ZAPATEKO II - Project Closing Report

"POST-CONSUMER FOOTWEAR RECOVERY METHOD VIA AUTOMATIC SORTING AND ASSISTED SEPARATION BY TEARING"

Amongst automated footwear recycling technologies that have emerged over the past few years, a project carried out by the University of Loughborough in the United Kingdom in 2004 can be cited as an example (SMART)[1-2]. This project led to the creation of the first footwear recycling demonstrator in Europe by SOEX in 2012. As this process is based on the entire shredding of footwear followed by the separation of the various shredded materials, it is clear that the level of purity in the isolated materials needs to be high so that these elements can be efficiently recycled.

Several footwear models exist on the market, e.g., tennis shoes, boots, high heels, brogues, mules, sandals, etc. All these models have significant differences but the upper shoe and sole are the only parts that do not vary in these products: When these two parts are assembled together the footwear is formed. Assembly can be performed using different methods, e.g. welding (or gluing), injection, sewing, etc.

The upper shoe is the upper part of the footwear and is composed of a very high number of different materials and components that may or may not be visible. These can be assembled in different ways (sewn, glued, welded, etc.).
The sole can be made from a single material but more often than not it is comprised of two or even more, particularly in the case of pre-manufactured soles thereby making disassembly complicated.

The ZAPATEKO II project follows on from a first study carried out with other partners and conducted by ESTIA (Ecole Supérieure des Technologies Industrielles Avancées) in order to identify technological obstacles in the industrial and automated deployment of a footwear recycling system.
Based on the issues highlighted above and the preliminary work conducted by ESTIA, the issues raised concern the following areas:

- End-of-life footwear sorting: As with certain industrial technologies for clothes sorting, footwear remains a complex product due to its shape, its volume or the number of components from which it is made.
- Separation: Considering both the significant number of bonds that exist between the footwear's materials and the fact that it is essential to design sustainable products (via the strength of the bonds between components), industrial disassembly is a major problem in order to enable materials to be efficiently separated.
- The recovery of materials from disassembly operations: following the technical possibilities in recycling, and the condition in which these said materials are extracted, it is important to identify all possible outlets in technical, economic and environmental terms.
- The purpose of the ZAPATEKO II project is therefore to study the technical and environmental feasibility of an automated industrial recycling process.

1. Background and the relevance of the study by artificial intelligence

On 18 June 2021 a day-long event on the theme of "Optical Sorting" was held at ESTIA's campus within the framework of funding by REFASHION in the ZAPATEKO II project. This event was attended by footwear marketers (Decathlon, ERAM Group), collection-sorter operators (GEBETEX, SYNERGIES TLC), technical centres and French federations (CTC, REFASHION, etc.) and solution providers (VALVAN, LASER 2000).

Footwear model recognition with a view to recycling via visual identification using artificial intelligence was retained as interesting solution especially as it enables:

- Footwear components to be accessed
- Assembly techniques to be accessed
- Footwear to be sorted by category
- Soles to be sorted by material
- Data to be generated.

The points that require attention during the initial development of this technology include:

- **Man-machine interaction remains a priority.** At this stage it is still too early to measure the capabilities of this technology. However, it is necessary to distinguish between reuse, which requires sorting carried out by a human being, and recovery for recycling purposes, which generates less added-value. Indeed, in financial terms, this technological solution will be only relevant if it is combined with human intervention (initial sorting).
- **A solution to be compared to other technical solutions in the future.** It is obvious that this technology shall be compared to other solutions available on the market (QR code, RFID, spectral analysis, etc.). Moreover in accordance with its capabilities and performance, a hybrid solution may be considered (e.g. combined with spectral analysis in order to identify surface materials).
- **Access to a database that is shared by the entire industry,** so as to enable efficient recycling.

2. Study on disassembling the bond between the upper shoe and sole

The two objectives were:

- To characterise the conditions under which to tear apart the upper shoe from the sole of welded and injected footwear (sub-condition),
- To establish a specifications document for automated machinery based on the initial findings.

Several partner marketers participated in this study; 297 ERAM Group products, representing 20 models, were analysed. Optimal conditions in which to weaken the bond per model followed by the specific tearing apart of said elements were defined, the purpose being to also characterise the condition of the soles.

2.1. Test bench and upper shoe-sole separation process

The process implemented consists in a first stage where footwear heat reactivation takes place followed by separation by tearing apart the upper shoe in order to recover the sole. Footwear heat reactivation reactivates the glues used (welded assemblies). For other types of assembly it was decided to test the same process in order to define its feasibility. Heating modifies the structure of the materials thereby making it possible to tear apart the upper shoe from the sole. A test bench (see figure below) allowed tearing forces to be characterised but also to establish the conditions for maintaining the position of the sole, for hooking the upper shoe, etc.

From the tests carried it was possible to define footwear configurations and the optimum conditions in which to weaken the interfaces that are common to all footwear with the process examined. Lastly, the process does not appear to damage the material, which is the subject of the study's next phase: recovery of materials used in footwear.

Figure 2: Example of visuals resulting from separation by tearing apart

2.2. Upper shoe-sole separation demonstrator design

As mentioned above, the project's first phase consisted in characterising the separation of the upper shoe of footwear's from the sole. This study enabled a specifications document to be established for the demonstrator in which all the functions and limits of the system were presented, such as:

- Types of footwear that can be integrated
- Conditions for weakening the upper shoe-sole interface,
- The minimum force required for separation by tearing apart
- Average capacity for disassembly operations.

The yield can be improved in the future.

3. Sole recycling study and initial environmental impact assessment

By using the results from the previous stages and with the help of our sales partners, specific disassembly work was possible for certain models as well as a study on the reincorporation of the disassembled raw materials from specific soles in new soles.

The study focused on elastomer and thermoplastic soles. The analysis of soles resulting from this work (technical specifications, e.g. density, level of abrasion, the Shore rubber hardness value, etc.) enabled a series of prototypes to be made, themselves being characterised according to their level of durability, based on the PEFCR methodology (by measuring the IQM indicator) along with a comprehensive environmental impact assessment, starting from the automated disassembly's identification process and the preparation of disassembled soles. At the end of the study it was found that the process' environmental interest can only be shown if, after the dismantling of the elements, it is possible to obtain quality and robust materials, that could be reflected by the level of requirements in terms of physical properties such as abrasion.

According to the study, an average incorporation of post-consumption material (of sole categories studied) would lead to a decrease in the related impact, with at least more than 3% on the effect of climate change.

Bibliography:

[1] S.Rahimifard, T.Theodoros Staikos, G.Coates, Recycling of Footwear Products, A Position Paper Prepared by the Centre for Sustainable Manufacturing and Reuse/recycling Technologies (SMART) Loughborough University, December 2007

[2] http://refashion.fr/eco-design/sites/default/files/fichiers/Experimentation%20Assessment%20of%20Air-Soex%20Project.pdf, nov.2022

[3] https://pefapparelandfootwear.eu/whats-behind-the-methodology/, Nov.22