Assessing Textile Modularity for Circular PPE: A Case Study on High-Visibility Workwear

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Abstract

Achieving circularity in textiles requires design strategies that address the full product lifecycle, from material selection and production to use, repair, and end-of-life recovery. Textile modularity offers a promising approach, yet its application in performance textiles and personal protective equipment (PPE) remains insufficiently structured and assessed. A key challenge lies in the interface: every modular solution requires a fastening or joining mechanism that adds material, manufacturing effort, and functional complexity. Whether these trade-offs are justified depends strongly on the application context, yet structured criteria for this assessment are still lacking.

This contribution proposes a decision-support framework for assessing textile modularity in circular PPE. The framework comparatively evaluates conceivable fastening solutions through three application-oriented perspectives: cost-effectiveness, user experience, and circularity. It is developed within the BMFTR-funded research project ZIRTEX and demonstrated through a case study on high-visibility workwear. This use case is particularly relevant because retroreflective tapes often wear out before the underlying garment, thereby determining the service life of the entire product.

Based on a comparative evaluation of different textile interface solutions, the study analyzes how replaceable retroreflective elements affect cost-effectiveness, including material and labor costs as well as lifecycle costs; user experience, including handling, comfort, and safety; and circularity, including footprint, durability, repairability, and recyclability. It also opens up a design solution space that must be further developed in order to achieve functional, producible, economically viable, and circular solutions. The high-visibility workwear case demonstrates how a modular interface can decouple the wear component's lifespan from the garment's, thereby reducing replacement frequency, waste generation, procurement effort, and lifecycle costs. At the same time, the case serves to derive transferable criteria for assessing when textile modularity is economically justified, functionally robust, and ecologically beneficial in circular PPE design.

Keywords: Design for Circularity, Textile Modularity, Personal Protective Equipment (PPE), High, Visibility Workwear

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