COTTON IN ABSORBENT CORES

Edward C. McLean and H. Charles Allen, Jr.
Cotton Incorporated
Cary, NC

Abstract

This paper will discuss the effects of replacing the traditional 100% wood pulp fibers used to produce absorbent cores with 100% cotton linters and three blends of cotton linter and wood pulp fibers. The study produced absorbent cores in two densities with two superabsorbent powder loadings per core density. The cores were tested for absorption, liquid acquisition, wet web integrity, multiple insult rewet, horizontal and vertical wicking. The energy used to defibrillate the cotton linter and wood pulp fiber sheets were also measured. The properties of wood pulp and cotton linter fibers will also be discussed.

Discussion

Cotton Linters

Ginning, in the strictest sense, is the process of separating cotton fibers from the seeds. However, not all the fibers are removed from the seeds by the gin. Shorter fibers, less than one-eighth of an inch, which remain attached to the seeds after ginning are called linters. The seeds are sent to an oil mill and processed through a delinting machine, which removes the linter fibers from the seeds. Linter fibers are much shorter than the longer cotton fibers and they have a thicker secondary wall of cellulose, therefore they are stiffer and do not collapse on themselves. All cotton fibers, including linters are protected from the elements by a natural coating of oils and waxes which makes it hydrophobic. Cotton must be scoured and bleached where absorbency, whiteness and chemical purity are desirable properties. After proper scouring and bleaching cotton is over 99% pure cellulose.

In 1997 there were 604,000,000 pounds of bleached cotton linters produced in the U.S. Bleached cotton linters are normally formed into continuous sheets and placed on large rolls, just like wood pulp fibers; therefore they can be used to replace wood pulp fiber sheets without modifying existing production equipment. These linters are used primarily to produce: high quality paper, in paints and coatings and as a source of cellulose in the chemical industry. Only a very small amount of cotton linters are currently being used in absorbent core or other nonwoven applications. There are a number of nonwoven products produced from linters that are currently in the development pipeline.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:778-782 (2000)
National Cotton Council, Memphis TN

Fiber Properties

Both cotton and wood pulp fiber are constructed of cellulose polymers. Cellulose is made of anhydroglucose units linked together by 1,4, oxygen bridges (Figure 1). The anhydroglucose units are linked together as beta-cellobiose, so anhydro-beta-cellobiose is the repeating unit of the polymer chain. The number of these repeat units that are linked together to form the cellulose polymer is referred to as the degree of polymerization (dp). The degree of polymerization for cotton cellulose is 9,000 to 15,000 and wood pulp cellulose is 600-1,500. It should be noted that wood pulp contains 8-10% hemi-cellulose which means the anhydroglucose units are replaced by various other plant sugars, such as xylose.

Cotton cellulose also differs from wood pulp in that it has a higher degree of crystallinity; average values are 35% for wood pulp and 73% for cotton. Crystallinity indicates that the fiber molecules are closely packed and parallel to one another (Figure 2). Hydrogen bonds occur between the hydroxyl groups of adjacent molecules and are more prevalent between the parallel; close packed molecules in the crystalline areas. Higher crystallinity and degree of polymerization in polymers are associated with higher strength.

Table 1 shows the fiber characteristics of wood pulp and cotton linter fibers. This shows that cotton linters have the same characteristics as southern softwood except for diameter. The southern softwood fibers have a larger diameter, 40 microns, than the cotton linter fibers, 25 microns. Southern softwood fibers are the primary fibers used to produce commercial absorbent cores and are referred to as "fluff pulp".

Absorbent Core Study

The fibers used in the study were Foley southern Kraft fluff pulp and cotton linters, both supplied by Buckeye Cellulose. The five fiber blends produced are shown below:

1. 100% Fluff Pulp
2. 80% Fluff Pulp/ 20% Linters
3. 60% Fluff Pulp/ 40% Linters
4. 50% Fluff Pulp/ 50% Linters
5. 100% Linters

The above blends were loaded with two levels of Stockhausen Favor SCM 77 superabsorbent powder (SAP), 25 and 40% by weight. Cores using the above blends of fiber and SAP were produced at two densities, 0.08 g/cc and 0.12 g/cc. These blends of superabsorbent/fiber and densities represent the typical range of existing commercial products.

The cores were tested using MTS Tefo testing equipment and methodology to measure the following properties:

1. Energy to Defibrillate
2. Absorption
3. Liquid Acquisition
4. Multiple Insult Rewet
5. Wet Web Integrity
6. Horizontal Wicking
7. Vertical Wicking

The data shown in the attached tables and figures represent the average of ten replicate tests for all the above methods, except the data for energy to defibrillate which represent the average of five tests. These test methods will be explained individually and the data generated will be discussed below.

Energy to Defibrillate

The cotton linter and fluff pulp sheets were defibrillated using an H-01 Kamas hammermill. This machine also records the energy necessary to defibrillate the fiber sheets. Table 2 shows the energy needed to defibrillate to be much less for the cotton linter sheets at both hammermill conditions. Figures 3 and 4 show that the energy required to defibrillate the cotton linter sheets increases with rotor speed. Figures 5 and 6 show increasing rotor speed reduces the nits and increases the fiber content of the defibrillated cotton linter fibers. They also indicate that using a smaller screen reduces the nits. Nits are tight unopened bundles of fibers that are objectionable.

Cotton linter sheets require less energy to defibrillate. Increasing the rotor speed and decreasing the screen size reduces the number of nits and improves the quality of the hammermilled linters.

Absorption

This test is used to evaluate absorption and retention under three loading conditions. A barrier is placed beneath a weighed sample and placed on the absorption tester. The weight holder with the liquid application tube is placed on the dry sample; this equals a 0.1kPa load. The thickness of the dry sample is measured and recorded. A solution of 0.9% saline is applied to the sample at a flow rate of 7ml/second; a total volume of 100ml is applied. This completely saturates the sample. After two minutes the sample thickness and amount of liquid retained are measured. A 3kPa load is then applied to the sample and after two minutes the thickness and liquid retained are measured. A 5kPa load is added and the thickness and the amount of liquid retained is measured, again after two minutes.

The ideal performance on this test would be equal retention and ACI (absorbent capacity index which is the ml of liquid retained divided by the sample weight) at all loading conditions (i.e. no liquid is removed with increased loading) and without restricting initial absorption and penetration.

The test results (see Figures 7&8 for ACI and 9&10 for retention) shows that for the cores containing 25% SAP, the higher the percentage of fluff pulp, the better the absorption. However, at the 40% SAP loading, all the blends containing cotton performed better that the 100% fluff pulp (Figures 11&12 for ACI and 13&14 for retention). This gives an indication that adding linters to the cores improves the absorbency performance. This could be very important as the industry trend is to make thinner products by reducing the amount of fiber and increasing the amount of SAP used in absorbent cores without reducing absorbency.

Liquid Acquisition Test Method

The TEFO absorption tester was used to test liquid acquisition ability of the absorbent cores (Figure 15). Core samples (50 square cm in size) were placed between standard backsheet and coverstock fabrics and placed on the tester. Three (3) insults, 50ml each, of 0.9% saline solution are applied at a rate of 4ml/second. A 15-minute delay occurs between the insults. The amount of overflow and leakage is recorded on a graph with time being on the X-axis and milliliters on the Y-axis. The best results are to have instant penetration with no overflow or leakage. Failing that, the best results are as little overflow as possible and to have the onset of overflow delayed as long as possible.

The results of this test show that at the higher density (0.12 g/cc) the cores containing cotton linters in the blends performed better than the 100% fluff pulp. Although this trend is not as great at the lower density (0.08 g/cc) it is still there. Figures 16-20 show the results for cores containing 25% SAP at a density of 0.08 g/cc. Figures 21-25 show the results for cores containing 25% SAP at a density of 0.12 g/cc. Figures 26-30 show the results for cores containing 40% SAP at a density of 0.08 g/cc. Figures 31-35 show the results for cores containing 40% SAP at a density of 0.12 g/cc.

This can also be valuable in producing thinner products. Having linters present in the absorbent cores will allow them to be compressed to higher density and exhibit good liquid acquisition. On a side note, the cores produced with linters were found to be much more pliable than 100% fluff pulp at higher densities. Cores made from 100% fluff pulp were very stiff and had sharp edges at higher densities. Cores produced with linters were found to be pliable enough to function in absorbent products at densities as high as 0.24 g/cc, at a density of 0.30 g/cc even the cores containing linters were too stiff.

Multiple Insult Rewet

A 20ml volume of 0.9% saline solution is applied to the center of the test sample. After 300 seconds a weighed sheet of James River blotter paper is placed on top of the sample and a 3kPa load is applied for 120 seconds. The blotter paper is re-weighted and recorded. The above is repeated for a total of three tests. The core samples are tested with a standard backsheet and coverstock fabric in place.

Repeat insult testing has become more of a standard analysis as superabsorbent and acquisition/distribution layers continue to develop. The key is to have your product perform well in an overnight situation or other times when a product could receive more than one insult.

As expected the samples having higher loading of superabsorbent powder performed better. There was no measurable differences seen between the blends (Figures 36-39).

Wet Web Integrity

Rectangular pads are formed to 1 inch by 4 inches, weighing 1.5 grams and compressed to a density of 0.1 g/cc. The pads are bent around the breaking bar of the reservoir and the ends are connected to the jaws of a tensile tester. The reservoir is filled with 0.9% saline solution and the tester started. The force measured in kilograms (Kg) needed to break the pad is recorded.

The results did not differentiate any of the blends as having a better wet strength (Figures 40-41). This probably due to the presence of SAP in all the samples, which typically hinders wet web strength. An additional test was conducted using 100% fluff pulp and 100% linters, no SAP present. This showed superior wet web integrity in the sample made from linters(Figure 42).

Horizontal Wicking

Pads are formed to 4 inches by 7 inches and are weighed and compressed to a density of 0.08 g/cc or 0.12 g/cc. The pad is placed on the platen holding the liquid sensors so that the sensors penetrate the pad. Fifty (50) ml. of 0.9% saline solution is applied to the pad at 2ml/second and the pad is allowed to wick for 15 minutes. During that time the sensors are detecting the presence of liquid and the values are recorded. The best performance is the most sensors wetted in the smallest amount of time.

The testing did not differentiate any one of the 25% SAP loaded samples from the others (Figures 43-44) or between the 40% SAP loaded samples (Figure 45-46). The data does show that at 25% SAP loading the higher density cores (0.12 g/cc) exhibit much better horizontal wicking. However, for the cores containing 40% SAP the opposite is true, the higher density cores (0.12 g/cc) have less horizontal wicking. This is probably due to the increase concentration of SAP (40%) contained in the samples. It is well documented that as SAP's absorb liquid they swell greatly and form a gel that can slow or stop liquid flow. This is referred to as "gel blockage".

However, the frequency of the sensors wetted as compared to the potential number of sensors available at levels 3, 4 and 5 is greater on many of the linter blends as compared to 100% fluff pulp. This may indicate slightly improved wicking in the cores containing cotton linters.

Vertical Wicking

The samples are formed into 1 inch by 4 inches rectangular shapes to a weight of 1.5 g and to a density of 0.1 g/cc. The samples are placed into position making certain that the top of the sample is flush with the top of the stockade compartment. This is repeated until all ten compartments of the stockade are filled. Sensors are paced at three levels in each sample. The reservoir is filled to a depth of approximately 0.5 cm with 1% saline solution. The samples are lowered into the solution and left for 600 seconds, the sensors record the time it takes for the liquid to reach them. At the end of the test, the samples are raised and allowed to drain for 15 seconds. The pins are removed and the amount of solution retained by the samples is recorded. The best performing samples have the fastest wicking speed at all three sensor locations.

The fluff pulp samples had a little faster vertical wicking rate than the linters at all three sensor locations and it also had a slight advantage in liquid retention (Table 3).

ABSORBLEND™ Trademark

To support the use of cotton linters in absorbent cores, Cotton Incorporated has developed a new trademark, ABSORBLEND™ (Figure 47). In order to use this trademark, the absorbent core of the products must contain 60% cotton linters (by weight), note that the weight of the SAP is not included in this calculation because it is not a fiber. A consumer survey conducted by Cotton Incorporated shows that over 7 out of 10 adults recognize the Seal of Cotton, making one of the most widely identifiable trademarks in America. The survey also revealed that 66% of those surveyed thought that personal care products with the Seal are better quality, 59% stated that they expect to pay more for products with the Seal and 57% said they would be willing to pay more for products with the Cotton Seal.

Conclusions

The above data shows that cotton linters do perform well enough to be a direct substitute for fluff pulp in absorbent cores, even in blends with fluff pulp. At a density of 0.12 g/cc all blends containing cotton display superior liquid acquisition properties. This coupled with the improved absorbency performance of the cotton blends at higher SAP loading (40%) suggest that using cotton linters or linter/fluff blends will allow for production of absorbent cores which have higher densities and SAP loading thereby making production of thinner cores a possibility.

Overall the result indicate that absorbent cores of cotton linters or blends with fluff pulp can be formed to perform as well as existing fluff pulp cores and that liquid acquisition properties of cotton linter containing layers in ultra-high density pads will have merit.

Acknowledgements

The author would like to thank the staff at MTS for the professional manner in which this project was conducted and for help putting this presentation together. A special thanks to Buckeye Cellulose for supplying the fluff pulp and cotton linter fiber sheets. A special thanks to Debby Long of Cotton Incorporated for doing the hard work of typing this paper and producing the quality slides.

FIBER CHARACTERISTICS--WOOD PULP VS. COTTON

	Length	Diameter	Wall	Fraction of Total Fiber	Fibers/Gram (in millions)
Southern Softwood	3.0 mm	40 µ			1
Summerwood			8µ	50	
Springwood			3µ	50	
Northern Softwood	2.5 mm	35µ			3
Summerwood			5µ	25	
Springwood			2µ	75	
Hardwood	1.0 mm	20µ			6
Fiber			5µ	65	
Vessel			2µ	35	
Cotton					1
Linter	3.0 mm	25µ	8µ	90	
Staple	30 mm	25µ	2µ	10	

Table 1

KAMAS HAMMERMILL ENERGY FOR DEFIBRATION (PULP VS. LINTERS)

FIBER	ROTOR (%)	FEEDER (%)	SCREEN (mm)	TIME (sec)	ENERGY (kw hrs/ton)
Southern Kraft	85	75	12	2.4	63.67
Linters	85	75	12	2.4	29.40
Southern Kraft	75	75	8	2.4	61.52
Linters	75	75	8	2.4	46.58

Table 2

VERTICAL WICKING - COTTON LINTERS VS. FLUFF PULP

	TIME TO REACH SENSORS (seconds)			
	1st LEVEL	2nd LEVEL	3rd LEVEL	RETENTION (g)
100% Cotton Linters	7.83	26.86	34.69	13.03
100% Fluff Pulp	6.91	24.39	31.31	12.64

Table 3

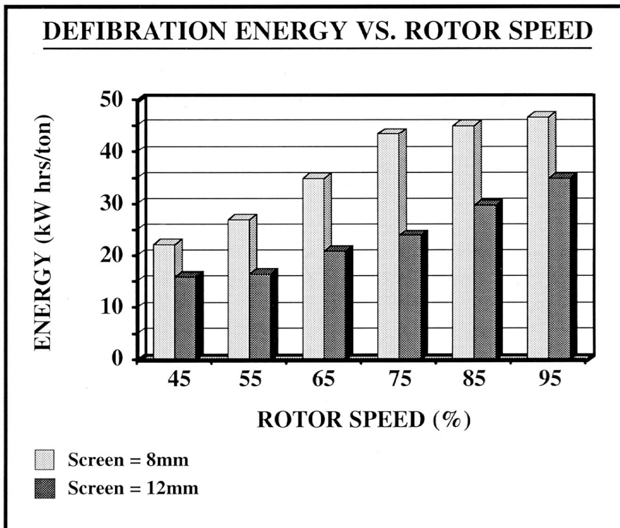

Figure 1

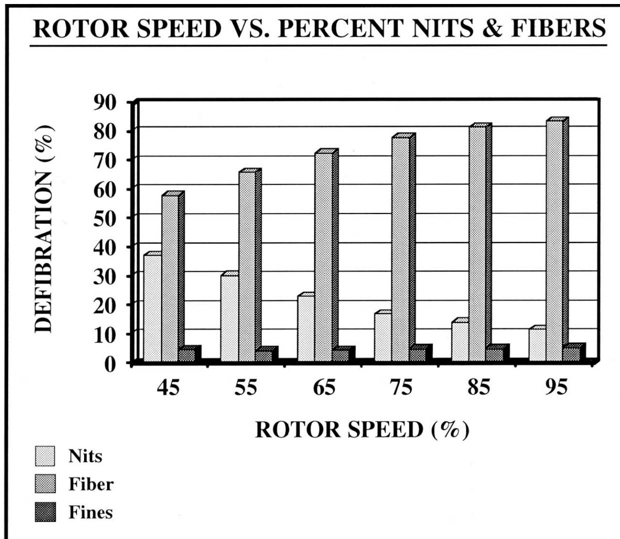

Figure 2

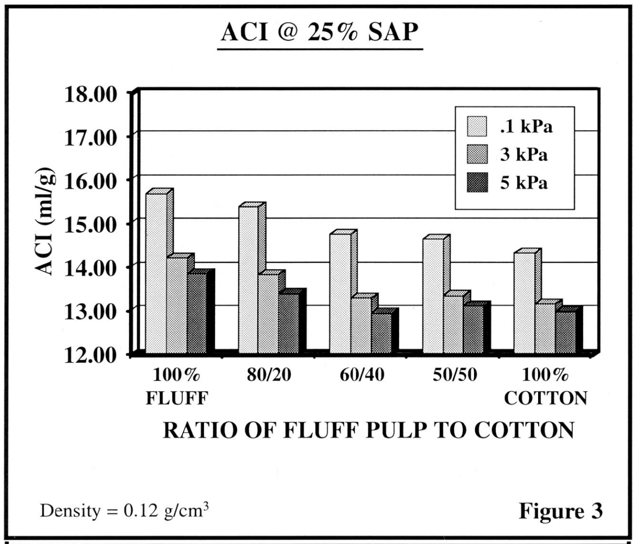

Figure 3

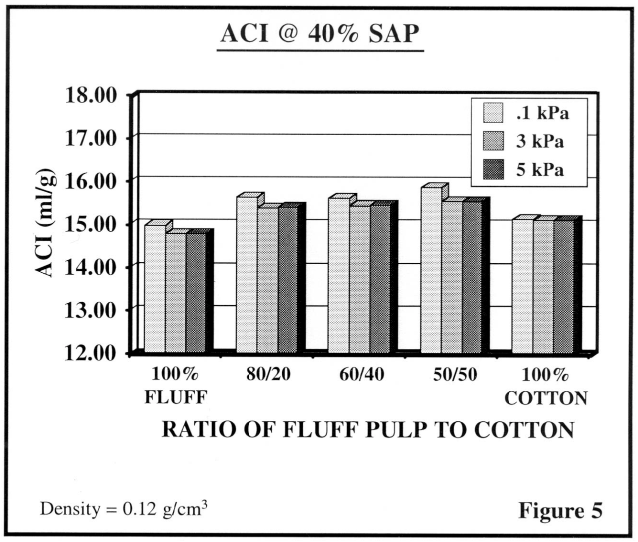

Figure 5

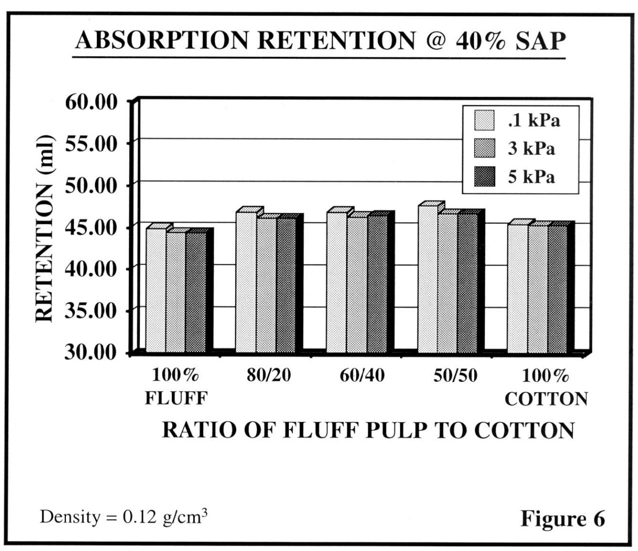

Figure 6

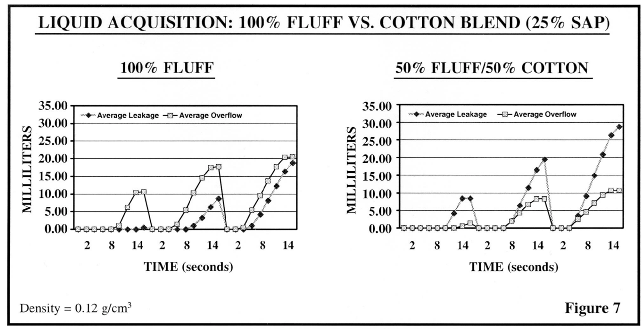

Figure 7

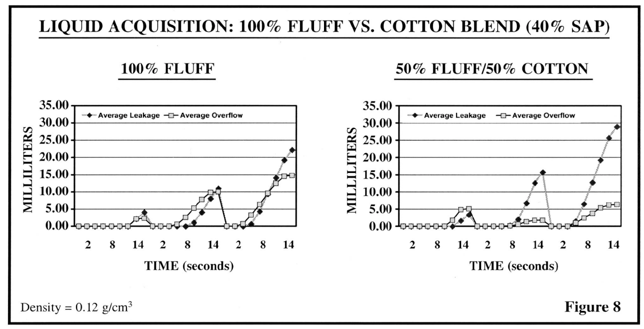

Figure 8

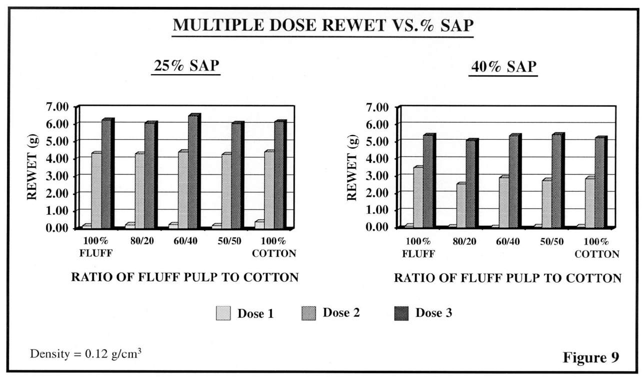

Figure 9

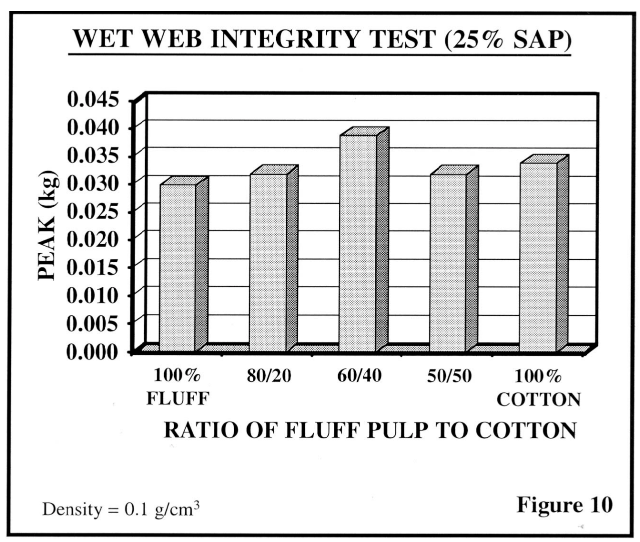

Figure 10