3-D Printing Fabric Swatches with Recycled Materials

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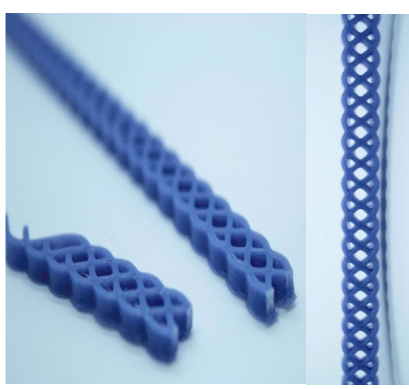
Traditional apparel manufacturing, which involves weaving, dying, cutting, and the use of mass amounts of energy produces considerable amounts of waste. As of 2017, 11,150 tons of apparel created using these processes have been deposited into landfills (Textiles: Material-Specific Data, 2019). Additive manufacturing (3-D printing) may be one way to reduce waste when producing apparel. The purpose of this case study was to explore producing textile swatches that could potentially reduce waste and meet consumer needs using one of two available 3D printing methods: fused deposition modeling (FDM) technology and selective laser sintering (SLS printing). To fulfill this purpose, the Functional, Expressive, and Aesthetic (FEA) Consumer Needs Model (Lamb & Kallal, 1992) was used to analyze the desired characteristics, develop, and evaluate a textile swatch, which could be produced using reusable materials, meet functional needs for mobility, comfort, and protection, as well as expressive and aesthetic needs by producing an opaquer material with good hand, texture, and pattern that would be appropriate for a range of uses, such as office wear (Steinhardt, 2010).

Previous literature was explored to identify 3-D printing methods that would reduce waste and/or could be used for apparel. It became clear that the ability to 3D-print a textile that reduces waste and meet consumer needs depends largely on: 1) the raw or virgin materials used for printing, and 2) the type of in-fill pattern used. Recently, Zander, Gillan, Burckhard, and Gardea (2019) experimented with printing with blends of raw materials that could produce a 3-D printed fabric with flexibility and a comfortable hand, while using discarded plastics in landfills. However, this is only possible using a fused filament fabrication printer (FFF). FDM has become one of the most used 3-D printing methods because it offers the opportunity to design and manufacture new materials (Ujeniya, & Rachchh, 2019). FDM printing material includes polylactic acid (PLA) and Polyethylene terephthalate (PET). PLA is sourced from corn or sugar cane, degradable, and strong, but has little flexibility. However, the material may take 30 or more years for PLA to biodegrade, making it a less environmentally-friendly option (Gutierrez, 2020). Polyethylene terephthalate (PET), is a slightly softer polymer, reusable, and has good abrasion resistance (contributing to the functional need of protection) (Varotsis 2020). However, PET is heavier than PLA, and garments made of this material may restrict mobility due to its weight. The raw material used in SLS printing is nylon PA12 or nylon PA11 that is made up of a powder that when leftover from a print can be reused and mixed with more powder in subsequent prints (Guide to Selective Laser Sintering (SLS) 3D Printing, 2020). Currently, creating in-fill patterns for 3D printed textiles is a major challenge. While some non-homogenous infill patterns have been developed that provide better flexibility and shape-retention (Chynybekova & Choi, 2019), which contributes to mobility, they are highly transparent and seldom seen as suitable for apparel.

A qualitative case study was conducted to determine which 3-D printing method (FDM or SLS) would better produce a textile swatch that would reduce waste and meet consumer needs. Unstructured, open-ended interviews with two graduate students studying material science engineering (Engineering GAs) and one student library media center attendant (library attendant) were conducted. The Engineering GA's were asked questions regarding the capabilities of each printer, as well as reusability of the raw materials, the flexibility of the final product, and required print time. The interview data was analyzed using thematic analysis (Saldaña, J. (2009). In addition, a test fabric swatch was printed and evaluated using the (FEA) Consumer Needs Model (Lamb & Kallal, 1992).

Three themes emerged from the interview data: 1) waste reduction; and 2) end-product characteristics. While both FDM and SLS printing provided opportunities for waste reduction, each method had its limitations. One advantage of the PLA used in FDM printing is that it is biodegradable, although it takes a long time to biodegrade (Engineering GA 1). While the powder in SLS printing may be re-used, only small amounts of the powder may be re-collected from the printer bed and re-used (Engineering GA 2). As a result, FDM printing was recommended because the small customizable pieces printed using that method utilizes less raw materials in the first place. While the end product resulting from FDM printing may be more flexible than SLS, PLA material used in FDM printing tends to absorb water and dry out, which can affect the degree of flexibility.

Based on the results of these interviews and available printing methods, the FDM printing method was selected to design a textile swatch. By using this method, only the necessary materials were used, thus creating little to no waste. Therefore, printing garments using FDM versus traditional garment production methods could contribute to waste reduction, provided the 3D printed textiles meet consumer needs. To address consumer needs, a non-homogenous infill pattern was designed using Adobe Illustrator and Tinkercad 3-D printing software (Figure 1) and evaluated using the FEA Consumer Needs Model (Lamb & Kallal, 1992). The flexibility of the fabric was evaluated to determine potential mobility and comfort.



A B

Figure 1. Images of 3-D printed strip of potential fabric structure: (A) Front view showing the in-fill pattern; (B) Side view showing the width of the in-product.

The swatch was very hard, brittle, and had little flexibility, which meant that it would break if it were forcibly shaped around a body. The print also had a rough hand, detracting from comfort, as well as the aesthetic of the material. However, the use of the non-homogeneous in-fill pattern reduced transparency, making the design more appropriate for apparel (expressive need) in terms of providing more skin coverage and modesty.

This case study was part of an ongoing project. With FDM printing, one limitation expressed by the Library Attendant is the difficulty of printing smaller in-fill patterns and details. This method is more favorable for printing larger patterns and basic shapes. However, the larger pattern would not fulfill consumers needs regarding desired opacity/ or reduced transparency in 3D printed fabrics. After printing the swatch, it was determined that the characteristics of the swatch could be improved by creating a larger, interlocking in-fill pattern. Future researchers should continue to develop in-fill patterns suitable for potential 3D printed apparel use, while also experimenting with FFF printing to reduce waste through using recycled raw material.

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