BLEACHED COTTON

Finish applications on bleached and scoured cotton in improving nonwoven processing

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ABSTRACT

Bleached and scoured cottons present difficulties in sequent processing into nonwovens. These difficulties can be minimized by adding some lubricant/antistatic finishes to the fibers. Four commercial finishes were studied in improving the nonwoven processing. One silicone-based softener (Ucarsil® EPS) was found to be most effective. Fourier transform infrared (FTIR) spectroscopy was used in this study to determine the distribution and the amount of finish applied to the cotton web, and to study the physical and chemical interaction between finish and fiber.

Application:

This paper shows how to determine the best type of fiber finish for bleached and scoured cotton and how to determine the finish add-on level.

MOST OF THE COTTON textiles used in the consumer market are bleached and scoured during the manufacturing process. In conventional textiles, these operations are done in fabric form as one of the last steps in the manufacturing process. Bleaching and scouring of cotton nonwoven fabric are usually considered impractical, either because of possible dimensional changes in the fabric during the process or because of the possible interaction of bleach and scour with the adhesive chemicals in the fabric. In nonwoven production, cotton must be bleached and scoured as raw stock prior to the manufacturing process. Therefore, the natural oils and waxes are removed from the cottons during bleaching and scouring. The lack of an adequate finish for the bleached and scoured cotton stock is responsible for poor opening, clogging of the card cylinder, clumps or neps in the carded cotton web, and on occasion, broken needles on the needlepunch machine. Most of these problems can reasonably be attributed to interfiber or fiber-to-metal friction.

A limited amount of research has been done on finishes for the bleached and scoured cottons. A combination of butoxyethyl sterate (BES) and sodium acetate has been found effective as a bleached and scoured cotton finish in previous research *(1)*. Additional work is needed in developing an optimum finish for the bleached and scoured cotton stock to improve the card processing. Also, an analytical method to determine the distribution and the amount of finish applied to the cotton web, and to study the physical and chemical interaction between finish and fiber, would be greatly helpful in evaluating the performance of the finish.

PREVIOUS WORK

Fiber friction is a property of great fundamental importance, because it affects both the efficiency of a manufacturing process and the quality and performance of the resulting end product. In this section, we discuss the effects of the following factors on the values of the frictional characteristics based on the early research findings: fiber surface roughness, fiber cross-sectional shape, fiber crimp, and chemical treatment.

Effect of fiber surface roughness

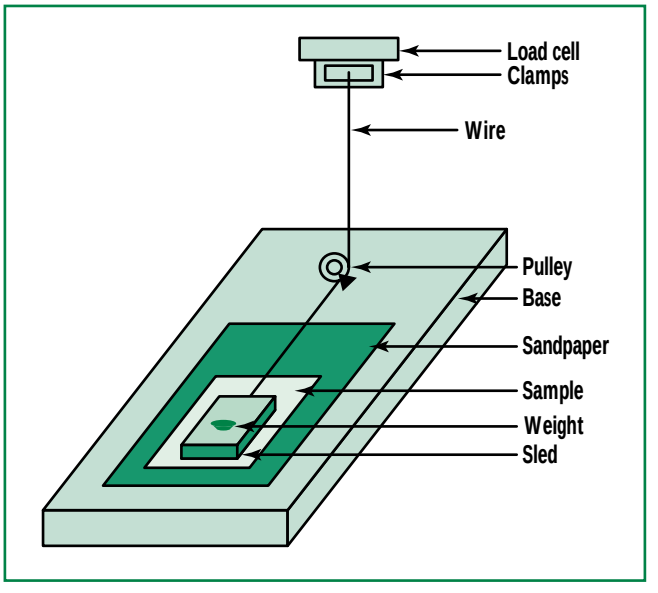
Fiber separation. Geometrically smoother fibers have been found to be more difficult to separate from one another during opening and carding. The rougher fiber samples appear to open more easily and more thoroughly than the smooth samples in the same number of operations. Also, more uniform webs are produced from the rougher samples *(2)*.

Cohesion in loose fiber assemblies. Fibers with geometrically smoother surfaces lead to greater cohesion and friction than fibers with geometrically rough surfaces *(3)*. The explanation for these findings is that the geometrically smoother fibers offer greater areas of contact between neighboring fibers or contiguous surfaces.

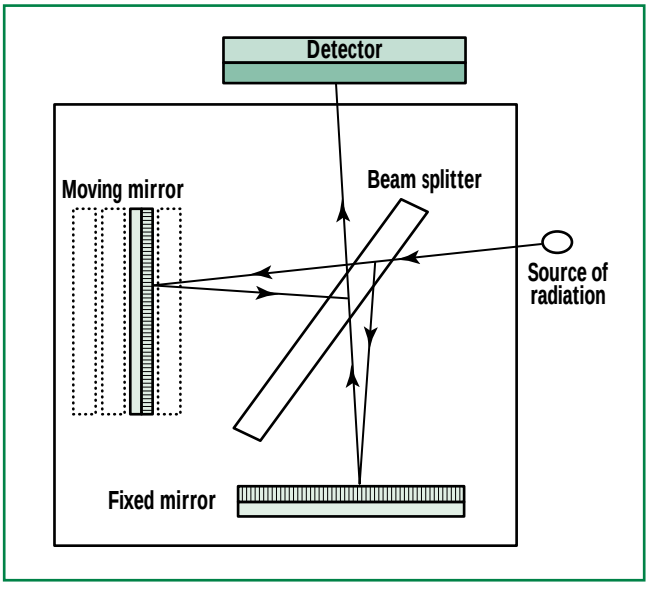
Blending of smooth and rough fibers. In blends of smooth- and rough-model fiber in webs, the cohesion has been found to increase consistently with an increasing percentage of smooth fibers. In webs composed of blends of polyester fibers with cotton fibers, the cohesion has been found to increase steadily with an increasing proportion of polyester fiber *(4)*.

Effect of fiber cross-sectional shape

Fibers of circular cross section produce greater cohesion in webs than do trilobal fibers. In general, the drafting tenacities of a sample composed of fibers having a circular cross section are substantially greater than the drafting tenacities of the counterpart samples composed of fibers having a trilobal cross



1. Sled test apparatus



2. Schematic of the Michelson Interferometer

section. The explanation for this tendency is that a circular cross section provides a greater area of contact between adjacent fibers than does a trilobal cross section because, with twist in the fibers, the trilobal configuration will be in contact only where adjacent ridges cross one another. This situation is somewhat analogous to the differences in friction between a twistless multifilament yarn and the same yarn with twist. It is well known that the twisted multifilament yarn makes much less contact with a contiguous frictional surface because of the spiraling filament ridges in the yarn structure caused by the helical twist geometry.

Effect of fiber crimp

In the opening and carding process, the crimp geometry in synthetic fibers has been very pronounced. Fibers with crimp have been found to open much more easily and much more thoroughly than uncrimped fibers. Crimp also leads to a more uniform distribution of fibers on the working surfaces of the opening and carding equipment *(5)*.

Effect of chemical treatment

Normally, cotton fibers are coated with a natural oil and wax matrix when harvested. This matrix permits the fibers to pass smoothly through all phases of cotton processing by providing sufficient interfiber lubrication to overcome fiber-to-fiber friction. Anything, therefore, that causes a degradation of the natural oil and wax matrix, which causes the fibers to be weak or causes shortening or embrittlement of cotton fibers, will also cause difficulty in processing.

Early studies have shown that the finish application of the bleached and scoured cottons can improve the processability of such cottons. Finishes used in the early studies to improve the processing efficiency of the bleached and scoured cottons can be divided into the following three categories *(6)*:

Compounds containing long-chain alkyl groups, such as C20+ alcohol, the quaternaries, the fatty acid derivatives, and the long-chain alcohol ethers

The so-called water-soluble lubricants and other materials whose aqueous solutions have a slippery feel. This group includes the broad range of polyethers and modified polyethers.

Materials that are traditional textile softeners, such as polyethylene or silicone softeners.

Although a number of finishes have been studied for bleached and scoured cottons to improve the nonwoven manufacturing process, several have been found to perform better than others. Apparently, more work should be done to determine an optimum finish application.

EXPERIMENTAL

Materials

Cotton fibers used. There were two types of cotton fibers used in this study, both from Cotton Inc. in Raleigh, NC. One was a raw cotton having no treatment. The other was a control cotton, bleached and scoured with no finish.

Chemicals used. The following chemicals were used in this study:

PEG 400, a long-chain polyethylene glycol, Fisher Scientific

Butoxyethyl stearate (BES), a fatty acid ester, Stepan Co.

Silwet® L-7605, a capped silicone with a polyethylene component, Union Carbide

Ucarsil® EPS, an epoxy-modified silicone fluid, Union Carbide.

The chemical add-ons ranged from 0.25% to 2.0%.

Processing

Web producing. The following process steps were used for web formation:

1. Fiber opening
2. Webs were produced on the University of Tennessee Textile Laboratory card by processing 75 g of cotton and collecting on a rotating cylinder. The web was about 1 cm thick, 20 cm wide, and 150 cm long; the web weight was 200–260 g/m^2.

Chemical application. Each chemical except the BES was prepared in tap water to the desired percent solution. Because BES is relatively insoluble in water, a solution of 75% isopropanol (IPA) and 25% water was used to prepare all BES solutions.

A 20 x 30–cm cotton web was cut and wrapped with polypropylene spunbond fabric to avoid losing the cotton fibers during immersion in solution for 30 min. Wet pickup was reduced to 100% of the fiber weight by squeezing through pad rolls. The web was then air dried and conditioned at 70°F and 60% RH for one week.

Test method

***Measuring friction value using the ICI Sled test* (7).** The sled test apparatus is shown in **Fig. 1.** A 7.5 x 10–cm sample of cotton web was cut and placed on the platform of the sled tester. The weighted 2.0-kg sled was placed on top of the sample and moved across the surface of the layered web at a rate of 2.5 cm/min. The machine direction of the card web was laid in the direction of sliding. The sliding force was measured and recorded by the tensile test instrument.

FTIR measurements of the distribution and amount of finish applied to cotton webs. The fundamentals of FTIR spectroscopy state that a molecule may absorb infrared radiation of the appropriate frequency to excite it from one vibrational or rotational state to another. When a beam of infrared energy covering a broad frequency range is passed through a sample, the energy at a certain frequency is absorbed by the sample. A graph of the energy absorbed vs. the frequency is the absorption spectrum of the sample. The spectrum is characteristic of the particular molecule and its molecular motions.

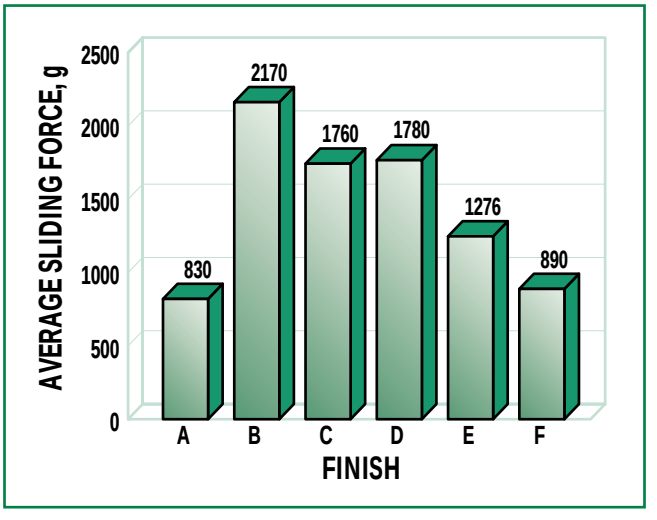
As FTIR spectroscopy developed rapidly during the past decade, it has become one of the most commonly used analytical tools for textile and nonwoven research. This technique has the advantage that all types of solid samples can be directly analyzed with little or no sample alteration prior to analysis.

An FTS-40 BIO-RAD spectrometer was used to collect all the spectra. The main component of the spectrometer is the Michelson Interferometer, which is shown in **Fig. 2.** Resolution for all the spectra was 4 cm^{-1}. The average number of scans was 250.

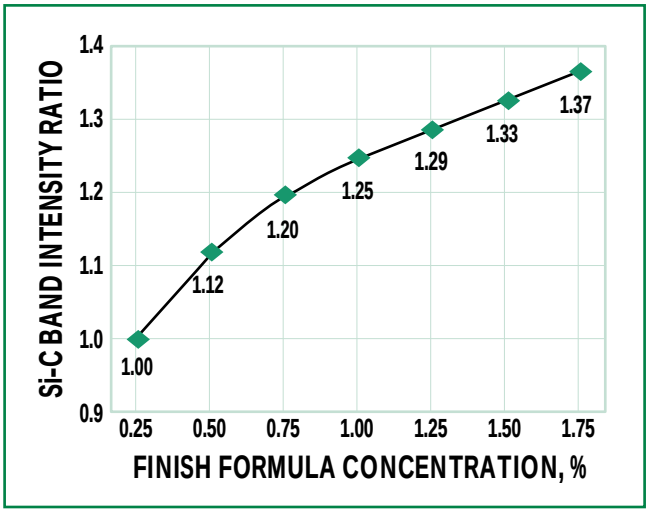
Cotton fibers were laid flat and evenly across the hole and mounted with Scotch tape on the sample holder; the fibers were then dried at 150°C for 48 hours. The finish was placed on a KBr disk to form a thin film. Both fiber and finish samples were placed in separated vacuum desiccators at room temperature for 48 hours.

Sample no.	Treatment	Avg. sliding force, g	Cardability
1	Raw cotton	830	Excellent
2	Control cotton	2170	Very poor
	PEG 400		
3	0.50%	2080	Very poor
4	1.00%	1920	Poor
5	1.50%	1810	Fair
6	2.00%	1760	Good
	BES		
7	0.25%	2180	Very poor
8	0.50%	1980	Poor
9	1.00%	1810	Fair
10	1.50%	1780	Good
11	2.00%	1800	Fair
	Silwet® L-7605		
12	0.25%	1620	Good
13	0.50%	1480	Good
14	0.75%	1310	Good
15	1.00%	1280	Good
16	1.25%	1276	Good
17	1.50%	1275	Good
18	1.75%	1271	Good
	Ucarsil® EPS		
19	0.25%	1340	Good
20	0.50%	1110	Very good
21	0.75%	890	Excellent
22	1.00%	884	Excellent
23	1.25%	882	Excellent
24	1.50%	881	Excellent
25	1.75%	881	Excellent

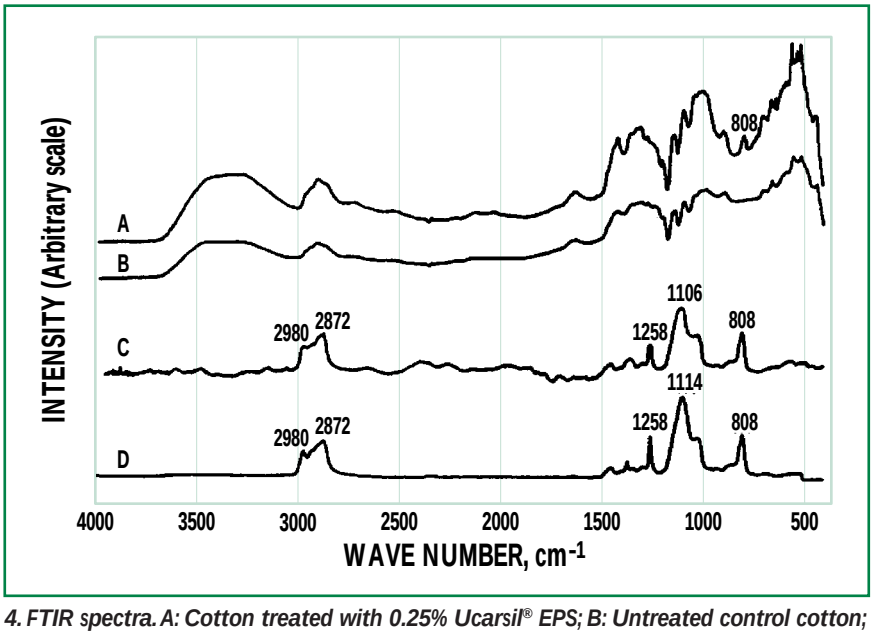
I. Sliding force and cardability measures



3. Comparison of different finishes with raw cotton and control cotton on the sliding forces. A: Raw cotton; B: Control cotton; C: 2.00% PEG 400; D: 1.50% BES; E: 1.25% Silwet® L-7605; F: 0.75% Ucarsil® EPS.



5. Determining the finish levels by the Si-C band intensity ratio



4. FTIR spectra. A: Cotton treated with 0.25% Ucarsil® EPS; B: Untreated control cotton; C: Different spectrum A–B; D: Finish (Ucarsil® EPS).

A spectrum was obtained using the following steps:

1. Obtain a background spectrum. A single command will collect the interferogram and compute the single-beam spectrum.
2. Insert the sample, and select the type of spectrum desired (transmittance or absorbance). A single command will collect the interferogram, compute it, and produce the desired type of spectrum.

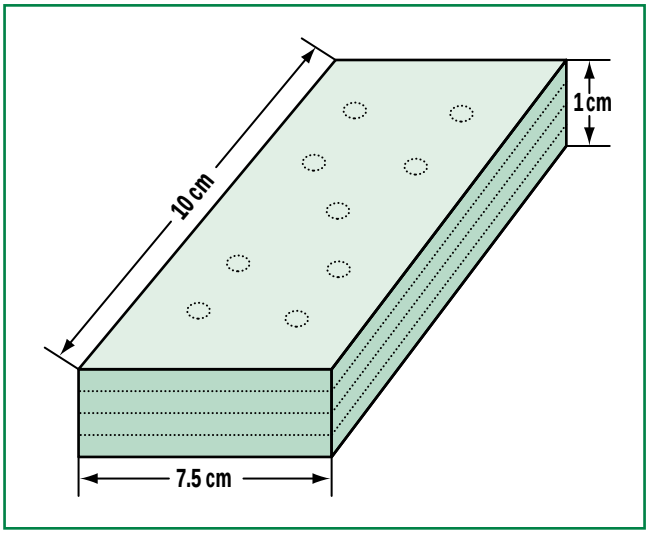
RESULTS AND DISCUSSION

Discussion of sliding force

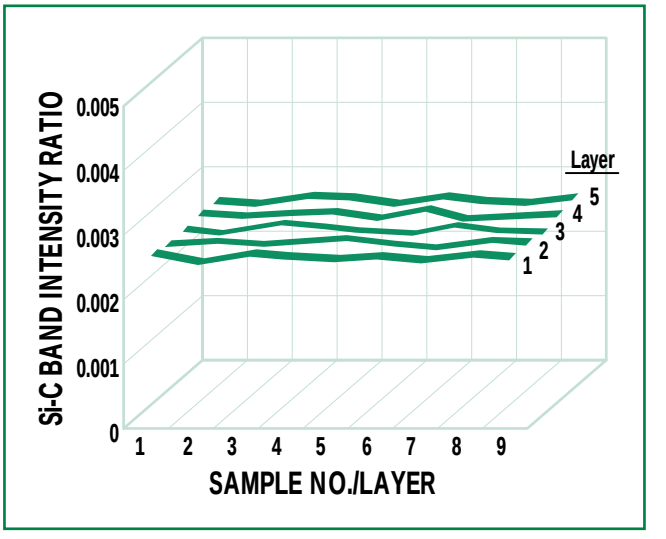
The results of sliding forces and cardabilities of cotton webs are presented in **Table I.** As expected, the raw cotton had the lowest sliding force (sample 1) and carded with no problems. The control cotton had the highest sliding force (sample 2) and carded very poorly. All finish applications did reduce the sliding forces, and the sliding force was related to the cardability of cotton fibers. The lower the sliding force, the better the cardability.

Samples 3–6 indicated that the higher the level of PEG 400 treatment, the lower the sliding force. The results also showed that a sliding force above 1800 g on the bleached and scoured cottons will present problems in card processing, and the fibers with sliding forces below 1800 g may card well.

The effect of varying the concentration of BES on the sled test and the card processing was evaluated. It is interesting that an application of 0.25% BES solution did not reduce the sliding force. In fact, the sliding force was slightly higher than that of the control cotton. This could be due to nonuniform bleaching and scouring; for example, some areas of the fibers experienced a higher alkali concentration removing the oils and waxes. A small amount of BES may have been insufficient to offset the damage caused to the oil and wax matrix. Therefore, the fiber in sample 7 still behaved like the control cotton (sample 2). When the amount of BES was increased to 1.5%, the sliding force was further reduced. However, a further increase in BES con-



6. Sampling for determining the finish distribution by the FTIR technique



7. Determining the finish distribution by the Si-C band intensity ratio

centration from 1.5% to 2.0% had no notable effect on sliding force.

Applications of two commercial silicone softeners on the bleached and scoured cottons were investigated. Both treatments noticeably decreased the sliding forces because of reduced cohesion between fibers. The treatments permit adjacent fibers to slip away from one another. The more finish that is present, the more easily the fibers can slip apart and the lower the sliding force. The sliding force generally leveled off at add-on levels of 1.0% and 0.75% with Silwet L-7605 and Ucarsil EPS, respectively.

There was a general increase in the sliding forces for the BES-treated fibers when compared with the other finished fibers. With the BES treatment, any residual oils and waxes are more soluble in the isopropanol/water solvents used. In the water-based finish treatments, water caused less disruption to the oil and wax matrix of the cotton fibers than the isopropanol/water mixture.

A comparison of the fabrics treated with different finishes at their optimum levels is shown in **Fig. 3.** From the data available, we must conclude that the Ucarsil EPS level of 0.75% is about optimum in facilitating card processing of the bleached and scoured cottons.

Study of treated cotton fibers by FTIR spectroscopy

Identification of finish on the fibers. The FTIR spectra of the cotton fibers treated with 0.25% Ucarsil EPS and the untreated control cotton fibers are presented in **Fig. 4,** lines A and B, respectively. These two spectra appear similar. The only apparent difference between these two spectra is the Si-C stretch band at 808 cm^{-1} in line A due to the Ucarsil EPS finish (line D).

Obviously, it is impossible to identify the finish simply by comparing these two spectra. However, when the spectrum of the untreated control cotton (line B) was subtracted from the spectrum of the treated cotton (line A), most spectral features of the finish (Ucarsil EPS) appear in the difference spectrum (line C). Although the spectrum of the treated fiber appears to be identical to the spectrum of the untreated fiber in the CH stretch region, two bands at 2980 cm^{-1} and 2872 cm^{-1}, due to the Ucarsil EPS finish, are shown in the difference spectrum (line C).

In the fingerprint region, the bands at 1258 cm^{-1} and 808 cm^{-1} revealed in the difference spectrum are identical to the frequencies of those bands in the spectrum of the Ucarsil EPS finish (line D). We also observed that the Si-O band was shifted from 1114 cm^{-1} in the spectrum of the finish (line D) to 1106 cm^{-1} in the difference spectrum (line C). This shift is probably due to the hydrogen bonding between the Ucarsil EPS finish and the cotton cellulose.

The spectral subtraction technique provides valuable information about the near-surface chemical species. This makes the identification of the finish in the fibers much easier compared with simply interpreting the spectra of the treated fibers.

Determination of the finish levels in the cotton fibers. As previously discussed, the intense band at 808 cm^{-1} in the spectrum of the Ucarsil EPS–treated fibers (Fig. 4, line A) is due to the Ucarsil EPS finish (line D). The spectra of the fibers treated with different Ucarsil EPS concentrations were collected under the same conditions. The intensities of the Si-C bands in the spectra of the Ucarsil EPS–treated fibers were normalized against the intensity for the same band in the spectrum of the 0.25% Ucarsil EPS–treated fibers. The results are shown in **Fig. 5.**

The Si-C band intensity ratio (intensity of the treated fibers/intensity of the 0.25% treated fibers) at 808 cm^{-1} is used as a semiquantitative measurement of the finish level applied to the cotton fibers. A large

KEYWORDS
Cotton, fabric, finished fabric, Fourier analysis, infrared spectra, lubricants, mathematical analysis, nonwovens, properties, static inhibitors, surface properties.

intensity ratio indicates that a higher concentration of the finish exists in the fibers. It can be seen from Fig. 5 that the Si-C band intensity ratio increased with a greater Ucarsil EPS concentration applied to the fibers; however, the relationship between the intensity ratio and the concentration is not linear.

Determination of the finish distribution in the cotton web. The distribution of the Ucarsil EPS–treated cotton web has also been investigated using the intensity ratio. Samples were collected from five different layers and nine spots/layer in the web, as shown in **Fig. 6.**

All the Si-C band intensities at 808 cm^{-1} in the spectra of the Ucarsil EPS–treated fibers were normalized against the intensity for the same band in the spectrum of the Ucarsil EPS finish (Fig. 4, line C). The band intensity ratio at 808 cm^{-1} for the 0.25% Ucarsil EPS–treated cotton fibers is plotted in **Fig. 7.**

The band intensity ratio indicates that the Ucarsil EPS finish is homogeneously distributed in the web. This is consistent with the observation of the ease of carding. The Si-C band intensity ratio (intensity of the treated fiber/intensity of the Ucarsil EPS finish) at 808 cm^{-1} can be used as a semiquantitative measure of the distribution of the finish in the cotton web.

CONCLUSIONS

We reached the following conclusions based on our experiments:

- The sled test results allowed us to predict the cardability of the fibers. Generally, the lower the sliding force, the better the cardability.
- The sliding forces above 1800 g on the bleached and scoured cottons will present problems in card processing. Fiber finishes that yield sliding forces equal to or less than 1000 g will have excellent cardability.
- The card processing of the bleached and scoured cottons was greatly improved by all finish treatments evaluated in this study. Of all the finishes evaluated, an add-on level of 0.75% Ucarsil EPS finish would be the optimum choice in facilitating carding.
- There was a positive relationship between the finish level on the cotton fibers, measured by the FTIR spectroscopy technique, and the amount of finish applied to the cotton fibers.
- The finish distribution in the cotton web appeared to be uniform as determined by the FTIR spectroscopy technique.

SUMMARY

The bleaching and scouring of cottons as raw stock removes the natural finishes and causes the cottons to be difficult to process. This paper extends previous research, which indicated that finish application can greatly improve the processability of such cottons. Our research shows that the cardability is inversely proportional to the sliding forces, as measured by the sled test. The data suggest the optimum finish and its application level. Finally, the study demonstrates that the FTIR spectroscopy technique has some advantages in predicting finish add-on level and uniformity of application. FTIR spectroscopy therefore appears to have great potential to become an important analytical technique for the textile and nonwoven industry. TJ

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