Moisture Responsiveness of Seamless Knitted Wool Fabrics

Adriana Gorea, Syracuse University, USA, Fatma Baytar, Cornell University, USA,
and Eulanda Sanders, Iowa State University, USA

Keywords: seamless knitting, responsiveness, wool fabric

Background. The amount of moisture which textile fibers are capable of absorbing affects their use in activewear. By making a functional analogy to natural systems via the biomimetic framework, the aim is to develop knitted fabrics that can change shape in response to changing environmental conditions, without any other control mechanisms or energy (Fratzl & Weinkamer, 2007). Few researchers have studied the responsive behavior for fibers and textiles, specifically natural fibers in a knitted fabric (Scott, 2015). This research documents the exploration of moisture responsiveness for forty different wool based fabrics, constructed via Santoni seamless knitting technology.

Literature review. There is a very generous literature studying properties of knitted fabrics made of various fibers and yarns as applied to activewear (Tiwari et al., 2013). Merino wool has been reported to have properties suitable for activewear; pure Merino wool has been blended with other fibers to regulate absorption, wicking, air circulation and to enhance the comfort of the wearer (Venkatraman, 2016). Welo et al. (1952) observed large changes in the swelling properties of different fabrics made of natural fibers (wool, cotton etc.) due to the presence of moisture. Blending wool with polyester or wool with bamboo improved the moisture management properties of the fabrics compared with 100% wool and 100% bamboo fabrics (Troynikov & Wardiningsih, 2011). Sarkar et al. (2010) reported on the dimensional changes of hygroscopic yarns when utilized to develop responsive fabric structures. (Hatch (1993) found that conventional fibers swell as they absorb moisture. Scott (2015) argued that the dimensional change at a local scale within individual fibers is amplified throughout a knitted structure. Variations in knitting loop length, stitch structures, yarn twist, and knitting technology have been found to influence the moisture transport properties of the fabrics (Őner & Okur, 2013). A knowledge gap however exists in documenting moisture responsiveness of wool based seamless knitted fabrics, despite the increased use of seamless technology in activewear.

Methods. Based on yarn specifications required for Santoni seamless machines, the following two yarns were sourced: (a) 90% wool 10% Nylon in the 60/1 size, S twist and Z twist cones, undyed yarn, and (b) 100% merino wool, 60/1 size, S twist and Z twist cones, in color light grey. To simulate the commercial applications of seamless knitted fabrics, each yarn was combined with 20-20/10/1 cover core spun 210 D bare elastic yarn. Each yarn combination was knitted in 460 courses, using twenty patterns (combinations of tuck, jersey and float stitches), in a 28 gauge seamless tube. The two resulting seamless knitted tubes were conditioned in order to relax the knitting but not alter the wool yarn texture Moisture management testing as per AATCC 195-2009 was initially considered but, after studying the textural properties of the swatches, it was deemed inappropriate. Therefore, the testing was limited to gathering the physical measurements for all patterns. Mass per unit area measurements and fabric thickness were determined according to ASTM D3776/D3776M-09ae2 (2009) and ASTM D1777-96e1 (2011). Fabric densities and weight/thickness ratios were computed for each swatch for the dry condition, and results were compared, To observe responsiveness to moisture, the thickness test was performed three more times: (a) after wetting, (b) after air drying for 30 minutes, and (c) after air drying for 60 minutes. In order to simulate the human sweating conditions, a salty solution that is currently used for moisture management testing was used. Statistical matched pair tests were analyzed, checking for significance of thickness changes between the moisture conditions.

Results. In the dry condition, sixty percent of the fabric swatches were thicker in wool yarn than the wool/nylon yarn combination, but the mean differences in change rates were insignificant. The statistically significant results showed that: (a) on average, thickness after 30 minutes of air-drying measures 0.02mm less than the thickness in the Wet condition ($p=$ 0.007), and (b) on average, the after 60 minutes- air drying thickness measures 0.15mm less than the thickness in the Dry condition($p=$ 0.0001). Moreover, during the wetting process of the fabric swatches, mechanical change was observed, such as the edges curling at different speed rates, shown in Figure 1. Attempts were made to find a method to consistently quantify the changes for all swatches, but they were unsuccessful. The textural structure of the swatches made some patterns to curl upward while others to curl downward, and the pattern itself was observed to affect the degree of curling much more than the amount of moisture or the time allowed for responsiveness action. A clear difference between the wool yarn swatches versus the wool/Nylon swatches was not able to be quantified and evaluated.

(A)  (B)  (C)  (D) 

Figure 1. Screen shots from a video recording showing responsiveness of pattern #10 in wool yarn: (A) 1 second after applied moisture, (B) 5 seconds after applied moisture, (C) 10 seconds after applied moisture, and (D) 15 seconds after applied moisture.

A linear correlation between fabric thickness in the Dry condition and fabric density was found, showing that with each unit increase in fabric density, the fabric thickness in the Dry condition increases by 0.002mm (r=0.53, n=39, $p<$ 0.001). Also, significant correlations were found between fabric thickness in Wet conditions with Density as an independent variable (r=0.51, n=39, $p<$ 0.001), and thickness after 30 minutes- air drying and Density. (r=0.52, n=39, $p<$ 0.001). There was a positive correlation between thickness in Wet condition and Weight of fabric (r= 0.86, n= 39, $p<$ 0.0001). Similarly, a positive correlation was found between fabric thickness for the after 30 minutes- air drying and Density variable (r=0.52, n=39, p <0.0001), as well as with the fabric Weight variable (r=0.85, n=39, p <0.0001). Although an increase in fabric thickness was expected to be observed, instead, a relaxation of the wool fibers was observed, with fabrics becoming thinner when wet.

Significance and future research. This study confirms Scott's (2015) findings regarding moisture responsiveness of wool knitted fabrics, but videography documenting methods should be pursued, as the motion of the fabric edges, determined by the stitch structures, is more visible than the changes in the physical properties of the knit swatches. The use of wool yarn as a functional material in activewear is in the infancy stages, as revealed by the difficult yarn sourcing process experienced during this study, and further yarn development steps should be pursued. The knit fabrics resulted from these experimental approaches could be subjected to additional moisture management testing, to better fill the knowledge gap in the responsive materials field.

References

AATCC, T. (2009). 195: 2009. *Liquid Moisture Management Properties of Textile Fabrics, American Association of Textile Chemists and Colourists. Google Scholar*.

ASTM D3776/D3776M-09ae2 (2009). Standard Test Methods for Mass Per Unit Area (Weight) of Fabric. ASTM International, West Conshohocken, PA.

ASTM D1777-96e1 (2011). Standard Test Method for Thickness of Textile Materials. ASTM International, West Conshohocken, PA.

Choi, M. S., & Ashdown, S. P. (2000). Effect of changes in knit structure and density on the mechanical and hand properties of weft-knitted fabrics for outerwear. *Textile Research Journal*, *70*(12), 1033-1045.

Fratzl, P., &Weinkamer, R. (2007). Nature's Hierarchical Materials. *Progress in Materials Science*, 52 (8), 1263-1334.

Öner, E., & Okur, A. (2013). The effect of different knitted fabrics' structures on the moisture transport properties. *Journal of the Textile Institute*, *104*(11), 1164-1177.

Sarkar, M. K., He, F. A., & Fan, J. T. (2010). Moisture-responsive fabrics based on the hygro deformation of yarns. *Textile Research Journal*, *80*(12), 1172-1179.

Scott, J. (March, 2015) Mutate: The Evolution of a Responsive Knit Design System. *In Proceedings of the 2nd Biennial Research Through Design Conference, 25-27.*

Tiwari, S. K., Fei, P. T. C., & McLaren, J. D. (2013). A pilot study: Evaluating the influence of knitting patterns and densities on fabric properties for sports applications. *Procedia Engineering*, *60*, 373-377.

Troynikov, O., & Wardiningsih, W. (2011). Moisture management properties of wool/polyester and wool/bamboo knitted fabrics for the sportswear base layer. *Textile Research Journal*, *81*(6), 621-631.

Venkatraman, P. D. (2015). Fabric Properties and Their Characteristics. In *Materials and Technology for Sportswear and Performance Apparel* (pp. 53-86). CRC Press.

Welo, L. A., Ziifle, H. M., & Loeb L. (1952). Swelling Capacities of Fibers in Water: Part I: Desiccation Rate Measurements, *Textile Research Journal, 22(4*), 254–261.