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HIGHLY ABSORBENT BIODEGRADABLE COTTON COMPOSITES

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Abstract

As reported at the Insight 2000 Conference, a thermally bonded Cotton-Core Nonwoven (CCN) with spunbond (SB) PP on one side and a melt blown (MB) PP web on the other side was shown to have greater wicking rate, water absorptive capacity and water retention capacity than a similar construction with light weight MB PP webs on both sides. In this paper, SB/Cotton/MB (SCM) CCN's with Bio Eastar GP Copolyester MB webs, a completely biodegradable web; instead of MB PP webs were produced, and compared to CCN's containing PP in both the MB and SB components. The absorbent cores had a weight of 1.5 oz/yd^2 (51 g/m^2) and consisted of carded 75/25 and 50/50 Cotton/PP staple fiber blends. The laminates were all infrared bonded and evaluated for tearing strength, tenacity, and water absorption rate and maximum absorption. The use of Bio Eastar GP Copolyester MB in place of MB PP resulted in stronger well-bonded laminates with exceptionally high absorbency on the Bio Eastar MB side as well as in the cotton core.

Introduction

Cotton-based nonwovens include Cotton-Core Nonwovens (CCN's) and Cotton-Surfaced Nonwovens. (CSN's). CCN laminates are a three-layered structure with cotton or cotton/PP webs in the center layer bonded with SB and MB webs as top and bottom layers. These biodegradable cotton composites have been developed at TANDEC, University of Tennessee, Knoxville with sponsorship from Cotton-Incorporated.

Cotton-Core Nonwovens

Cotton-Core Nonwovens are produced by sandwiching the cotton webs between the outer layers of melt blown (MB) and or spun bond (SB) webs using a thermal calendaring process. In Figure 1, the process showing the production of CCN's is shown. The bleached cotton web is introduced into the production line after the extrusion and laying of SB PP, and the MB PP web is introduced into the production zone after the cotton webs so as to develop a three layered structure in which the cotton webs are bonded in between the SB and MB layers. These SB and MB PP webs act as binder fibers in the thermal bonding and are engineered to transport liquid into the highly absorbent cotton core from the surface. The absorbent core and the dry surface makes CCN's highly suitable for diaper components, feminine hygiene products, wipes for baby, sponges, bandages, surgical gowns and other industrial and consumer applications. "Fibrous web having cellulosic fibers", a U.S. Patent No. 5,683,794 is assigned to The University of Tennessee Research Corporation (UTRC).

Elastic or Heat-Stretched Cotton-Core Nonwovens

Heat-Stretching the CCN's imparts instantaneous elastic recoveries of up to 70%-80% from an extension of 50% [U.S. Patent 5,683,794]. The Heat stretching in one direction imparts elasticity to the laminate in the other direction. In other words if the laminate is heat stretched in machine direction then it will be elastic in the cross-machine direction These elastic nonwovens possess excellent comfort and fit properties useful in applications such as inexpensive elastic leg cuffs and waist bands for disposable diapers. Elastic CCN's have improved wicking properties, in addition to stretchability, due to the greater orientation of Cotton and PP fibers in the machine direction which makes them ideal for protective apparel, face masks, bandages, wound dressings, feminine hygiene products and diapers. The following patents including this technology are assigned to UTRC: U.S. Reissue Patent No. 35,906 and U.S. Patent No. 5,441,550.

Cotton-Surfaced Nonwovens

Cotton-Surfaced Nonwovens (CSN's) have been developed with cotton on one or both sides of a base structure, generally spunbonded polypropylene web, in which the cotton content varies from 20-70% of the fabric weight. As shown in Figure 2, CSN's are made by placing the carded cotton/PP web on one or both sides of SB PP filament webs prior to the calendaring rollers. The thermally bonded two or three layered laminates are soft but strong and have excellent wetting, wicking, water absorption and water retention properties. They are ideally suited as cotton-surfaced outer fabrics for diapers, acquisition layers in diapers and feminine hygiene products, disposable bed linens and textile interfacings. A post-treatment process enhances the extensibility of the fabrics produced with instantaneous elastic recoveries of 83%-93% from an extension of 50%.

These elastic fabrics also exhibit minimal linting characteristics and would be suitable as isolation gowns, or drapes and gowns (if fluorochemical finished), physical therapy pants, head covers and shoe covers, bed sheets, pillow cases and for consumer applications such as disposable underwear, towels, wipers and personal hygiene products.

The bleached cotton staple used for the initial stage of fabric development was a premium medical grade with excellent absorbency, entanglement potential and comfort characteristics. Amidst ongoing technology advancements within the nonwovens industry, additional grades of cotton can now be incorporated into these CSN's and CCN's composites with similar results as well. Cotton staple and comber processing parameters have been defined, offering a wide range of economically competitive fibers for product consideration. With this new flexibility comes the opportunity for manufacturers to consider cotton where cost and processability were once a deterrent.

Experimental Procedures

Preparation of Cotton-Core Nonwovens

The Cotton-Core Nonwovens (CCN's) were prepared by first carding 28-inch wide webs at the John D. Hollingsworth On Wheels Research Laboratory in Greenville, SC, in compositions of 100% bleached cotton (Veratec Easy Street), 50% cotton/50% staple PP (FiberVisions T-156, 2.2 denier x 1.5 in.), and 75% cotton/25% staple PP at weights of 51 g/m^2 (1.5 oz/yd^2) and 75 g/m^2 (2.2 oz/yd2) onto 30 inch wide SB PP (Exxon Mobil PP 3155, 35 MFR) with basis weights of 11 and 17 g/m^2. The SB PP webs were produced on the 1-meter Reicofil 2 SB Line at TANDEC. The rolls of unbonded carded web/SB PP fabric were then laminated with 30-inch MB PP webs (produced by Accurate Products Company, Hillside, NJ) with basis weights of 12 and 16 g/m^2 as shown in Figure 1, except the SB PP web was formed prior to the carding step. The 34 g/m^2 MB Bio Eastar GP Copolyester was produced on the 20-inch Accurate Products melt blown line at TANDEC. It was necessary to collect the web on release paper. However in future trials, water spray quench will be utilized between the die and collector in order to avoid the use of release paper to prevent the web from sticking to the collector. All the laminates were bonded utilizing the Infrared (IR) bonding pilot line at Eastman Chemical Company, Kingsport, TN. Laminates 1 and 2 were bonded by placing the SB PP side on top for impingement of the IR radiation with the IR heater 8 inches above the SB PP. The line speed was 34 feet/min and nip roller after the IR heater was heated to 164°F with a nip pressure of 80 PSI. These conditions were sufficient to bond the SB PP to the cotton/PP webs and also resulted in excellent bonding of the Bio Eastar GP Copolyester resulting in a well-bonded laminate on both sides. Laminates 3 through 7 were first IR bonded under the same conditions as samples 1 and 2, except MB PP were there on the cotton and the line was increased to 45 feet/min. It was later found that the MB PP webs were not well-bonded and samples 3-7 were IR bonded a second time with the MB PP webs on top and exposed to the IR unit but the height of the IR unit was reduced to 7 inches. Also, the nip roller was heated to 200°F. Table 1 shows the description of biodegradable cotton-core nonwovens.

As noted in Table 1, approximately 20-meter lengths of Laminates 3, 4 and 5were heat-stretched (Laminates 8, 9 and 10 respectively) through a 6-ft forced hot air oven at a temperature of 300 ºF. The first pair of nip rolls had a surface speed of 3.8 m/min and the second pair of nip rolls had a speed of 7.2 m/min, resulting in a draw ratio of 1.9.

Determination of Wicking and Absorption Properties

Wicking and absorption properties (to distilled water) of all the samples were evaluated at Sherwood Instruments Inc., Lynnfield, MA, using the ATS-600 Absorbency Testing System (Figure 3). "It is a table top instrument that measures the absorption and desorption rate and total capacity of absorbent materials [8]. Absorption is measured based on time and the amount of fluid displaced from a fluid reservoir." Although the desorption of these samples were not determined, "the Desorption test can be run after the absorption test and measure the amount of liquid that is removed from the sample. A sample is placed on the test table, which is connected to a liquid reservoir by a tube. A highly accurate and reliable optical sensor checks and zeros the fluid level at the beginning of the test to ensure accuracy. The optical system also monitors the fluid reservoir during the test and maintains a constant fluid level at a preset differential head ensuring high sample throughput and virtually limitless absorption capacity. Once the fluid level is zeroed, a small pulse of fluid is emitted through the tube and is absorbed by the sample to start the test cycle [8]."

Sample Preparation and Testing

"All samples were cut from the sheets into 2-inch squares and placed on the table oriented in the same direction. All samples were tested in the Machine Direction…. in the 0º - 180º direction…. MD/CD ratios were calculated independent of sample placement…All results were corrected for sample weight and appear in grams/gram. The samples were tested using a special sample-penetrating Direction Rate table. This new table enabled us to test the samples for fluid migration even though the surfaces stayed 'dry'. The pins of the table were passed through the samples and the time required for water to reach the pins from the center point was measured. No weight was applied to the samples for these tests…. The Cotton-Core samples were tested on the spunbond (SB) side. All tests were run for at least 300 seconds, to ensure that absorption had tapered off, and the differential fluid head was set approximately at zero [9]."

Results and Discussions

Figure 3, 4 and 5 show Laminates E 29-1-1 and E 29-1-2. The first laminate contains higher cotton/PP content (75%) whereas the later one contains lower cotton/PP content (50%). The figures show that the difference in the amount of cotton has little effect on the strength properties except the flexural rigidity increased in the laminate containing higher cotton content. Figure 6 shows that the air permeability value is notably less in the case of sample containing 50% cotton content.

Figure 7 and 8 show that an increase in the basis weight of MB web in the CCN laminate has decreased the tear strength and increased the tenacity values. The increase in tenacity value for the laminate containing higher MB weight (16 g/m^2) is probably due to the better bonding of the laminate. The laminate (E 29-1-6A) produced using MB of lower basis weight (12g/m^2) has a film-like appearance whereas the laminate (E 29-1-7A) containing higher MB weight is bonded fairly well and has a web structure.

Figure 9 shows that the tenacity values of the heat-stretched laminates are higher than that of as-bonded laminates. Heat stretching increased the fabric orientation and compactness of the fabric, which helped in increasing the strength of the fabric and tenacity of the fabric. The MD/CD ratio of tenacity values for all the laminates is > 2.5.

Figure 10 shows that heat stretched sample E 29-1-5A has higher tearing strength which may be attributed to the compacting of the melt blown web to the laminate under the given temperature and roller speed. The tearing strength values for the other two heat stretched samples has considerably decreased. It shows that heat stretching produces webs with soft handle. Also the MD tearing strength values are higher than that of CD values.

Air permeability of the as-bonded and heat-stretched samples can be observed from Figure 11. Heat stretching increased the air permeability of the laminates except in the case of E 29-1-3A. This laminates contains higher cotton content and an increase in the heat stretching temperature would probably have increased the air permeability of the particular laminate.

Figure 12 shows that melt blown web weight has an effect on the stiffness properties of the laminates. The CCN laminates containing higher MB weight (16g/m^2) has higher values of flexural rigidity. The flexural rigidity does not depend on the cotton content when observed for as bonded samples. For the heat stretching samples it is observed that higher cotton content in the laminates has increased the bending length and flexural rigidity values. The ratio of bending length values in machine direction and cross direction for as bonded laminates is higher than that of heat stretched laminates, which shows that heat stretching increased the bending length in the machine direction but did not effect the stiffness values in the cross direction except in the case of E 29-1-4A laminate. Heat stretching also increased the basis weight and thickness of the laminates.

Absorption and Wetting Properties

Figure 13 shows the CCN laminates (E 29-1-1, E 29-1-2) containing 75% cotton and 50% cotton respectively. The Bio Eastar GP Copolyester MB weight introduced on one side into both the samples is the same. E 29-1-1 Laminate has a maximum absorbency of 7.1 grams/gram in 400 seconds and the Laminate E 29-1-2 has a maximum absorbency of 6.4 grams/gram. Higher cotton content in the Laminate E 29-1-1 is the probable reason for the higher absorption of water in the tested time. The most rapid absorption rates resulted in the two laminates with the very hydrophilic Bio Eastar GP Copolyester MB webs, compared to MB PP webs as discussed below.

Figure 14 shows the maximum absorption values for the above laminates but with the spunbond web exposed to wetting. The maximum amount of water absorbed is the same for the two laminates. This is because of the hydrophobic nature of the spunbond web produced from PP. The maximum absorption values are 6.4 grams/gram and 6.1 grams/gram respectively for the laminates.

Observing Figure 15 gives an idea of the effect of heat stretching on the water absorption of the laminates. The graph shows the three heat stretched laminates in which the Laminate E 29-1-3 HS containing higher cotton content (75%) has higher absorption amount and surprisingly the Laminate E 29-1-5A containing 50% cotton has the second highest absorption amount. The probable reason for the reduction in the maximum amount of water absorbed is higher basis weight of melt blown web used in the laminate. The maximum absorption amount values for the three Laminates E 29-1-3, E 29-1-5A HS and E 29-1-4A are 9.6grams/gram, 9.4 grams/gram and 8.0 grams/gram respectively. Comparing the maximum absorption amount values of the heat stretched laminates with the as bonded laminates; the effect of heat stretching is clearly observed. For the laminate containing higher cotton content heat stretching did not produce any change in the absorption properties. Laminates containing lower cotton content absorbed less amount of water after the heat stretching process. After the heat stretching the laminates are oriented in the machine direction and their directional absorption properties are prominent in the machine direction. The absorption values are decreased to some extent due to the well-bonded laminates. But in the case of the Laminate E 29-1-3 the set temperature of 290-300 °F may not be high enough to produce the similar effect in the case of this laminate.

Summary and Conclusions

Bio Eastar GP Copolyester MB bonded better than did the MB PP webs in that the CCN laminates produced with MB PP and SB PP webs had to be run through the IR bonding unit twice so that each side could be exposed directly to the IR radiation. The Bio Eastar GP copolyester MB web resulted in very well bonded laminate in one pass through the IR unit. The use of 16 g/m^2 MB PP webs in the production of CCN laminates resulted in the higher tenacity of the laminated web but of lower absorption amount, compared to the laminates produced with 12 g/m^2 MB PP web. Heat stretching resulted in higher tearing strength and tenacity of laminates. Heat stretching produced webs of softer hand and a greater directional wetting in the machine direction.

Acknowledgements

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Table 1. Description of Biodegradable Cotton-Core Nonwovens (CCN's).

Sample #/Descr.		**Core Content* C/PP**	**Web Wt (G/m^2)**		**IR Bonded T/FPM**
			SB	**MB**	
1	E-29-01-1	75/25	11	34**	164F/34
2	E-29-01-2	50/50	11	34**	164F/34
3	E-29-01-3A	75/25	11	12	200F/38
4	E-29-01-4	50/50	11	16	200F/38
5	E-29-01-5	50/50	11	12	200F/38
6	E-29-01-6A	75/25	11	12	200F/38
7	E-29-01-7A	75/25	11	16	200F/38
8	E-29-01-3 HS***	75/25	11	12	200F/38
9	E-29-01-4A HS***	75/25	11	-	200F/38
10	E-29-01-5A HS***	50/50	11	16	200F/38

Note: Laminates 1 and 2 were bonded using Bio Eastar GP copolyester.
Laminates 3-7 were first bonded with SB on top (line speed 45 ft/min) and were turned over and then were bonded a second time with MB on top (line speed 38ft/min, nip roller temperature 200°F, height of IR unit 7”).
* Composition of center carded web of cotton/PP staple fiber.
** MB Web consisting of 34 gsm Bio Eastar GP Copolyester; all other MB and SB Components consisted of 100% PP.
*** As-Bonded laminate heat-stretched in oven at 290-300F with a draw ratio of 1.9.

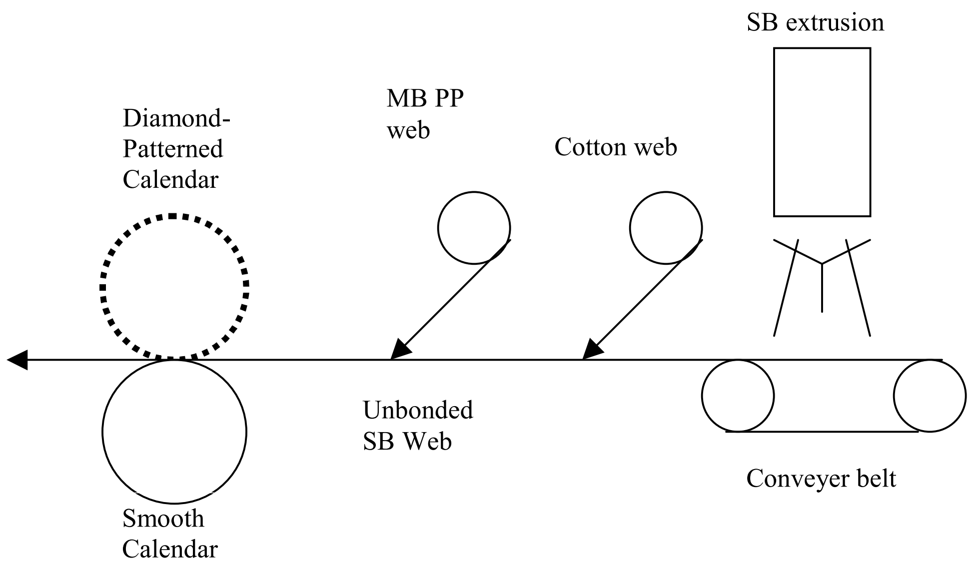

Figure 1. Preparation of Cotton-Core Nonwovens (CCN’s) on spun bond line introducing Cotton and MB webs.

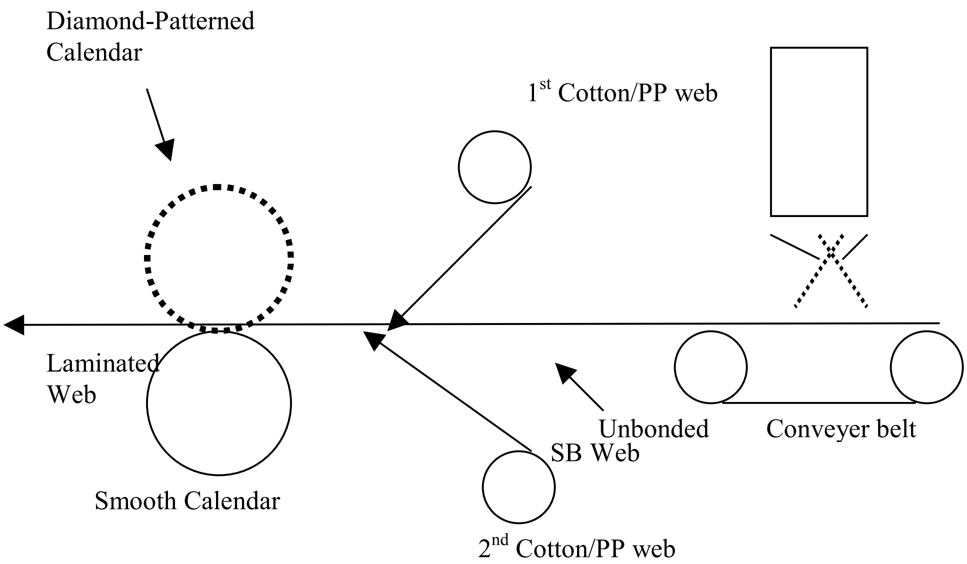

Figure 2. Preparation of CSN's on the spun bond line inducing Cotton/PP webs.

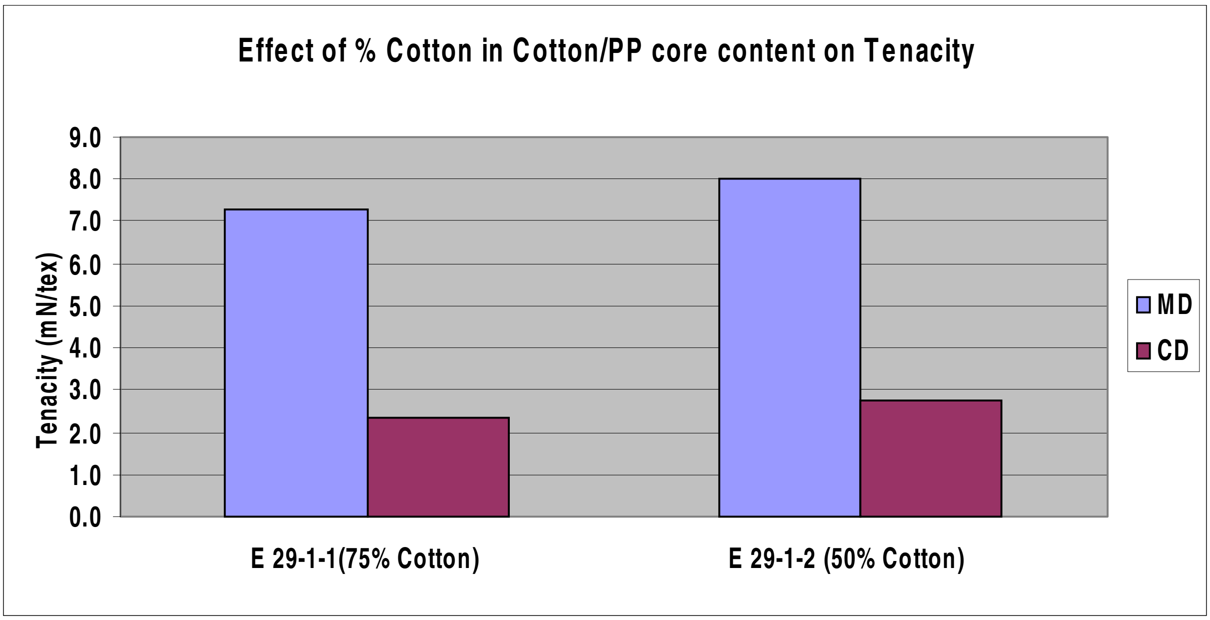

Figure 3. Effect of % Cotton in Cotton/PP core content on Tenacity.

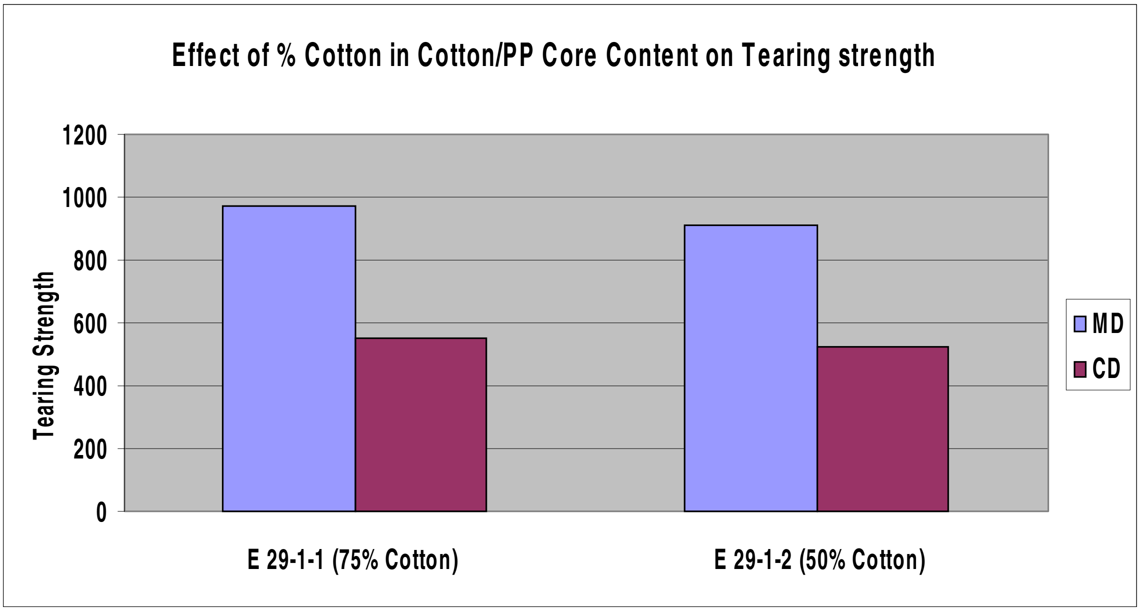

Figure 4. Effect of % Cotton in Cotton/PP core content on Tearing strength.

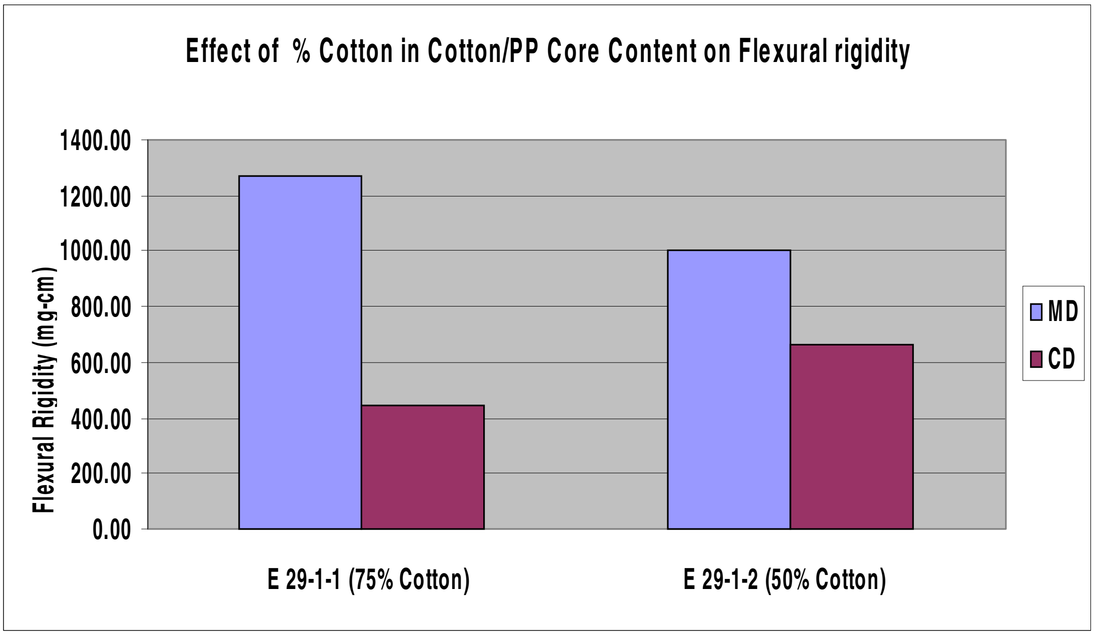

Figure 5. Effect of % Cotton in Cotton/PP core content on Flexural rigidity.

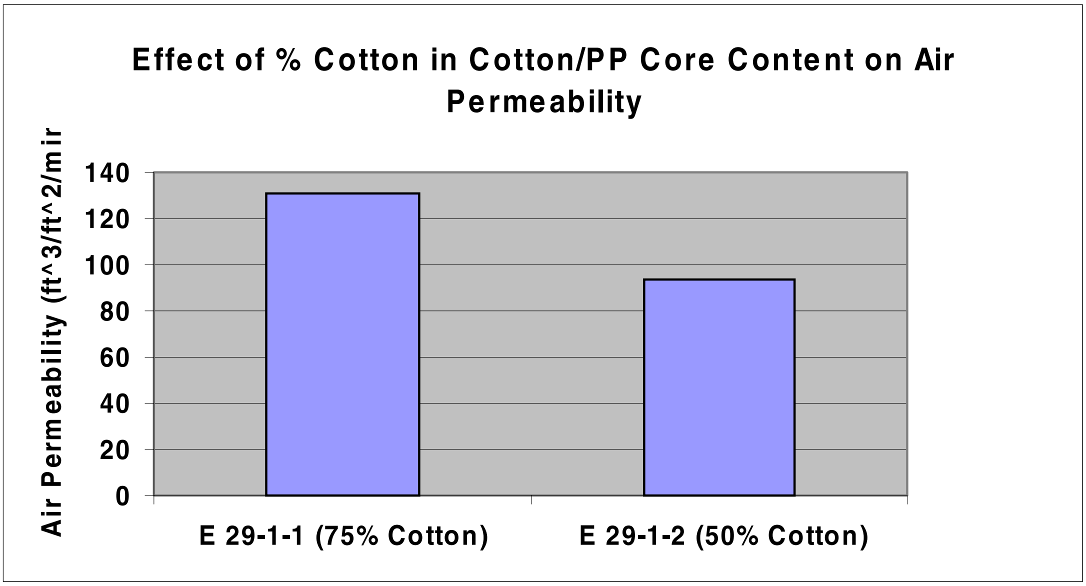

Figure 6. Effect of % Cotton in Cotton/PP core content on Air permeability.

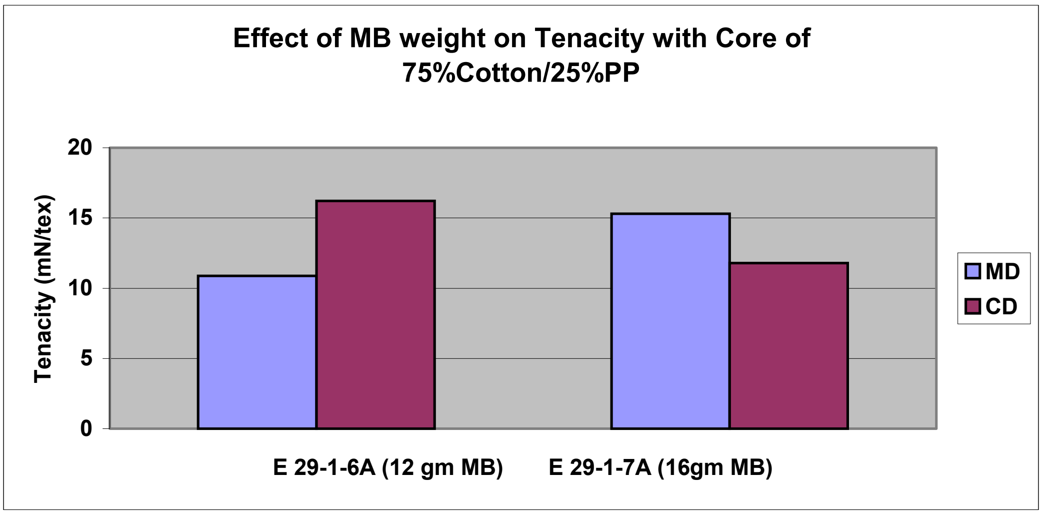

Figure 7. Effect of MB weight on Tenacity with core of 75%Cotton/25%PP.

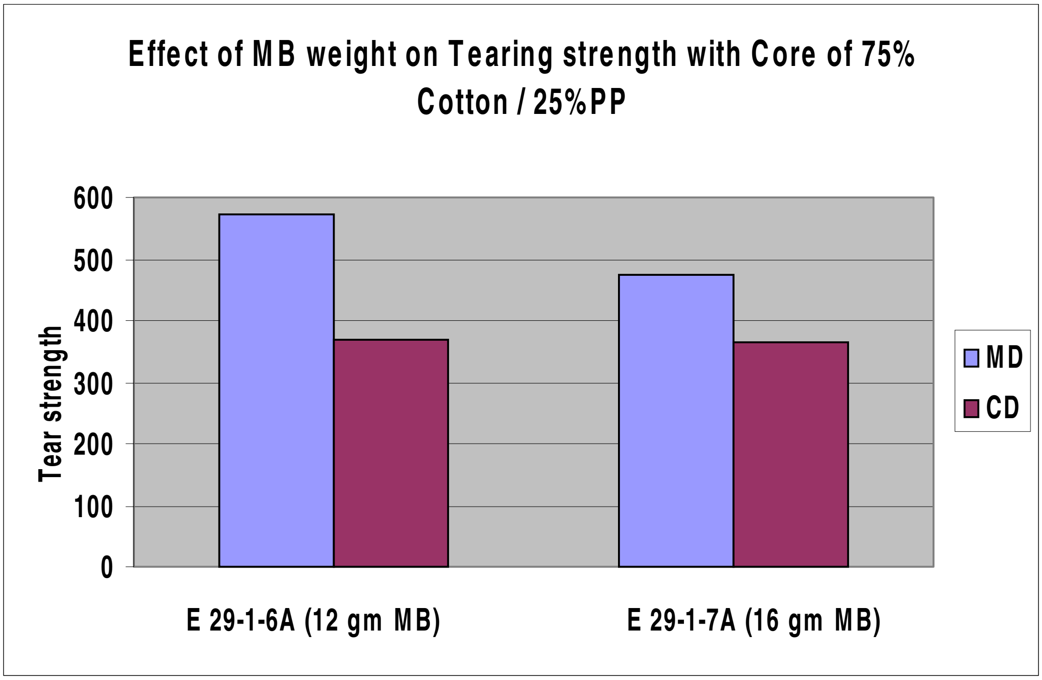

Figure 8. Effect of MB weight on Tearing strength with core of 75%Cotton/25%PP.

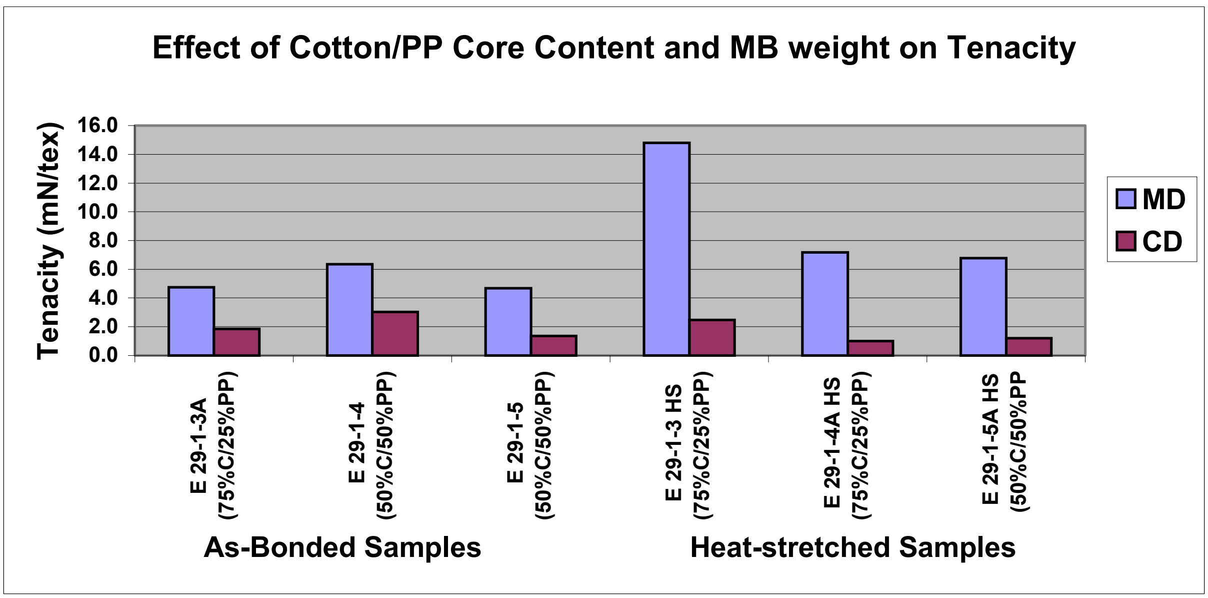

Figure 9. Effect of Cotton/PP core content and MB weight on Tenacity.

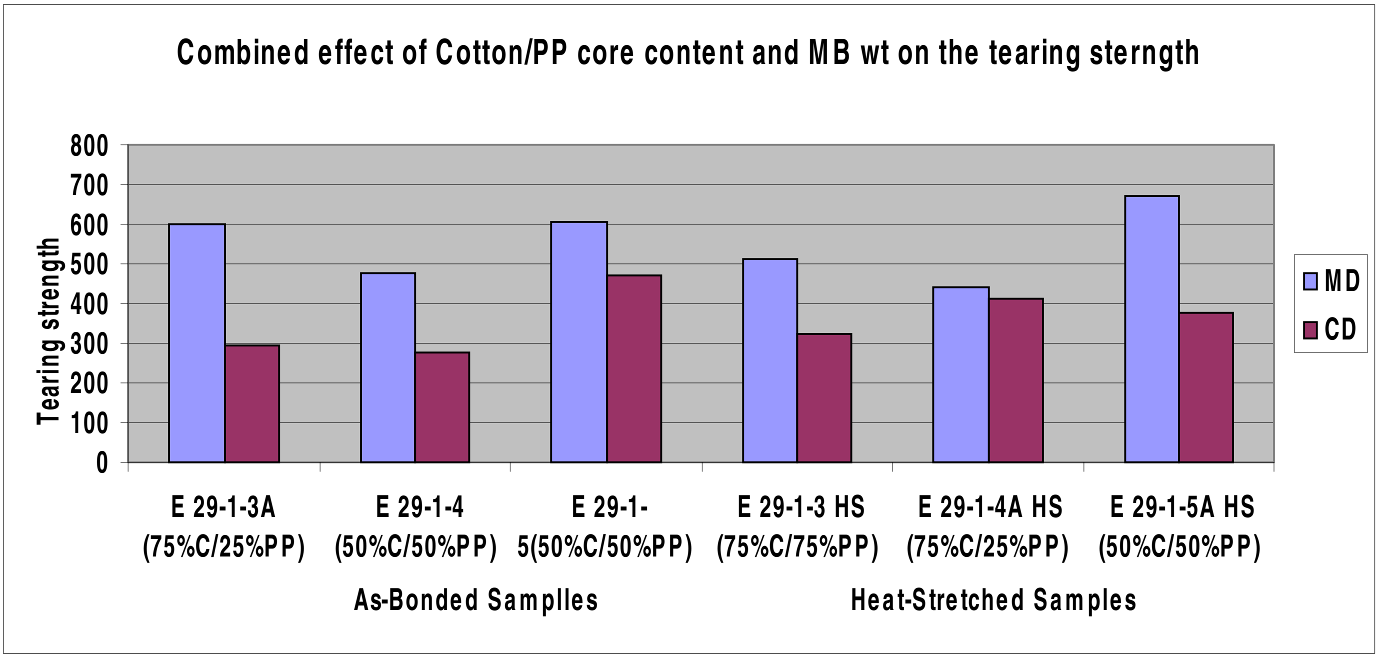

Figure 10. Effect of Cotton/PP core content and MB weight on Tearing strength.

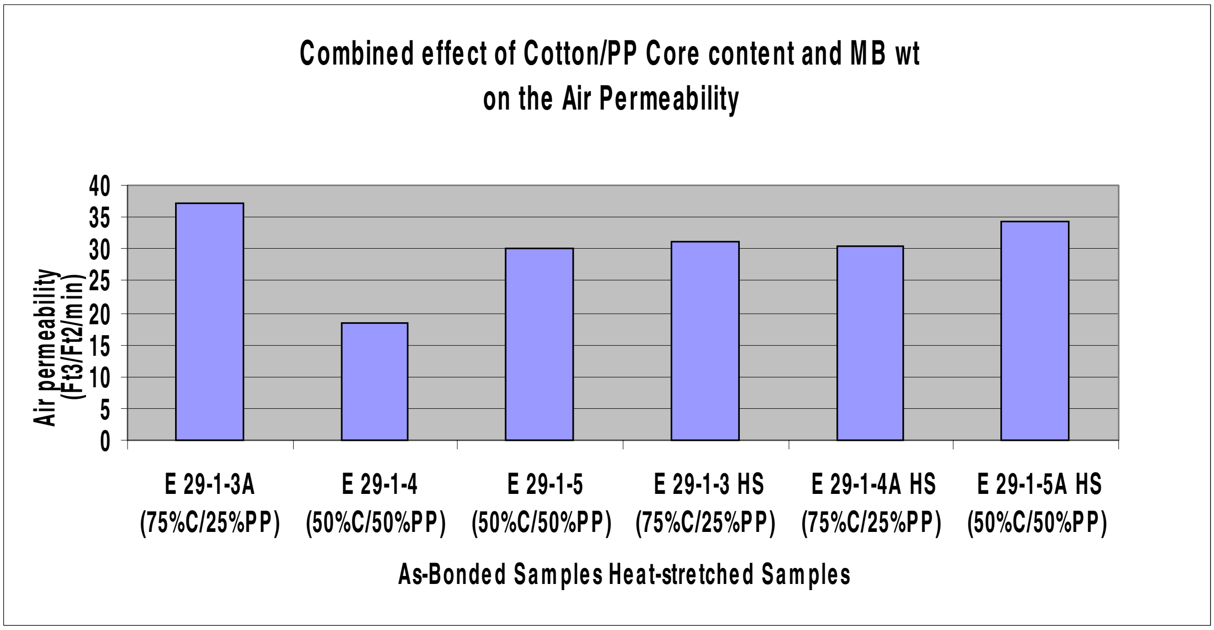

Figure 11. Effect of Cotton/PP core content and MB weight on Air permeability.

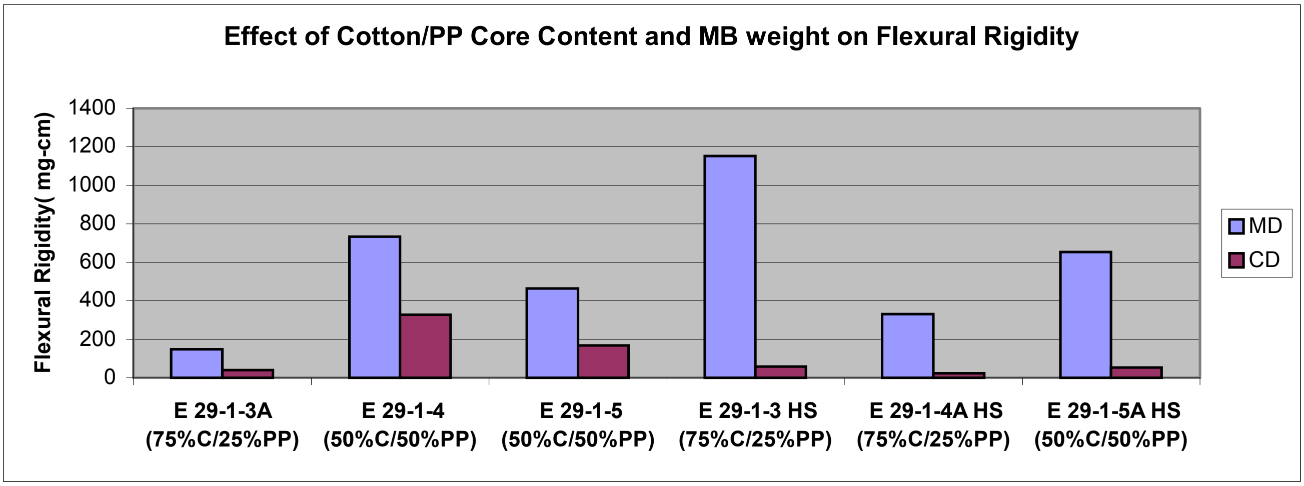

Figure 12. Effect of Cotton/PP core content and MB weight on Flexural rigidity.

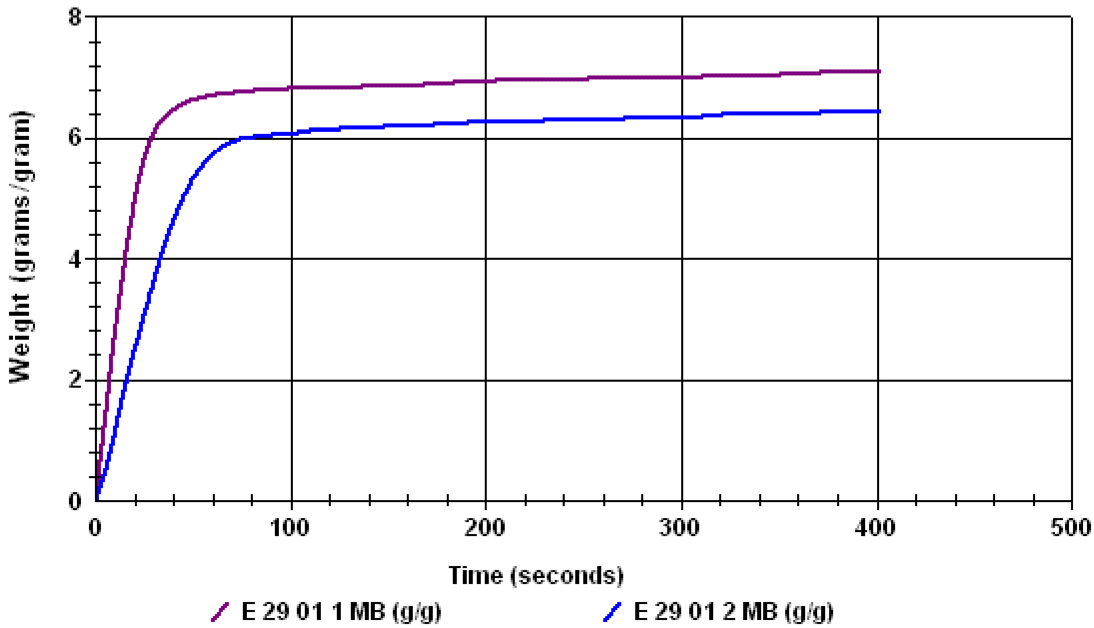

Figure 13. Absorption versus time curves (MB side) for Laminates containing Bio Eastar GP copolyester MB.

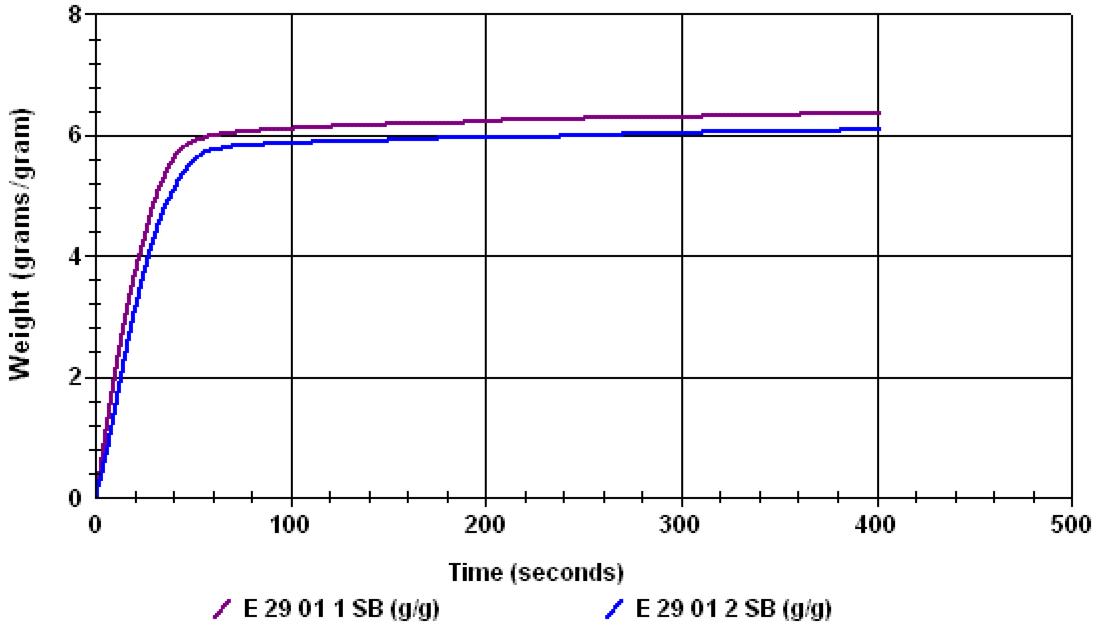

Figure 14. Absorption versus time curves (SB side) for Laminates containing Bio Eastar GP copolyester MB.

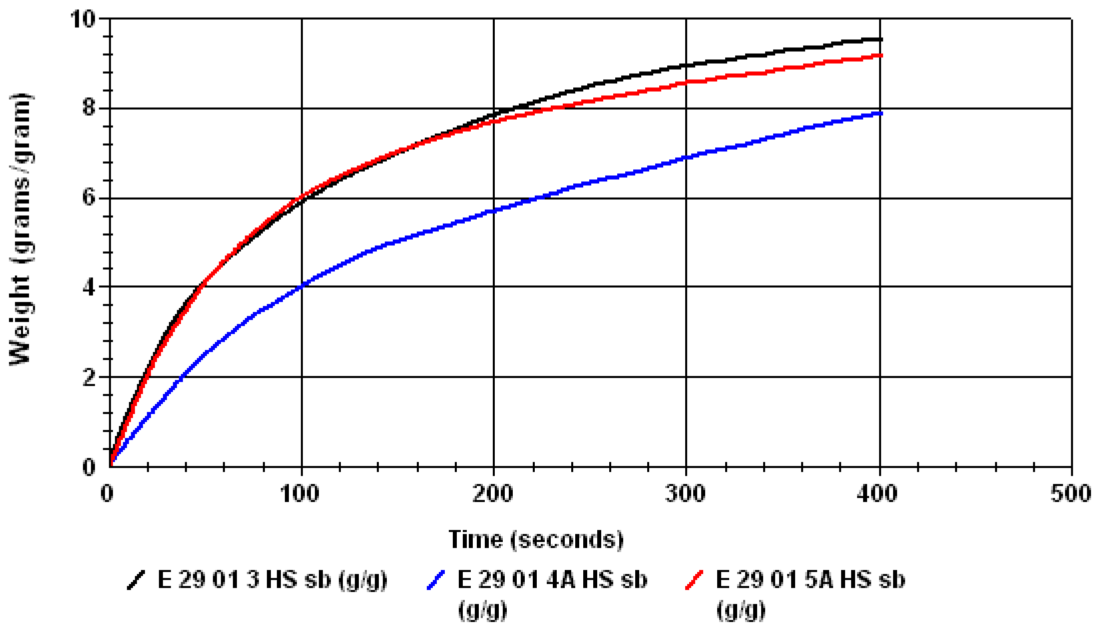

Figure 15. Absorption versus time curves for Heat stretched laminates.

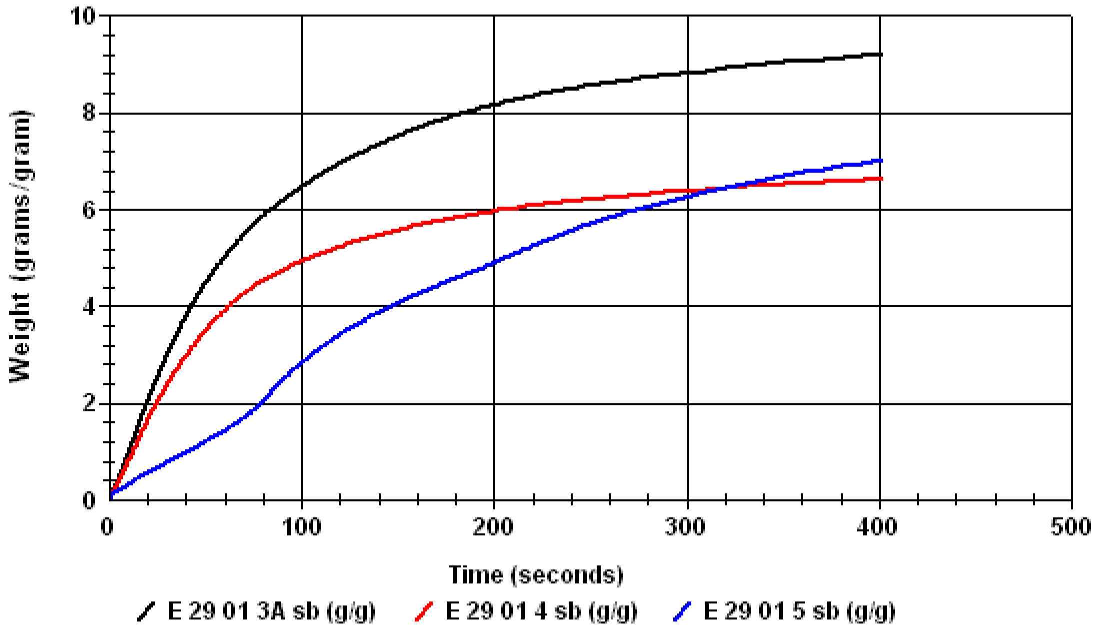

Figure 16. Absorption versus time curves for As-bonded laminates.