2010

The Effect of Cyclic Loading on the Wicking Performance of Nylon 6.6 Yarns and Woven Fabrics Used for Outdoor Performance Clothing

Nyoni, A.B.

SAGE


http://ir.nust.ac.zw/xmlui/handle/123456789/224

Downloaded from the National University of Science and Technology (NUST), Zimbabwe
The Effect of Cyclic Loading on the Wicking Performance of Nylon 6.6 Yarns and Woven Fabrics Used for Outdoor Performance Clothing
A.B. Nyoni and D. Brook
Textile Research Journal 2010 80: 720 originally published online 23 March 2010
DOI: 10.1177/0040517508094093

The online version of this article can be found at:
http://trj.sagepub.com/content/80/8/720

Published by:
SAGE
http://www.sagepublications.com

Additional services and information for Textile Research Journal can be found at:

Email Alerts: http://trj.sagepub.com/cgi/alerts
Subscriptions: http://trj.sagepub.com/subscriptions
Reprints: http://www.sagepub.com/journalsReprints.nav
Permissions: http://www.sagepub.com/journalsPermissions.nav
Citations: http://trj.sagepub.com/content/80/8/720.refs.html

>> Version of Record - Apr 28, 2010
OnlineFirst Version of Record - Mar 23, 2010

What is This?
The Effect of Cyclic Loading on the Wicking Performance of Nylon 6.6 Yarns and Woven Fabrics Used for Outdoor Performance Clothing

A. B. Nyoni¹ and D. Brook
Performance Clothing Research Group, School of Design, University of Leeds, Leeds, United Kingdom

Abstract  The effects of short interval dynamic loading and unloading on yarn and fabric wicking performance were evaluated at different cyclic load ranges using the conventional extension-recovery method on a modified Instron Tensile Tester. This was based on the principle that during use, the constituent yarns in a fabric are continuously stressed and relaxed as the garment shape changes. Results showed that the straining forces generated between the filaments of the yarns resulted in spasmodic pumping of the liquid which was dependent on the yarn and fabric construction, contact between the yarns, volume of liquid in yarns, and duration of the force applied.

Key words  cyclic loading, dynamic loading, wicking, spasmodic

The mechanical properties of textile fibers, i.e., the responses of the fibers to applied forces and deformations are probably their most important properties technically, contributing both to their behavior in processing and to the properties of the final product [1]. In use, textiles are subject to complex, variable, and probably unknown intensive dynamic loads in individual temporary cycles [1, 2], which keep changing the shape of a garment. However, due to the elasticity and viscoelasticity [2, 3] of the fibers, these changes are temporary unless the stresses are too great or last too long resulting in permanent or irreversible deformation. Most often, such deformations occur during pressing and leaning motions [4], and on those parts of garments that are exposed to the greatest stresses, i.e., the fabric covering the elbows, knees, backside, etc.[2, 5, 6] in both knitted and woven fabrics.

The link between human performance and clothing and textile products in a variety of situations, variable environmental conditions, and the development of a number of new fibers [7–12] and yarn manufacturing processes has enhanced the need for studies to yield more information about textiles that could be used in engineering fabrics which can provide not only comfort but enhance human performance.

Research [13] has shown that 3–5 % added moisture is ample to stimulate sensations of discomfort, therefore, free movement of water within fibers in a vapour phase or through the pores in a liquid phase to the fabric surface is essential if perspiration discomfort, causing fabric wetness with resulting freezing in winter or clamminess [14, 15] in summer, is to be prevented. Kisilak [2] simulated the flexing during knee or elbow movements by cyclic loading fabrics with a maximum force of 100 N and a minimum force of 0.6 N every 15 minutes. His objective was to establish the effects that different strains have on yarn and fabric wicking performance so as to facilitate the engineering of fabrics with specific wicking capabilities.

¹ Corresponding author: e-mail: babsnyoni_dr@yahoo.co.uk
Experimental

Development of the apparatus for measuring the effect of cyclic loading on yarn and fabric wicking

The Instron Table Model 1026 [16] (see Figure 1a), a versatile and accurate tool for evaluating the stress-strain properties of materials utilizing electronic load weighing, recording, and logic control principles, was modified by substituting the bottom grip with an attachment consisting of a lower fixed holder with a grooved yarn clamp (1) that dipped into the liquid reservoir (3) fixed to a nut and bolt (4) to enable simple, precise, and repeatable placement of all samples. The upper clamp was fixed to the traversing head A. For these experiments, a 0–500 g (0–5 N) tension cell 2512-107 intended primarily for fiber, light yarn, and fine wire measurements was used and the testing load ranges used are shown in Figures 2–5.

The basic principle of this apparatus was to measure the effect of yarn and fabric displacement on the wicking rate as the samples were subjected to different ranges of cyclic loads. The test results were presented on a strip chart-recorder (8), which was driven synchronously at a wide variety of speed ratios with respect to the crosshead, thus enabling measurements of sample extension to be made with a large choice of magnification factors. The machine was connected to a computer (9) for direct reading and recording of test results with graphical output.

To change from straight-forward tensile testing to automatic cyclic operation, the crosshead A was programmed to move between preset load points to facilitate extension, relaxation, and recovery during a test. The two toggle switches marked C maximum and D minimum (cycle stop) provided a selection whereby the crosshead was caused either to reverse at the cycling point or to stop. The movement of the crosshead between C and D was defined as one cycle, and the extension of the yarn as the crosshead moved from D to C as the maximum displacement.

Preliminary yarn tests

To simulate strains likely to be encountered during use and to determine their effect on the wicking performance of yarns, preliminary tests of 20 cycles were carried out at 0–500 mg, 0–300 mg, 0–150 mg, 150–500 mg, and 300–500 mg load ranges to obtain different degrees of yarn displacement. All the five load ranges used were found suitable for testing textured yarns as it was relatively easy to set the reversing position to correspond to the set load value and to wick the yarns. However, the use of load ranges 0–500 mg, 0–150 mg, and 0–300 mg proved difficult with flat continuous filament yarns due to separation of the filaments at zero tensioning, and the wicking results obtained were not repeatable. Therefore, these methods were deemed unsatisfactory and the results obtained have not been quoted in this work.

Even though preliminary tests on flat continuous filament yarns indicated that load ranges 150–500 mg and 300–500 mg yielded satisfactory and repeatable results, only load range 150–500 mg was adopted for the final tests, as this method gave the desired optimum test conditions due to minimum filament separation when the motion was reversed at 150 mg pre-tension.

As a control, static tests of the yarn samples were carried out at maximum loading for the duration equivalent to the total cyclic wicking time in each case. In addition, to determine the effect of increase in the number of cycles on...
wicking performance, the flat continuous filament yarns were also tested at twice (40 cycles) the initial experiment number of cycles.

Sample preparation and test method

The yarn and fabric wicking experiments reported in this paper were conducted in a standard atmosphere of 20 ± 2 °C and 65 ± 2 % relative humidity, and the samples were conditioned in a standard atmosphere for 24 hours before the wicking performance was determined by extending the samples on an Instron Tensile Tester. To enhance observation of the liquid front advancement, an indicating ink (Staedtler Lumocolor 315, Germany) was used to mark the samples, and it was assumed its effect on viscosity and surface tension of the distilled water was small and did not affect the wicking behavior. Once the required degree of tension was attained, distilled water was added in the reservoir and the height of the advancing liquid front as a function of time was observed through a traveling microscope (6). The wicking length was noted by observing the height of the advancing liquid through the crossline graticule eyepiece of the microscope focused on a ruler (2) attached to the bottom clamp and parallel to the sample. A computer printout of the test parameters of each sample was produced at the end of each test. To avoid contamination by the indicating ink, the test liquid was changed after each test and premature wicking in the yarn and fabric samples was avoided by drying the bottom clamp and liquid reservoir with a filter paper before a new sample was clamped.

Yarn sample lengths of 30 cm each were cut with at least 5 m of yarn being unwrapped between samples. The samples were then mounted on the bottom clamp (see Figure 1b) before it was fixed to the nut and bolt so that the grooved sample clamp (see Figure 1c) hung into the empty water reservoir and a mark 1 cm above the bottom grip was made on the yarn. The top end of the yarn was then clamped in the top grip and the desired pre-tension applied.

For the fabric tension tests, sample strips of 1.5 cm × 30 cm each were cut in the warp and weft directions from the conditioned fabrics and mounted on the clamps in a similar way as in yarn testing, but with a pre-tension of 120–150 mg and wicking performance was determined by extending the fabrics in the warp and weft directions.

Results and Discussion

The wicking of textured yarn 195dtexf170

Figure 2 shows that varying the load ranges had an effect on the wicking performance of textured yarns which was significant at the 5 % level in most cases [17]. The yarn extension that occurred when the load was increased caused relative movement between filaments, and since the ability of liquids to react to shearing stress gives them their characteristic ability to change their shape or to flow, the continuous
stretches and relaxes the yarn caused the liquid trapped in the voids to wick. However, at a certain stretching point, the flow was restricted as the yarn “tortuosity” changed due to the locking of the textured yarn structure. When the tension was released, the liquid slowly found its way through the voids until the cycle of forces required to alternately squeeze and accelerate it along the yarn capillaries was repeated resulting in a spasmodic pumping effect of the liquid up the yarn structure. In the static load test, the pumping effect was absent and this was confirmed by the fact that, even though the static loaded samples exhibited a higher mean displacement value (8.892 mm) compared to that of the cyclic loaded samples (3.120–4.680 mm), wicking in the former samples was low. Figure 2 shows that when the nominal pre-tension was zero, wicking performance of the yarns increased with the increase of the load applied reaching a maximum at load range 0–500 mg. This could be attributed to the fact that the rhythm of the cycle of forces required to alternately squeeze and accelerate the liquid along the yarn capillaries increased with displacement resulting in a prolonged pumping effect of the liquid up the yarn structure. However, the pumping effect gradually decreased as the pre-tension was increased (150–500 and 300–500 mg). Hypothetically, wicking would be expected to increase at higher pre-tension levels since the filaments can be assumed to be at an optimum capillary arrangement and the rhythm of forces required to alternately squeeze and accelerate the liquid along the yarn repeat more frequently. However, the results in Figure 2 show a gradual decrease in wicking and this may be attributed to the commencement of the locking

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Yarn characteristics.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property</td>
<td>Method</td>
</tr>
<tr>
<td>Linear density dtex</td>
<td>BS 946:1970</td>
</tr>
<tr>
<td>Filament x-section</td>
<td>SEM</td>
</tr>
<tr>
<td>Filament diameter µ</td>
<td>SEM</td>
</tr>
</tbody>
</table>

SEM = scanning electron microscope.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Fabric characteristics.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property</td>
<td>Test method</td>
</tr>
<tr>
<td>Ends/cm</td>
<td>BS 2862:1984</td>
</tr>
<tr>
<td>Picks/cm</td>
<td>BS 2862:1984</td>
</tr>
<tr>
<td>Linear density warp (dtex)</td>
<td>BS 946:1970</td>
</tr>
<tr>
<td>Linear density weft (dtex)</td>
<td>BS 946:1970</td>
</tr>
<tr>
<td>Fabric weight (g/m²)</td>
<td>BS 2471:1978</td>
</tr>
<tr>
<td>Filament x-section</td>
<td>Microscopy-SEM</td>
</tr>
<tr>
<td>Warp Filament Ø</td>
<td>Microscopy-SEM</td>
</tr>
<tr>
<td>Weft Filament Ø</td>
<td>Microscopy-SEM</td>
</tr>
</tbody>
</table>

SEM = scanning electron microscope; Ø = circular.

Figure 2 Effect of cyclic loading on the wicking performance of textured yarn 195f170 – 20 cycles.
of the yarn structure that resulted in the change of yarn “tortuosity” which hindered continuous liquid pumping.

The wicking of flat continuous filament yarn 160dtexf80

The wicking performance of the continuous filament yarns was tested with a load range of 150–500 mg because preliminary tests had shown that other test methods led to filament separation when the minimum (zero) reversing position was reached. Results shown in Figure 3 indicated that dynamic yarn loading significantly increased wicking performance of the yarns at 20 and 40 cycles. However, Figure 3 shows that doubling the number of cycles had an insignificant effect on wicking of the yarns in both static and cyclic loading tests. This was attributed to the effect of evaporation that occurred when the filaments separated during the relaxation of the yarns at low tension levels.

The effect of cyclic loading on wicking performance of fabrics

A dynamic test method was developed to measure the effect of yarn and fabric displacement on wicking rate as they were subjected to different ranges of cyclic loads. The key parameter that was considered in assessing the wicking performance of each fabric sample under load was the weave direction, i.e., to determine the role played by the warp and weft yarns during wicking.

Wicking performance of fabrics S1F and S2F

The deformation of woven fabrics during cyclic loading may be considered as consisting of three components namely, the elongation of crimped portion of the yarn, the elongation of the yarn itself, and the elongation of the fabric which resulted in high displacement values ranging between 8.15–9.86 mm for fabric S1F and 8.79–9.76 mm for fabric S2F (see Figures 4 and 5).

In fabrics, the load per yarn was lower; however, a wicking trend similar to that exhibited by wicking of single yarns was also observed when wicking the woven fabrics. Results in Figures 4 indicated that in most cases, there was a significant change in wicking of fabric S1F in both the warp and weft directions when a cycling motion was introduced. However, doubling the load resulted in an insignifi-
cant increase in warp direction wicking and a significant increase in wicking in the weft direction due to the high absorption capacity of the textured feeder yarns. Figure 4 shows that in all cases, weft direction wicking was higher than warp direction wicking in fabric S1F due to the absorbing capacity of the textured yarns. On the other hand, when the flat continuous filament yarns were the feeder yarns, i.e., when wicking in the warp direction, there was very little liquid fed into the fabric such that doubling of the load did not significantly change the fabric wicking behavior. However, Figure 4 shows that there was more increase in wicking in the weft direction as the load was increased, and this was attributed to the absorbing capacity of the feeder textured yarns.

In the case of the second fabric S2F where the same flat continuous filament yarns (44f34) were used for both the warp and the weft but with different yarn density, i.e., more ends/cm (70) than picks/cm (50), the results in Figure 5 show that there was a significant difference between warp and weft direction wicking of the fabrics in both the static and cyclic loading tests. However, this difference was insignificant when warp-warp and weft-weft direction wicking results were compared, and this could be attributed to the effect of evaporation since the amount of liquid fed into the fabric structure by the feeder yarns was limited. Figure 5 also shows that with fabric S2F there was more increase in wicking when the fabric was wicked in the warp direction due to the high number of the feeder yarns (70 ends/cm) compared to weft direction wicking (50 picks/cm).

**Conclusion**

Results of this work showed that the stretching and relaxation of yarn filaments and yarns during fabric deformation resulted in spasmodic pumping of the liquid and led to its distribution over a wide region of the fabric, thus improving the rate of evaporation. The fabric wicking behavior was dependent on the structure of the constituent yarns, their orientation in the fabric, the fabric structure, the pretension, and the force applied.