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# Pilling in knitwear: a clothing longevity problem beyond design

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**Abstract**
The environmental impact of clothing could be reduced by extending garment lifetimes, and many clothing retailers are now exploring design for longevity as a sustainable approach. In order for products to meet durable design standards consistently, global supply chain processes must be managed and controlled to avoid quality problems and early product failure. This paper uses a single case study to explore the challenges of meeting specified durable product standards in production by tracing and observing the identification and resolution of a quality issue affecting the durability of luxury knitwear. The research demonstrates that new tests and processes could enable durable products to be produced more consistently, but also identifies the obstacles and limitations to implementing these enhanced procedures. The paper proposes that effective production management of durable clothing may be more difficult within global supply chains where differences in business culture, operational practice and knowledge exist between companies. Supply chain models that emphasise shared values, knowledge and information exchange, trust and collaboration are considered as the most effective in delivering sustainable products. It concludes by identifying a range of conflicting priorities between commercial and sustainable practice that must be addressed to achieve consistency in durable clothing production, and makes recommendations for industry and future research.

## Introduction

Some 80% of the environmental impact of clothing is established at the design stage (Defra, 2011), therefore New Product Development (NPD) has a significant impact on determining the sustainability of clothing products. Research suggests that extending average clothing usage by three months could reduce its environmental footprint by 5-10% (WRAP, 2012), and clothing longevity has become a key area of focus for sustainable design (Cooper et al., 2013; Gwilt, 2014). Research in this field tends to focus on describing approaches to design for longevity, and on prescribing the benefits. However, there is a lack of research into the challenges of managing the quality and consistency of longer lasting products during production within global supply chains that are often complex and fragmented (Oxborrow and Claxton, 2016).

This paper discusses research undertaken during a project supported by Defra to investigate the issues affecting design for clothing longevity. It considers one specific case to explore the challenges of meeting product standards specified at the NPD stage during the manufacturing process, and investigates issues related to process control that can impact the durability and longevity of clothing.

## Literature Review

Clothing retailers and suppliers acknowledge that poor durability leads to high product return rates which are costly and damage their reputation for quality (Cooper et al., 2013). Design for clothing longevity is now widely discussed as a sustainable approach, focusing on the extension of garment lifetimes by improving durability and reducing the potential for product failure (Cooper et al., 2013; Gwilt, 2014; Laitala, Boks and Klepp, 2015). In order to achieve this, those involved in design and NPD processes should be empowered to develop and specify materials, garment fit and manufacturing methods that lead to longer lasting products.

Garments must be approved as meeting the design specification before manufacturing can proceed, and should then be produced to a consistent quality level. The clothing industry follows routine quality assurance procedures which include the setting of clear garment performance standards and undertaking voluntary testing during production to assure the consistency and quality of materials and processes at each stage of the supply chain. The frequency of and responsibility for testing can vary according to the product type, the supply chain model and the retailer's quality standards (Keiser and Garner, 2012). However, some garments regularly fail tests, leading retailers to take risks with product quality due to commercial pressures, meaning that problems are not always addressed (Oxborrow and Claxton, 2016). Design for clothing longevity or durability may require companies to adopt a more considered and rigorous approach to

product specification; however, testing regimes designed to quality assure, measure and control compliance to durable design standards can add complexity, cost and time to NPD and production processes (Cooper et al., 2013). Therefore, testing of both materials and finished garments for longer life is an obstacle.

Many clothing retailers encounter a further level of complexity in managing sustainable design and NPD processes which are more in-depth, integrated and multi-disciplinary (Oxborrow and Claxton, 2016); organisational values and a system thinking approach should enable all perspectives to be addressed collectively (Hong et al., 2009) and empower those responsible for NPD to act effectively. Effective engagement and management of the supply chain also plays a critical role in enabling clothing retailers to deliver sustainable products. Gam et al.'s sustainable clothing design model C2CAD (2008) focuses on collaboration where inputs are selected, tested and valued for cost and potential environmental impact; supplier networks are engaged in information sharing to address issues with materials; and production efficiencies and quality are considered. Curwen et al. (2012) identify five principles of sustainable clothing design: a clear company mandate, shared values within the supply chain, effective knowledge gathering and sharing, cross-functional organisation and supply chain simplification. However, design for clothing longevity research is prescriptive regarding what should be achieved, but lacks the practical detail of how this could be realised that appears in models such as those of Gam et al. (2008) and Curwen et al. (2012).

Global sourcing affords clothing retailers the opportunity to reduce costs, but speed to market is reduced, putting pressure on NPD teams to shorten design lead times. It also fragments the clothing industry clusters previously able to acquire and share fashion and technical knowledge (Aage and Belussi, 2008) and also results in poor transparency, data reliability and influence over upstream suppliers (Rauer and Kaufmann, 2015). Globalised firms attempting to achieve sustainable outcomes need to address their product-service mix, governance structures, commercial objectives, and agency within the NPD process (Bostrom et al., 2015); smaller companies may find this easier to achieve where there is more control and visibility of the end to end supply chain (Caniato et al., 2012).

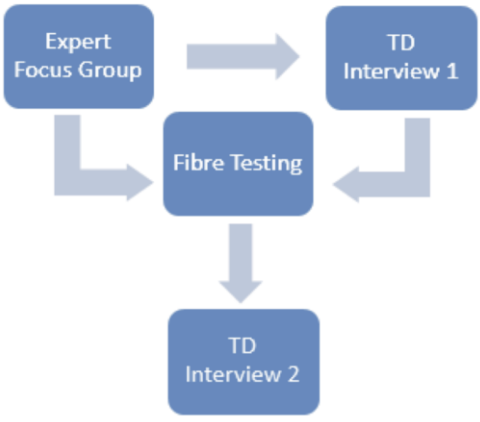


*Figure 1. Research Process*

This paper goes on to explore the barriers, including technical limitations, conflicting priorities, and organisational influences that hinder the adoption of design and supply of longer lasting clothing. It then discusses ways in which the commercial, technical and design limitations of reducing the environmental impact of clothing through extending its useful life can be mitigated.

## Methodology

The research followed a single case study approach to investigate a quality problem affecting garment durability, leading to customer returns. Case studies are considered an appropriate strategy when 'the focus is on a contemporary phenomenon within some real-life context' (Yin, 2003:1). The company is a small luxury knitwear brand selling in high-end retail markets in the UK and China, with the company head office based in the UK, and in-house manufacturing in China. The supply chain is vertically integrated from the fibre processing stage through to the finished garment, however yarn dyeing and spinning are outsourced to an external contractor. Pilling is a key factor limiting the durability of knitted products and can result in significant customer dissatisfaction (Cooper et al., 2013). The case company had received an unusually high number of customer complaints and garment returns for pilling during the Autumn / Winter 2014-15 season, and wished to investigate the cause.

The research took place between July 2015 and April 2016. A mixed methods approach was utilised, including a technical expert focus group, semi-structured interviews with the UK based technical director (TD), and exploratory testing of upstream materials (see figure 1).

The focus group included experts in textile testing, knitwear production and textile finishing. The discussion resulted in the identification of strategies for reducing the risk of pilling during the NPD and manufacturing processes under the broad headings of 'Technical Product Development' and 'Testing and Monitoring'. Discussion of these with the TD resulted in a hypothesis that the likely cause of the excessive pilling was a higher proportion of short cashmere fibres being present in the yarn. The TD faced resistance to carrying out any extra tests on the fibre from the outsourced dyeing and spinning processes as this was seen as a criticism of individual workers, managers and the external contractor. The focus group findings and first TD interview provided a rationale for carrying out additional independent testing of these fibres in order to assess whether quality levels were being maintained. A second interview with the TD discussed the implications of the test results and how the findings were used to inform

changes in management and control of the outsourced processes.

## Research Results

### *Expert Focus Group and 1st TD Interview*

Cashmere fibre quality is controlled by specifying the mean diameter and length of the fibre measured in the raw white (undyed) state. In-house tests demonstrated that the raw white fibre met the specification at the point where it was sent to the external contractor. As fibre quality was not normally tested during the dyeing and spinning processes, a series of extra tests were carried out at an accredited textile testing laboratory to assess whether damage was occurring at the external contractor. Figure 2 demonstrates the in-house and outsourced processes from fibre to finished spun yarn, and identifies the existing and additional testing points.

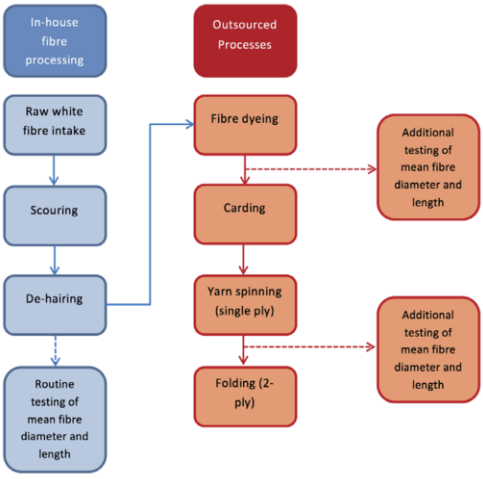


*Figure 2. Yarn spinning process: in-house and outsourced processes with existing and additional testing points*

## Fibre Testing

Samples taken from the same raw white cashmere fibre batches as the Autumn / Winter 2014-15 production were tested for average length and diameter to corroborate the case company's in-house results. In addition, the same tests were carried out on two colours at different stages of the outsourced yarn production process: after the dyeing stage and after spinning. Figure 3 shows the fibre and yarn samples that were tested.

*Figure 3. Bags of fibre and cones of yarn observed during the testing process*

| | Test: Single fibre length BSISO6989 method | | | | |
|---|---|---|---|---|---|
| | Mean Fibre Length (mm) | % Fibres < 20mm | % Fibres < 30mm | % Fibres < 40mm | % Fibres < 50mm |
| **Raw white fibre** | **43** | **21.1** | **36.5** | **50.3** | **62.1** |
| Pink dyed fibre | 39.4 | 21.7 | 35.1 | 52.8 | 70.7 |
| Pink dyed yarn | 29.4 | 37.3 | 57.3 | 73.5 | 84.8 |
| **Raw white fibre** | **43** | **21.1** | **36.5** | **50.3** | **62.1** |
| Black dyed fibre | 41.5 | 25.6 | 40.2 | 49.5 | 62.3 |
| Black dyed yarn | 28.5 | 44.2 | 63.5 | 76.3 | 84.7 |

*Figure 4. Fibre test results*

The test results shown in figure 4 demonstrate that the mean fibre diameter remains consistent during the dyeing and spinning processes when compared to the raw white fibre. The mean fibre length of the raw white fibre is 43mm, with 21% under 20mm. After dyeing, the mean fibre length of both shades has reduced slightly, but is within commercial tolerance. However, the mean fibre length within the finished yarn has been significantly shortened: the pink has reduced to 29.4mm and the black to 28.5mm. The proportion of short fibres below 20mm in length has also increased substantially at this stage. The results indicate that the fibres are relatively unchanged after dyeing, but have been damaged after this, either during the outsourced carding or spinning stages, both of which are mechanical processes causing friction.

## 2nd TD Interview

The TD visited China in January 2016 to discuss the test results with the external contractor and to review the dyeing and yarn spinning production processes. Three possible causes of fibre damage were found. Firstly, fibres were being excessively dried out at the end of the dyeing process; secondly, the dyed fibres were not sufficiently humidified in preparation for carding and spinning; and thirdly, the lubrication oil applied before carding and spinning was not suitable for a protein fibre. In each case, the increased dryness and brittleness caused would make it difficult for the fibre to withstand the friction of these processes. The external contractor agreed to make the necessary improvements to process control and implemented additional testing of the mean fibre length after the carding and spinning stages to monitor fibre quality. The TD reported that the pilling issue for the Autumn / Winter 2016-17 season was resolved by taking these measures, and pilling resistance tests carried out on finished garments from production showed significant improvement.

## Discussion

The research aimed to investigate the challenges of managing the quality and consistency of longer lasting products during the production process. A robust NPD process was demonstrated, where fibre specifications were used to achieve the required level of quality and durability as advised by Cooper et al.'s best practice advice on design for longevity (2013). In addition, appropriate voluntary testing described by Keiser and Garner (2012) had been undertaken within the in-house manufacturing processes

to monitor consistency. This proved effective in assuring quality at the raw white fibre stage, but once the product passed to the external contractor for dyeing and spinning, it was apparent that weak process management had caused the fibre to become damaged. It is possible that the UK team's remoteness from the supply chain, especially the outsourced processes, led to a lack of influence and poor transparency of issues that might arise. According to Rauer and Kaufmann (2015), this is a common problem within globalised and fragmented supply chains.

It could be argued that had the additional testing stage undertaken to ascertain the cause of the excessive pilling been a routine activity, the issue would have been identified earlier. However, this would have added cost and time into the production process, which is seen as an obstacle within the industry (Cooper et al., 2013). It would have been more productive to follow Gam et al.'s sustainable clothing design model C2CAD (2008) or Curwen et al.'s five key principles of sustainable design (2012), both of which emphasise the importance of information sharing within supplier networks to address issues with materials, and prioritise production efficiencies and quality. A collaborative approach is seen as being most effective to investigate problems, as well as knowledge sharing to achieve solutions. In practice, the TD was unable to overcome initial resistance to investigating the pilling issue and the case company's in-house team in China appeared reluctant to engage with the external contractor to investigate the problem: the reason for this is unclear, but could point to variations in business culture, management and values between different companies and global locations within the supply chain, cited by Curwen et al. (2012) as one of the five key principles that need to be addressed for effective sustainable design and production. The case company would benefit from reviewing their governance systems, ensuring that management structures and roles are defined effectively to allow those with appropriate knowledge and skills to contribute to the achievement of sustainable outcomes as advised by Bostrom et al. (2015).

Caniato et al. (2012) suggest that smaller companies with less complex supply chains are better able to address problems arising in the production process; however, the research demonstrates that although the case company was able to control NPD and in-house manufacturing processes, the outsourced processes were very difficult to influence and manage. According to Aage and Belussi (2008), such issues may be exacerbated in larger, more complex globalised supply chains as clothing industry clusters have become more fragmented; language barriers and differences in business culture, management practices and technical knowledge can limit the ability to acquire, share and apply knowledge effectively.

## Conclusion

The investigation successfully explored the challenges of achieving consistent standards in production for clothing that has been designed to be durable. The results demonstrated that product durability had been compromised due to weak management of production processes. Although the supply chain was simple in structure, the company had little control and influence over the outsourced processes and were only able to resolve it by undertaking additional independent testing of materials. Differences in business culture and operational practice between the UK based NPD team, the Chinese in-house manufacturer and the external contractor resulted in resistance to investigating the problem; this perhaps indicates a lack of shared values, knowledge sharing and collaboration which are seen by some experts as key principles of sustainable design and production.

This single case study model offered the opportunity for the researchers to trace and observe one company's approach to durable clothing NPD and production, enabling the development of hypotheses about the causal mechanisms involved (Bennett and Checkel, 2012). However, the limitations of single case study research include the lack of generalisability and external validation of results (Yin, 2003). There is considerable variation within the industry in terms of product types, retail models and supply chain networks, meaning that it is difficult to make generalised recommendations. However, the findings have been used to inform the development of a toolkit intended to assist clothing retailers to resolve issues that affect product durability during production. The case study is used to demonstrate the value of tracing a product's supply chain and identifying processes, quality assurance systems and management structures at each point in order to support the investigation of quality issues.

The research is based on a single brand and its high-value knitwear supply chain. While it demonstrates that new tests and processes could enable durable products to be produced more consistently, it also identifies the obstacles and limitations to implementing these enhanced procedures. Further research could explore similar issues in additional cases to uncover opportunities to reduce early product failure.

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