A WORLD OF IDEAS

TECHNOLOGIES FOR SUSTAINABLE COTTON TEXTILE MANUFACTURING

VOLUME 2

A World of Ideas:

Technologies for Sustainable Cotton Textile Manufacturing

Volume 2

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Contents

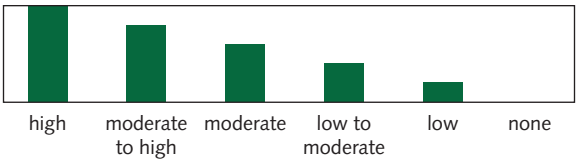
Introduction

In 2009, Cotton Incorporated published *A World of Ideas: Technologies for Sustainable Cotton Textile Manufacturing,* which identified practical and effective technologies for reducing the the use of water, energy, and chemicals (WEC) in cotton textile processing. This booklet updates and adds to our list of proven commercial technologies that can help reduce the WEC footprint in textile manufacturing.

The original *World of Ideas* publication was based on the findings from in-depth interviews conducted with more than 40 cotton textile processing companies in regions that accounted for over 75% of global textile processing. These companies had implemented changes in their processes, dyes and chemicals, equipment, and control systems that significantly reduced WEC requirements. From their reports, we selected and described 26 technologies, and we reported on the companies' experiences with implementing these technologies.

As a leader in facilitating innovations to make textile manufacturing more efficient and effective, Cotton Incorporated, along with a worldwide network of universities, cotton textile manufacturers, and equipment and chemical suppliers, continues to identify and promote the most up-to-date strategies to reduce WEC use in the global textile industry. As processes and products evolve and change, we will continue to help businesses reduce their environmental footprint with the latest technologies and inspire you to take action. In this companion volume to *A World of Ideas,* we identify 13 additional processes, chemicals and dyes, and types of machines that have been successfully implemented to reduce WEC in cotton textile manufacturing.

These technologies can be employed to varying degrees with wovens, knits, denim, and yarn-dyeing operations. Cotton Incorported's technical experts have also rated each technology's potential for reducing the WEC environmental footprint, as summarized graphically on the following scale:



Also shown for each technology are the required economic investment and expected payback time, as estimated by our technical experts. A chart summarizing these factors for these 13 technologies is provided on page 23, and contact information for the vendors is provided at the end of this booklet.

Process

Liquid Ammonia Mercerization

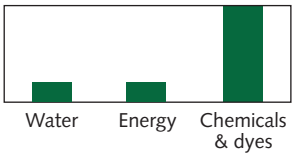
Spray Technology for Dyeing, Finishing, and Coating

Liquid Ammonia Mercerization

Mercerization of cotton enhances fabric sheen, hand, and drape, reduces shrinkage, and improves wrinkle resistance, elasticity, tensile strength, dimensional stability, and color retention by transforming the crystal structure of cellulose and causing the fibers to swell. In the traditional mercerization process, cotton yarn or fabric is treated with sodium hydroxide (caustic soda), which converts the native type I cellulose to type II. When liquid ammonia is used instead of sodium hydroxide, cellulose is converted to type III. The fibers swell less but more evenly than with sodium hydroxide, resulting in a softer hand, better wrinkle resistance, and greater tensile strength.

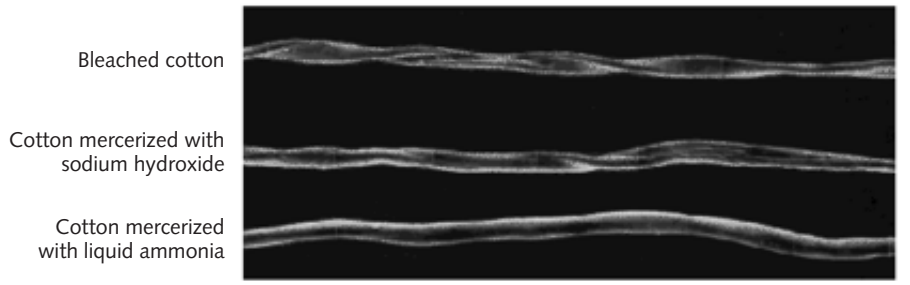
Liquid ammonia mercerization is commonly used with woven fabrics but is a new process for knits. During the process, the fabric passes through a liquid ammonia bath for several seconds. It then passes through steam-heated cylinders, where the ammonia is evaporated and collected for re-use. Finally, the fabric is rinsed or steamed to remove any remaining ammonia.

Environmental Footprint Reduction



Commercial Operating Experience

As an alternative to sodium hydroxide, liquid ammonia provides similar benefits in fabric feel, appearance, and characteristics. It reduces the need for additional softeners, resins, or other finishing chemicals and additional processing steps, thus providing cost savings. Most of the liquid ammonia used can be recycled, and because the process takes place within a closed system, no ammonia is released into the work environment.

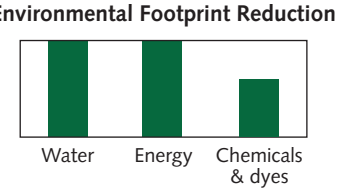


Investment: over $500,000
Payback: 2 to 5 years

Vendors: KOTERI, Lafer SpA

Spray Technology for Dyeing, Finishing, and Coating

Single-sided application methods have long been used in the textile industry; their benefits include reduced wet pick-up, chemical use, and energy consumption for drying. Reducing wet pick-up can reduce migration of chemicals during steaming or drying, resulting in more efficient dye fixation or optimum placement of finishes or coatings. Application technologies introduced over the last quarter-century to reduce wet pick-up include spray, foam, and kiss roll.

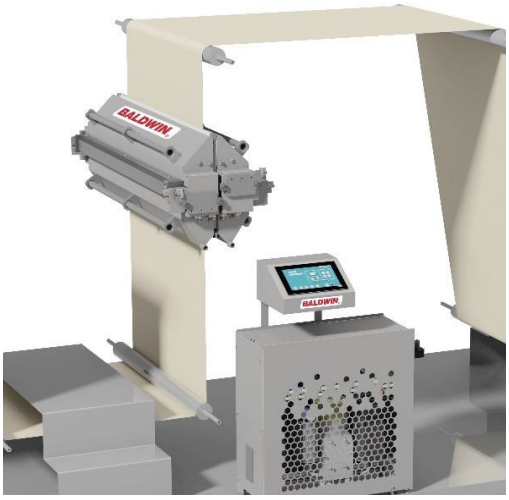


Recently, Baldwin Technology, Inc., has introduced a new spray technology that avoids problems with nozzle clogging and uneven application, while reducing WEC use.

Commercial Operating Experience

Launched in 2015, the Baldwin Spray Applicator is now installed at major textile finishing facilities worldwide, for use with knits, wovens, and nonwovens. This new technology has reduced water and chemistry use by up to 50%, total changeover time by up to 85%, and chemistry waste by up to 99%.

The Spray Applicator's individual nozzle control and automatic volume adjustment ensure precise and uniform finishing under various process conditions and production capacities. The Spray Applicator applies the exact amount of chemistry needed based on fabric width, weight, and textile characteristics. Fully automatic flushing reduces changeover times to less than 5 minutes, compared with 15 to 30 minutes for traditional application methods.



The Spray Applicator can handle a wide range of low-viscosity chemistries, single- and dual-sided applications, and various textile characteristics, as well as wet-on-wet applications, which are made without contamination from other chemistry sources. The Spray Applicator's mist containment cover prevents aerosols from escaping into the work environment.

Investment: $80,000 or more
Payback: within 1 year

Vendor: Baldwin Technology, Inc.

Chemicals & Dyes

Cationization for Salt-Free Dyeing — Update

Enzyme Treatment — Update

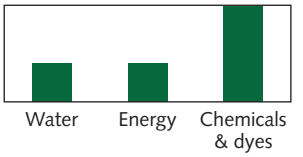
Dye Produced from Cotton By-products

Environmentally Sustainable Reactive Dyes

Cationization for Salt-Free Dyeing—Update

Cationization is the permanent chemical modification of cotton to produce cationic (positively charged) dyeing sites in place of existing hydroxyl (-OH) sites. The cationic charge enables the cotton to easily attract anionic dyes (direct, fiber reactive, pigment dispersion, and acid) without the need for salt. Up to 100% dye utilization is possible, accompanied by reductions in the use of energy, water, and steam, resulting in overall cost savings.

Environmental Footprint Reduction

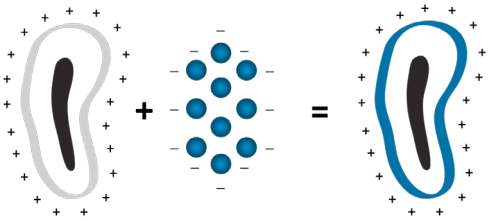


Commercial Operating Experience

This technology has been available for many years and is being used commercially in a number of mills for dyeing yarns, knits, wovens, and garments. However, implementation of cationization at the mill level remains relatively low, for various reasons:

- Low fixation of cationic agents by exhaust methods can increase chemical and processing costs. The cationization process is much more efficient with a cold pad batch pretreatment.
- Cationic cotton requires some modification of existing dyeing procedures.
- Production of seconds may be high until a mill has had substantial experience with the cationization process and dyeing of cationic cotton.

Cationization is a versatile chemistry, allowing variations in processing time, temperature, and caustic level. It can be used with many processes and combinations of processes, including exhaust, cold pad batch, pad steam, and pad-dry-cure, and it can be applied to fiber, yarn, or fabric. The efficiency of the reaction and the resulting degree of cationization are directly related to the amount of cationic agent applied, the substrate, and the process used. For safety reasons, the cationic agent should be applied by a method that avoids worker exposure.



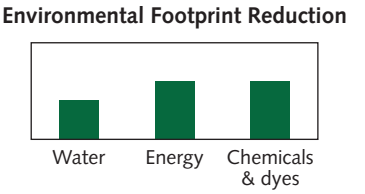
Through this technology, the use of chemicals and dyestuffs can potentially be reduced by as much as 50%. Recent research has improved prediction of cationization treatment and dyeing formulas, has identified ways to improve levelness, and has developed processes for bleaching heavily cationized greige fiber. Research continues on evaluating new cationization chemistries and their potential applications.

Investment: less than $200,000
Payback: within 2 years

Vendors: Dow, Evonik, QUAB Chemicals

Enzyme Treatment—Update

Enzymes have found a major role in the processing of cotton textiles, from desizing, scouring, and bleaching to special effects and wet finishing. Industry experience with enzymes has grown rapidly in the past 15 to 20 years, promoted by ongoing research and development.



Commercial Operating Experience

Enzyme technology is being used widely, in most mills and in various applications. The technology is being applied to all textile forms and in most types of processing equipment, both continuous and batch. Mills have reported savings in water, time, chemicals, and energy, as well as in achievement of special product effects.

The most widespread use of enzymes is in desizing, but scouring with enzymes is gaining favor. Because enzyme scouring will not remove all of the natural oils and waxes removed by a conventional scour, it leaves the fabric somewhat yellow, but this is acceptable for fabric that will be dyed in medium to heavy shades. Furthermore, enzyme-scoured fabrics usually have a better hand. Certain enzyme technology can also be used as a catalyst for the bleaching process. Operating at lower temperatures and a more neutral pH, this bleaching technology can be used on delicate fabrics or to reduce energy and water use.

Enzyme technology is being used to some extent in finishing, especially for removal of surface fibers from denim dyed with indigo, to mimic the look of stonewashing, or to destroy the indigo dye, for a bleaching effect. Use of enzymatic treatment in place of stonewashing can reduce solid effluent.

Enzymes are also used on knit fabrics and yarns in a process referred to as "bio-polishing," to remove short fibers that contribute to surface fuzz, which affects the appearance of garments and contributes to a perception of color loss. Bio-polishing may reduce fabric strength and weight but will improve the appearance of a garment through repeated home laundering cycles. Bio-polishing may require a separate bath; however, a carefully selected compatible enzyme can be included in the dyebath, saving additional water, time, and energy.

Investment: less than $200,000
Payback: within 2 years

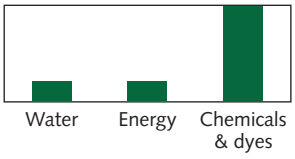
Vendors: DuPont, Dymatic, Novozymes

Dye Produced from Cotton By-products

Most textile dyes are synthetic, usually oil-based. Archroma has developed a line of sustainable dyes, called EarthColors, that are made from natural waste, including almond shells, bitter orange residues, rosemary waste, and beet residues. This collection now includes a dye made from cotton by-products—for the first time, cotton can be used to dye cotton. Cotton by-products are an abundant resource; a 480-lb bale of cotton can produce 150 to 200 lb of by-product.

In addition to sustainability, EarthColors offers traceability. Archroma has implemented near-field communication (NFC) chips in hang tags as a tracking method for full transparency in the supply chain. NFC chips can track information for each garment, such as the textile mill, dye batch number, garment maker, and bio-waste provider.

Environmental Footprint Reduction



Commercial Operating Experience

Archroma's EarthColors dyestuffs are up to 100% petroleum-free and are bioeliminable. The cotton by-products (burs, stems, and leaves) are ground into very fine particles, and caustic soda is added to the heated grounds, forming a paste that becomes the basis of the dye. Almost 100% of the cotton plant by-product is used to create the dye, and no harmful chemical waste is produced.

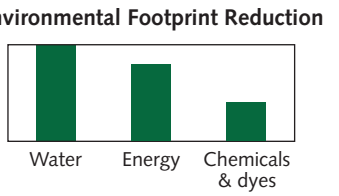
The EarthColors cotton dye can be used to dye woven and knit fabrics and yarns. The range of shades is limited by the natural color of gin waste, but different shades of brown dye can be produced depending on the concentration of dye used.

Investment: less than $200,000
Payback: within 2 years

Vendor: Archroma

Environmentally Sustainable Reactive Dyes

Several chemical and dyestuff manufacturers have developed new dye technologies that save water, time, and energy by reducing the amount of water used per kilogram of cotton fabric, the number of baths, and the temperature of the baths. Three such technologies are the Avitera SE dyes from Huntsman Textile Effects, the Bezaktiv GO dyes from CHT, and the Cadira Reactive dyes from DyStar.



Commercial Operating Experience

The Avitera SE dyes from Huntsman are polyreactive dyes that ensure rapid and very high exhaustion for cotton. More of the dye is absorbed by the cotton fabric, and the fixation rate is 93%, making it easier to remove unfixed dye at lower washing-off temperatures (about 60°C). As a result, mills can increase productivity without additional capital investment, saving water and energy by using fewer baths and lower temperatures.

The Bezaktiv GO dyes from CHT introduce a new technology, part of CHT/Bezema's 4Success program, that enables reactive dyeing with even lower temperatures during exhaust dyeing and rinsing. For most dyeing applications, 40°C dye baths and rinse baths are sufficient, with a fixation rate as high as 90% and liquor ratios as low as 4:1. As a result, considerably fewer rinse baths are required, saving water and energy.

The Cadira Reactive dye concept from DyStar considerably reduces water use, waste, and energy consumption by using select Levafix and Remazol dyes with high fixation yield and good wash-off properties. The Cadira process uses an optimized dyeing process, with improved dye fixation at 50°C, and the soaping agent Sera Fast C-RD, which allows the use of a soap-off rinse bath at only 60°C.

Investment: less than $1,000
Payback: within 1 year

Vendors: CHT, DyStar, Huntsman

Equipment

Combined Spinning and Knitting Machines

Double-Sided Transfer Printing

Digital Printing

Abrasive Drum Alternative to Stonewashing

Laser Finishing

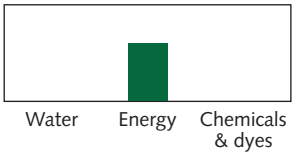
Ozone Finishing

Water-Pressure Finishing

Combined Spinning and Knitting Machines

In traditional textile manufacturing, the spinning and knitting processes are completely separate—the yarn is first spun and wound onto packages before being transferred and loaded onto the knitting machine. New circular knitting machines combine spinning and knitting in one machine, producing knit fabric directly from roving or sliver. The fiber is spun before the yarn is fed to be knitted. Some machines also incorporate cleaning.

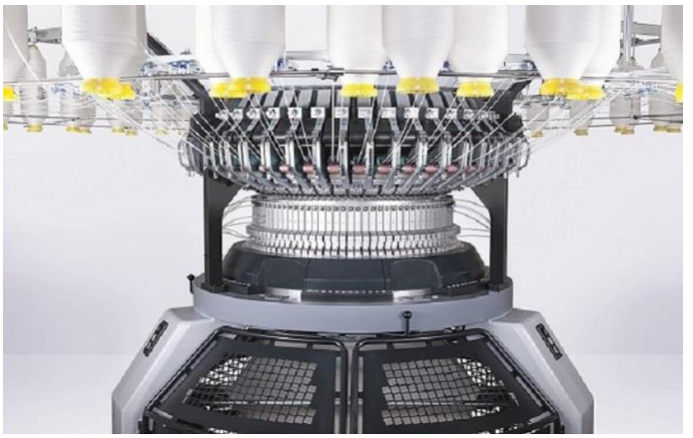
Environmental Footprint Reduction



Commercial Operating Experience

Some combined spinning and knitting machines produce jersey knits, while others can knit rib and interlock fabrics, and some machines allow Spandex to be incorporated. The combined spinning and knitting process results in improved efficiency, reduced waste, and savings in space, energy, storage, labor costs, and material costs. The energy savings from combining the processes can reduce carbon dioxide emissions by up to 30%.

One factor limiting implementation is the high cost of the machines, since the new technology combines the work of at least two processes.



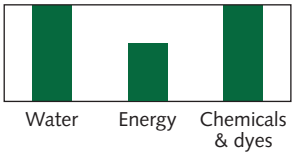
Investment: $200,000 to $500,000
Payback: 2 to 5 years

Vendors: Mayer & Cie., Pai Lung Machinery Mill Co., Terrot GmbH.

Double-Sided Transfer Printing

Traditional transfer printing uses heat and pressure to transfer a print pattern from a substrate, usually paper, to synthetic fabrics. Newtech Textile Technology has developed an innovative technology, called COOLTRANS, for transfer printing under ambient conditions and on 100% cotton fabrics. The process accommodates a wide variety of print designs, and the quality is comparable to that of digital printing. With the development of a duplex printing machine, this technology can now be used to print both sides of a fabric in one pass.

Environmental Footprint Reduction



Commercial Operating Experience

Use of the duplex cool transfer printing process on woven cellulosic fabrics offers high processing speed, a transfer rate of over 95%, energy efficiency, water recovery and reduction, waste reduction, cost savings due to paperless printing, consistent printing, and low ink consumption.

Investment: over $500,000
Payback: 2 to 5 years

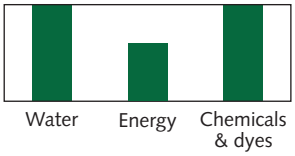
Vendor: Newtech Textile Technology

Digital Printing

Traditional rotary screen printing has limitations: colors typically are limited to 8 to 16 per design, and the repeat size is limited by the circumference of the print screen. In addition, unused print paste must be disposed of and screens washed thoroughly after production runs.

Digital printing offers the opportunity to create photorealistic prints with thousands of colors and virtually unlimited repeat sizes. Using colorants such as reactive dyes, acid dyes, disperse dyes, and pigments, digital printing can print designs the full widths of fabrics or garments, with little or no waste of colorant between designs.

Environmental Footprint Reduction



Commercial Operating Experience

Digital printing technology has matured rapidly in recent years. A large majority of digital printers currently in use (over 80%) use a bank of traversing printheads and are slower than rotary screen printing. However, the development of fixed-array printheads has enabled digital printers to match the speed of rotary screen printers. Digital printing uses dyes or pigments much more efficiently than screen printing. In addition, eliminating the need for rotary screen preparation, printing, and cleanup reduces consumption of water and electrical energy.

Investment: $25,000 to $2,000,000
Payback: 6 months to 2 years

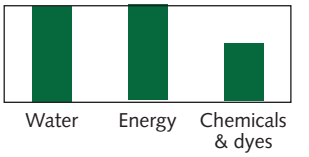
Vendors: AGFA, Atexco, Durst, EFI Reggiani, Konica Minolta, Mimaki, MS Printing Solutions, Mutoh, Robustelli

Abrasive Drum Alternative to Stonewashing

Denim fabric or jeans are commonly stonewashed in order to create a vintage, washed-down appearance. The stones used are pumice, whose rough surface wears down and lightens the fabric. However, pumice stones produce grit as waste, and labor is required to remove the stones and particles from garments and pockets during processing. In addition to increasing labor costs, the stonewashing process can damage the washing machines.

An alternative is Tonello's NoStone process, which uses abrasive drums instead of pumice stones to achieve the same worn effect.

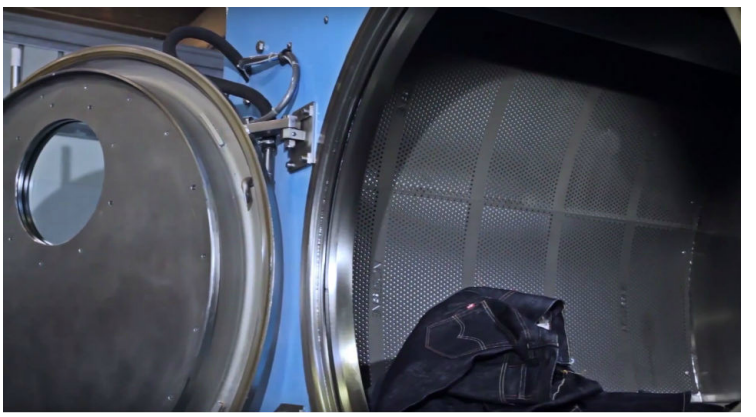
Environmental Footprint Reduction



Commercial Operating Experience

In collaboration with Levi Strauss & Co., Tonello has developed a new denim-washing system based on the use of an abrasive stainless-steel drum. The abrasive lining can be used in any Tonello machine, without reducing the load capacity, and is removable, so that the machines can still be used for other washing or dyeing processes. Different levels of abrasion are determined by the fineness of the texture on the drum and the processing time.

The NoStone process reduces water consumption, production costs, emissions, waste, processing time, and manual labor. It does not damage the machines, and it eliminates the dust or sludge generated by pumice stones.



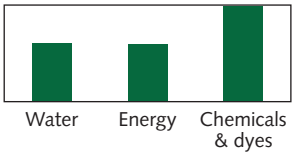
Investment: $200,000 to over $500,000
Payback: 2 to 5 years

Vendor: Tonello

Laser Finishing

Methods commonly used to distress denim and other fabrics in order to give a worn, faded appearance include sandblasting, spraying with potassium permanganate, and using sandpaper to abrade the fabric surface by hand.

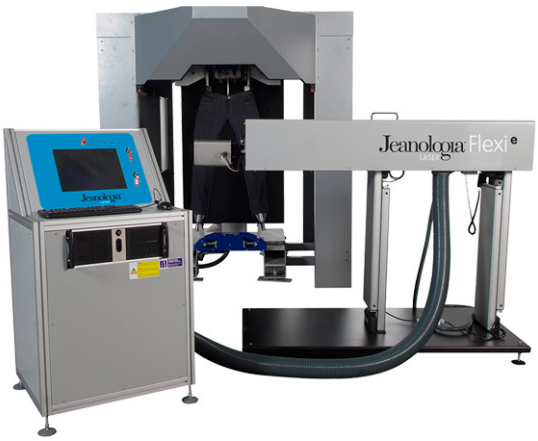
Environmental Footprint Reduction



Sandblasting is a fast and low-cost process; factory workers spray jeans with abrasive sand under high pressure. Although brands, retailers, and countries have banned sandblasting because of its harmful effects on workers' health, it is still prevalent in denim finishing. Spraying the fabric with potassium permanganate at various concentrations achieves distressed appearances and whitening effects. However, potassium permanganate can irritate and burn workers' skin and eyes, and long-term exposure can cause lung damage. Hand sanding also exposes workers to dust and is labor-intensive. Laser finishing technology offers a more efficient and safer way to achieve the same distressed looks.

Commercial Operating Experience

Laser machinery is available for use with garments or fabrics. Laser systems can create whiskers, fading, and customized designs and images on knit or woven garments. Compared with sandblasting, potassium permanganate spraying, or sanding, laser finishing improves efficiency, maintains consistency, and reduces energy or chemical use, increasing productivity without risking workers' health.



Investment: $200,000 to over $500,000
Payback: 2 to 5 years

Vendors: Jeanologia, Tonello

Ozone Finishing

Chemical bleaching is commonly used in garment wet processing to create fashion effects and is especially prevalent in denim finishing. Sodium hypochlorite and potassium permanganate have been used as chemical bleaching agents, but manufacturers are seeking to reduce their use because of environmental and worker safety concerns that can arise from improper handling or disposal of these chemicals. An alternative is the use of ozone gas (O_3), a powerful bleaching agent that is generated from oxygen, either in the atmosphere or stored in gas cylinders.

Environmental Footprint Reduction

Commercial Operating Experience

Ozone bleaching can be carried out as a wet or dry process at ambient temperatures. Compared with other bleaching methods, it tends to be much faster and requires fewer rinses.

Ozone is generated by applying electricity to oxygen. The O_3 molecule is unstable and does not persist in the environment. At the end of the bleaching process, any remaining ozone is converted back to oxygen before being released. Safety features and practices should be implemented to prevent exposure of workers to ozone gas.

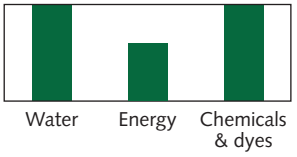
Investment: $50,000 to $250,000
Payback: 1 to 2 years

Vendors: Blastex, Jeanologia, Tonello

Water-Pressure Finishing

Sandblasting, potassium permanganate spraying, and hand sanding are methods commonly used to distress denim and other fabrics to create a worn, faded appearance. However, these methods are labor-intensive, generate waste, and can create health risks for workers (as discussed on page 19). Tonello has developed a new technology using only water pressure to achieve the same looks on denim while protecting workers' health and reducing WEC use.

Environmental Footprint Reduction



Commercial Operating Experience

Tonello's Water Brush system is controlled by a robot and uses only water pressure for abrasion. The Water Brush is used only on garments. A technician first "trains" the robot in the desired placement of the water pressure. Once programmed, the robot repeats the sequence of movements to process each garment, producing consistent results. The programmed movements can easily be saved and reused. The water is recirculated in the machine, and the use of chemicals is eliminated.

Investment: $200,000 to over $500,000
Payback: 2 to 5 years

Vendor: Tonello

Summary Chart

Applicability to Yarn, Knits, Wovens, and Denim

Potential Impact on WEC Reduction

Estimated Investment and Payback Time

Key to Chart—WEC reduction:

- ● = high *or* moderate to high
- ◒ = moderate *or* low to moderate
- ○ = low

Technology (page)	Applicability			
	Yarn	Knits	Wovens	Denim
Process				
Liquid Ammonia Mercerization (5)	✓	✓	✓	
Spray Technology for Dyeing, Finishing, and Coating (6)		✓	✓	✓
Chemicals and Dyes				
Cationization for Salt-Free Dyeing—Update (9)	✓	✓	✓	✓
Enzyme Treatment—Update (10)	✓	✓	✓	✓
Dye Produced from Cotton By-products (11)	✓	✓	✓	
Environmentally Sustainable Reactive Dyes (12)	✓	✓	✓	
Equipment				
Combined Spinning and Knitting Machines (15)		✓		
Double-Sided Transfer Printing (16)		✓	✓	
Digital Printing (17)		✓	✓	✓
Abrasive Drum Alternative to Stonewashing (18)		✓	✓	✓
Laser Finishing (19)		✓	✓	✓
Ozone Finishing (20)		✓	✓	✓
Water-Pressure Finishing (21)				✓

Potential WEC Reduction				
Water	Energy	Chemicals	Investment	Payback
○	○	●	> $500 K	2 to 5 years
●	●	◒	≥ $80 K	< 1 year
◒	◒	●	< $200 K	< 2 years
◒	◒	◒	< $200 K	< 2 years
○	○	●	< $200 K	< 2 years
●	●	◒	< $1 K	< 1 year
	◒		$200 K to $500 K	2 to 5 years
●	◒	●	> $500 K	2 to 5 years
●	◒	●	$25 K to $2 M	0.5 to 2 years
●	●	◒	$200 K to > $500 K	2 to 5 years
◒	◒	●	$200 K to > $500 K	2 to 5 years
●		●	$50 K to > $250 K	1 to 2 years
●	◒	●	$200 K to > $500 K	2 to 5 years

Vendors

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