Deep grooved polyester fiber for wet lay applications

William A. Haile and Bobby M. Phillips

ABSTRACT: A new polyester fiber has a unique deep grooved, eight leg cross-section. The grooves can spontaneously transport fluids. The fiber exhibits high surface area and bulk. This paper provides an introduction to the new polyester fiber technology and discusses some key wet lay application areas.

KEYWORDS: End use, grooves, nonwovens, polyesters, product development, synthetic fibers, wet process.

Earlier approaches to develop better absorbent and wicking structures concentrated mostly on cellulosics, round cross-section synthetic fibers, or special treatments. For improvements in filtration, novel cross-section or shaped fibers are receiving much attention. The limitation is that until now the shape factor for these fibers is considerably below two. Shape factor is the ratio of the perimeter of any fiber cross-section to that of a round fiber with the same denier/filament (d/f) measurement.

The introduction of a new 40G deep grooved polyester staple fiber has changed this. This fiber is spontaneously wettable. The grooved surface provides single fiber liquid transport along its length. It also has a very high surface area with shape factors in the 2.3–2.8 range. The high specific volume of the new material can increase the structural bulk in nonwoven forms and composites. This paper will describe the new fiber and highlight some potential wet lay applications.

Technology

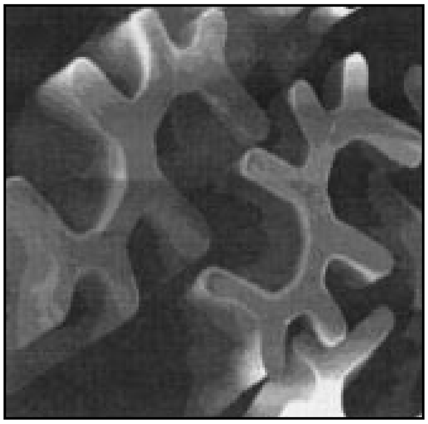
The photomicrograph in **Fig. 1** shows that the new polyester fiber is unusual. **Table I** provides a summation of its important characteristics. It has a unique, eight-leg cross-section with deep grooves along the longitudinal fiber axis. One can consider these grooves as open pipes to convey fluids both horizontally and vertically. A hydrophilic finish provides the necessary surface energetics for the transport of aqueous fluids. A hydrophobic finish is available for movement of light oils and nonpolar liquids. Some oils will spontaneously wet the fiber with little or no finish on the surface.

Figure 2 shows the distribution of fluids by this fiber by examining the movement of drops of an aqueous tint placed on the surface of nonwoven samples made from the new fiber compared to a round cross-section polyester fiber. All other variables such as nonwoven basis weight, fiber denier, and hydrophilic fiber finish are identical for both materials. The tint rapidly spreads across the nonwoven from the new fiber. After 20 s, the fluid reaches the edge of the support hoop. Maximum potential flux values determined by an internally developed company test for the individual new fibers generally range from 100–200 $cm^3/g/h$ (cubic centimeters of water per gram of fiber per hour). In optimally engineered assemblies, the new fiber can solve some challenging fluid management needs.

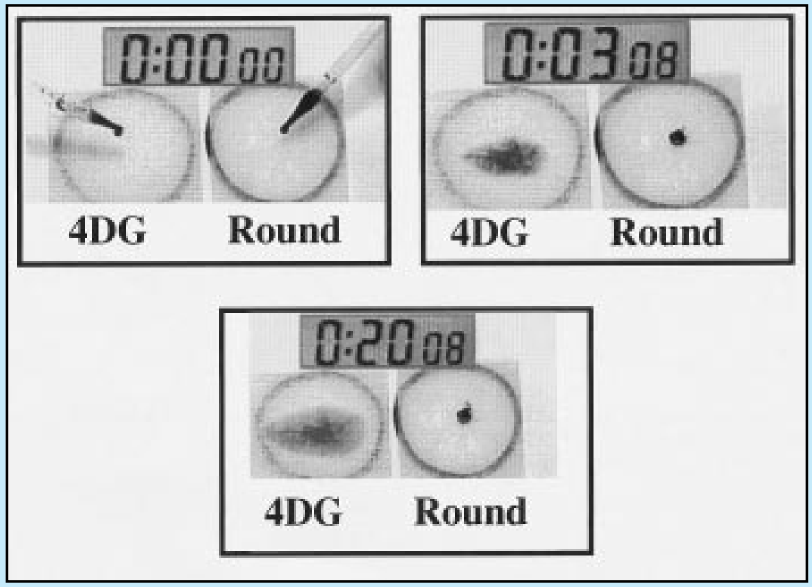
There are also many dry applications. The grooves can be filled or serve as depositories for particulate matter and other loadings. As indicated earlier, measured surface areas for the deep grooved fibers are 2.3–2.8 times that of the same denier round cross-section polyesters. When comparing specific surface areas, the new fiber with 6 d/f is equivalent to round polyesters of approximately 0.8 d/f. The deep grooved fiber occupies more volume than its round polyester counterpart. This results in less dense nonwovens

Haile is research associate and Phillips is research fellow at Eastman Chemical Co., P.O. Box 511, Kingsport, TN 37662.

1. Photomicrograph of deep grooved fibers



2. Comparison of fluid movement for nonwovens made from the new polyester vs. round cross-section polyester fibers showing fluid movement in elapsed time in seconds



I. Characteristics of the deep grooved fibers

Characteristic	*Comment*
Physical	Eight-leg cross-sectional shape with eight deep groves to move fluids spontaneously
Finish	Hydrophilic and hydrophobic for different fluids and needs with hydrophilic preferred for wet lay
Surface area	Very high compared to round
Chemical	Polyester (polyethylene terephthalate)
Crimping	Uncrimped fiber available for wet lay and air lay and crimped version for carding and air lay
Denier	Staple fiber currently available in 6, 10, and 15 d/f and various cut lengths of 3–28 mm uncrimped and 32–152 mm crimped

especially under compression. When making hand sheets using only the new fiber, the loftiness is very apparent.

The new fiber is commercially available in 6, 10, and 15 deniers with uncrimped, short staple lengths suitable for wet lay processing. **Table II** shows some physical properties of these fibers.

Most of the work to date has focused on the 6 d/f new fiber. The uncrimped fiber with the hydrophilic finish has shown excellent dispersibility. There is also a developmental slightly curl-crimped version available for evaluation. This is useful in applications requiring bulk or more open structures. Dimensions for the two main grooves are denier dependent. They range from 8–12 µm wide and 13–21 µm deep. Typical fiber tenacity for 6 denier is approximately 3.2 g/denier.

Applications

Fluid management

Fluid management applications for the new fiber cover many market segments. These include industrial, cosmetic, and medical uses. Typical products are wipes, oil-absorbent mats, battery separators, wound dressings, ink reservoirs and wicks, evaporative cooling fabrics, and air freshener delivery systems.

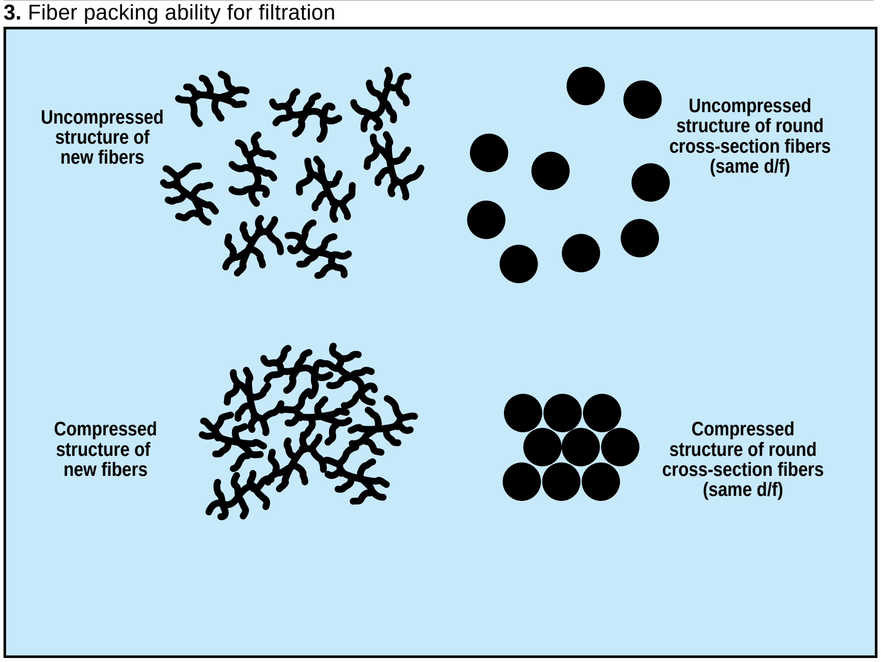
Because many of these applications have proprietary aspects, few details are available now. An important aspect of the use of the new fiber is its placement and the thoughtful design and optimization of the fluid managing structure. Since there are competing affinities for the fluid, layering or segregating are often better approaches than just blending the new fiber with the storage material. Another precaution is that any bonding agents or binder fibers should not interfere with the majority of the grooves. Total engineering of the final product makes

II. Properties of the eight-leg cross section deep grooved fiber

	Denier		
	6	*10*	*15*
Fiber tenacity, g/denier	3.2	2.8	2.6
Fiber shape factor[a]	2.7	2.7	2.4
Specific volume, cc/g[b]	1.8	1.8	1.7
Specific surface area, cm^2/g[c]	3130	2210	1710
Main groove width, µm	8	10	12
Main groove depth, µm	13	18	21
Specific capillary volume, cm^3/g[d]	0.49	0.47	0.39
Groove area, %[e]	40	40	35
Maximum potential flux, hydrophilic finish, water, cc/g/h[f]	125	-	150

[a]Shape factor for round cross-section polyester fiber of same d/f is 1.0.
[b]Total volume per g of uncrimped fiber filaments. Specific volume of round cross-section polyester fiber of same d/f is 1.0.
[c]Ratio of fiber perimeter to fiber cross-sectional area x 1/polymer density
[d]Ratio of groove to fiber cross-sectional area x 1/polymer density which equates to g of water the filled grooves can theoretically hold per g of fiber
[e]Ratio of groove to total groove plus fiber cross-sectional area x 100
[f]Internal test procedure

3. Fiber packing ability for filtration



the difference between marginal improvement and real success.

Variants and advanced forms of the new fiber are in the development stage. These would have use for absorbent products, cores, and distribution layers. These developments include lower deniers, higher shape factors, and further improvements in fiber finishes.

Filtration

Filtration is a major potential use for wet laid structures containing the new short-cut fiber. **Figure 3** shows the unusual packing ability of the fiber in compressed forms. This can provide greater depth or equivalent thickness at lower filter weights allowing incorporation of high surface areas and fiber grooves into the structure. In filter media, particles collect at the interstices between fibers. The pressure drop, ΔP, increases as more pores become blinded or impeded. The new fiber allows trapping and holding of particulates in the grooves in addition to the interstices. Buildup in the grooves remains mostly hidden. Trapping the particulates in the grooves should not influence ΔP significantly until the grooves are nearly full. Lower pressure drops at higher loadings will then occur. This greatly extends the life of the filter. **Figure 4** summarizes and graphically depicts these ideas.

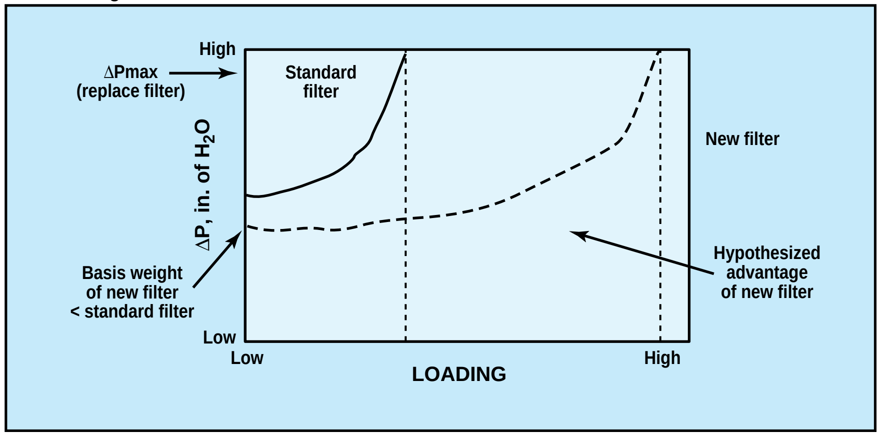
Use of dry laid needle-punched structures has demonstrated these advantages. Needle-punched fabrics underwent laboratory air filtration tests using Society of Automotive Engineers fine test dust. The test fabrics were 17 ounce per square yard (osy) commercial filter media made from 2-3 denier round ployester fibers and a development media of the same weight made from the 6 denier new polyester fiber. Although the new polyester version was not calendered and did offer greater filtration depth, the test data essentially confirmed the grooved concept. **Figure 5** shows that high loadings were obtained at low values of ΔP. The filtration capacity for the new needled fiber was over six times that of the commercial needled felt. Although this is impressive, the lower ΔP values and slope of the curve indicate there is still considerable filter life remaining in the new fiber structure. The testing of the felt made from the new fiber could have continued, but the test arbitrarily stopped at this point. Gravimetric filtration efficiency for the new material was higher than the commercial control. **Figure 6** provides substantiation with a photomicrograph showing the accumulation of fine test dust in the fiber grooves.

Filtration fabrics from the new fiber can be engineered for specific applications. These range from stand-alone filters to prefilters and composites. There are many prospective uses for uniform, optimally designed wet laid filter systems incorporating the deep grooved fiber.

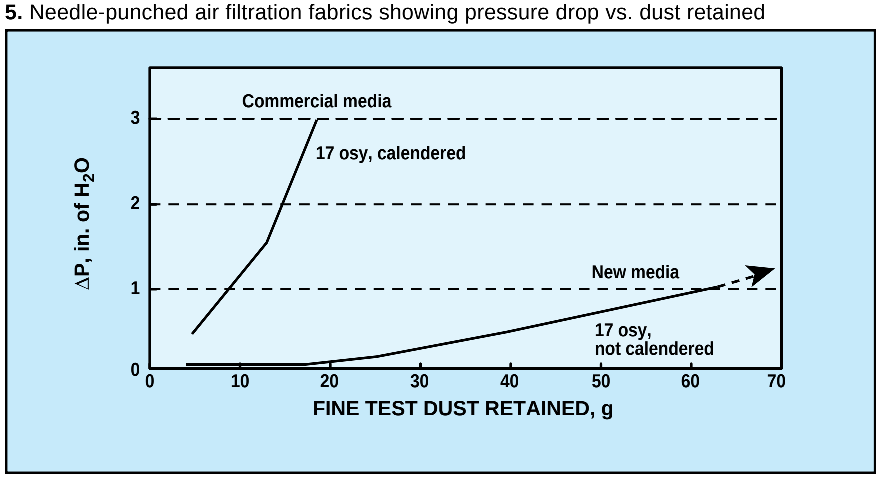
Filling the grooves

One other use for the new material is filling or loading the grooves with substances such as activated carbon, abrasives, other types of particles, metal coatings, indicators, pesticides, flavorants, and even medicines. Many of these are durable by design. Some, however, may be prefilled for temporary storage such as medicines and first aid fluids for timed release or later dispensing. Loading the grooves may synergistically combine several technologies. Potential applications vary as the materials for loading incorporating the deep grooved fiber.

4. Advantages in air filtration for new fiber



5. Needle-punched air filtration fabrics showing pressure drop vs. dust retained



Summary

The new polyester material has many important attributes—deep grooves, spontaneous fluid transport, high surface area, and fiber bulk. The work presented in this paper shows the advantages available from such properties. This new, versatile fiber is commercially available in 6, 10, and 15 deniers in short-cut staple lengths for wet lay operations. Opportunities include filtration, a variety of absorbent and fluid managing structures, and other innovative applications. TJ

Received for review Oct.18, 1994.

Accepted Jan. 9, 1995.

Presented at the TAPPI 1995 Nonwovens Conference.

6. Photomicrograph of fine test dust collected in 6 d/f new polyester fiber grooves from needle-punched fabrics after air filtration testing