS (Gravimetric Absorbency Testing System) which permit continuous measurement of thickness during absorption.

The model is as follows:

$$C = A\frac{T}{W_f} - \frac{1}{\rho_f} + [(1-\alpha)\times\frac{V_d}{W_f})] \qquad (2)$$

With

C : Absorption capacity g cm^{-3} dry mass;
A : Area, cm^2;
T : Thickness, cm;
W_f : Dry web weight,
g; ρ_f : Dry fibre density, g cm^{-3};
α : The ratio of the increase in volume of a fibre upon wetting to the volume of fluid diffused into a fibre;
V_d : Amount of fluid diffused into the structure of the fibres, cm^3.

In the same context, through this study, absorption capacity of absorbent structures, containing SAP is evaluated and modelled while basing on physical properties of absorbent structure (total porosity of structure, fluff and SAP characteristics). Absorption capacity measurement were realized according to conditions imposed by standards STN2:117/87.

Our experimental study previously tried, showed that the most influent factors on this parameter are the SAP/fluff ratio and structure compression; consequently our modelling will be based on these parameters. The total absorbed liquid quantity absorbed by absorbent structure is the sum of the liquid absorbed by the fluff; by SAP particles and even liquid in pore structure (liquid absorbed by the cover stock and the high loft is neglected). It results that the suggested model has the following expression (3):

$$\text{Abs Cap}(g\ g^{-1}) = \frac{Tr_{Fluff}\times M_f + A_{SAP}\times M_{SAP} + \varepsilon\times\rho_{liquid}\times v_t}{M_{Diaper}}$$

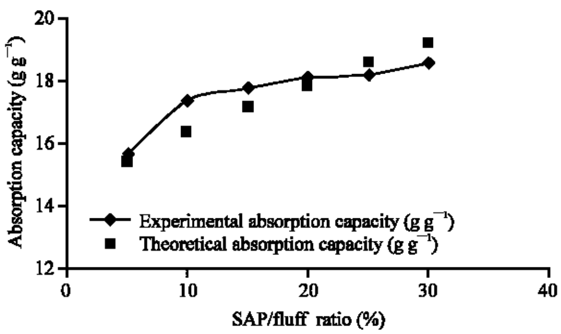

Fig. 5: Effect of SAP/fluff ratio on experimental and theoretical values of absorption capacity

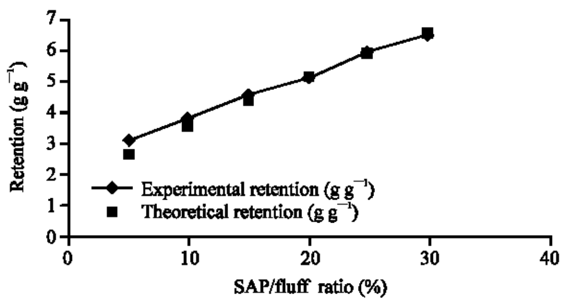

Fig. 6: Effect of SAP/fluff ratio on experimental and theoretical values of retention

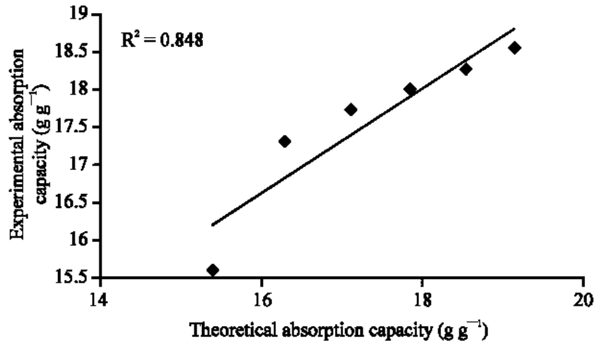

Fig. 7: Correlation between experimental and theoretical values of absorption capacity

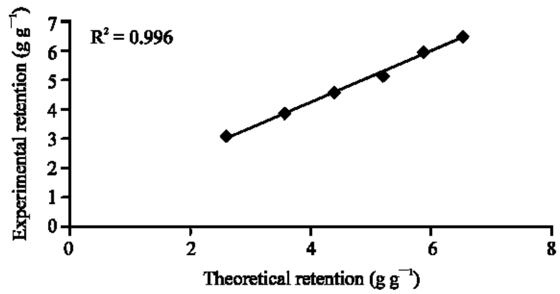

Fig. 8: Correlation between experimental and theoretical values of retention

With

Tr_{Fluff} : Fluff regain at 100% of moisture;
Tr_{Fluff} : 84% (Morton *et al.*, 1975);
A_{SAP} : SAP absorption coefficient;
A_{SAP} : 35 g g^{-1};
ρ_{liquid} : Test solution density;
V_t : Structure volume;
M_{diaper} : $M_F + M_{SAP}$;
M_F : Fluff weigh which is constant during various tests and is equal to 2 g
M_{SAP} : SAP weigh.

From this theoretical expression, we calculated absorption capacity values for each test and compared them with those obtained in experiments.

As it's shown, we obtain good correlation since experimental and theoretical absorption capacity values are almost corresponding (Fig. 7). For retention, we suppose that after centrifugation, only liquid contained in pores is eliminated.

Thus:

$$\text{Retention}\,(\text{g g}^{-1}) = \frac{C_{Fluff} \times M_F + C_{SAP} \times M_{SAP}}{M_{Diaper}} \qquad (4)$$

With C_{Fluff} and C_{SAP} are respectively fluff retention coefficient and SAP retention coefficient C_{fluff} = 1.6 g g^{-1}; C_{SAP} = 23 g g^{-1}. Fluff weigh is constant during various tests and is equal to 2 g.

Results obtained from theoretical expression and experimental were shown in figures below.

Concerning retention, we denote a linear variation between SAP/fluff ratio and retention (Fig. 6), which reflects a good correlation between theoretical and experimental values (Fig. 8). Whereas, for absorption capacity, we remark an evolution in two phase (Fig. 5): the first phase corresponding to a progressive rise and where theoretical values are corresponding to experimental ones. The second phase starts from a certain threshold (20%) from which experimental values are superior. This can be explained by a gel blocking phenomenon which decreases experimental values Dutkiewicz, 2003. This phenomenon is not detected in theory.

CONCLUSION

Baby diaper is a complex structure characterized with its absorbent core. Baby diaper can be assessed from certain criteria such as absorption capacity, retention which allows absorption rate characterization. In this survey, we studied, by means of an experimental design method, the most influent parameter on these criteria. We can affirm that for absorption capacity SAP/fluff ratio and compression are the most influent parameters. For retention, only SAP/fluff ratio is influent. Concerning strike through time, it is essentially affected by compression. Given that, a modelling, describing absorption and retention phenomenon through absorbent structure containing SAP particles and taking account of tests conditions required by STN2:117/87 standards, was achieved. The proposed models can predict these parameters almost exactly.

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