Development of High-Absorbent Light-Weight Sanitary Napkin

A. Das, V. K. Kothari, S. Makhija, K. Avyaya

Department of Textile Technology, Indian Institute of Technology, New Delhi-110 016, India

Received 7 July 2006; accepted 16 April 2007
DOI 10.1002/app.26936

ABSTRACT: This article presents a method of preparing the absorbent core for an ultrathin sanitary napkin using super absorbent fiber (SAF) and viscose fiber blends with varying SAF percentages and mass per unit area (g/m^2). The SAF/viscose blended carded webs were sandwiched between two layers of nonwoven fabric to integrate and encapsulate it. The prepared napkin samples showed significantly better rates of absorption for saline solution even though the glass tube wicking (gravimetric) test gave only comparable results. The saturation absorption of the core also follows a definite trend, dependent on two variables, i.e., mass per unit area (g/m^2) of the core web and proportion of SAF in the core web. Based on the results, the absorption of the core has been optimized and equations have been developed for prediction of the absorption of the core from mass per unit area and the proportion of SAF in the core web. © 2007 Wiley Periodicals, Inc. J Appl Polym Sci 107: 1466–1470, 2008

Key words: blending; card web; rate of absorption; sanitary napkin; saturation absorption; SAF; viscose

INTRODUCTION

Puberty comes with all kinds of changes in a woman's body—including the way the body looks and smells. Once women begin menstruating, they need to use something to soak up the menstrual blood—either a pad or a tampon. In Europe, some 42 billion sanitary napkins, tampons, and panty liners were sold in 2004 compared to more than 35 billion products in 1997, according to Euromonitor International. The total European sales corresponded to ~ 30% of global sales of sanitary protection products and reached more than $5.2 billion in 2004 compared with more than $3.9 billion in 1997. A closer look into the numbers shows that the biggest movements in feminine hygiene are the increasing use of ultrathin pads and panty liners in place of thick pads. There is a general trend that sales of full-size or maxi pads are declining significantly across all of Europe, giving way for the ultrathin products. Thanks to the presence of super absorbent polymers (SAP), these provide the expected absorption capacity. They also give girls and women the discretion, comfort, and feminine design that has been sought after for generations. As raw material prices are increasing, sanitary protection product component suppliers are trying to ease this situation by developing technology to lessen the amount of SAP needed per unit. The objective of the present research is to study the absorption behavior of sanitary napkin with different proportion of SAF and at different level of mass per unit area. The specific objective is to optimize the proportion of SAF and mass per unit area of the product for optimum absorption behavior to have low cost product. The super absorbent fiber used in the present study is composed of crosslinked polymerized acrylic acid. The results obtained in the present study are guidelines for developing high-absorbent sanitary napkin with reduced cost.

EXPERIMENTAL

Sample preparation

The new absorbent core was prepared as follows: carded webs of viscose and SAF blend were prepared with varying SAF percentages and mass per unit area. The webs were carded a second time to achieve better fiber opening, better fiber alignment, and homogenous blending. The card webs were then sandwiched between two layers of same nonwoven fabric to integrate the web and encapsulate it to get the absorbent core. Figure 1 shows the schematic diagram of the cross section of the sandwiched layers of the absorbent core. It led to compaction of the web, providing a highly absorbent and thin core.

The nonwoven fabrics used for encapsulation of webs in different samples were of two types, i.e. parallel laid viscose (type A: 20 g/m^2) and random laid viscose (type B: 60 g/m^2) (made out of waste fiber) to get the absorbent cores. This absorbent core was

---

Correspondence to: Dr. A. Das (apurba@textile.iitd.ernet.in).

Journal of Applied Polymer Science, Vol. 107, 1466–1470 (2008)

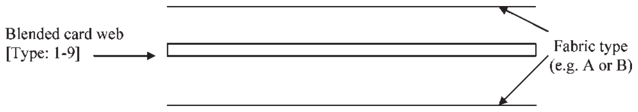

Figure 1 Layers of absorbent core; blended card web (Type: 1–9); Fabric type (e.g., A or B).

then swapped with that of an available sample (market sample) and the product was tested using the developed core. Nine different combinations of webs were prepared and those webs were sandwiched between two types of nonwoven fabric layers, i.e. total 18 absorbent core samples were developed for study. The details of the samples are given in Table I. The nomenclature of the sample (e.g., A1) implies a sandwiched absorbent core sample of fabric type A and web type 1.

The cross sections of the control sample (standard market sample which is the sandwich one) and the developed absorbent core (i.e., developed carded web sandwiched between two layers of nonwoven fabrics) are shown Figures 2 and 3, respectively. The absorbent core of the controlled sample is a mixture of wood pulp and the granules of super absorbent polymer (SAP). The developed absorbent core was then inserted within the polymeric cover stock (one side perforated sheet and other side impermeable sheet) of an available sample (market sample). Figure 4 shows the cross sectional view of napkin with developed sandwiched core.

Test methods

The rate of absorption of water by the sample was tested using ASTM standard D 824-94 for bibulous papers, by measuring the time required for the paper to absorb completely a specified quantity of water (it caters for a multi-ply specimen as well).[1,2] The water transport rate, which correspondingly relates to vertical wicking, is measured according to a vertical strip wicking test. One end of a strip (25 mm wide × 170 mm long) was clamped vertically with the dangling end immersed to about 3 mm in distilled water. The height to which the water was transported along the strip is measured at 1, 2, 3, 5, and 10 min intervals and reported in centimeters.[3] The horizontal water transport rate of the fabric is measured by the ''Umist Wettability Tester'' using a 50 μL distilled water droplet.[4] In the Glass Tube Wicking (GTW) test, the absorbent core mass was uniformly packed into a length of 1.0 cm ID glass tube.[5] One end of this core packed tube was immersed vertically into a reservoir of 0.9% saline water. The mass of solution absorbed by a vertical wicking mechanism into the absorbent material was measured in terms of a weight change as a function of time. The saturation absorption of the absorbent core was determined by immersing it in physiological saline (0.9% saline) for 30 min and then draining it for 30 min. The difference between the weight (g) after drainage and the weight (g) before immersion was taken as a saturation absorption. The time taken by the napkins to completely absorb 5 mL of 0.9% salt solution (i.e., absorption time) was measured

TABLE I
Details of Sandwiched Absorbent Cores

		Nonwoven fabrics		Blended web details			Sandwiched core details		
Variables	Sample no.	Type	Mass g/m^2	SAF %	Viscose %	Total mass (g/m^2)	Viscose %	SAF %	Total mass (g/m^2)
Web blend proportion with 60 g/m^2 mass	A1	A	20	10	90	60	94	6	100
	A2	A	20	30	70	60	82	18	100
	A3	A	20	50	50	60	70	30	100
Web blend proportion with 80 g/m^2 mass	A4	A	20	10	90	80	93.3	6.7	120
	A5	A	20	30	70	80	80	20	120
	A6	A	20	50	50	80	66.6	33.4	120
Web blend proportion with 100 g/m^2 mass	A7	A	20	10	90	100	92.8	7.2	140
	A8	A	20	30	70	100	78.6	21.4	140
	A9	A	20	50	50	100	64.3	35.7	140
Web blend proportion with 60 g/m^2 mass	B1	B	60	10	90	60	96.6	3.4	180
	B2	B	60	30	70	60	90	10	180
	B3	B	60	50	50	60	83.3	16.7	180
Web blend proportion with 80 g/m^2 mass	B4	B	60	10	90	80	96	4	200
	B5	B	60	30	70	80	88	12	200
	B6	B	60	50	50	80	80	20	200
Web blend proportion with 100 g/m^2 mass	B7	B	60	10	90	100	95.5	4.5	220
	B8	B	60	30	70	100	86.4	13.6	220
	B9	B	60	50	50	100	77.3	22.7	220

Figure 2 Cross sectional view of control sample. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

according to the previously used ASTM standard D 824-94.

RESULTS AND DISCUSSION

Thickness of different samples

In a sanitary napkin, along with the weight and absorbency, the thickness is also a very important characteristic. A thicker napkin is not at all desirable. The thickness values of the developed samples and the control sample are given in Table II.

For samples of both types A and B, we notice a significant increase in thickness with an increase in the mass of blended web portion of the absorbent core. It is evident from the Table II that the thickness of the prepared samples is significantly lower, in most cases (A1–A9 and B1–B3), compared to the control sample, which would be an added advantage for an ultrathin sanitary napkin. It has also been observed that a change in content of SAF in the core does not affect the thickness of the sample significantly.

Horizontal wicking

The horizontal transport rate (tested in Umist wettability tester) of transporting layer of control sample (Layer 2) and the two types of nonwoven fabrics is given in Table III.

From the Table III, it is observed that as fabrics A and B are made of viscose, which being absorbent in nature, give wide variation in wicking time depending on fiber alignment. The parallel laid sample A gives shorter time along the direction of the laid fibers, whereas the random laid sample B takes relatively higher time of wicking and approximately equal times in both directions. The control sample shows wide difference in wicking characteristics between *X* and *Y* directions.

Figure 3 Cross sectional view of developed absorbent core. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Figure 4 Cross sectional view of napkin with developed absorbent core. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Vertical wicking

The vertical wicking of transporting layer of control sample (layer 2) and the two types of nonwoven fabrics is given in Figure 5.

Capillary action is governed by the properties of the liquid, the fiber surface wetting characteristics, and the geometric configurations of the porous medium.[6] Both fabrics A and B give comparable rates of vertical wicking with that of layer 2 of the sample MA (control sample), though the random-laid sample B gives slightly higher rate than the parallel-laid one. This may be because of the difference in their mass per unit area.

Glass tube wicking

Figure 6 shows the comparative glass tube wicking results of different developed sandwiched samples from different web blend proportion with 60 g/m^2 mass of web and the control sample.

Capillary flow behavior is quantified by the capillary pressure and permeability parameters.[7] From the graph plotted for the samples A- and B-type nonwoven fabrics (Fig. 6), we notice that with the increase in the SAF % of the web part of the absorbent core, the rate of transport of the salt solution in the vertical direction increases (rate is measured by gravimetric

TABLE II
Mean Thickness of Samples

Sample	Mean thickness (mm)	Sample	Mean thickness (mm)
Control sample	2.91		
A1–A3	2.54	B1–B3	2.67
A4–A6	2.73	B4–B6	2.97
A7–A9	2.82	B7–B9	3.12

TABLE III
Horizontal Transport Rate of Samples

Sample	Layer	Volume (μL)	Time (s) *X* axis	Time (s) *Y* axis
Control sample	Layer 2	50	44.4	2.02
Fabric A	–	50	7.06	3.23
Fabric B	–	50	14.02	16.98

method). This may be due to the much greater tendency of SAF to absorb the fluid compared to viscose fiber, even though there would not be a significant increase in the number of capillaries as the web mass remains unchanged. It can be seen that this general trend holds for both the fabric types and increasing mass per unit area of web, barring a few points of discrepancy. Figures 7 and 8 show the similar trend for web mass of 80 g/m^2 and 100 g/m^2, respectively.

On comparing the rates of transport by samples having different web mass per unit area (g/m^2) but same SAF %, no significant change is observed. This may be due to the very nature of the test, as the glass tube used for the tests is the same. This caused the amount of sample inserted into the tube to be nearly the same and hence a change in g/m^2 would not affect the relative rates. On comparing the developed samples with the original control sample, it is observed that B8 and B9 give better results in this test than the standard sample. These are made using random laid fabric in combination with a high SAF %. Samples B1, B2, B3, B7, A8, and A9 are comparable though slightly less than that of the standard sample. Therefore, it is clear that on an average, the developed samples are comparable in performance in the Glass Tube Wicking test, as shown above.

Absorption time

The time taken to absorb 5 mL of 0.9% salt solution by the napkin samples, i.e., absorption time, for all the developed absorbent core samples along with the control sample is given in Table IV.

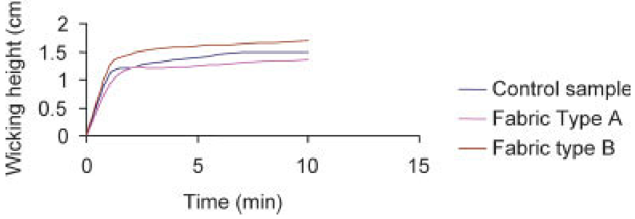

Figure 5 Vertical wicking heights of control sample and nonwoven fabrics (Fabric Type A, Fabric Type B). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

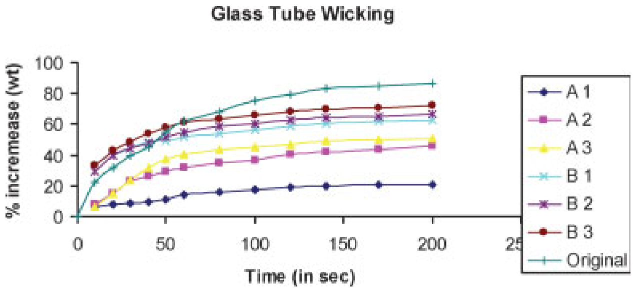

Figure 6 Glass tube wicking comparison for 60 g/m^2 web mass (A1, A2, A3, B1, B2, B3, Original). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

From this test, there are three important things to be noted. Firstly, it is clear that with an increase in g/m^2 of web part of the absorbent core, the time taken by the samples to absorb 5 mL of 0.9% physiological saline decreases significantly. Secondly, all the developed samples give an absorption time, which is significantly lower than that of the control sample. Thirdly, the samples having the absorbent core containing the fabric of type B give significantly lower absorption times compared to those having fabric type A. This can also be inferred as fabric B gives higher vertical wicking rate than fabric A, as can be seen from Figure 4. Moreover, these tests have been performed without the presence of a PP distribution layer thereby showing that the function of distribution of the fluid is being performed by the absorbent core itself. This not only demonstrates the superior performance of the developed sample but may also help in reducing the cost and thickness by eliminating an entire layer from the napkin. In practice, surfactants are often used to promote spreading of liquids on the surface of solids.[8] No definite trends were observed when the SAF % was increased.

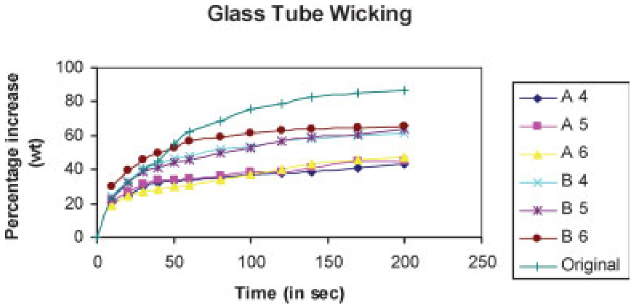

Figure 7 Glass tube wicking comparison for 80 g/m^2 web mass (A4, A5, A6, B4, B5, B6, Original). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

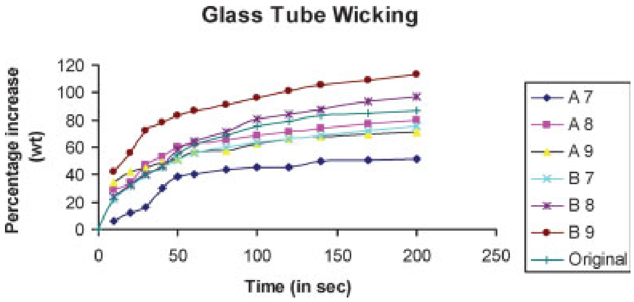

Figure 8 Glass tube wicking comparison for 100 g/m^2 web mass (A7, A8, A9, B7, B8, B9, Original). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Saturation absorption

Saturation absorption for 0.9% saline solution of developed and control samples are shown in Figure 9. It is clear from Figure 9 that the saturation absorption increases with the increase in the proportion of SAF, due to obvious reason. Also, the type A samples show higher saturation absorption values than the type B samples. This is because the effective proportion of SAF in the B samples are lower than the corresponding A samples.

As the saturation absorption is dependent on both overall SAF % and mass per unit area of the core, an attempt was made to try to get a relationship between these parameters. The idea of getting the relationship was to predict the required saturation absorption and accordingly select the SAF % and mass of sandwiched web. The least squaring technique was adopted for this and the relationship was found to be a straight line. The relationship with the existing experimental data was found to be

$$Y = 1.1137X_1 + 0.0179X_2$$

where Y is the saturation absorption, and X_1 and X_2 are the SAF % and g/m^2 of the overall sandwiched web. Hence, one can predict the absorption capacity of the absorbent cores prepared by present method, for any known values of total g/m^2 of the core and the SAF %. This will help optimize the amount of SAF needed and the g/m^2 of the absorbent core according to the desired performance.

TABLE IV
Absorption Time Developed and Control Samples

Sample	Time (s)	Sample	Time (s)	Sample	Time (s)	Sample	Time (s)
Control	13.11	A5	10.30	B1	9.32	B6	8.92
A1	11.02	A6	10.34	B2	9.36	B7	8.64
A2	10.89	A7	9.76	B3	9.20	B8	8.61
A3	10.96	A8	9.84	B4	9.01	B9	8.68
A4	10.38	A9	9.70	B5	8.90		

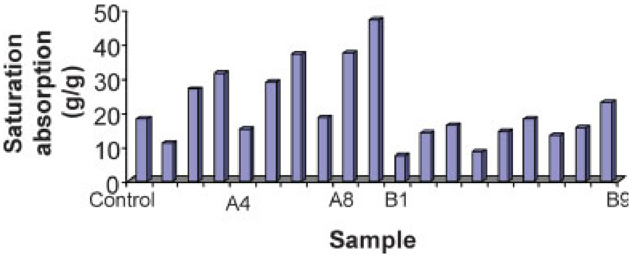

Figure 9 Saturation absorption developed and control samples. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

CONCLUSIONS

The prepared napkin samples were mostly thinner or equivalent to the control sample. They showed significantly better rates of absorption for saline solution even though the glass tube wicking (gravimetric) test gave only comparable results. The saturation absorption of the core also follows a linear relationship, dependent on two variables, namely the g/m^2 and SAF %. This will help to predict and optimize the absorption capacity of the core according to the desired performance. So, the present research has, therefore, improved upon the napkins performance for similar super-absorbent polymer (SAP) content, opening arenas for further research.

References

1. Standard Test Method for Rate of Absorption of Water by Bibulous Papers 1, ASTM No. D 824-94, ASTM, West Conshohocken, 1994.
2. Standard Test Method for Ink Absorption of Blotting Paper, ASTM No. D 2177-99, ASTM, West Conshohocken, 1999.
3. http://www.tx.ncsu.edu/tpacc/comfort/.
4. University of Manchester Institute of Science and Technology (UMIST), UMIST Wettability Tester Manual, UMIST, Manchester, England.
5. University of Massachusetts, Technical Report No. 17: Chelsea Centre for Recycling and Economic Development, University of Massachusetts, April 2000.
6. Crow, R. M.; Osczevski, R. J. Text Res J 1998, 68, 280.
7. Hsieh, Y. L. Text Res J 1995, 65, 299.
8. Slater, K. Text Prog 1977, 9, 15.