2004 BELTWIDE COTTON CONFERENCES, SAN ANTONIO, TX – JANUARY 5-9

DIFFERENTIALLY ABSORBENT COTTON-SURFACED SPUNBOND COPOLYESTER AND SPUNBOND PP WITH WETTING AGENT

Bhupender S. Gupta
College of Textiles
North Carolina State University
Raleigh, NC
Larry C. Wadsworth
Materials Science & Engineering
University of Tennessee
Knoxville, TN

Abstract

Cotton-Surfaced Nonwovens (CSN's) are developed at The University of Tennessee's Textiles and Nonwovens Development Center (TANDEC) and reported in which cotton-rich webs are bonded to one or both sides of a base structure, generally spunbond (SB) polypropylene (PP), with the cotton content ranging from 20-80% of the fabric weight. The thermally bonded two or three layered laminates, which are produced directly on the SB line, are soft but strong and have a hand similar to those of the hydroentangled fabrics. In one set of experiments of this study, 3% by weight of active hydrophilic ingredients (5% by weight as received) of Ciba's hydrophilic Irgasurf HL 560 was mixed with the PP pellets prior to the spinning of 12 and 17 g/m^2 SB PP onto which 13 and 20 g/m^2 of carded 60%/40% bleached cotton/PP staple webs were overlaid prior to the calendering step. In the second set, CSN's were produced by overlaying onto 25 g/m^2 of SB Eastar Bio GP Copolyester just prior to the calendaring step carded webs with nominal weights of 12.5 and 22.6 g/m^2 consisting of 70% bleached cotton and 30% bicomponent binder fiber with a core of PP and a sheath of Eastar Bio GP Copolyester. Likewise, a 25-g/m^2 carded web of the same 70/30-cotton/bicomponent-fiber web was thermally laminated onto a 48 g/m^2 SB Eastar Bio web. Eastar Bio GP Copolyester is more hydrophilic than PP or PET without hydrophilic additives. The Eastar Bio GP Copolyester is biodegradable (Haile et al. 2001). The bicomponent fiber in the 70/30 cotton / bicomponent web had a core of PP to reduce elasticity for ease of carding and a sheath of Eastar Bio (for greater biodegradation and enhanced adhesion/thermal bonding). The CSN's were evaluated for absorption properties using the Gravimetric Absorbency Testing System (GATS), vertical wicking, and drop tests. It was generally found that the presence of cotton on the opposite side of either SB PP with hydrophilic additive or SB Eastar Bio webs resulted in more rapid wicking on the SB side and more rapid wetting on the cotton side, which showed that these CSN's could function as both the acquisition and distribution layers in hygiene products such as the diapers and feminine hygiene napkins.

Introduction

Cotton surfaced nonwovens were produced using a carded bleached cotton/synthetic fiber web overlaid and thermally bonded with a spunbonded polypropylene (SB PP) or Eastar Bio GP Copolyester (Eastar Bio) synthetic fiber web. Two sets of specimens were prepared. In one, a wetting agent (3% by weight) was incorporated in the SB PP web. The carded fabric overlaid on it consisted of 60% bleached cotton and 40% PP staple. In the other set, biodegradable Eastar Bio (a more hydrophilic polymer than PP or PET) was used in the manufacture of SB web. In this set, the carded web consisted of a blend of 70/30 bleached cotton and synthetic fiber, the latter being a bicomponent fiber (bico) with the sheath of the Eastar Bio and core of PP.

Cellulosic fibers offer the advantage of biodegradability of that component of the composite and render the latter more comfortable for wear and more useful in hygienic personal care products due to enhanced liquid absorption. The cotton-surfaced composites in this study were thus enhanced in one case by incorporating more biodegradable Eastar Bio GP Copolyester in addition to cellulosic fibers and in the other case by the addition of a wetting agent to improve the wetting properties of the SB PP components.

Inherent properties of fibers that can be produced from different biodegradable polymers (Haile et al. 2001; Woodings 2000) may be a factor in engineering structures to produce the laminate with the required mechanical strength, flexibility, barrier, filtration, absorbency properties and other traits. For example, Eastar Bio GP Copolyester (Eastar Bio) fibers are very elastic and do not process well through a carding machine. In the carding process, the staple fibers of Eastar Bio tend to stretch and snap back and roll up into balls of fiber that can soften and become tacky due to the friction of carding. With a stiffer core such as PP or polylactic acid (PLA), the bico fiber with a sheath of Eastar Bio is stiffer and more cardable. It is also more difficult to make fibers as small in diameter from Eastar Bio GP Copolyester with the MB or SB process as is possible with PP because the elastic Eastar Bio filaments stretch and spring back during the melt spinning and fiber attenuation steps. In fact Eastar Bio MB and SB webs are excellent adhesive webs for thermally bonding layers of different fabrics or films together to form composite structures (Negulescu et al., 2002). Additionally, the Eastar Bio fibers and MB and SB fabrics are more hydrophilic than PP or PET (Haile et al. 2001) without hydrophilic additives, which is a desired attribute in personal hygiene products, wound dressings, and industrial applications such as meat packaging (to absorb blood and fluids).

Experimental Procedures

Carded Webs for CSN's

Bleached cotton was blended with PP staple (60% cotton/40% PP) and with bico c/s PP-Eastar Bio fibers (70% cotton and 30% bico staple) and carded at the John D. Hollingsworth Laboratory in Greenville, SC at nominal basis weights of 13 and 20 g/m^2 for the cotton/PP webs and at nominal weights of 12.5, 22.6 and 25 g/m^2 for the 70/30 cotton/bico fiber webs. It was desirable for the bico fiber to have a core of PLA and a sheath of Eastar Bio for it to be completely biodegradable. Since the Bico binder fiber containing a PLA sheath was not available at the time of these trials, a bico core/sheath of PP/Eastar Bio staple fiber which was available from Eastman Chemical was selected for blending with cotton to form carded webs for the preparation of the CSN's.

Wettable Spunbond

Ciba Specialty Chemicals Corporation, Tarrytown, NY, provided 30 pounds of the hydrophilic concentrate Irgasurf HL 560, which has 60% active hydrophilic ingredients. One add-on level of 3% by weight (5% as received) was mixed with 35 MFR PP (Exxon Grade 3155) before SB extrusion. 200-meter rolls (1.0 m wide) of both 12 and 17 g/m^2 SB PP with and without the 3% Ciba Irgasurf were produced and 13 and 20 g/m^2 carded 60/40 cotton/PP webs were laminated on the SB webs with and without wetting agent during the SB production.

Copolyester Polymer and Fiber

Approximately 500 pounds of Eastman's biodegradable Eastar Bio GP Copolyester (Eastar Bio) was provided by Eastman Chemical Company, Kingsport, TN, for the preparation of the CSN's. The CSN's were produced during spunbond production of Eastar Bio by unwinding carded cotton-blend webs onto the SB Eastar Bio prior to the calender on the SB line, as described in the next section.

Eastman Chemical Company also provided 50 lbs of bicomponent (bico) core/sheath staple fiber with a core of PP and a sheath of Eastar Bio GP Copolyester with the following specifications: 50% PP core/50% Eastar Bio; 4 denier/filament; 1.4 inch staple length; and 9.4 crimps/inch. This bico fiber was then mixed at the John D. Hollingsworth R&D Center, Greenville, SC, and carded in blends of 60% bleached cotton/40% bico and 70% bleached cotton/30% bico to produce carded webs as described above.

Preparation of CSN's on SB Line

CSN's were prepared on the 1.0 meter Reicofil 2 SB line as shown in Figure 1 (Wadsworth et al., 2000; Sun et al. 2000), in which 13 g/m^2 carded bleached cotton/PP staple fiber webs (60/40 cotton/PP) were thermally bonded to the 12 or 17-g/m^2 SB PP web with and without the Ciba Irgasurf.

The SB run conditions for the preparation of the above samples on the 1.0 m SB line at TANDEC were as follows and it should be noted that in the preparation of all CSN's on the SB line in this study, the top heated calender roller had a raised diamond pattern with a bonding area of 14.7% and the bottom heated calender roller was smooth steel:

A. Preparation of 12 g/m^2 SB PP with and without the wetting agent
   1) Die Zones 4.1 and 4.7: 445F (229C)
   2) Melt temp: Die 1: 384F (195.6C); Die 2: 422F (216.7C)
   3) Thru-put of 0.15 gram/spinneret hole/min (g/h/m
   4) Quench Air Temp of 64 F; Cooling Air Fan at 1586 RPM
   5) Suction Fan at 1469 RPM
   6) Belt Speed of 59.4 m/min
   7) Calender Speed of 62 meter/min (m/m)
   8) Winder Speed of 64 m/m
   9) Calendering Conditions: 265 F Top/261 F (Bottom); 141 PLI (lbs/linear inch) Nip Pressure.

B. Preparation of CSN's with and without the wetting agent
   1) Increase Calender Temps to 290 F Top/285 F Bottom
   2) Increase PLI to 618 PLI
   3) Unwind unbonded carded cotton-blend webs (while removing the tissue paper used to roll up the carded webs at John D. Hollingsworth R&D Lab) onto unbonded SB filament web prior to the thermal calender section
   4) Other line conditions same as "A" above without cotton lamination

In all of the above runs, the belt speed, calender speed and winder speeds were simply reduced to produce 17 g/m^2 SB PP.

The SB Eastar Bio was produced on the 1.0 m Reicofil 2 SB line at TANDEC. First two 200-meter rolls 25 and 48 g/m^2 SB Eastar Bio were produced without the application of cotton-blended surface webs. Then carded webs with nominal weights of 12.5 and 22.6 g/m^2 consisting of 70% bleached cotton/30% bico staple consisting of a core of PP and a sheath of Eastar Bio were unwound onto a 25 g/m^2 Eastar Bio SB web just before the calendering component of the SB line. Likewise, a 25 g/m^2 70/30 cotton bico fiber carded web was laminated to a 48 g/m^2 SB Eastar Bio web prior to thermal calendering. Excellent bonding of the cotton blended webs to the SB Eastar Bio webs were achieved. The SB conditions applying to the 1.0 m SB line at TANDEC for the preparation of 25 g/m^2 SB Eastar Bio were as follows:

A. Preparation of 25 g/m^2 SB Eastar Bio GP Copolyester without cotton web addition:
   1) Extruder: Zone 1.1-332 F (166.7 C); Zone 1.4-378 F (192 C)
   2) Die Zones: Die 4.1-405 F (207 C); Die 4.4-384 F (195.6 C); Die 4.7-404 F
   3) Melt temp: Die 1-365 F (185 C); Die 2-389 F (198 C)
   4) Thru-put of 0.15 g/h/m
   5) Quench Air Temp of 46 F; Cooling Air Blower at 1859 RPM
   6) Suction Fan at 1652 RPM
   7) Belt Speed of 41 meters/min. (mpm)
   8) Calender speed of 53 m/min
   9) Winder Speed of 55 m/min
   10) Calendering Conditions: Top Roll-171 F; Bottom Roll-167 F; 53 PLI Nip

B. Preparation of CSN's on 25 g/m^2 SB Eastar Bio GP Copolyester:
   1) Increase calender nip to 544 PLI and leave all of the above "A" conditions the same
   2) Unwind the carded cotton-blend webs onto the unbonded 25 g/m^2 Eastar Bio filament web prior to the thermal calender.

The conditions for the preparation of the 48 g/m^2 Eastar Bio GP Copolyester SB web were essentially the same, except the conveyer belt speed was reduced to 20 m/min and the calender and winding surface speeds reduced to 26 and 28 m/min, respectively. To produce CSN's with the 48 g/m^2 SB Eastar, the only change made was to increase the calender nip pressure to 544 PLI.

Description of the SB Webs and CSN Samples Evaluated for Wetting Performance

A. Eastar Bio Webs and CSN's Based on Eastar Bio
   1) 27 g/m^2 MB Eastar Bio GP Copolyester
   2) 25 g/m^2 SB Eastar Bio
   3) 48 g/m^2 SB Eastar Bio
   4) Sample D1E consisting of a 12.5 g/m^2 carded web of 70% bleached cotton and 30% bico binder fiber (core of PP/sheath of Eastar Bio GP copolyester), thermally bonded to a 25 g/m^2 SB Eastar Bio web
   5) Sample D3E consisting of a 22.6 g/m^2 carded web of 70% bleached cotton and 30% of the above bico fiber, thermally bonded to a 25 g/m^2 SB Eastar Bio web
   6) Sample AH consisting of a 25 g/m^2 carded web of 70% bleached cotton and 30% of the above bico fiber, thermally bonded to a 48 g/m^2 SB Eastar Bio web

B. Spunbond PP webs and CSN's Based on SB PP
   1) Sample A1: 12 g/m^2 SB PP with no wetting agent (WA) and no cotton surface
   2) Sample A2: 17 g/m^2 SB PP with no WA and no cotton surface
   3) Sample B1: 12 g/m^2 SB PP with 3% Ciba Irgasurf HL 560 (WA) and no cotton surface
   4) Sample B2: 17 g/m^2 SB PP with 3% Ciba WA and no cotton surface
   5) Sample C1: 13 g/m^2 carded 60/40 Cotton / PP on 12 g/m^2 SB PP with no WA
   6) Sample C2: 20 g/m^2 carded 60/40 Cotton / PP on 12 g/m^2 SB PP with no WA
   7) Sample D1: 13 g/m^2 carded 60/40 Cotton / PP on 12 g/m^2 SB PP with WA
   8) Sample D2: 20 g/m^2 carded 60/40 Cotton/PP on 12 g/m^2 SB PP with WA
   9) Sample E1: 13 g/m^2 carded 60/40 Cotton/PP on 17 g/m^2 SB PP with WA
   10) Sample E2: 20 g/m^2 carded 60/40 Cotton/PP on 17 g/m^2 SB PP with WA

Determination of Wicking and Absorption Properties

The absorption properties using 0.9 % saline were evaluated using the Gravimetric Absorbency System (GATS), the vertical wicking method and the drop test. The GATS, shown schematically in Figure 2, consists of a specimen cell connected to a fluid reservoir by flexible tubing (Gupta and Hong 1995). The specimen cell allowed measurements of web thickness at two positions diagonally across from each other while holding the test material in place for absorbency. The specimen is die cut with a circular stamp to the required size and centered over the cell. The fluid is delivered from a single hole in the middle, which spreads radially outward through the sample. The tests were conducted under a hydrostatic pressure head of zero (ΔP=0) and an environmental pressure of 12 gf/cm^2, obtained by placing fixed weights on the web. The outputs from the GATS balance and the sensors are collected by a computer and evaluated using commercial software. Two parameters assessed were the absorption capacity, C (g fluid/g dry mass), and absorption rate, Q (g fluid/g dry mass / sec). The former was obtained by dividing the volume of fluid absorbed at equilibrium with the dry mass of the web. The latter was measured in the time interval corresponding to 20% and 80% of the maximum amount of fluid absorbed by taking the slope of the fluid uptake line and dividing it by the dry mass of the specimen.

For vertical wicking, a U-frame device was set that allowed wicking measurements under controlled conditions. The specimens used were tensioned for keeping the material vertical and crimp-free. Graduated scales fixed on both sides of the 8" x 1" sample allowed precise determination of the fluid front level. For drop test, the absorbent fluid was dropped from 1" height on to a specimen held under tension in a hoop, and the time for the disappearance of the drop was noted in seconds.

The GATS and the drop tests were performed from both the synthetic and the cotton side in the CSN's. In the other specimens, that contained no cotton, tests were performed from only one but randomly selected side.

Results and Discussion

CSN's Based on SB Co-Polyester

The CSN's described in Table I were prepared by laying a carded cotton blend web on to 25 and 48 g/m^2 (gsm) SB Eastar Bio GP Copolyester webs during spunbond production of Eastar Bio prior to the calendering step. Samples D1E and D3E have top carded webs with weights of 12.5 and 22.6 gsm consisting of 70% bleached cotton and 30% bicomponent (bico) staple fiber with a core of PP and a sheath of Eastar Bio, on a 25 g/m^2 SB Eastar Bio. Except for the PP component used in the blend with cotton, these samples are biodegradable. As mentioned earlier, the PP in the bicomponent fiber can be replaced with a biodegradable fiber such as PLA, which also has stiffness required for carding, and thereby make the CSN completely biodegradable/compostable. The absorption values from the GATS listed in Table 1 indicate that the absorption from the SB side is faster than from the cotton blend side. The rate from either side is directly related to the amount of cotton in the laminated fabric (Table II and Figure 3).

The capacity is governed by the total interstitial space available in the structure to imbibe and hold fluid. A model that characterizes it is as shown below (Gupta and Hong 1995).

$$C = \frac{AT}{W} - \frac{1}{\rho_{av}}$$

In this A is the area of the test specimen, T is the web thickness, W is the dry mass of the web and ρ_{av} is the average density of the fibers in the composite. Of the terms on the right hand-side, the second as compared to the first is quite small and in most analyses can be neglected. With "A" being a constant, the factor having the direct effect on capacity is then the value of the thickness/unit mass. A plot of the measured capacity against the calculated is given in Figure 4 that includes the points related to all fabrics. With some scatter, a linear relation is seen indicating that the more resilient a fabric (higher T/W value), the higher the capacity.

The wicking height is also directly related to the amount of cotton in the web (Table II). The drop test values given in the table show that the time for disappearance of the drop is less on the cotton than on the synthetic (Eastar Bio) side and it decreases with increase in the areal density (g/m^2) of cotton.

CSN's Based on SB PP

A summary of results is given in Table III. The role of the wetting agent Irgasurf HL560 (Ciba) in governing absorption is clearly evident. Its role surpasses that of cotton in some aspects of absorbency in this set of materials. Samples A1 and A2 that have no wetting agent have no affinity for absorbing or wicking fluid. None of the methods used for measuring absorption yielded results. Likewise, Samples C1 and C2, that have cotton but no wetting agent, showed little absorption. Samples B1 and B2 have no cotton but 3 % wetting agent, the highest of all samples. These materials absorb fluid rapidly in the GATS tests and in the vertical wicking tests. In an earlier paper, as also illustrated above, the GATS values have been shown to be strongly correlated with T/W for a fabric in a given set of materials. This parameter has been correlated not only with the pore volume (above equation), that governs capacity, but also with the pore size that affects the rate (Gupta and Hong 1995; Gupta 1988). The values of T/W for this set of fabrics are given in Table IV. It is seen that the higher GATS values in B1 over B2 are due to higher T/W value of the former. In samples D and E, that have both cotton and wetting agent, the GATS' rate (horizontal wicking) is coupled somewhat more strongly with the amount of wetting agent present than with the amount of cotton present, substantiating the behavior noted in samples C. There is little difference in the rate measured from the cotton or from the SB side. Lower GATS values in Samples E (heavier) than D (lighter) is due to the lower T/W values in the former (Table IV). Although the presence of cotton in these samples show weak correlation with GATS rate, it does have a strong influence on the drop values and the wicking height values, especially the former. The time for the disappearance of the drop is substantially smaller on the cotton than on the SB side and it decreases with increase in the areal density (g/m^2) of cotton on the surface. An interesting and worth noting observation is that in samples B, that have the highest amount of wetting agent, although the rate of absorption is highest of all samples, the drop disappearance time is undesirably long (Table III). It appears, thus, the presence of a hygroscopic material is needed to absorb and distribute fluid that is intermittently presented as droplets.

Conclusions

Resiliency of the webs played direct role in affecting absorption capacity with the lighter webs containing less collapsible cellulosic fibers having higher capacity. In sanitary applications, however, lower absorption capacity coupled with higher absorption rate is desirable. Presence of cotton directly influenced the rate in several of the structures examined. The drop appearance time was found to be consistently lower on the cotton than on the synthetic side even if the latter included a wetting agent. These preliminary results indicate that in highly porous webs, presence of an actually absorbing, as against surface wicking, material presents an advantage in rapidly absorbing and distributing fluid. Thus, pending further substantiating research, it appears that a cotton-surfaced nonwoven, having synthetic fiber with a wicking agent on the assault side and cotton on the receiving side can function as an efficient acquisition as well as a distribution top sheet in hygiene products such as the diapers and feminine napkins.

Acknowledgements

Special acknowledgements are due Cotton-Incorporated, Cary, NC, for funding this project (Cooperative Agreement No. 93-947) as well as to the UTK Agricultural Experiment Station Regional Project S-272 for providing additional funding for this work. We are also indebted to Eastman Chemical Company, Kingsport, TN, for providing the Eastar Bio GP Copolyester polymer and the Bicomponent PP-Eastar fiber, to Ciba Specialty Chemicals, Tarrytown, NY, for providing the Irgasurf HL 560 hydrophilic concentrate, to Carl West, Jr., Fiber Visions, Covington, GA, for donating the T-196 PP staple used in the project. We greatly appreciate the assistance provided by James Murphy, Jack Wreck, Gary Wynn and Yeaning Lee for the assistance in preparing the laminated samples spunbond line at TANDEC. Finally, we thank Ms. Burcak Karaguzel for performing the absorbency tests and Mr. Pankaj Agrawal for generating the tables and figures for the manuscript and the presentation.

References

Gupta, B. S., and Hong, C. J., "Absorbent Characteristics of Nonwovens Containing Cellulosic Fibers," *INDA Nonwoven Journal, 7,* 1:34-43 (1995).

Gupta, B. S., "The Effect of Structural Factors on Absorbent Characteristics of Nonwovens," *TAPPI Journal,* 147—152, August (1988).

Haile, W. A., M. E. Tinker and C. M. Tanner, "New Biodegradable Copolyester for Fibre and Nonwoven Applications," Proceedings, EDANA'S 2001 Nonwovens Symposium.

Negulescu, I. I., C. Yen, O. Chippers, M.M. Warlock, L. C. Wadsworth, and V. G. Yachmenev, "Biodegradable Sandwich-Type Cellulosics/Polyester Nonwovens: Manufacture and Properties, Proceedings, Joint INDA-TAPPI INTC 2002, Atlanta, GA, September 24-26, 2002.

Sun, C. Q., D. Zhang, L. C. Wadsworth and E. M. McLean, Jr., "Processing and Property Study of Cotton-Surfaced Nonwovens," Textile Research Journal 70 (5), 449-453 (2000).

Wadsworth, L. C., H. S. Suh and H. C. Allen, Jr., "Cotton-Surfaced Nonwovens for Short-Wear-Cycle Apparel," International Nonwovens Journal 9 (2), 13-17, 2000.

Woodings, C., "New Developments in Biodegradable Nonwovens," Proceedings, EDANA'S 2000 Nonwovens Symposium, Prague, Czech Republic.

Table 1. Weight, Thickness, Air Permeability and Absorption Capacity and Rate on GATS of Thermally Bonded (TB) CSNs Containing 25 gsm and 48 gsm SB Eastar Bio GP Copolyester Substrates.

Sample No.	Description	Wt (gsm)	Thickness (mm)	Air Perm ($cm^3/cm^2/s$)	T/W (mm/g)	Absorption Capacity (g/g)		Absorption Rate (g/g-s)	
						S	C	S	C
D1E	12.5 gsm 70 C/30 Bico PP/Eastar on 25 gsm SB Eastar Bio	42.0	0.24	310.6	2.02	6.7	6.4	0.15	0.10
D3E	22.6 gsm 70 C/30 Bico PP/Eastar on 25 gsm SB Eastar Bio	56.0	0.32	184.9	2.03	7.2	6.5	0.24	0.18
AH	25 gsm 70 C/30 Bico PP/Eastar on 48 gsm SB Eastar Bio	73.3	0.35	115.8	1.68	5.5	5.3	0.24	0.20

Note: S – absorption from the spunbond or synthetic side. C– absorption from the cotton side.

Table 2. Absorption Rate (GATS), Wicking Height and Drop Test Values of Thermally Bonded, CSNs Containing 25 gsm and 48 gsm SB Eastar Bio GP Copolyester Substrates.

Sample No.	Description	Web Weight (gsm)		Q (g/g-sec) Average	Wicking Height (Cm)	Drop Absorption (Sec)	
		Total	Cotton			C	S
D1E	12.5 gsm 70 C/30 Bico PP/Eastar on 25 gsm SB Eastar Bio	42.0	8.8	0.125	1.7	4	13
D3E	22.6 gsm 70 C/30 Bico PP/Eastar on 25 gsm SB Eastar Bio	56.0	15.8	0.214	4.1	2	4
AH	25 gsm 70 C/30 Bico PP/Eastar on 48 gsm SB Eastar Bio	73.3	17.5	0.220	5.6	2	10

Table 3. Weight, Finish %, Absorption Capacity and Rate, Wicking Height and Drop Test Values of CSNs Containing SB PP and 60/40 Cotton/PP Webs.

Sample No.	Description	Web Weight (gsm) Total	Cotton	Finish (%)	Capacity (g/g) Average	Rate (g/g-sec) S	C	Wicking height (Cm)	Droplet Absorption (sec) C	S
A1	12* SB PP	12.0	0	0	-	-		-	-	
A2	17 SB PP	17.0	0	0	-	-		-	-	
B1	12 SB PP w/ 3% WA[++]	12.0	0	3	15.1	1.23		4.1	67	
B2	17 SB PP w/ 3% WA	17.0	0	3	11.3	0.46		3.0	65	
C1	13 60C/40PP[+] on 12 SB PP	25.0	7.8	0	-	-		-	-	
C2	20 60C/40PP on 12 SB PP	32.0	12.0	0	-	-		1.5	100	180
D1	13 60C/40PP on 12 SB PP w/WA	25.0	7.8	1.44	11.9	0.38	0.36	2.3	10	44
D2	20 60C/40PP on 12 SB PP w/WA	32.0	12.0	1.13	11.5	0.34	0.31	2.8	8	13
E1	13 60C/40PP on 17 SB PP w/WA	30.0	7.8	1.70	10.9	0.33	0.34	2.9	6	7
E2	20 60C/40PP on 17 SB PP w/WA	37.0	12.0	1.38	10.2	0.28	0.28	3.0	5	8

* Numbers designate weight in gsm.
[+] 60 % bleached cotton / 40 % polypropylene carded web laminated on spun bonded PP web and thermally bonded.
[++] 3 %by weight Irgasurf wetting agent in SB PP web.

Table 4. Weight, Finish %, Thickness/Mass and GATS' Absorption Values of CSNs Containing SB PP and 60/40 Cotton/PP Webs.

Sample No.	Description	Web Weight (gsm) Total	Web Weight (gsm) Cotton	Finish (%)	T/W (mm/g)	C (g/g) Average	Q (g/g-sec) Average)
B1	12 SB PP w/WA	12.0	0	3	3.53	15.1	1.23
B2	17 SB PP w/ WA	17.0	0	3	2.51	11.3	0.46
D1	13 60C/40PP on 12 SB PP w/WA	25.0	7.8	1.44	3.05	11.9	0.37
D2	20 60C/40PP on 12 SB PP w/WA	32.0	12.0	1.13	3.04	11.5	0.33
E1	13 60C/40PP on 17 SB PP w/WA	30.0	7.8	1.70	2.86	10.9	0.33
E2	20 60C/40PP on 17 SB PP w/WA	37.0	12.0	1.38	2.89	10.2	0.28

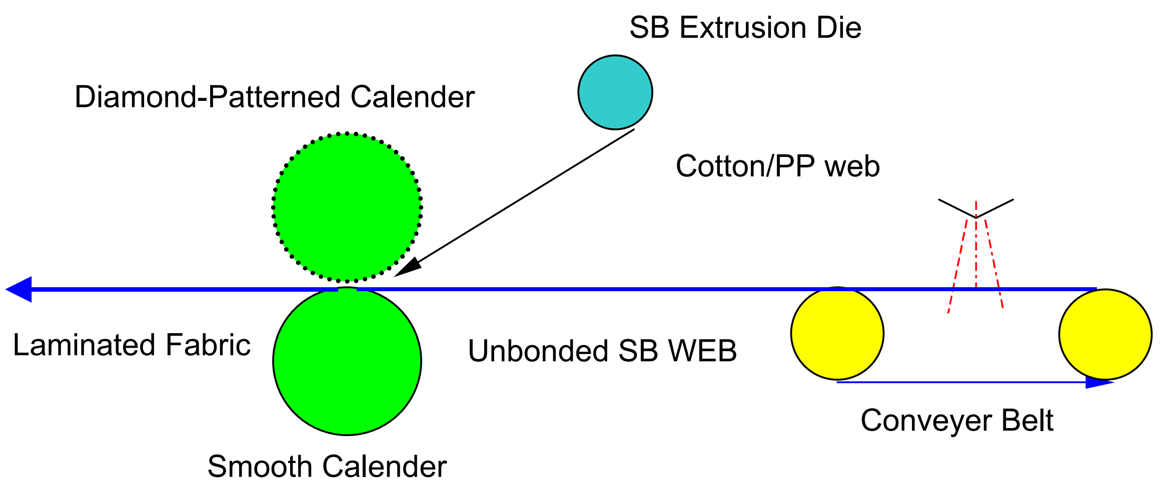

Figure 1. Preparation of CSNs on the spunbond line.

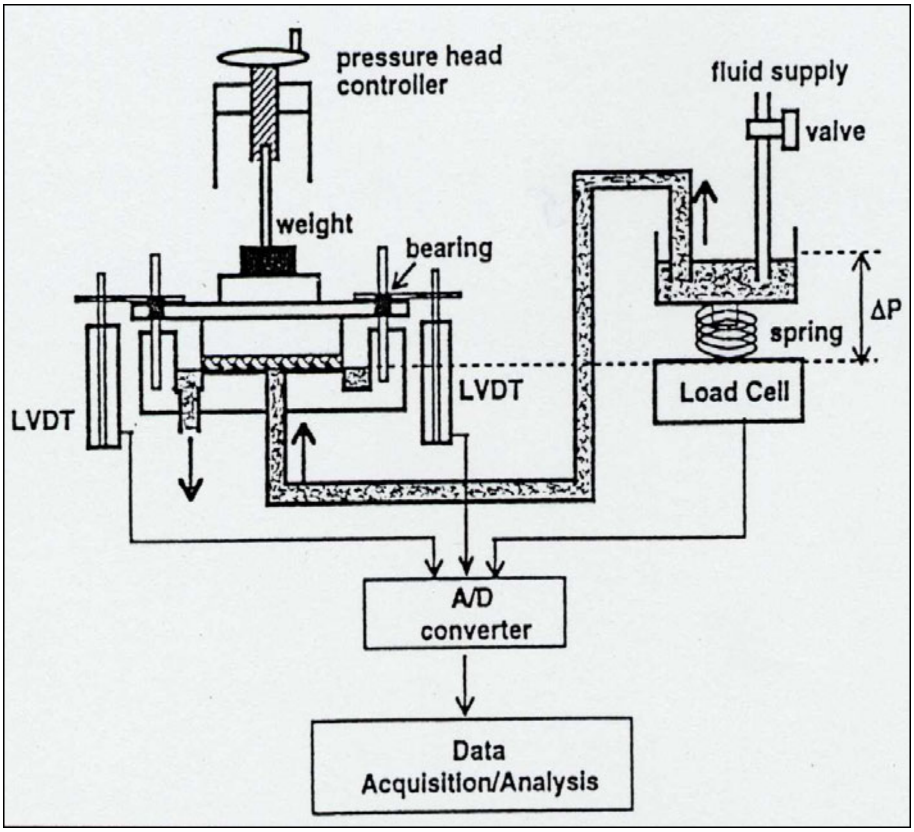

Figure 2. The Gravimetric Absorbency Testing System of NCSU.

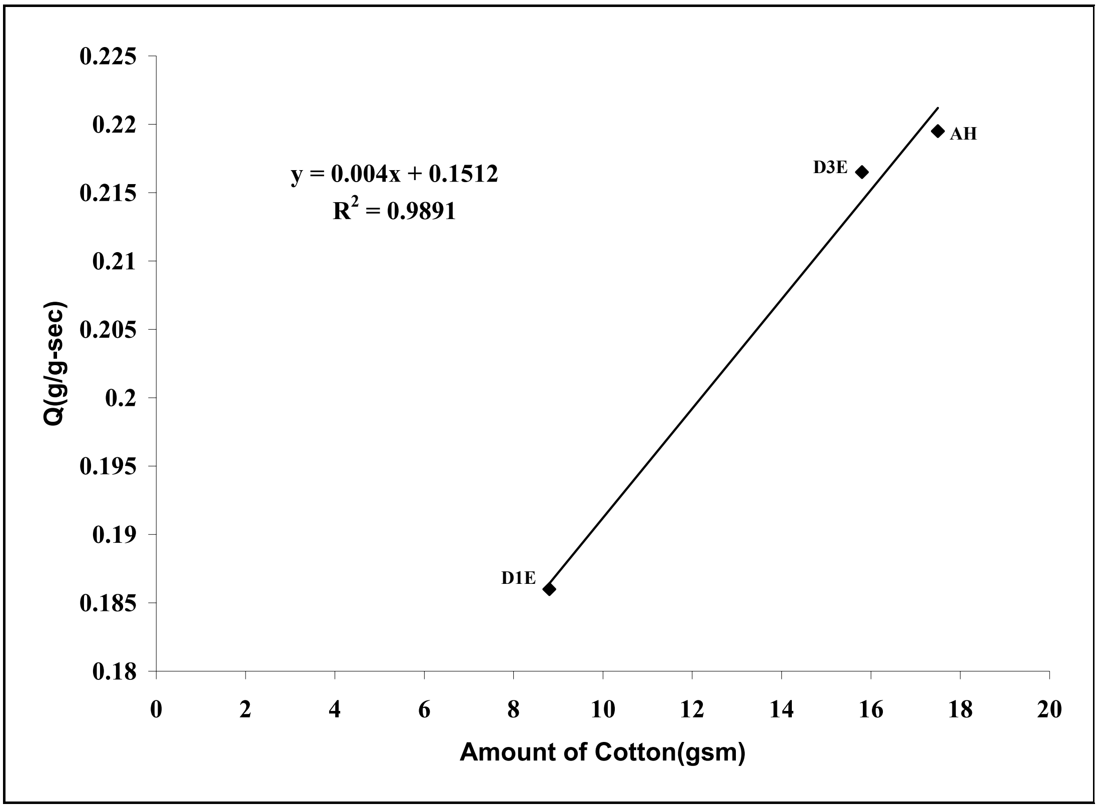

Figure 3. Rate vs. Amount of Cotton in CSNs Based on SB Eastar Bio GP Copolyester Webs.

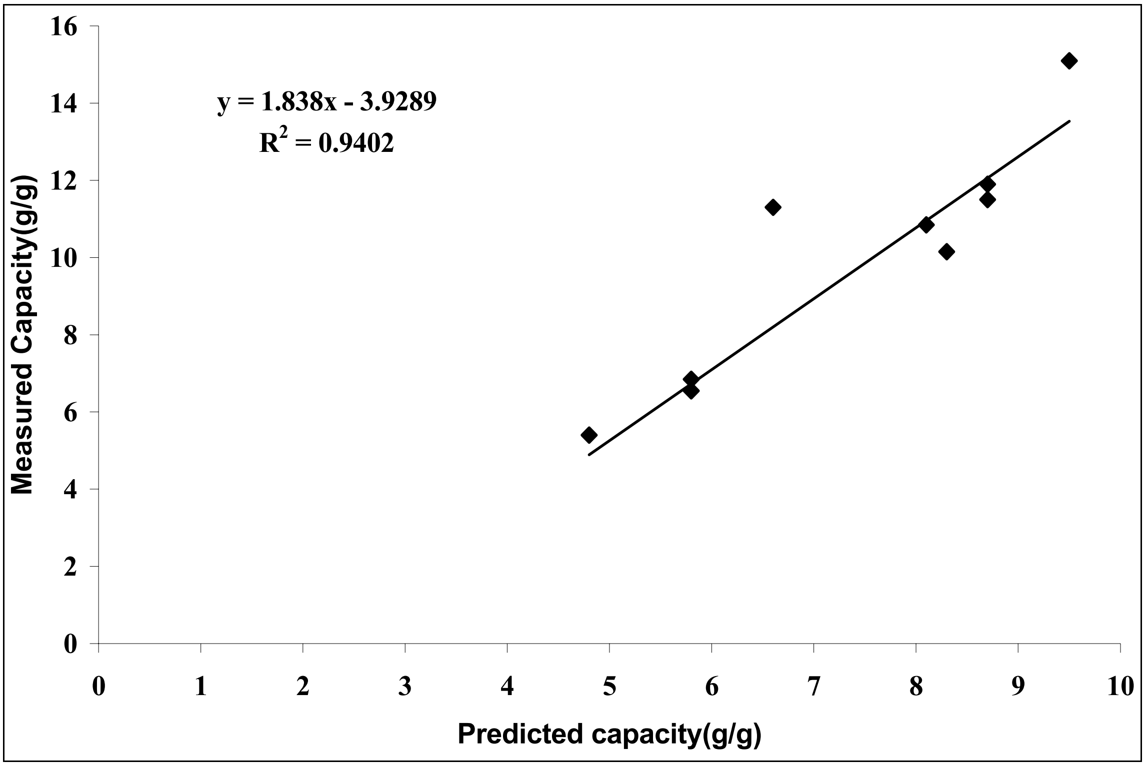

Figure 4. Measured vs. Predicted capacity Values of All Webs of the Study.