RECYCLING OF SECONDARY RAW MATERIALS FOR THE PRODUCTION OF NEW COMPOSITE PRODUCTS: DEVULCANISED CRUMB RUBBER CASE STUDY

[1] V. Lapkovskis, [2] V. Mironovs, [3] K. Irtiseva, [4] D. Goljandin

[1,2,3] Riga Technical University, Kipsalas Str. 6B-110, Riga, LV - 1048, Latvia

Tel. +371 29536301, e - mail: vjaceslavs.lapkovskis@rtu.lv

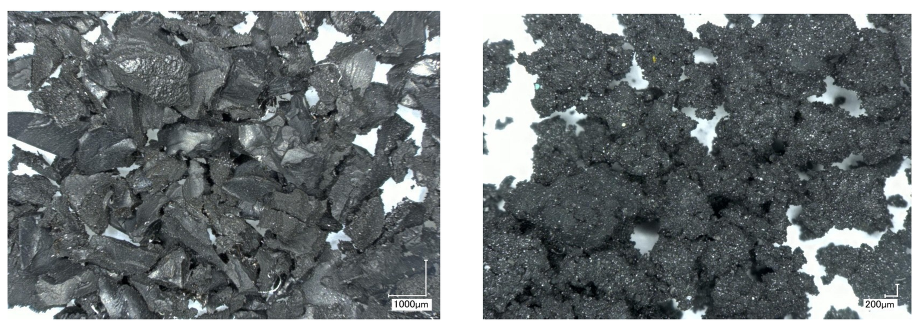
[4] Tallinn University of Technology, Ehitajate tee 5, 19086, Tallinn, Estonia.

Introduction

Novel composite materials become more and more finely tailored for specific applications, containing many different matrices and fillers. Thus, recycling methods should take into account the possibility of reusing components with obtaining new materials during the recycling process. Current investigation is devoted to application of disintegrator equipment as an up-to-date method for materials recycling, including critical raw materials, composites, and elastomers. Disintegration technique can be considered as an integral method, which combines grinding and homogenisation in a single processing stage. Moreover, disintegration provides creation of composite mixtures of materials with different properties. In current research special attention is given to development of coposite mixtures based on devulcanised crumb rubber with metallic and electronic scrap (WEEE) powders components. Further application of obtained mixtures include: materials for spilled oil adsorbent and materials for electromagnetic shielding (low- and high- frequency sources).

Materials and Methods

Devulcanised crumb rubber used for current research was produced by patented mechano-chemical treatment (MCD) technology at semi-industrial pilot plant located in Riga (Latvia). A method comprises a processing of crumb rubber by grinding rolls at temperature 60-70 °C with addition of devulcanisation agents. Obtained products represent a sponge-like aggregates of devulcanised crumb rubber (Fig.1).



Crumb rubber before mechano-chemical treatment. Devulcanised crumb rubber - crumb rubber after mechano-chemical treatment

Figure 1. Crumb rubber before and after mechano-chemical treatment.

A scheme of devulcanised rubber conversion into composite mixture with different constituents is presented Figure 2.

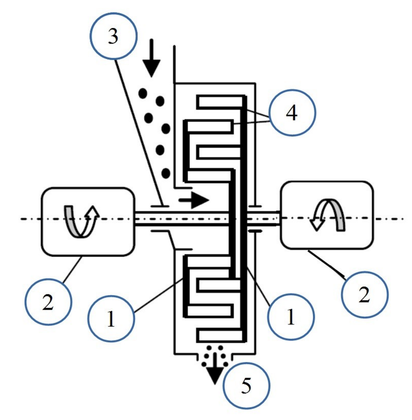


Figure 3. Impact disintegrator DSL-175 (TalTech).

1 - Rotors; 2 - Electric drives; 3 – Inlet for raw material; 4 - Grinding elements (pins, blades); 5 – Outlet for processed (milled) material.

Figure 4. Schematics of selective grinding mode (material fractionation).

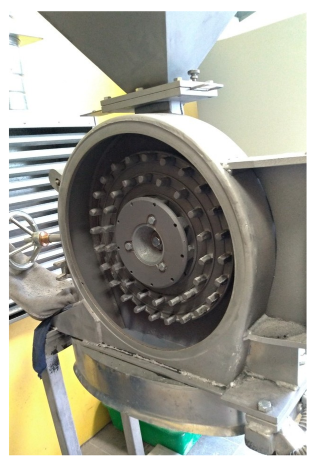


Figure 5. Impact disintegrator DESI in RTU.

Grinding in high-energy rotating disintegrator (Fig. 3, 5) leads to formation of new composite materials and may provide energy supply for further mechanochemical processes. During disintegration process, collision between particles and rotating element provide energy transfer from rotating gears to processed materials. Mechanical energy from rotating gears actuates particles comminution, the particles of raw materials decrease in size, while specific surface and surface energy levels increase. Mechano-physical phenomena caused interaction between particles and rotating elements may provoke structural changes and chemical reactions in processed materials. Thus mechanochemical reactions and transformation of processed materials occurs.

Iron or other hard solid particles act as erosion agent facilitating rubber wearing and partially desintegration of larger agglomerates.

Selective grinding mode has been applied for separation of composite mixture and its constituent materials (Fig. 4)

Results and Discussion

Obtained composite mixtures have been analysed by means of digital optical microscopy. Morphological analysis has shown that materials with different properties create a fairly homogeneous compositions. Additional experiments with obtained composite mixtures (specifically DCR-FE, DCR-ID) have demonstrated multi-functionality of composite mixture: material for spilled oil collection (Fig. 6) and, at the same time shielding material (Fig. 7) for low-frequesncy electromagnetic sources (electric power supply).

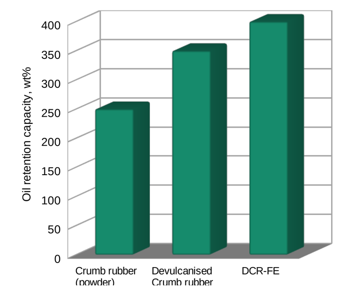


Figure 6. Spilled oil collection trial (DCR-FE)

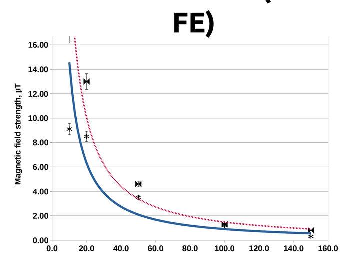


Figure 7. Elctromagnetic shielding trial (DCR-FE)

Elelctromagnetis shielding propeties in high-frequency range of obtained composite mixtures (DCR-SM, DCR-WEEE, DCR-AL) will be evaluated

Further Developments

Further modifications of powder composite materials based on devulcanised crumb rubber
Free powder filling in cartridges
Composite mixture sheets produced by pressing
Use of organic (bio-binders based on peat, cellulose) and inorganic (binders based on gypsum or cement compositions) material aggregated in sheets or mats.
Granulation using inorganic and organic binders to create porous granules.
Reinforcement of structures by means of perforated materials (steel bands), organic and inorganic fibres and reticular structures.

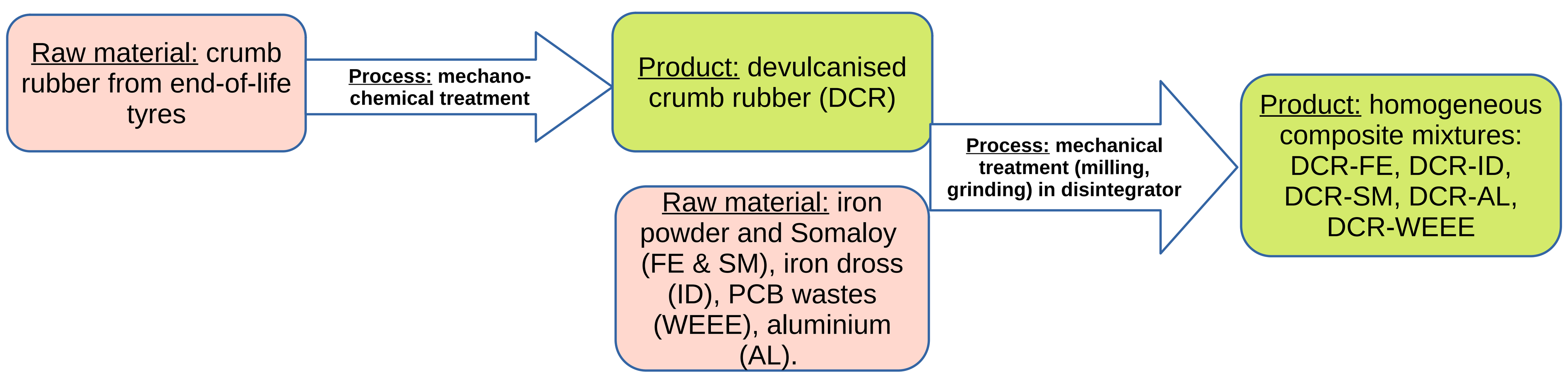
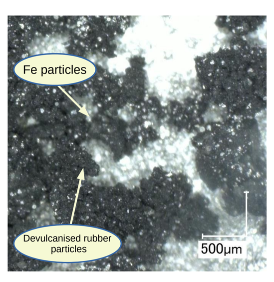
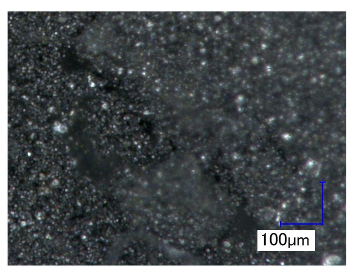
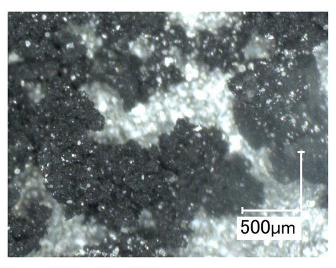
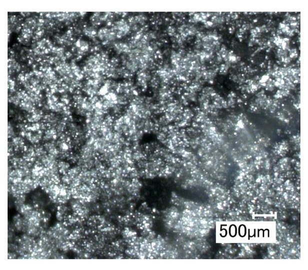
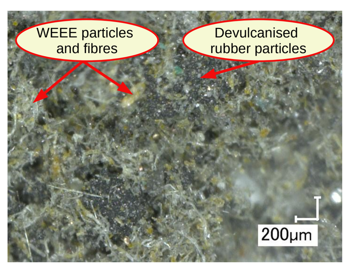


Figure 2. Scheme of conversion from raw materials to homogenious composite mixtures

Table 1. Developed devulcanized crumb rubber (DCR) composite mixtures with different constituents.

Composite Material Mixture	DCR-FE	DCR-ID	DCR-SM	DCR-AL	DCR-WEEE
Mixture composition	DCR + Iron powder (Fe contents 96-98 wt%) (Höganäs AB)	DCR + Iron dross particles (steel manufacturing wastes)	DCR + Somaloy 500 powder (Höganäs AB)	DCR + Aluminium powder	DCR + Printed circuit boards wastes
Digital microscopy image					
Foreseen applications	Spilled oil adsorbent, electromagnetic shielding applications for low-frequency sources	Spilled oil adsorbent, electromagnetic shielding applications for low-frequency sources	Electromagnetic shielding applications for low-frequency sources	Electromagnetic shielding applications for low and high-frequency sources	Electromagnetic shielding applications for low and high-frequency sources

Conclusions

Current work suggests a method of devulcanised rubber transformation into composite mixtures suitable for environmental applications (in particular, spilled oils collection and shielding against electromagnetic fields) by means of up-to-date disintegration method.

Obtained composite mixtures are characterised by multifunctional performance featuring sorption properties for spilled oil collection and electromagnetic field shielding (patent pending).

Suggested further processing of obtained composite mixtures may provide a strong basis for up-scaling applications of obtained composite mixtures not only for environmental application, but also for development of new compositions, which can be used for efficient raw materials recovery (including critical raw materials) .

Acknowledgements

This work has been supported by the European Regional Development Fund within the Activity 1.1.1.2 "Post-doctoral Research Aid" of the Specific Aid Objective 1.1.1 "To increase the research and innovative capacity of scientific institutions of Latvia and the ability to attract external financing, investing in human resources and infrastructure" of the Operational Programme "Growth and Employment" (No. 1.1.1.2/VIAA/1/16/175).

PostDoc Latvia · NACIONĀLAIS ATTĪSTĪBAS PLĀNS 2020 · EIROPAS SAVIENĪBA Eiropas Reģionālās attīstības fonds · IEGULDĪJUMS TAVĀ NĀKOTNĒ

11th International Conference "BioSystems Engineering 2020"
May 06-08, 2020, Tartu, Estonia

Eesti Maaülikool Estonian University of Life Sciences