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Production of Crumb Rubber – Iron Powder Mixture for perspective synthesis of Carbon-Iron powder sorbent

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Abstract. A sustainable technique for conversion of end-of-life tyres (ELTs) to products with added value is of a great importance for resource-efficient circular economy. However, obtaining products with added value often requires multi-stage procedures, which include traditional and emerging technological approaches. In current paper, the authors suggest an efficient approach for recycling of ELT tyres, obtaining products which can be subsequently used for environmental applications. This approach introduces a synthesis path for new materials by transformation of industrial wastes i.e. ELT rubber wastes to crumb rubber and further mixing with iron powder. Particular attention is driven to perspective processing of obtained crumb rubber-iron powder mixture by means of microwave pyrolysis for synthesis of carbon-iron powder mixture and its use as a composite absorbent material along with emerging application for electromagnetic and microwave irradiation protection.

Key words: crumb rubber, iron powder, high pressure grinding rolls, disintegrator, microwave pyrolysis.

INTRODUCTION

The European Union recognises end-of-life tyres as a valuable resource with growing potential (ETRMA, 2011). A significant amount of ELTs in the European Union 220 million/year rises an up-to-date agenda for research of effective ELTs treatment methods with the aim of producing final treatment/recycling products with added value by means of sustainable treatment processes (Lam et al., 2010).

In current paper, the authors suggest an efficient approach for recycling of ELT tyres, obtaining products which can be subsequently used for environmental applications. The suggested approach represents a synthesis path for new materials by transformation of industrial wastes i.e. ELT rubber wastes to crumb rubber and further mixing with iron powder, describing processing stages 1, 2 (Fig. 1) for preparation of crumb rubber-iron powder mixture. Thus, producing a 'crumb rubber-iron powder mixture' for further processing by pyrolysis (microwave), facilitating a preheating of crumb rubber by means of iron particles incorporated into milled crumb rubber granules.

Pyrolysis processes are widely used for treatment of end-of-life shredded or granulated (particles size range: 0.5 mm – 3 cm) tyres (Athanassiades, 2013). However, applying a microwave heating brings an additional advantage, leading to devulcanisation (Ramos et al., 2011) of rubber material (i.e. ELTs), hence producing higher quality carbon particles. Iron powders, having distinct absorbing properties (An et al., 2008), influences on microwave treatment, acting as an absorber in microwave-range wave band. In case of solid waste processing, application of iron powder as a microwave absorber agent increases an effectiveness of material degradation, meanwhile decreasing a treatment residence time (Gedam & Regupathi, 2012). In case of rubber-iron mixture, particles of iron powder can be rapidly heated by microwave irradiation up to 700 °C (Yoshikawa et al., 2006), accelerating pyrolysis of rubber along with formation of carbon-iron powder mixture. Obtained carbon-iron powder mixture can be directly used as a composite absorbent material with distinctive magnetic properties (Shishkin et al., 2014) Additionally, there could be several emerging applications of fine carbon-iron powder as a raw material for catalyst applications (Xiao et al., 2012), as well as for electromagnetic and microwave irradiation shielding (Sano et al., 2007; Micheli et al., 2011).

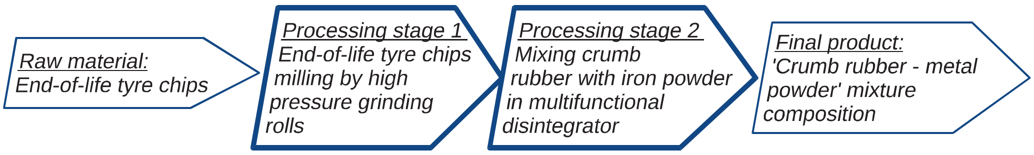
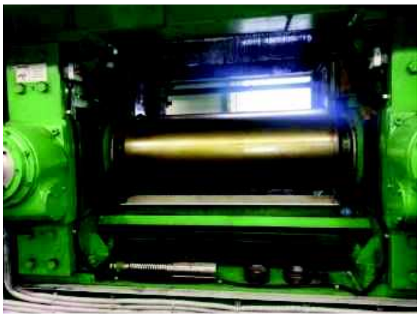


Figure 1. ELT rubber wastes transformation stages from tyre chips to 'Crumb rubber – metal powder' mixture composition.

MATERIALS AND METHODS

High pressure grinding rolls (HPGR) is known as milling technique for mineral processing (Ozcan et al., 2015). However, HPGR can be considered as a perspective technological approach for ELT disintegration (Fig. 1, Processing stage 1.) (Jevmenovs, 2015), competing to widely-used shredding (ETRMA & Chemrisk, 2009). In order to obtain crumb rubber granulate suitable for further mixing with iron powder, an experimental studies of rubber chips disintegration process in high pressure grinding rolls have been performed by means of industrial HPGR schematically shown in (Fig. 2). Further mixing of crumb rubber with iron powder (Fig. 1, Processing stage 2) has been performed by means of multifunctional disintegrator developed in Tallinn University of Technology (Estonia) Fig. 3 (Tumanok et al., 1997). The disintegrator operates in direct, separation and selective milling modes (Tumanok & Kulu, 1999) reaching maximum rotation speed up to 12,000 rpm.



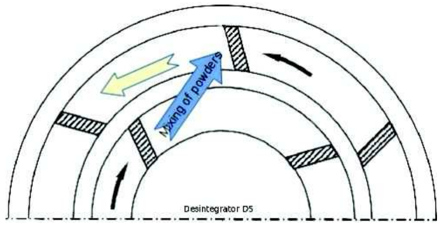


Figure 2. Experimental setup for the study of the ELT chips disintegration process (in partnership with Rubber Products Llc (Latvia)).

Figure 3. Multifunctional disintegrator: mixing process schematics (Tallinn University of Technology).

RESULTS AND DISCUSSION

ELTs rubber chips before disintegration in HPGR and a final product after HPGR processing have shown in Fig. 4, a, b. It is evident that treatment in HPGR has leaded to comminution of rubber chips up to 0.1–1.0 mm. After HPGR treatment, obtained rubber particles (or granules) were processed in multifunctional disintegrator for mixing with iron powder.

a) b)

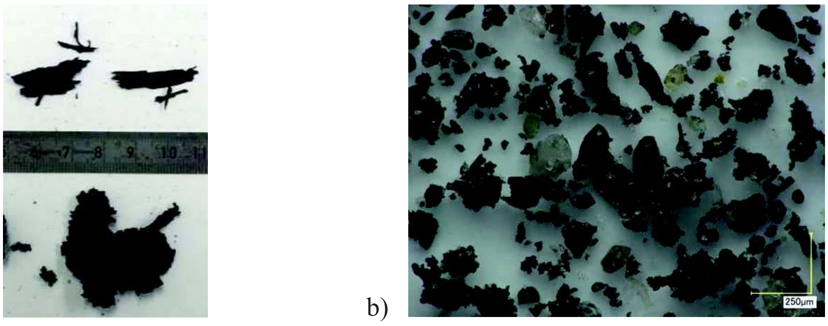


Figure 4. Optical microscopy of a crumb rubber before (a) and after (b) HPGR (Fig. 2) processing.

Iron powder is composed mainly of metal with insignificant impurities in form of scale and rust. Particle size distribution of iron powder and crumb rubber used for experimental mixing (Processing stage 2, (Fig. 1)) in multifunctional disintegrator (Fig. 3) is shown in (Fig. 5). Volumetric mixing ratio of crumb rubber with iron powder is 1:3. The final product – 'crumb rubber – iron powder mixture' was prepared by applying a single direct grinding mode.

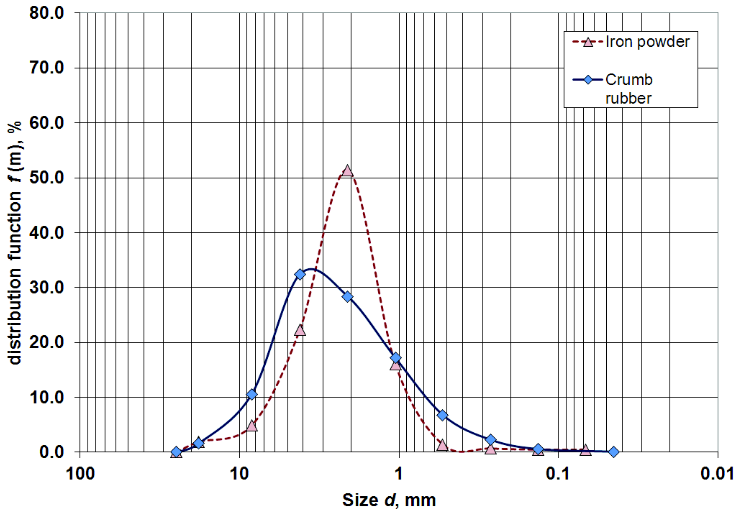


Figure 5. Crumb rubber and iron powder particles size distribution (Equipment: Analysette 22) used for feeding of multifunctional disintegrator (Processing stage 2, Fig. 1.).

During the high-energy processing of mixture in disintegrator, iron particles (Fig. 7) were incorporating to the surface of rubber granules, forming a stable rubber-iron composition with granule size up to 500 µm (Fig. 6).

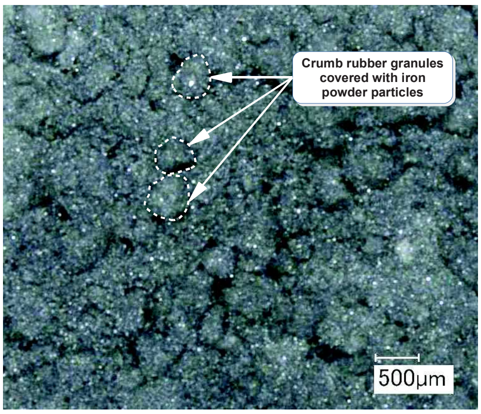


Figure 6. Crumb rubber granules covered with iron powder (Equipment: Keyence VHX-2000).

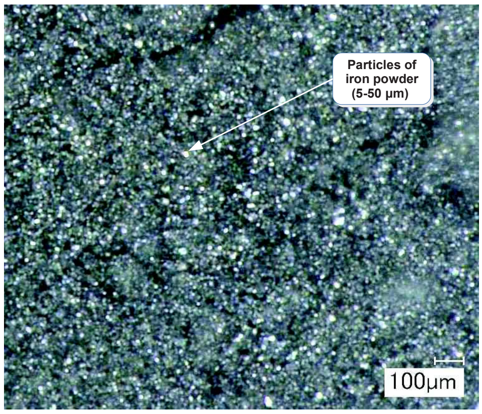


Figure 7. Iron powder particles after processing in disintegrator (Equipment: Keyence VHX-2000).

As it follows from (Fig. 1), the obtained rubber-iron mixture will be subsequently processed by pyrolysis for carbon-iron powders composition recovering. Further research activities will cover several emerging applications of carbon-iron powder composition, such as composite absorbent material with distinctive magnetic properties for spilled oil collection (Treijs et al., 2013), and as a material for electromagnetic/microwave irradiation shielding.

CONCLUSIONS

Two-stage processing approach for conversion of ELTs rubber into 'Crumb rubber - metal powder' mixture has been proposed and tested. Application of high pressure grinding rolls along with disintegrator has proven a concept of developing a new raw material based on crumb rubber and iron powder.

A disintegrator has been used for mixing rather than for comminution process. As a process product, a stable composition of crumb rubber with iron powder has been obtained, with granule size up to 500 μm (Fig. 6).

The obtained 'Crumb rubber – metal powder' composition will be subsequently processed by pyrolysis for synthesis of new composite absorbent material based on carbon-iron powders composition.

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