Exploring Washability of Flexible 3D Printed Textiles

Yu Li and Young-A Lee, Auburn University, USA

Keywords: 3D printing, flexible 3D printed textiles, washability

Introduction and background. Washing is one essential process in textiles and clothing lifespan which has a significant impact on restoring functionality (Easter et al., 2013; Kotb, 2012). Textile washability represents the ability of textiles to withstand washing without losing its functionality (Textile Adviser, 2019). Dimensional stability is one of the most important components of washability which refers to textiles' capability to resist a change in their dimensions during the washing cycles (Topalbekiroğlu & Kübra Kaynak, 2008). Textiles with poor dimensional stability may exhibit their shrinkage or growth (Collier & Epps, 1999), which greatly affects fit, appearance, and comfort of the final textile product (Kadolph, 1998).

For the past decades, 3D printing (3DP) has attracted great attentions from both academia and industry. Fused deposition modeling (FDM) 3DP method is one of the most commonly used techniques for the 3D printed wearable product development (Spahiu et al., 2020; Uysal & Stubbs, 2019). With the use of novel thermoplastic polyurethane (TPU) filaments, designers can develop flexible 3D printed textiles with similar properties to traditional textiles (Melnikova et al., 2014). For example, Lee and Li (2022) developed a 3D printed dress with 3D printed layered textiles by using an FDM 3D printer with TPU filaments. Despite this new 3D printed textile development effort, washability of flexible 3D printed textiles has not been fully examined. TPU is a moisture sensitive filament and is greatly affected by the water in production and use (Add:North, 2022), which may result in weight changes of flexible 3D printed textiles and affect comfort of the final wearable product. No previous studies were identified to investigate the weight change of flexible 3D printed textiles with TPU filaments in the washing process. Thus, we aimed to explore washability of flexible 3D printed textiles with different textile structures. The specific objectives were to: (a) investigate the dimensional stability of different flexible 3D printed textiles lengthwise and widthwise in the washing and drying process and (b) examine the weight change of various flexible 3D printed textiles after being washed.

Method. An experimental research design, consisting of 3 (flexible 3D printed textile samples) x 6 (wash and dry cycle) x 3 (repetition), was conducted. The sample development procedure was followed by Lee and Li's (2022) 3D printed textile development method. All 3D printed textiles with different structures (S1 to S3) were developed and prototyped using an FDM 3D printer with TPU filaments. Re-entrant honeycomb auxetic structure (S1), star-shaped auxetic structure (S2), and plain weave woven structure (S3) were purposely selected for the sample development. Each sample has an identical size of 10" x 10" with two pairs of 3D printed cylinder benchmarks parallel to the length and width which have a 2.5" distance from all the edges.

The AATCC TM135 testing method (AATCC, 2021) was used to evaluate the dimensional stability of 3D printed samples. A top-loaded portable washing machine with a normal washing condition of 16-minute washing time and cold washing temperature (74°F) was used. The flat dry method was adopted to dry each of the samples. The distance between each pair of benchmarks was measured after each wash and dry cycle with a digital caliper to determine the average dimensional change (DC). The DC was calculated using the formula, DC = [Average Original Dimension – Average Dimension After Laundering] / Average Original Dimension x 100%, ranging from 0% to 100%. The negative and positive DC values represent shrinkage and growth, respectively. The original weight of each sample and the weight after each wash and dry cycle were also measured with a high precision digital scale. SPSS 26 was used for statistical analysis at $p < .05$. A mixed factorial ANOVA was used to determine the significant difference of DC in length and width directions among the three samples. A repeated measures ANOVA was used to examine the weight change of the three samples after being washed.

Results and discussion. To determine the dimensional stability of flexible 3D printed textiles, the DC of length and width for the three samples after six wash and dry cycles were calculated. In terms of the textile length, the DC indicated that all samples exhibited shrinkage (DCS1 = -0.7; DCS2 = -0.6; DCS3 = -0.3). For the textile width, S1 and S3 exhibited shrinkage (DCS1 = -1.1; DCS3 = -0.4), but S2 showcased growth (DCS2 = 1.0). The F-test in mixed factorial ANOVA revealed no statistical significance of all three samples on lengthwise shrinkage ($F(2,6) = 2.71$, $p = .145$) and the two samples on widthwise shrinkage ($F(1,4) = 5.5$, $p = .079$). The results demonstrated that S1, S2, and S3 have similar lengthwise shrinkages at different wash and dry cycles; S1 and S3 have similar widthwise shrinkages at different wash and dry cycles. The F-test in repeated measures ANOVA also revealed no statistical difference of the weight change between different wash and dry cycles: S1 ($F(6,12) = 1.00$, $p = .47$), S2 ($F(6,12) = 1.43$, $p = .28$), and S3 ($F(6,12) = 1.00$, $p = .47$). The results demonstrated that all 3D printed samples with TPU filaments in this study did not exhibit significant weight changes after being washed.

Unlike traditional textiles, dimensional changes occurred in the flexible 3D printed textile samples because of the special elastomeric property of 3DP materials. TPU is a linear segmented block copolymer consisting of soft segments which are built upon a polyol and an isocyanate to equip flexible and elastomeric characteristics (Omnexux, n.d.). The unique stretchable feature of TPU might cause dimensional changes in flexible 3D printed textiles. Both 3D printed textiles with re-entrant honeycomb auxetic structure and plain weave woven structure (S1 and S3) exhibited lengthwise and widthwise shrinkages. However, the textile with star-shaped auxetic structure (S2) presented shrinkage only in one direction, which might be because of the four-way stretchability in star-shaped auxetic structure, allowing textiles to be stretched easily in all four directions. The circular motion of the portable washing machine also might apply inconsistent inward forces to this 3D printed textile (S2) in two directions and cause the opposite direction of dimensional changes. Furthermore, all 3D printed samples in this study showcased a fast-drying speed and dried in less than 5 minutes at the 72°F room temperature without a spinning process.

Conclusion. This experimental study explored washability of flexible 3D printed textiles by measuring and evaluating dimensional and weight changes. The results presented that all 3D printed textiles with re-entrant honeycomb auxetic structure (S1), star-shaped auxetic structure

(S2), and plain weave woven structure (S3) had dimensional changes after being washed. The findings provide insights for designers and manufacturers to manipulate flexible 3D printed textiles with the estimation of dimensional changes before manufacturing 3D printed textiles. The weight of flexible 3D printed textiles was not affected by washing and drying, which convinces the suitability of 3D printed textiles for the wearable product development. The fast drying speed of 3D printed flexible textiles also proves the potential of adopting 3DP in wearable product design for simplifying the laundry process and extending the product lifespan.

This study only examined washability of flexible 3D printed textiles with limited textile structures with TPU filaments. In future studies, researchers need to investigate washability of 3D printed textiles with different textile structures using various 3DP materials. No detergent was used during the washing cycles in this study. It is recommended for future researchers to explore the influence of various detergents on flexible 3D printed textiles' washability. Only dimensional and weight changes were evaluated in this study. Other components of washability such as colorfastness, abrasion resistance, and seam strength need to be further examined for the true implementation of flexible 3D printed textiles in the wearable product development.

References

AATCC. (2021). Test method for dimensional changes of fabrics after home laundering. In *Manual of International Test Methods and Procedures* (pp. 259-262). AATCC.

Add:North. (2022). *How to improve your 3D-prints–easily*. https://addnorth.com/knowledge/articles/How%20to%20improve%20your%203D-prints

Collier, B. J., & Epps, H. H. (1998). *Textile Testing and analysis*. Prentice Hall.

Easter, E. P., Baker, E., & McQuerry, M. (2013). Assessing the impact of wash water temperature, detergent type and laundering platform on basic clothing attributes. In *American Association of Textile Colorists & Chemists International Conference, AATCC 2013* (pp. 205-214). AATCC.

Kadolph, S. J. (1998). *Quality assurance for textiles and apparel*. Fairchild Publications.

Kotb, N. A. (2012). Changes in knitted cotton/polyester fabric characteristics due to domestic laundering. *Journal of American Science*, *8*(5), 677-682.

Lee, Y. A., & Li, Y. (2022). Bouncing with 3D printed soft cells, *International Textile and Apparel Association Annual Conference Proceedings, 78*(1). https://doi.org/10.31274/itaa.13291

Melnikova, R., Ehrmann, A., & Finsterbusch, K. (2014). 3D printing of textile-based structures by fused deposition modelling (FDM) with different polymer materials. *IOP Conference Series: Materials Science and Engineering*, *62*, 012018. https://doi.org/10.1088/1757-899x/62/1/012018

Omnexux. (n.d.). *Comprehensive guide on Thermoplastic Polyurethanes (TPU)*. https://omnexus.specialchem.com/selection-guide/thermoplastic-polyurethanes-tpu

Spahiu, T., Canaj, E., & Shehi, E. (2020). 3D printing for clothing production. *Journal of Engineered Fibers and Fabrics*, *15*, 1-8. https://doi.org/10.1177/1558925020948216

Textile Adviser. (2019). *Washability of the Fabric*. https://www.textileadvisor.com/2019/03/washability-of-fabric.html

Topalbekiroğlu, M., & Kübra Kaynak, H. (2008). The effect of weave type on dimensional stability of woven fabrics. *International Journal of Clothing Science and Technology*, *20*(5), 281-288. https://doi.org/10.1108/09556220810898890

Uysal, R., & Stubbs, J. B. (2019). A new method of printing multi-material textiles by fused deposition modelling (FDM). *TEKSTILEC*, *62*(4), 248-257. https://doi.org/10.14502/tekstilec2019.62.248-257