D3.3 Fibre reinforced PP materials from recycled textiles

Executive summary

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Number and name of deliverable: D3.3 Fibre reinforced PP materials from recycled textiles

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1. Introduction

The URBANREC project aims to develop and implement an eco-innovative and integral bulky waste management system (enhancing prevention, improving logistics and allowing new waste treatments to obtain high added value recycled products) and demonstrate its effectiveness in different regions. In this respect the project intends to improve the separation and disassembly of bulky waste, implementing advanced fragmentation techniques to obtain high quality raw materials. In this way, innovative valorisation routes are also promoted, especially for those fractions that are considered more problematic (PUR foam, mixed hard plastics and mixed textiles), and that are currently not being recycled due to a lack of eco-innovative cost-effective solutions.

The objectives of Work Package 3 "Pre-treated waste materials' validation in industrial manufacturing; PU foam, mixed textile, hard plastics and wood" include:

(i) Demonstration of the technical feasibility of the different routes implemented to recover waste fractions obtained from bulky waste which include rebonding, solvolysis, unravelling techniques, controlled fibre fractioning and compounding

(ii) Production and validation of demonstrators, including foam core layer, foam top layer, adhesives, nonwovens, foam mattress, fibre reinforced composites and wood plastic composites.

Figure 1 Overview of the role of each partner in task 3.4

This deliverable focuses on Task 3.4 “Industrial manufacturing and validation of short fibre reinforced PP composites (FRC).” This task was accomplished by a close collaboration of the partners involved. VANHEEDE (task leader) conducted additional clean-up of the rigid plastics fraction from bulky waste obtained in WP2, while PROCOTEX prepared the textile fibres by controlled fractioning to obtain fibre lengths of 1 to 6 mm. Moreover, fibre granulation tests were carried out in order to supply better dosable fibres. Finally, CENTEXBEL performed compounding trials in order to optimize the FRC composition.

2. Clean-up of the recycled plastics fraction

A fraction of the separate collection of bulky waste in Belgium, is composed of mixed rigid plastics. This is a mixture of different polymer types (including PP, PE, PVC, ABS, PS, PA, PC, PMMA, etc.) on the one hand and a mixture of different production types (such as extrusion, blow moulding, injection moulding, etc.) on the other hand. Moreover, the mixture is also contaminated with metals, wood, stones, etc. Thus, for the valorisation of this particular bulky waste fraction further clean-up was performed by VANHEEDE as described below. In a first step, the mixed rigid plastic fraction obtained from bulky waste was sorted into different polymer grades. Second step is cutting the materials into pieces of ca 10-15 cm (as described in WP2). The presorting resulted in 71% polyolefin (PO) materials of which the different fractions were further processed in the recycling line for PO plastics. The treatment includes size reduction, washing and flotation, removal of the different metal fractions (ferro and non-ferro), regrinding and dedusting. The PO injection moulding fraction (PO mix, see Figure 2 right) is a blend of PP and PE which could already be used in plastic processing, however the mix was further purified to a 98% PP fraction in order to increase the material value. The start mix and sorted PP fraction of the PO injection moulding grade were processed via melt filtration to remove any residual non-melting impurities that could damage pilot scale equipment and/or would impair the FRC’s mechanical properties. The resulting grades were thoroughly characterized and the mechanical properties are presented relative to virgin PP in Figure 2 (left).

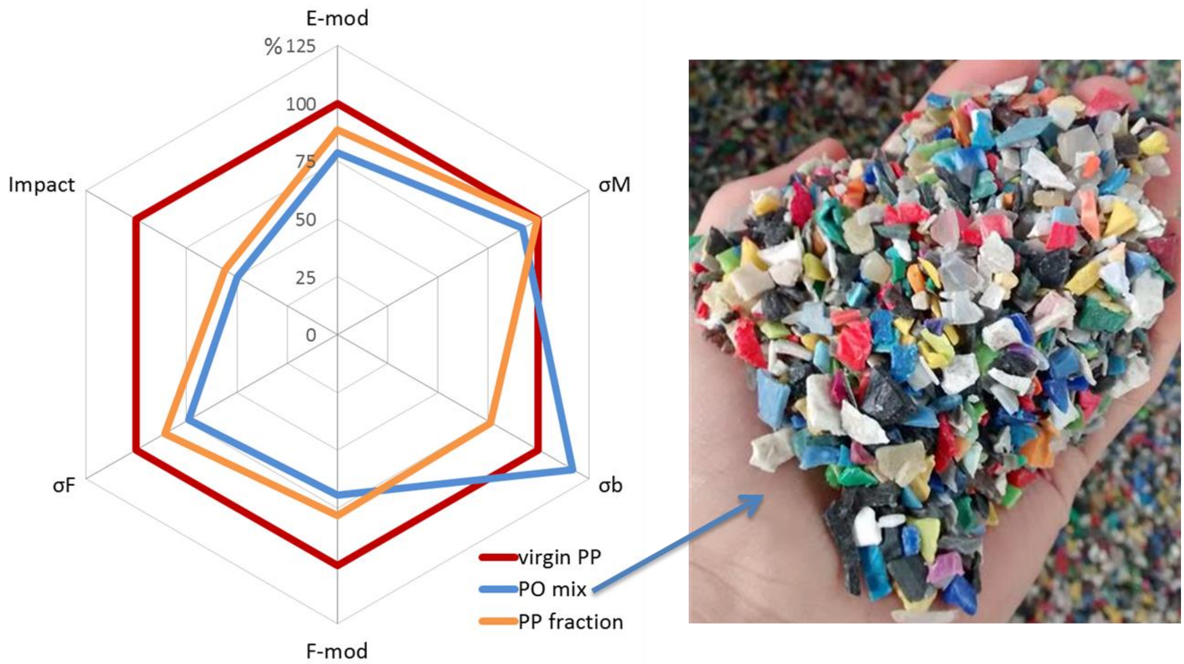

Figure 2 Radar plots comparing the mechanical properties* of the recycled plastics to virgin PP (left) and illustration of the recycled PO mix regrind.
including elastic modulus (E-mod), tensile strength (σM), strength at break (σB), flexural modulus (F-mod), flexural strength (σF) and impact strength (Impact)

The recycled plastics show a 10-20% lower tensile and flexural stiffness compared to the virgin PP grade used as a reference. Moreover, much lower impact strengths were obtained which was expected as the selected virgin PP grade is a high impact grade. Interestingly, compared to the virgin PP grade, both recycled fractions show similar tensile strength but lower flexural strength, while the PO mix fraction has a higher fracture strength.

3. Fibres from post-producer and post-consumer bulky textile waste

Post-producer (cotton, polyamide (PA) and polyester (PES)) and post-consumer (mattress textile) waste was precision cut by PROCOTEX to 2 or 4 mm fibres using a milling machine. Following these tests, a set of minimum specifications for the raw material for FRC production was defined. The chemical composition of the mattress textile waste materials was determined:

- Post-producer from Delax: >90% PES
- Post-consumer from Ecofrag: 90% PES/cotton + PA
- Post-consumer from Vanheede: 90% PES/cotton + wool

Additionally, optical microscopy was performed in order to evaluate the fibre morphologies and actual lengths Moreover, in order to improve fibre dosing on pilot scale compounding equipment, PROCOTEX has prepared granules of different types of fiber fluff (PES, cotton, jute, aramid) using a fiber compacting machine. These granules were inspected using a microscope with camera and image processing in order to examine the granule size, fibre length and if the fibres are still intact after compacting (see Figure 3).

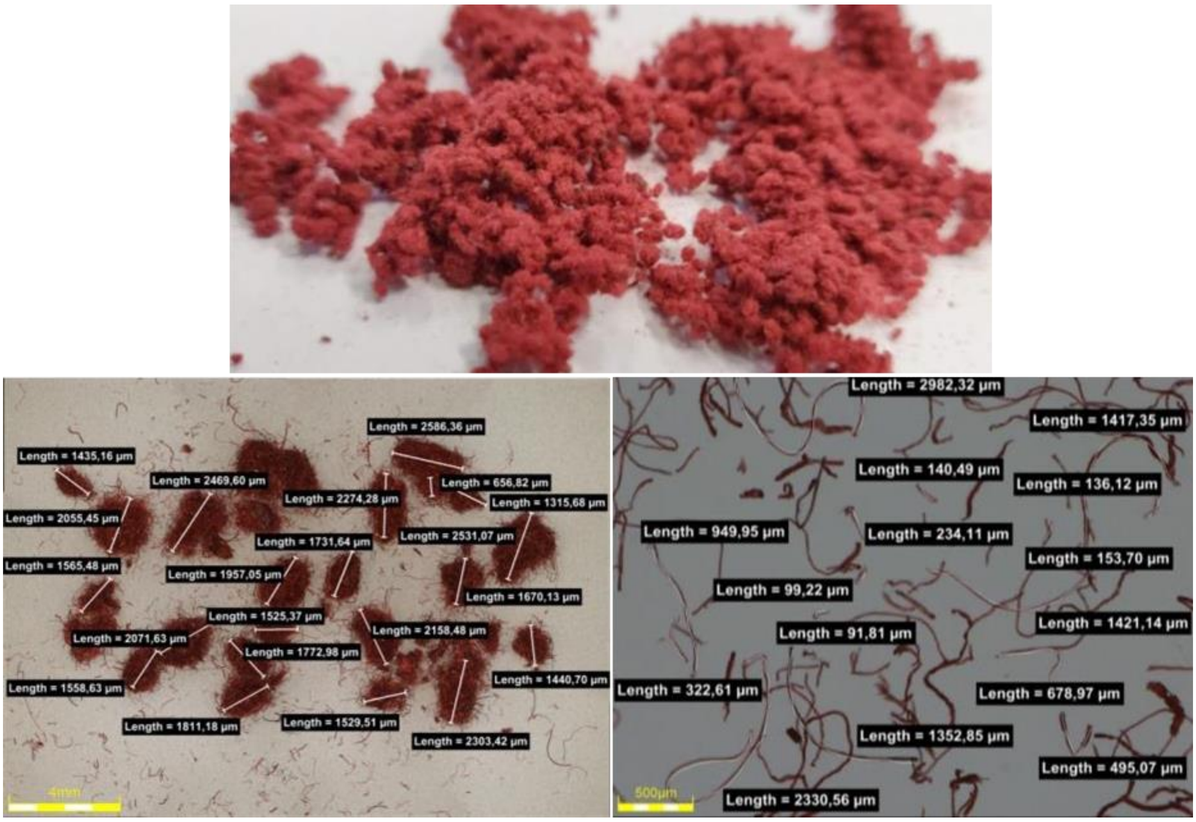

Figure 3 Images of the PES fibres granulated by Procotex including the determination of the granule size and fibre length.

4. Development of short fibre reinforced composites

Small and pilot scale compounding trials followed by injection moulding of standard test samples were performed by CENTEXBEL in order to optimize the FRC formulation. Varying fibre types (prepared by PROCOTEX) and amounts were added to a PP matrix. Moreover, a range of additives (compatibilizers) was tested to improve fibre/matrix interaction. Tensile, flexural and impact properties were determined and compared to glass fibre reinforced composites (GFC) and wood plastic composites (WPC). The results presented in Figure 4 show that the stiffness (i.e. tensile and flexural moduli), fracture and flexural strength as well as the impact resistance were improved upon the addition of cotton fibres. Moreover, increasing fibre concentrations resulted in further enhancement of elastic modulus and strength. The addition of the 2 mm mattress textile fibres also resulted in increased elastic and flexural moduli and thus materials with increased stiffness as well. Additionally, the ECOFRAG fibres induced a slightly higher fracture and flexural strength, comparable to the cotton FRC's. However, a reduced impact resistance was obtained, while the DELAX compound on the other hand showed increased impact strength but decreased flexural and tensile strength. The varying properties for the different FRC's are likely to be caused by a combination of different fibre/matrix interaction, different fibre properties and morphologies. In terms of stiffness, the developed FRC's are outperformed by the GFC to a great extent. However, they are comparable or even superior to the WPC material. An ice bucket demonstrator was produced from the PP-Delax FRC compound (see Figure 4).

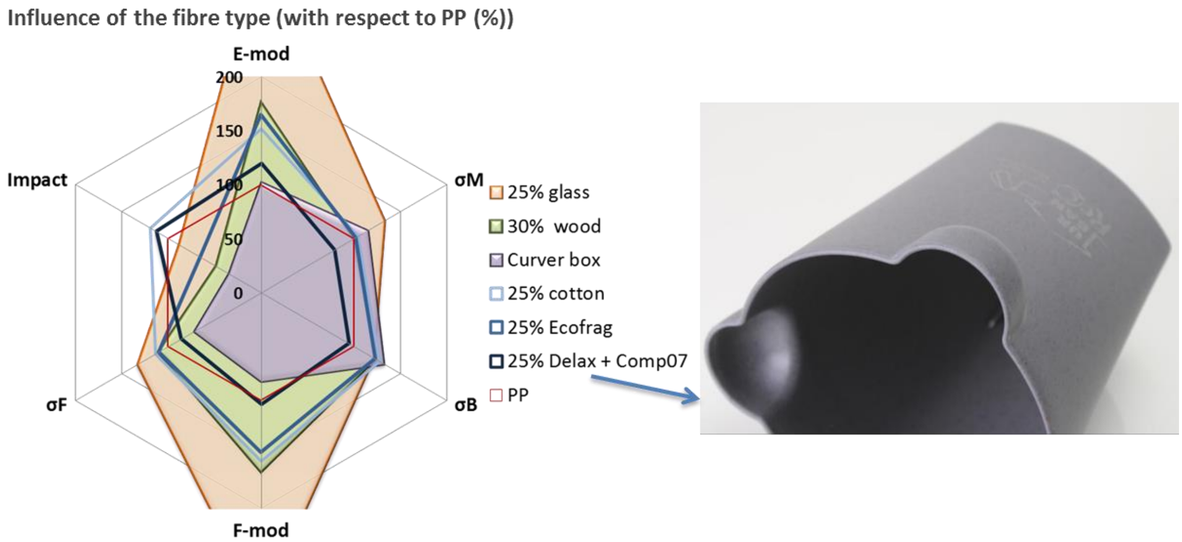

Figure 4 Radar plots comparing the mechanical properties* of the FRC's with cotton, Ecofrag and Delax fibres to virgin PP (left) and illustration of an ice bucket demonstrator produced from the PP-Delax FRC (right).

including elastic modulus (E-mod), tensile strength (σM), strength at break (σB), flexural modulus (F-mod), flexural strength (σF) and impact strength (Impact)

Furthermore, virgin PP was replaced with the recycled plastics obtained by VANHEEDE and rulers were produced as demonstrators (see Figure 5). Adding the cotton fibres and a compatibilizer resulted in a considerable improvement of the mechanical properties. The tensile and flexural moduli and strengths even exceed those of the virgin PP grade.

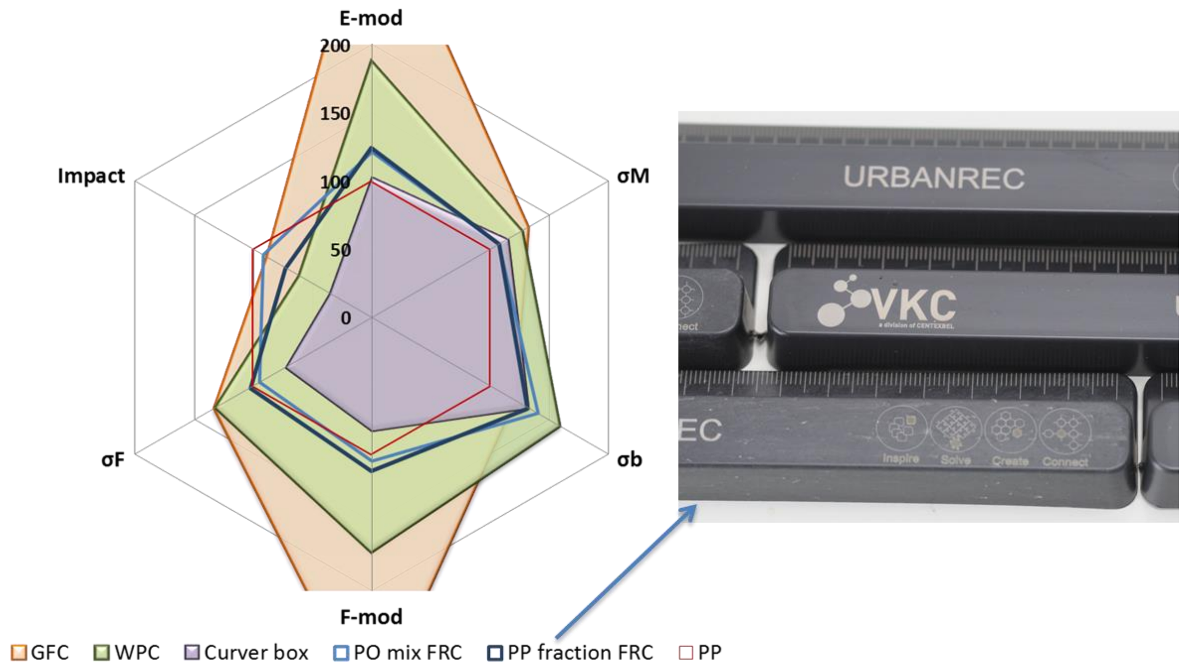

Figure 5 Radar plot comparing the mechanical properties* of the recycled plastics FRC's to unfilled, virgin PP and to virgin WPC and GFC (left) and illustration of the demonstrators produced from the PO mix FRC (right).

including elastic modulus (E-mod), tensile strength (σM), strength at break (σB), flexural modulus (F-mod), flexural strength (σF) and impact strength (Impact)

Ultimately, compounding and injection moulding of the final demonstrator, a storage box, was performed. For this purpose, mattress textile fibres from VANHEEDE were selected as these were actual post-consumer bulky waste. In Figure 6**Error! Reference source not found.** the properties of the 2 mm mattress fibre-FRC's are again compared with the GFC and WPC produced at CENTEXBEL as well as with the store-bought curver box. As expected, the GFC outperforms the FRC's to a great extent, however also the WPC shows a better overall performance. Nevertheless, the FRC containing compatibilizer is definitely suitable for the production of storage boxes as it shows higher stiffness, flexural and impact properties than and similar tensile strength as the store-bought curver box.

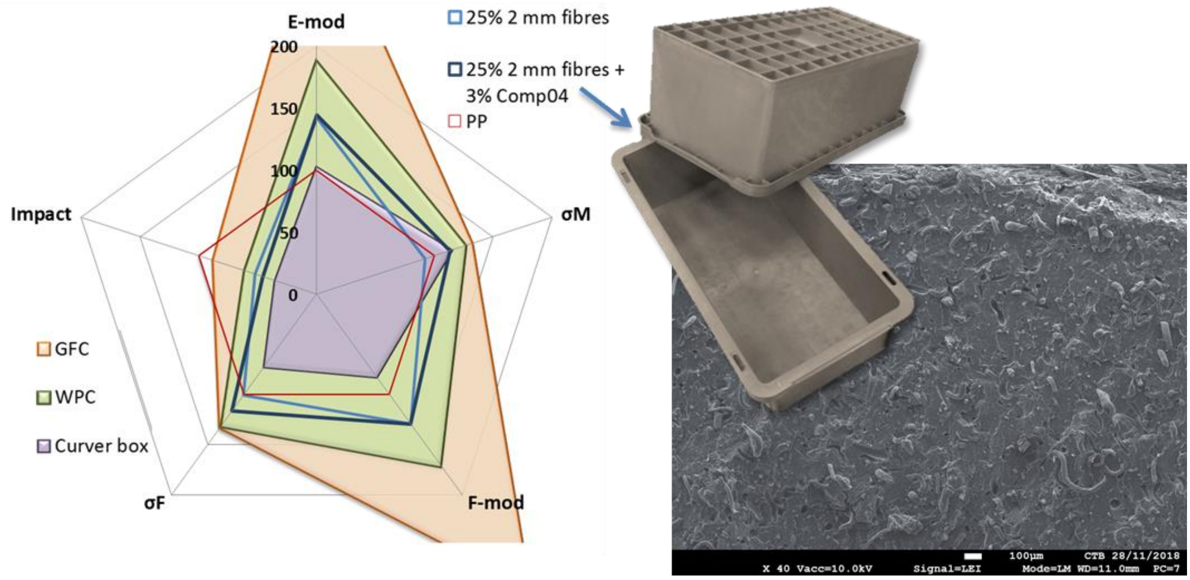

Figure 6 Radar plots comparing the mechanical properties* of the 2 mm mattress fibre-FRC's to unfilled, virgin PP and to virgin WPC and GFC (left) and picture of the final demonstrator as well as a microscope image of the fracture plane of the FRC illustrating the homogeneous distribution of the fibres.
including elastic modulus (E-mod), tensile strength (σM), strength at break (σB), flexural modulus (F-mod), flexural strength (σF) and impact strength (Impact)

Next steps will include determination of the mechanical properties of the produced boxes as the injection moulding parameters might require further adjustment to optimize the product properties. Additionally, as the compounding was performed on semi-industrial scale, future work should include industrial scale compounding to investigate if the fibres can still be distributed homogeneously using large scale extruders. Furthermore, life cycle analysis will be performed for the developed demonstrator(s) and an ecolabel will be selected.