CONTINUOUS MERCERIZATION OF RAW COTTON FIBERS

Gregory F. Ward
Advanced Technology Development, Inc.
Alpharetta, GA

Abstract

A process is described for the continuous mercerization of raw cotton fibers. The process uses novel methods for fiber handling and reducing the costs for chemicals and dying. No additional spin finish is required.

Introduction

The benefits of mercerization are significant. Tension mercerized yarn or cloth has increased luster, which enhances appearance and improved tensile strength. More importantly their affinity for dyes is increased so that yarns and fabrics take brighter, longer lasting colors from less dye. Slack or tensionless mercerization has less improvement in luster.

Sodium hydroxide's beneficial effect on cotton was discovered in 1844 by John Mercer, an English calico printer, who received a patent for it in 1850 in Great Britain and in 1851 in the United States. His process, now referred to as mercerization, consists of submerging yarn or fabric in a solution of sodium hydroxide for a short period of time and then rinsing the material to neutralize the sodium hydroxide. In some cases weak acids are used to ensure a neutral pH. When the material is held under tension during the process shrinkage is minimized. If no tension is used during processing the material may shrink up to twenty percent.

Differences in the reactivity of cotton and mercerized cotton to chemical modification, dyeing, crosslinking reactions, graft polymerization, and the like are well known in textile finishing. The rate and extent of these textile-finishing processes in these heterogeneous wet systems are dependent on whether the reactions are being conducted with cotton or mercerized cotton.

The crystal lattice type of natural cotton is cellulose I with a beta angle of about 84 degrees, and a crystallinity index of about 80 percent. The crystal lattice type of mercerized cotton is cellulose II with a beta angle of about 62 degrees, and a crystallinity index of about 60 percent.

Chemical modification, dyeing, crosslinking reactions and the like occur to a greater extent with mercerized cotton than with cotton. Since the rate and extent of these reactions are dependent on the crystallinity index and upon the related accessibility of the hydroxyl groups of the cellulose mole,cule to the chemical reagents and dyes, the lower crystallinity index and lattice type of mercerized cotton as compared with the higher crystallinity index and lattice type of cotton accounts for the higher reactivity of mercerized cotton as compared with the lower reactivity of cotton.

The benefits of mercerization are significant. Increased luster, and improved tenacity or tensile strength are important. Still more important is that the mercerized cotton's affinity for dyes is increased so that yarns and fabrics take brighter, longer lasting colors from less dye. Slack or tensionless mercerization has a somewhat lesser improvement in luster but higher tenacity.

On the other hand the expense of yarn and fabric mercerization is a significant drawback despite the inherent benefits. Costs of mercerized yarns and textiles are from 40 to 120 percent greater than equivalent non-mercerized yarns and textiles.

These improved attributes would indicate a large market for mercerized fibers. Unfortunately fiber mercerization has been, until recently, virtually impossible to accomplish commercially.

Discussion

Background

The interest in fiber mercerization has existed at least over the past century based on the number of patents issued for fiber mercerization. None of the patents, as so often is the case, became commercially viable. There was, to my knowledge, only one commercial process for the continuous mercerization of raw cotton fiber in the United States. That process was developed by Doran Textiles and Advanced Technology Development, Inc. using portions of the patented Cotton Incorporated Continuous Bleaching System. The improved process under discussion was invented and developed by Advanced Technology Development, Inc. A patent is pending.

Continuous Mercerization Process Rationale

There are three major features that make this process viable.

1. A short but efficient saturation step provides a 98% complete mercerization of the cotton. This is important because the fibers' waxes are not removed consequently a spin finish is not required for subsequent carding and spinning. The residual wetting agent and high pressure showers augmented by the vacuum system ensures good rinsing without removing the waxes.
2. The use of the specially designed press rolls for caustic recovery and water removal improve

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:818-820 (2000)
National Cotton Council, Memphis TN

operating economy through high caustic recovery and reduced loads on the drying system
3. The ability to reduce batt water content to low levels eliminates the need for dry cans and a steam supply.

Continuous Mercerization Detailed Description

The process is designed to produce 17,500,000 pounds per year of mercerized cotton. A 60-inch-wide batt of cleaned cotton, weighing approximately 32 ounces per square yard, is generated by a modified Rando web-former. The batt is transported into a caustic saturator containing a minimum of 22% sodium hydroxide by weight and up to 1.2% by volume of a high-pH, stable wetting agent such as Dypanol. The batt is constrained between two moving layers of 60 mesh 304 SS screen. Caustic solution at 70˚ F is sucked through the screen at a rate of 2 gallons per minute per ft^2. This provides an apparent caustic velocity of about 6 inches per minute through the batt. Actual velocity is higher due to the small interstitial spaces in the batt. This is sufficient to saturate the batt without disturbing the fiber formation. Residence time in the saturator is approximately 1 minute at a line speed of 35 ft/minute. This is sufficient to complete the swelling of the fibers. Further residence time is gained through the transport system to the rinser section.

The batt, which is still between the two screens, enters a series of three press rolls. The lower press roll in each stack is specially perforated which permits expressed caustic to enter the roll. Since the caustic has a straight line vertical path to a lower pressure zone directly blow the highest pressure point liquid removal is improved over single or multiple non-perforated press rolls. (Table 1)

After the first press roll the batt is stable enough to leave the screens. The remaining two rolls extract the remaining caustic solution down to 0.86 pounds of caustic solution per pound of cotton. This system extracts about 90 to 95% of the free liquid in the batt. The caustic is returned to the saturator.

The batt then enters another screen pair. The screens constrain the batt, which in turn reduces mobility of individual fibers when they begin to shrink during the subsequent rinsing steps. The three-stage caustic rinse section is unique in that it uses a shower rinse augmented by suction applied to the lower support screen. The rinse section uses counter current rinse water flow. In other words, the first stage rinse water comes from the second stage sump and the second stage rinse water comes from the third stage sump. The first stage rinse water comes from the plant water supply. In some cases, depending on process economics and available heat sources, it may be possible to improve rinsing dynamics by heating the rinse water to about 120 to 150˚ F. Total throughput of rinse water is about 200 gallons per minute. Counter current flow gives the equivalent of 600 gallons per minute.

In the third rinse section it may be desirable to add a weak acid to the rinse water. This is, again, a matter of economics and depends on the cost of water versus the cost of acid and the control system needed to provide a stable fiber pH.

In order to reduce the load on the through air dryer it is advantageous to extract as much rinse water as possible. Following the first, second and third rinse stages a specially designed press roll system is used. These press rolls also have a perforated lower roll, which is designed to use a vacuum slot directly under the top roll point of contact. This arrangement permits maximum extraction of water. The third and final rinse stage uses a triple press roll system. This improves rinsing and reduces water usage. (Table 2)

Depending on caustic and recovery costs the first rinse stage water, in some cases, may be worthwhile recovering. If a caustic recovery system is installed the excess system heat can be used to heat rinse water or other plant processes such as dyeing.

The batt then enters a through air dyer with up to five separately controlled temperature zones. After drying to the desired moisture content the batt enters an picker/opener and is transported to the carding and spinning room or may be baled.

Baled product should not be made heavier than 300 pounds per bale. This improves opening in subsequent processing.

The result is an excellent mercerized fiber .

Mercerization Benefits: Process

1. Exempt from cotton dust standards
2. Saves 40% in bleaching and preparation chemicals
3. Shorter dyeing cycles decrease energy costs
4. Reduces amount of dyes and chemicals in dye-house water effluent
5. Reduces pollution control costs

Mercerization Benefits: Product (Using Fiber Reactive Dyes)

1. Increased color yields of up to 60%
2. Equivalent shade strength and depth at equal dye concentrations with 50% less salt for dyes of any fiber reactive class
3. Increased yarn strength
4. Deeper dye shades approach the richness seen in acrylic fiber
5. Wash fading and bleeding like acrylics

Process Control

The overall process is controlled by a programmable logic controllers (PLC) which are monitored by a supervisory computer (distributed control system or DSC) that reads and stores all of the process data in a digital format. The system also uses indicators and alarms to warn operators of process problems such as web breaks or other process problems that might occur. The process is instrumented to automatically measure and adjust process chemical concentrations, pH, line speed, differential web draws, and other critical process parameters.

This system can also support the accounting function by inputting process cost data (electric gas, chemicals, water and steam consumption) and finished bale data to an accounting computer. This control system also permits easy and continuous access to all process and production data which simplifies management and accounting control functions. It also provides a good basis for meeting ISO 9000 requirements.

Chemical Preparation

All process chemicals are made up automatically by a computerized chemical mix system and the correct quantities are pumped to the appropriate use point. At the use point chemicals are fed automatically based on level and concentration controls. Control is provided through the DCS.

Summary

The use of high efficiency caustic recovery, water extraction and drying coupled with the elimination of a spin finish step creates a viable commercial method of fiber mercerization. The existence of a mercerized fiber source provides a basis for a number of novel textile designs using mixed cotton and mercerized fibers in one yarn. Cotton and mercerized yarns can also be used to create novel but economical color shaded patterns and designs.

Table 1. Caustic Recovery

System	Caustic in Web (wt%)
Single Press	183
Triple Press	120
Triple Press w/ permeable bottoms	86

Table 2. Water Extraction

System	Water In Web (wt%)
Single Press	160
Triple Press	114
Triple Press w/ permeable bottoms	79