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Seam Separation Technology to Facilitate Re-use and Recycling of Textile Products

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Abstract The lack of effective disassembly technologies for clothing acts as a barrier to cost-effective and sustainable recovery of valuable raw materials at the end of life. Wear2™ technology has been developed to enable the seams in garments to be selectively disassembled at the end-of-life with minimal manual intervention. The appearance, durability and performance of garments remain unaffected during use but at the end-of-life auto-disassembly facilitates economic separation of different polymeric and/or metallic components. During garment manufacture a yarn that is highly sensitive to electromagnetic radiation in the microwave frequency range is incorporated into the seams. A short exposure time leads to degradation of the yarn and mechanical failure of the seam enabling the rapid removal of zips, buttons, fastenings, linings, labels, pockets or other "contras" that would otherwise contaminate the recyclate or would compromise the potential for the garment to be reused. The ability to economically recover fibre from disassembled garments of known composition, opens the door for re-use of materials to supplement or replace virgin fibre in new products, realising savings on raw material costs, easing potential supply constraints and reducing environmental impact in a virtuous closed loop system.

1. Introduction

Textile and clothing products are generally not designed for ease of disassembly at the end of life, adversely affecting the economic viability of bulk-scale recovery of the raw materials they contain. Recently, methods of semi-automated disassembly of clothing have been investigated that rely on modifications to the way in which products are designed and constructed [1]. A recently developed technology known as Wear2™ enables labels, logos, buttons and zips to be removed from clothing without damage to the surrounding fabric. Importantly from an economic standpoint it uses an automated process that requires minimal manual intervention. This makes it possible to rapidly fail seams and separate dissimilar materials into

pure material streams providing new options for products that might otherwise have been disposed of via landfill or incineration.

Microwave heating is an established, cost-effective industrial technology that is widely used in food and beverage processing and advanced manufacturing applications, making it ideally suited for exploitation in the re-use /recycling industry. By incorporating a yarn in to garment seams with high sensitivity to electromagnetic radiation in the microwave frequency range, there is scope to rapidly reduce the mechanical properties of the joint by exposure to microwaves at the end of life. Unintended disassembly of the garments, while being worn, is extremely unlikely because uncontained electromagnetic radiation at the required microwave frequency would not be encountered in normal practice. In microwave ovens and other similar devices, microwave energy is always contained within a sealed unit for reasons of safety. In this paper, the application of this approach as an industrial process is outlined.

2. Methodology

Staple core spun polyester (PET) sewing threads were produced with a linear density of 310 dtex (dtex= weight (g) of 10,000m of yarn) containing an electrically conductive polymer composite within the outer sheath [2]. This yarn was utilised to manufacture articles garments in which: (a) all constituent seams contained the new yarn, and (b) only the buttons, zips, labels or decorative pockets contained the new yarn. In the former garment samples, the aim was to facilitate complete garment disassembly and in the latter, partial garment disassembly. Industrial sewing equipment was utilised with no modification to the procedures used for normal garment assembly. Subsequently, garments were exposed to short-duration microwave treatment in a newly constructed process line.

3. Results and Discussion

3.1 Microwave Process Technology

A bespoke industrial microwave unit was designed and constructed for processing used clothing. To promote a cost-effective solution, the microwave unit was designed to operate at low power levels (kW m^{-3}) orders of magnitude below the norm for industrial equipment. The low power usage coupled with short cycle time ≤30 s minimises electricity consumption and running costs. The initial unit was designed with a 130 litre operating capacity and capability to process up to 500kg or ca.1,800 garments per hour. The operation of this microwave unit is also unaffected by the presence of buttons, metal zips or other items that may be attached to the garment.

3.2 Seam and Joint Failure as a result of Microwave Exposure

A short burst (<10 seconds) of microwave energy at an industrially applicable frequency was capable of degrading the yarn tensile strength such that a >80% reduction in seam tensile strength could be obtained (BS EN ISO 13935-2:1999). This enabled garment seams to be failed such that it came apart into its constituent component pieces (Fig. 1). Discrete components such as buttons, zips, labels or decorative pockets could also be removed with minimal force. The rest of the garment remains undamaged and complete, ready for re-use.

Figure 1: Seam separation after microwave processing

3.4 Commercial Scale Up

A route for bulk yarn production has been established and yarns are package dyed according to end use requirements. Garments manufactured by a major clothing retailer (George at Asda) demonstrated that the new yarn was compatible with high speed sewing processes. The garments also passed standard consumer clothing durability trials. When incorporated in corporate wear, wearer trials conducted by the Royal Mail confirmed that garments containing the yarns were durable in use. Disassembly trials at Oxfam using the new industrial microwave processing system, demonstrated that garments could be easily disassembled enabling their separation in to component elements. Although the cost of the yarn is slightly higher than standard sewing yarn, this is offset by the added value of recycling garments that otherwise would be landfilled.

4. Summary

In place of shredding, incineration or landfill, the Wear2 technology makes it possible to efficiently de-brand corporate wear and reuse the garments. Considering the approximate costs associated with end-of-life clothing, the cost to the retailer/brand owner of landfilling clothing is approximately £85 per tonne. Disposal of corporate-wear through incineration using energy from waste process is a zero cost option for the brand owner but generates revenue for the processer. It is estimated that 20% of the value may be recovered through resale (since there is currently no market for the resale of corporate-wear, quantifying exact resale values is subject to error) [3]

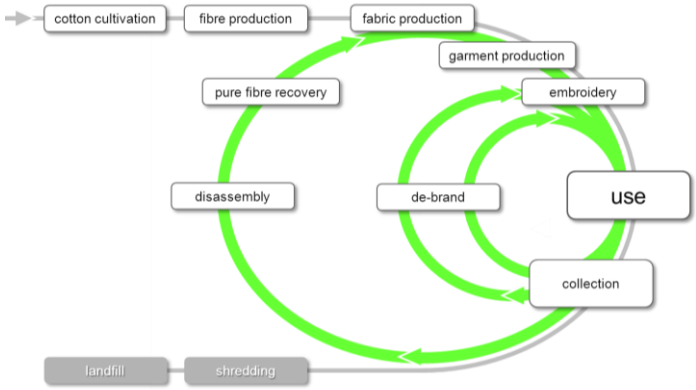

Figure 3: Closing the loop using disassembly technology

The Wear2 technology provides opportunities for the development of new business models based on (a) de-branding, (b) re-branding, (c) re-selling, (d) leasing and (e) repurposing, (Fig. 3). Furthermore the ability to remove contaminants (buttons, zips, linings and other contras) allows for uncontaminated fibre to be recovered, of known composition, quality and provenance for recycling. The wear2 technology can therefore transform a waste stream into a revenue stream, in addition to clear environmental benefits, including lowering CO_2 emissions and water consumption.

References

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