ASSESSMENT OF COMFORT AND BARRIER PROPERTIES OF FINISHED COTTON-SURFACED NONWOVENS

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Abstract

Surface modifications were made to As-Bonded and Heat-Stretched (elastic) Cotton-Surfaced Nonwovens (CSN's) to enhance barrier, repellency and abrasion resistance by the applications of foamed fluorochemical (FC), latex-only and a combination of latex and FC finishes using the Foam Finishing Technology (FFT) pilot equipment at TANDEC, The University of Tennessee, Knoxville. These finishes were applied as semi-stable foams with a wet pick-up of 50% or less to save energy in drying the fabrics and to better preserve fabric hand.

Both unfinished and finished CSN samples were evaluated for the resistance to penetration of water under static pressure (hydrohead), oil and alcohol repellency as well as air permeability. Other properties evaluated were tensile strength and extension, softness, and abrasion resistance of the fabrics. "Ring Friction" apparatus developed at Auburn University were also applied to evaluate hand related properties which predict responses to surface friction, folding and bending resistance and to fabric stiffness.

Introduction

Disposable nonwovens have been widely used in hospitals as surgical gowns, drapes, masks and wraps to shield professionals providing healthcare and patients receiving treatment from infection since nonwoven fabrics were introduced into medical products four decades ago. The penetration of nonwovens into U.S. medical textile products is 90% overall [Lickfield, 1998]. The market, on the order of 1.7 billion square yards of nonwovens per year (U.S.), is growing at a sustained rate of about 5% per year. Nonwovens now have almost complete acceptance in U.S. hospitals for applications such as surgical caps, masks and shoes covers and 90-100% penetration in operating room usage has resulted because nonwoven provides relatively inexpensive, lightweight and effective protection [Forest, 1996; Wadsworth, et al., 1994]. The ease of tailoring nonwovens for specific end uses has facilitated great convenience in storage and identification. Nonwoven protective apparel over the course of the years has become irreplaceable by virtue of superior patient care, a consistently high degree of protection, comfort, and performance while providing cost savings.

Much R&D has been directed towards providing the highest possible barrier, comfort and convenience of disposable nonwoven surgical gowns and drapes. Unique cotton-surfaced nonwoven fabrics have been produced in one step on the spunbond line at Textiles and Nonwovens Development Center (TANDEC), The University of Tennessee, Knoxville [Allen, et al., 1997]. It was found that the thermally bonded cotton/PP staple (TCPP) web could be laminated with spunbond (SB) polypropylene (PP) webs by thermal bonding during the actual preparation of SB nonwoven fabrics, with the cotton precursor web on one side or both sides. Although these as-bonded CSNs have unusually high elongation-to-break, it was shown that the substantial elasticity could be imparted into the fabrics in the cross machine direction by heat-stretching the fabric in the machine direction [Wadsworth, et al., 1998]. A comprehensive study was made of the effect of processing conditions on the properties of the laminates as bonded on the SB line (SUN, et al., 2000). In this paper, a low pick-up technique of foam finish is applied to enhance the repellency and barrier properties of the fabrics for the use as operating room apparel.

Finishing is the act of applying chemicals to fabric, drying the fabric to remove any excess solvent (usually water), and then curing the finish to activate the functional properties or drive to completion of any chemical reaction necessary for the performance of the finish [Baldwin, 1997]. Textile finishing is an old art. It is a highly developed technology with a great amount of diversity. A textile finishing operation is composed of a series of procedures which are linked together in a sequence commonly known as a routing. Unfinished fabrics are referred to as 'original' fabrics. Nonwoven fabrics in most cases, are not generally subjected to extensive finishing although there are cases where more than one process is required to achieve the final quality. Most we finishing processes would have a tendency to destroy the nonwoven web. The nonwoven finisher must accept the chemical and physical characteristics of the delivered original fabrics as the starting point for the development of the finished product.

In order to produce the nonwoven at the lowest cost possible, the processes, and the chemical finishes are usually combined, or installed sequentially on a single range. This reduces cost, wear and tear on the web, but increases the challenge for the formulator. In many cases, nonwovens are shipped directly from the production range with a minimum amount of inspection.

A wide variety of low wet pickup (usually WPU not greater than 50%) finishing techniques have been developed in the textile industry which lead to energy savings of 60-80%, increased processing speeds, more efficient utilization of chemicals and improved fabric performance properties, including pad vacuum extraction, air jet-assisted squeeze rolls, kiss roll, engraved roll, spray and foam application. A comparison of low pick-up finishing technologies was made in the literature [Potnis and Wadsworth, 1986]. It was suggested that foam application of repellent finishes be performed on-line on nonwoven fabrics for the medical operating room apparel [Wadsworth and Salamie, 1992; Stickler, 1984; Turner, 1980].

This paper studies the application of Fluorochemical (FC) and latex finishes by Foam Finish Technology (FFT) to further strengthen the fabric for application such as interlinings and enhance the barrier and repellency to liquid contamination of the new cotton-surfaced nonwovens for the use as hospital operating room apparel. The properties of original and finished CSNs were evaluated by hydrohead, oil and alcohol repellency, and air permeability. Tensile strength, breaking elongation, softness, ring friction test and resistance to abrasion were evaluated as criteria for possible use as hospital operating room apparel.

Experimental

Preparation of the Cotton Surfaced Nonwovens (CSNs)

Production of cotton-surfaced nonwovens on the spunbond (SB) line by in-line thermally bonding cotton/PP precursor webs with the SB web has been published (Sun, et al. 2000). Five as-bonded CSNs were selected for this study, as shown in Table 1.

Foam Finish Process

Foam finish technology (FTT) was developed by the Union Carbide Corporation and licensed to Gaston County Dyeing Machine Company, who manufactured the Laboratory Foam Finishing System installed at TANDEC. In the FFT process (Figures 1-2), a finish mix containing the required concentration of foaming agent is combined with a metered volume of air to produce foam. Foam of the required stability is delivered to the foam applicator head where it contacts the fabric. The fabric speed which produces the shearing forces, collapses the foam, whereby it reverts

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back to the liquid phase and distributes the finish throughout the fabric. Although this process uses "semi-stable" foam, it should be stable enough to be delivered through the applicator head without collapsing.

The unit was equipped with both top and bottom foam applicators for application across 18 inches of the fabric. Two foaming formulations were utilized in this preliminary research (Table 2): florochemical (FC) and latex. In the FFT process, the degree of penetration of the semi-stable foam is affected by foam density (which controls foam wetness and is usually in the range of 0.4-1.5 g/cm^3), fabric structure, and the hydrophilic/hydrophobic nature of the substrate. The liquid, foamer speed and air flow rate were adjusted to provide the foam density as 0.045 g/cm^3 for FC finishing and 0.074 g/cm^3 for latex finishing. The fabric speed was controlled around 7.5 yds/min to ensure the wet pick-up (WPU) at the level of 40-45%. Figure 3 is a picture taken form the actual foaming finishing process.

Three groups of finished CSNs were processed. The first two groups were finished with the FC formulation and the latex formulation separately as shown in Table 2, labeled as FC and Latex, respectively. The third one was first latex finished, dried and cured, and then FC finished , labeled as Latex/FC. The finish formulations were the same as the first two groups, as listed in Table 2.

Drying and Curing

The finished wet fabrics from the foaming finish machine were then dried and cured using the continuous oven at TANDEC Demonstration Lab with a temperature of 250°F for 3 minutes (Figure 4).

Repellency Test

The original and finished fabrics were tested for oil, alcohol and water repellency by the Oil Repellency: Hydrocarbon Resistance Test, AATCC Test Method 118-1997; Alcohol Repellency: Alcohol Resistance Test, INDA Test Method 80.6 (96), and Hydrostatic Pressure Test, INDA Test Method 80.4 (95).

Oil repellency is determined by placing drops of a series of hydrocarbons of different surface tensions ranging from 0 to 8 (8 having the lowest surface tension). The ratings were determined by the highest number in hydrocarbon series which did not show signs of wetting the fabric. This also provides an indication of fabric surface energy.

Alcohol repellency is desired due to the use of alcohol in surgical procedures. It is assessed on a scale of 0-10 by placing drops of alcohol-water mixtures with increasing concentrations of alcohol from zero to 100% on the fabric.

Hydrostatic pressure test measures the hydrohead of resistance of fabrics to penetration of water under hydrostatic pressure. Air permeability, bending length, tensile properties, and abrasion resistance were also evaluated. The test methods of these properties have been described in a previous publication [Sun et al., 2000].

Ring Friction Test

The test method used to measure fabric handle was based on the principle of how easily a fabric can be pulled through a ring [Grover et al. 1993]. A circular fabric specimen of10"diameter was pulled through a cylindrical nozzle of highly polished aluminum, 2 cm in diameter as shown in Figures 5. The force generated while withdrawing a fabric specimen through the cylindrical ring was measured. As more and more of the specimen is introduced into the ring, the force needed to withdraw the fabric through the nozzle increases. The maximum force occurs when the entire specimen has nearly passed through the ring. During the process of extraction, the specimen gets folded, sheared, bent, as it compresses and rubs the interior wall of the ring. The withdrawal force was recorded on the load-displacement chart of a tensile testing machine.

Results and Discussion

Figure 6 shows the basis weight of the original and finished cotton-surfaced nonwovens. The finished CSNs are heavier than the original ones by average increases of 5.1%, 14.2% and 17.6% for FC, latex, and latex/FC finishing, respectively. Interestedly, the fabric did not become thicker due to weight increase of finish chemicals added on. In fact, the fabrics became thinner after foam finishing (Figure 7), which may be due to the pressure of padding between two winding rolls in the FFT process (Figure 3).

The air permeability values of the original and finished CSNs are shown in Figure 8. It is well known that operating room apparel should also be sufficiently breathable to be worn by medical personnel. Air permeability provides a measure of fabric breathability and comfort. Air permeability generally correlates in an inverse manner with barrier performance [Olderman, 1984]. However, repellent finishes should enhance barrier performance in a certain range of air permeability. Thus, it is evident that both surface repellency and barrier performance are required to minimize flow of contaminated fluids by wetting, wicking and penetration. This is especially important in medical/surgical nonwoven fabrics which are designed to minimize transport of fluids that contain bacteria and viruses. Figure 8 shows that the foam application of FC, Latex only, Latex/FC did not affect the fabric breathability notably. In other words, the foam finished CSNs still exhibited good air permeability.

Figures 9-12 show the test results from tensile tests. The fabric strength properties decreased after the foam finish. Comparatively, the tenacity decreased slightly in the MD and CD directions, while the breaking elongation decreased notably in MD and CD directions.

Figure 13 shows the overall flexural rigidity of the original and finished CSNs. It reveals that the FC finish improved the softness of CSNs, while latex and latex/FC finishing enhanced stiffness of the fabric.

Figure 14 shows the percentage of peel-off cotton-surfaced area in the abrasion test. FC finished CSNs exhibited the greatest removed area, i.e. the lease resistance to abrasion compared to original and other finished fabrics. Latex and latex/FC finishing improved the resistance to abrasion. In summary, the resistance to abrasion in decreasing order was Latex finished CSNs, Latex/FC finished CSNs, original CSNs, FC finished CSNs.

Figure 15 shows the ring friction data of the original and finished CSNs, which were the force required to pull the sample trough the ring. The greater the force, the harder the fabric to be pulled through the ring. This device predicts responses to surface friction, folding and bending resistance and to fabric stiffness since the specimen gets folded, sheared, bent as it compresses and rubs the interior wall of the ring during the process of extraction. It appeared from the ring friction data (Figure 15) that the FC finish reduced the force to pull the laminates through the ring, but Latex and Latex/FC finish treatment increased the force, indicating that FC finish improved the hand related properties such as softness, folding, deforming, on the other hand, Latex and Latex/FC finishes enhanced the stiffness, resistance to folding and deforming, etc. The ring friction results agreed very well with the above flexural rigidity and abrasion test results.

The oil repellency ratings of original and finished CSNs are shown in Figure 16, which is 1 for all the original and Letex finished fabrics, and 4.7 to 5.3 in average for FC finished and latex/FC finished ones. Therefore, latex and Latex/FC finishing improves the oil repellency of cotton-surfaced nonwovens.

Figure 17 gives the alcohol repellency rating number of the original and finished CSNs. Latex finished fabrics shows the same rating value (0) as original ones. In other ward, latex finishing does not notably improve the alcohol repellency. However, FC and latex/FC finishing increased the alcohol repellency rating from 0 to 4.7-6.7.

Figure 18 shows the static hydro-head for original and finished CSNs. Latex finishing did not enhance the resistance to penetration of water under its static pressure. On the contrary, it decreased the hydrohead by an average of 38.0%. FC finish increased the hydro-head by 15.7% and latex/FC finish increased it by 38.2% in average. As was anticipated, it appeared that the interaction between latex and FC positively enhanced the barrier performance of the cotton-surfaced nonwovens.

It is well known that barrier properties are very important for the surgical gown to keep medical employees from contamination. The alcohol repellency, oil repellency, and water resistance are all necessary for the hospital operating room apparel. Latex finishing enhanced the abrasion resistance of the laminates with no improvement in the repellency to water, alcohol and oil. FC finish exhibited improvement in hydrohead, alcohol and oil repellency, but notably decrease the resistance to abrasion. The combination of these two finishing processes by first latex finish then FC finish effectively improved not only the alcohol repellency, oil repellency, and water resistance but also the resistance to abrasion. The physical and chemical interaction of these two finishes as well as optimization of foam finishing and curing procedures will be the subject of further investigation.

Conclusions

Cotton-surfaced nonwovens were finished by foam finish technology with FC, latex and latex/FC. The finished fabric exhibited a soft hand, improved resistance to abrasion without notable reduction in air permeability and comfort. The breaking elongation decreased after the foam finish. Latex finishing enhanced the abrasion resistance of the laminates with no improvement in the repellency to water, alcohol and oil. FC finishing increased hydrohead, alcohol and oil repellency, but notably decrease the resistance to abrasion. The combination of these two finishing processes by first latex finish then FC finish improved the repellent properties and the resistance to abrasion, which are especially useful for performance of hospital operating room apparel.

Acknowledgment

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Table 1. Description of the Cotton-Surfaced Cotton Nonwovens for FFT Processes.

			Cotton/PP Staple Thermally Bonded Webs (TCPP Webs)		
Sample ID	Sample Designation*		PP Staple Fibers		Cotton
			Den/length	Wt %	Wt %
1	Heat-Stretched	TCPP5/SB1	1.9den/1.5"	50	50
2		TCPP7/SB1	2.2den/1.5"	50	50
3		TCPP8/SB2	1.9den/1.5"	60	40
4	As-bonded	TCPP5/SB1	2.2den/1.5"	50	50
5		TCPP7/SB1/TCPP7	2.2den/1.5"	50	50
6		TCPP8/SB1	2.2den/1.5"	60	40

Note: *TCPP: Thermally-bonded Cotton/PP Staple webs with basis weight of 25-27g/m^2

SB1: Polypropylene (PP) spunbond webs with basis weight targeted to 34g/m^2.

SB2: Polypropylene (PP) spunbond webs with basis weight targeted to 17g/m^2.

Table 2. Formulations for Foam Finishing Processes

No	Description	Agent/Commercial Source	Composition (% by Wt)	Foam Density (g/cm^3)
1	Florochemical	Zonyl PPR /Dupont	12	0.045
		Dextrol Foamer 916 / Dexter Chemical	2	
		Dextrol Foam Stablizer HFR/Dexter Chemical	4	
		Water	82	
2	Latex	Hystretch V-29 /BFGoodrich Performance Materials	32	0.074
		Aerosol 18 Surfactant/ Cytec Industries Inc.	2	
		Water	66	

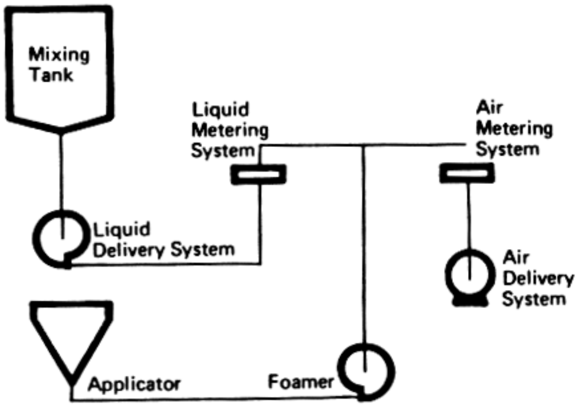

Figure1. Schematic of the FFT System.

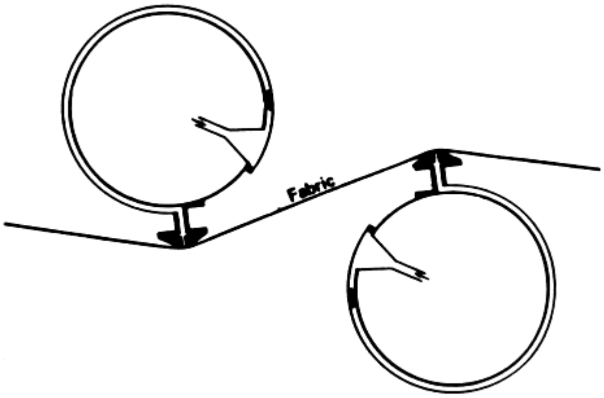

Figure 2. FFT Double Sided Application.

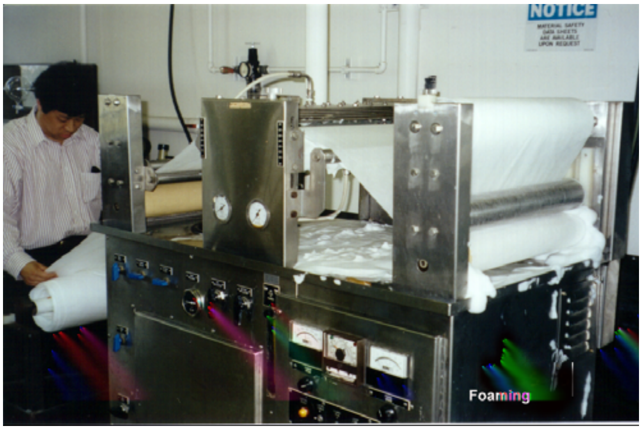

Figure 3. Operation on the Foaming Machine at TANDEC, The University of Tennessee.

Figure 4. Drying and Curing Process Using the Oven at TANDEC, The University of Tennessee.

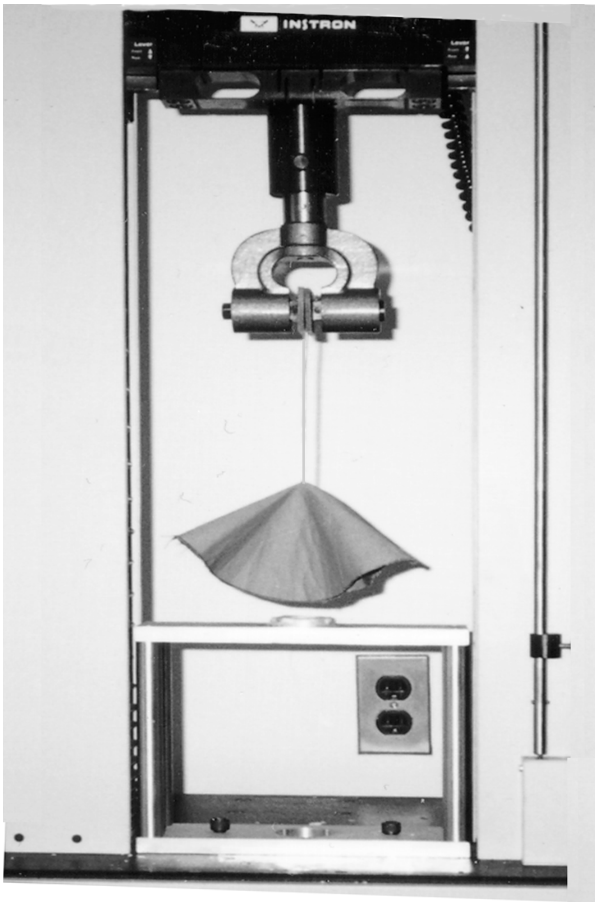

Figure 5. Apparatus for Ring Friction Test.

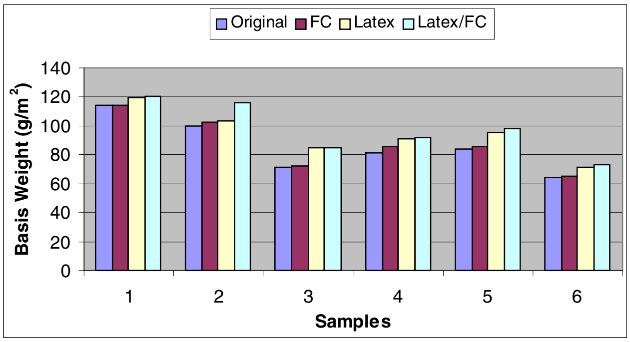

Figure 6. Basis Weight of Original and Finished CSNs.

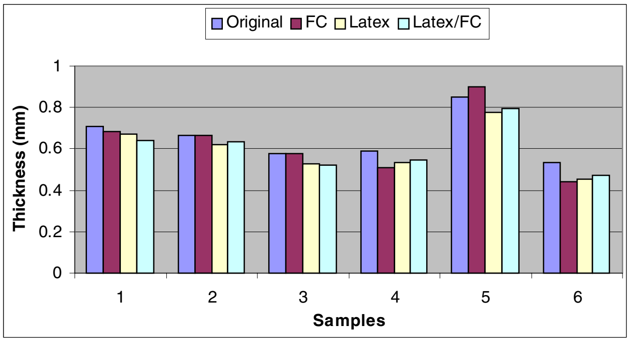

Figure 7. Thickness of Original and Finished CSNs.

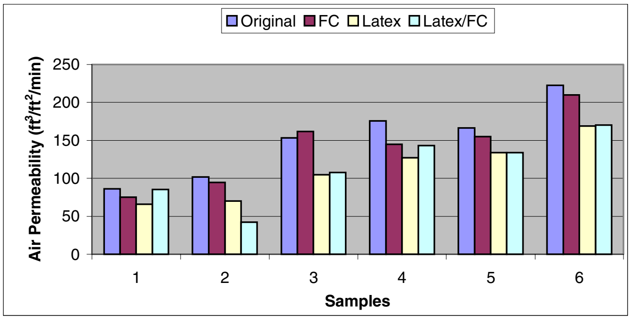

Figure 8. Air Permeability of Original and Finished CSNs.

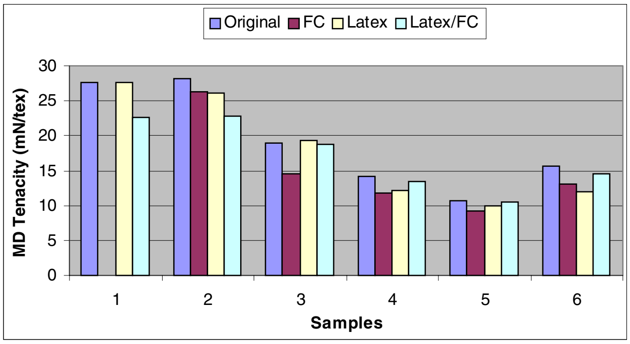

Figure 9. MD Tenacity of Original and Finished CSNs.

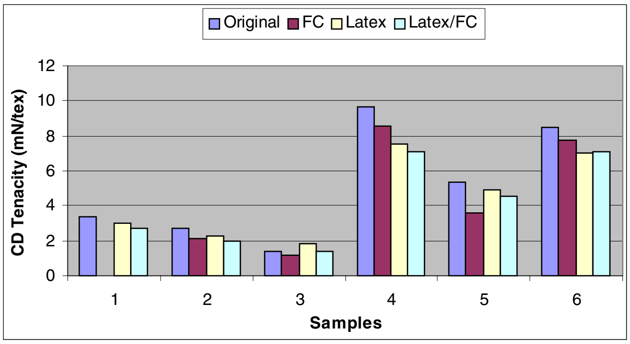

Figure 10. CD Tenacity of Original and Finished CSNs.

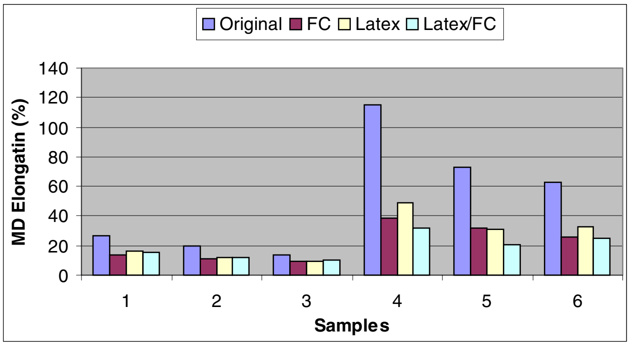

Figure 11. MD Breaking Elongation of Original and Finished CSNs.

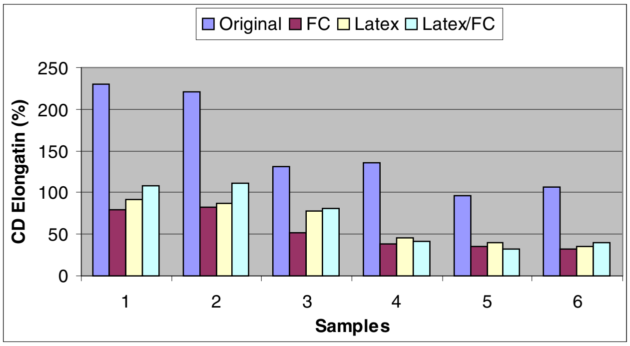

Figure 12. CD Breaking Elongation of Original and Finished CSNs.

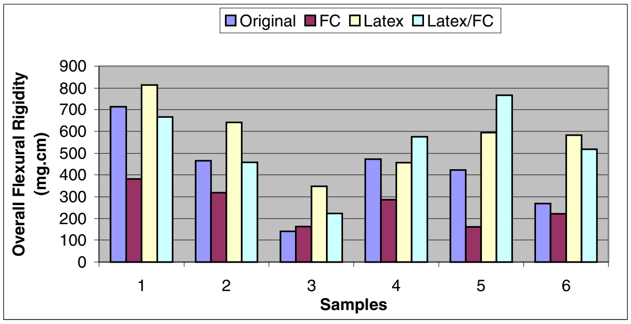

Figure 13. Overall Flexural Rigidity of Original and Finished CSNs.

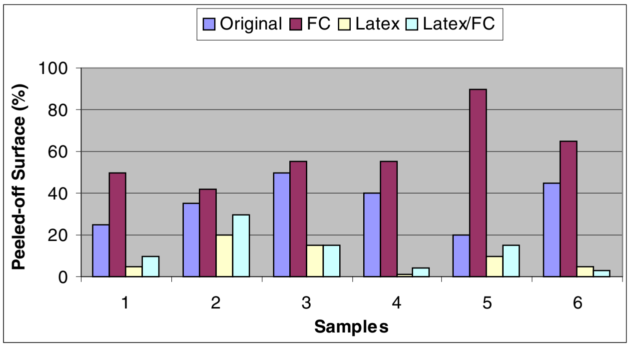

Figure 14. Removed Cotton-Surfaced Area in the Abrasion Test.

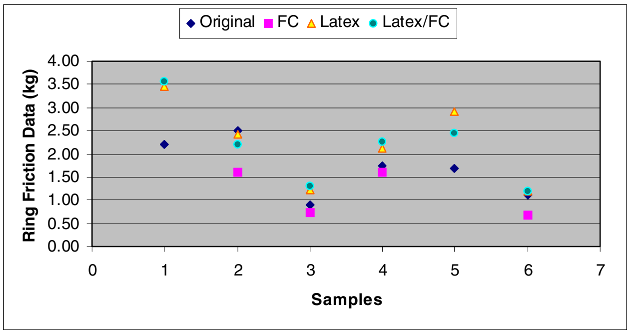

Figure 15. Ring Friction Data of Original and Finished CSNs.

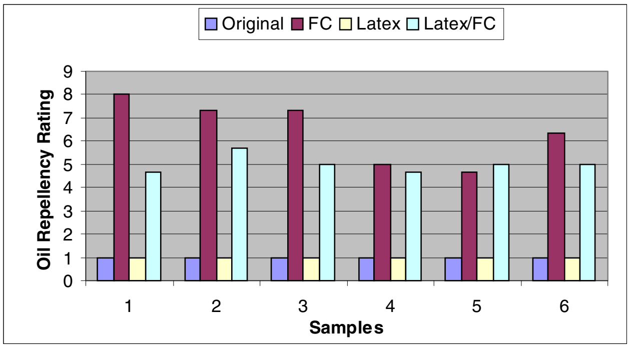

Figure 16. Oil Repellency Rating Number of Original and Finished CSNs.

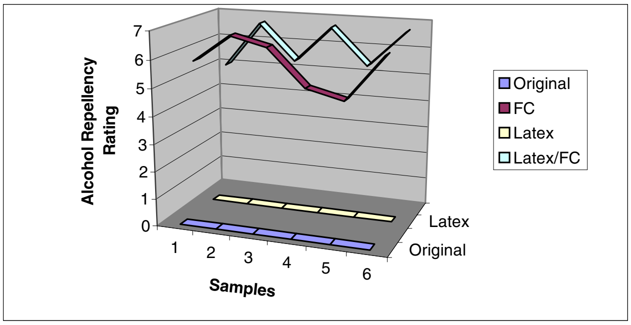

Figure 17. Alcohol Repellency Rating Number of Original and Finished CSNs.

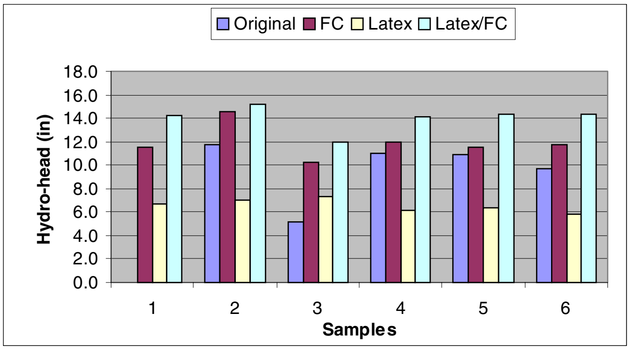

Figure 18. Stactic Hydro-Head of Original and Finished CSNs.