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# Seamlessness and Monomateriality in Sustainable Garment Design. A Knit/Woven Trousler Prototype

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## Abstract

This article points out strategies for designers to reduce the generation of pre- and post-consumer waste and in the textile industry by focusing on the aspects of seamlessness, mono-materiality and mechanical recyclability. It further presents "Trousler prototype 1", a proposal for a seamless, mono-material and fully recyclable garment that uses knit/weave hybrids and innovative fastening systems and that arose from an international and interdisciplinary design collaboration.

## Keywords

**Mono-materiality**  
**Recyclability**  
**Zero-waste fashion design**  
**Seamlessness**  
**Knit/weave hybrids**

As designers, we have a considerable influence on the ecological impact of our products. Acquiring detailed knowledge about these phases, e.g. on current production or recycling technology, could therefore be considered a key asset for designers trying to minimise the damage their products do to the environment. This article lists some of the aspects textile and fashion designers who are willing to conceive more sustainable clothing can take into account for their designs. It also presents *Trouser Prototype 1*, a practice-based design research prototype for cut- and seamlessly woven trousers developed by Juri-Apollo Drews that integrates a knitted fastening mechanism by Ludovica Rosato, as well as the production and end-of-life scenarios that were taken into account for its design. The research focuses on the importance of environmental criteria in the process technologies and assembly techniques throughout the design process. "Trouser Prototype 1" is not an industrial product, but an experimentation that can open up a discussion on certain problematic aspects designers face in the current textile industry, and possibly pave the way for future applications as well as participate in the discussion on the role of the designer in the development of solutions to reduce pre- and post-consumer waste in the textile and fashion industries. In the present prototype, we focus on the uses of techniques that make it possible to reduce pre- and post-consumer waste; a second part of that research will later focus on replicating the process in other materials.

### **Pre- And Post-consumer Textile Waste and Strategies for Reducing Them**

The textile industry in particular is considered to be one of the most polluting economic sectors (Cobbing & Vicaire, 2017). While holistic and systemic approaches to designing more sustainable garments have emerged in recent years (Coscieme et al., 2022; Ellen MacArthur Foundation, 2021; McQuillan, 2020; Niinimäki, 2017), attempts by a vast majority of textile and garment manufacturers to implement such strategies in the production and disposal of their products remain sporadic and superficial. In garment production, for example, the widespread use of the cut-and-sew technique leads to the generation of about 10 to 20% of pre-consumer textile waste, i.e. the leftovers from the process of cutting non-rectangular pieces from rectangular fabrics (Abernathy et al., 1999; Cooklin, 1997). This leads to the considerable number of 60 billion square metres of newly produced fabric that are designated for landfill or incineration each year (Rissanen & McQuillan, 2016). Fast fashion consumption patterns are a further source of waste, since many garments are only worn 7 to 10 times before being discarded (Ellen MacArthur Foundation, 2021). Large amounts of this post-consumer waste is disposed of in landfill sites, leading to the waste of potentially reusable resources<sup>1</sup>. A strategy for designers would be to anticipate using a Design for Recycling approach (Karell, 2021), meaning that they must be informed about current textile recycling processes in order to make the optimal later reutilisation of the material a central criterion during the design phase.

## Pre-consumer Waste Reduction Through Integral Garment Design

Among the strategies to reduce pre-consumer waste, techniques for making seamless or whole garments have gained in importance in recent years. These aim at producing whole garments directly in the desired shape, without the need to assemble them from cut-out pattern pieces. In this way, waste generated by pattern cutting can be eliminated. Although this method remains marginal in the current industry due to the low cost of fabric (McQuillan, 2020), an increasing scarcity of raw materials could increase interest in such methods in the future. Besides, integral garment techniques offer better structural stability as they eliminate seams that are potential breaking points in a garment (Nawaz & Nayak, 2015). Considerable progress has been made recently to produce commercially successful integral garments by knitting (ibid.; Gries et al., 2022), underlining that whole garment manufacturing provides both ecological and economic advantages (Allwood et al., 2006; Fletcher, 2014). However, three-dimensional or integral non-rectangular weaving remains a rather unexplored technique in garment production (Thomas, 2009). Some tubular, multilayer or elastic-based weaving solutions can be found in fields such as medicine and aeronautics, with sporadic attempts by engineers to apply them to the fashion context (LaPointe et al., 1988; Behera & Mishra, 2008; Ng et al., 2007; Wang et al., 2009). Integral weaving approaches as well as other alternative ways to assemble garments have emerged in design-based research as well (McQuillan, 2020; Piper, 2019; Harvey et al., 2019; Vicerial, 2019). Juri-Apollo Drews' ongoing practice-based PhD project *No Cuts No Seams* develops innovative solutions to produce woven garments in complex three-dimensional shapes that require neither cutting nor sewing (Drews, 2019).

### Design Strategies to Reduce Post-consumer Waste

Post-consumer waste can be reduced by garment life-cycle design and knowledge about applicable recycling technologies (Karell, 2021). Mechanical recycling, i.e. shredding textiles and producing new threads from the shreds, is currently the most widespread strategy for all types of textile recycling (ibid.). This process shortens the fibres and reduces their strength compared to virgin materials (Ghezzi & Vannucci, 2018). However, shredded fibres from heavily worn garments appear to have a longer length than those from less worn garments, thus increasing their reuse value (Aronsson & Persson, 2020). In order to shred a garment, rigid components such as buttons and zippers must be removed because they could affect the purity of the shredded material or cause damage to machines (Riemens et al., 2021). Today, this is mostly done manually and leads to a considerable loss of reusable material (ibid.). In addition, mechanical recycling does not allow for the separation of textiles composed of material blends into their original components. Indeed, in order to save costs and to guarantee good performance, many apparel fabrics are largely composed of mixed, interwoven fibres (Fashionary, 2020) that are difficult to separate industrially during disposal and often contain additional chemicals that are potentially harmful to the environment.

If post-consumer waste is to be avoided or at least optimised, the selection of (mono)materials is thus a central design decision that must be made at the beginning of the product's conception. Garments composed entirely of one unblended material and whose attachment systems are composed of that same material can be a solution to ease their reutilisation after mechanical recycling. Another strategy could be to design garments composed of modules that are easily disassemblable (Forst, 2020), with each module being strictly mono-material.

It should further be mentioned that considerations of materiality, recyclability and fasteners during the design phase must be associated with the design of the garment's extended life cycles. It is thus not only important to consider end-of-life scenarios, but also to employ strategies that push the necessity for recycling as far into the future as possible (Circular.fashion, 2019). The number of times a garment is worn has a direct impact on its ecological footprint, since the energy needed for production is only needed once. Therefore, increasing a garment's longevity decreases the need for the production of new garments, with designing for inner loops being an example for a strategy to achieve this (Earley & Forst, 2019).

### **Seamlessness and Monomateriality: Trousers Prototype 1**

*Trousers Prototype 1* Fig 1 is a practice-based research that was conceived with the aim of developing design solutions to eliminate pre-consumer waste and to limit post-consumer waste to closed-loop recycling. The research focus was on the garment's innovative seamless production, as well as on its absolute mono-materiality, its durability and its future mechanical recycling possibilities. Using practice-based methodology (Koskinen, 2012; Mosse & Bassereau, 2019), we aim to participate in the discussion on the role of the designer in the development of solutions to reduce textile waste. The creation of prototypes is a fundamental tool in design research as they materialise possible futures and outline possible trajectories of innovation (Iñiguez et al., 2014; Celaschi et al., 2014a; Celaschi et al., 2014b; Stappers, 2013).

*Trousers Prototype 1* is a seamlessly woven-to-shape trouser, meaning that it avoids the generation of pre-consumer cut waste entirely by using experimental hand-weaving techniques developed by Juri-Apollo Drews which allow for shaped weaving, as well as for direct links between woven and knitted surfaces. It is completely mono-material, since instead of buttons and zippers it uses the Knitted Fasteners developed by Ludovica Rosato in her PhD thesis project. It therefore facilitates post-consumer recycling because it can be shredded in one piece given that no rigid elements were added to the garment. For this particular prototype, a solid cotton thread was used to test the feasibility and stability of the seamless weaving/knitting techniques, even though a future adaptation to more sustainable materials such as linen or hemp (Rana et al., 2014) is envisioned.



Fig. 1  
Juri-Apollo Drews, Trousers  
Prototype 1, Toile model  
for "Trousers Prototype 1"  
currently still in produc-  
tion, credits: Juri-Apollo  
Drews.

### Knitted Fasteners

The prototype includes a *Knitted Fastener (KFs)* Fig. 2, which is an experiment developed by Ludovica Rosato during her PhD thesis aiming to enable fastenings in mono-material garments. Fasteners constitute connection points between fabrics and act as an adjusting and/or opening element (Mitchell & McLoughlin, 2014). KFs are a prototype of fasteners integrated into the fabric that aim to allow these components to be used in compliance with existing recycling technologies. KFs are the combination of buttonholes and loops varying in number, size and position that can offer different fastening, fixing and adjusting systems. This freedom of configuration allows the creation of different aesthetic shapes at the junction points and gives the fashion designer the creative freedom to customise fasteners without affecting contemporary recycling processes. The connection between the fabrics is achieved by inserting the loops of one flap into the buttonholes of the other. The loops are then concatenated vertically with each other. The concatenation closure system is derived from the interlacing of two loops. Fig. 3 This system allows for both a "punctual" connection like that of a row of buttons, and a "linear" connection like that of a zipper. This creates an opening and closing system that attempts to improve the performance of a button system by simulating that of a zipper.



Fig. 2  
Ludovica Rosato, Knitted fasteners developed for the prototype, credits: Ludovica Rosato.

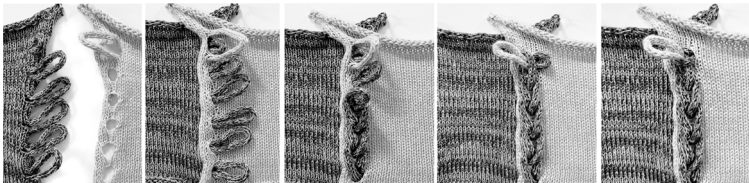


Fig. 3  
Ludovica Rosato, Knitted fasteners: The concatenation closure system, credits: Ludovica Rosato.

### Combining Knit and Weave

In order to integrate a KF into the woven surface of the trousers, a technique called modular weaving developed by Juri-Apollo Drews (Drews, forthcoming) was used. Two triangular patches were knitted that can be joined by a KF system. Loops of varying sizes were left on the slanted selvages of these knitted modules. During the weaving process, these were interlocked with individual weft threads, thus aligning with the weft and allowing for a direct and seamless transition between the knitted and the woven surfaces. This procedure is similar to the clasped or locked weft tapestry weaving technique, which permits the use of discontinued weft threads in order to create multi-coloured motifs. A thread used for the knitted part thus briefly turns into a woven weft thread, before returning into the knitted surface Fig. 4. Hybridising knits and wovens into one and the same fabric is not a common practice in fabric production, yet the potential for applications beyond the apparel sector is great since it permits a seamless and very stable connection between rigid and flexible zones within the same mono-material fabric.

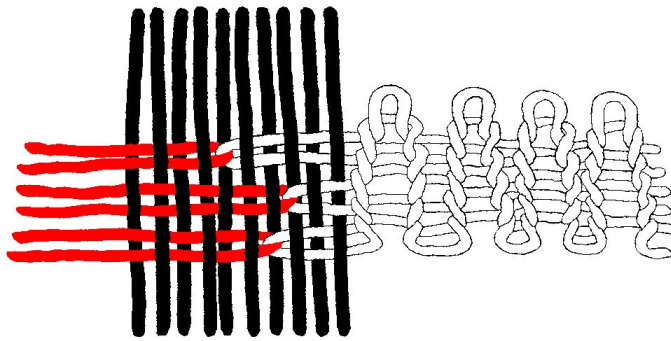


Fig. 4  
Juri-Apollo Drews, Schematic drawing of seamlessly joined knitted and woven surfaces., credits: Juri-Apollo Drews.

### Longevity and Transparency as Design Criteria

The longevity of a garment is enhanced by the integration of the knitted surface at the waist level, since its natural elasticity allows for the wearer to gain or lose some weight without the need for a new garment. Another strategy to prolong the garment's lifespan is to provide concrete information on its production method, material composition, wearability and recyclability through text woven into the fabric itself

Fig. 5. In the current system, the exact composition of the material is not known precisely and therefore not many textile fibres are actually processed into new yarns. To the recycling facility in which the garment is destined to be shredded, however, *Trouser Prototype 1* clearly communicates that the garment is fit for mechanical recycling and can be respun into a high-quality recycled yarn after the shredding process. This direct communication is also expected to reassure the wearer and create a sense of emotional attachment. Indeed, users might find it difficult to feel responsible for a product whose materials they are unaware of and are unable to handle when it no longer meets their needs (Rau & Oberhuber, 2019). Informing the user on the sustainable processes applied and thereby inviting them to play an active role in the garment's life cycles is a powerful awareness strategy as it creates amazement and affection towards the product and prolongs the relationship between user and artefact (Chapman, 2009; Karana et al., 2017).



Fig. 5  
Juri-Apollo Drews, Informative text woven into the prototype (the image here is a technical draft, the real image will be a photo of the final piece), credits: Juri-Apollo Drews.

**Ludovica Rosato**  
PhD Student, her research focuses on the designer's role in the transition to the new uses of polymers in the textile sector. Since 2019 she is a member of the Advanced Design Unit with which she carries out activities of applied research and education. She earned an undergraduate degree in Industrial Design and a Master's degree in Advanced design.

## Conclusion

*Trouser Prototype 1* presented here contributes to an advancement in the research into sustainable solutions to reduce pre- and post-consumer textile waste. The knit/woven strategies presented here, as well as the technical and aesthetic strategies to prolong the garment's use cycle as much as possible and designing in absolute mono-material for optimal recyclability of the fibres could be contributions to a reduction of both types of waste. Yet they can only be parts of the solutions to the numerous challenges the textile and garment industries are facing to manage a transition towards more sustainable production, retail/consumption and material recycling patterns.

Based on this first prototype, the potential of integral knit/woven fabrics beyond the apparel sector could be further studied in the future. In addition, the customisation, transformability and reparability of the garment and its fastening system during the cycle of use should also be studied in greater depth. The same holds true for the use of different coloured threads in the same fabric which might have an impact on the quality of the material during the mechanical recycling process, and design-for-disassembly or single-colour solutions should be considered. Other recycling processes not planned for here should be taken into account, as should the biodegradability of the material beyond the recycling process.

The prototype aims to open up the discussion on the need to consider garments, but also all goods in general, as materials in transformation whose flow is the responsibility of the designer. This process can be transversally applied to several sectors, such as architecture or packaging, for example, where waste is a critical element and where material cyclicality is strongly linked to product usability and temporariness. We are committed to promoting a way of designing that encourages the hybridisation of techniques and approaches on a micro and macro scale and promotes strategies of regeneration of value to humankind and the planet it inhabits.

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The article was co-written by all authors except paragraph 3.1 which was written by Ludovica Rosato and paragraph 3.2 written by Juri-Apollo Drews.

#### Juri-Apollo Drews

PhD student financed by Université Paris Sciences et Lettres (PSL) through the SACRe (Sciences Arts Création Recherche) doctoral programme. His practice-based research supervised by Aurélie Mosse (Ensadlab Paris), Claudia Mareis (HU Berlin) and Holly McQuillan (TU Delft) focuses on the replacement of the cut-and-sew technique by integral garment weaving. He holds a Master's degree in Textile Design (EnsAD Paris/KH Berlin) and a BA degree in Cultural Studies (Maastricht University).

#### Antoine Tour

PhD student in partnership with the Campus Mode Métiers d'Art, Design. Supervised by Jean-François Bassereau (Ensadlab Paris) and Nounja Jamil (Campus MoMAde) his research focuses on material classification, through a methodology that considers different states of matter: properties, qualities, values. He graduated with a Master's degree in Object Design (EnsAD Paris), Design and Materials (Mines/Ensad Nancy).

#### Jean-François Bassereau

Interior Architect (Beaux-Arts) and Industrial Designer (EnsAD), J.F Bassereau taught at Arts et Métiers for 18 years, his research is in Sensory Design. Director of SENSOLAB research, he is also a Professor, authorised to direct Research at the Mines School. He teaches at EnsAD and co-leads the Soft Matters research group within Ensadlab.

#### Aurelie Mosse

Dr. Aurélie Mossé is a design-led researcher working at the intersection of textile, architecture and new technologies. Co-leading the Soft Matters research group of Ensadlab at the École des Arts Décoratifs, PSL University, her current research investigates how microbially-induced materials can inform more resilient and poetic perspectives of inhabitation.

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