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TEXTILE FIBRES FROM RECYCLED TYRES

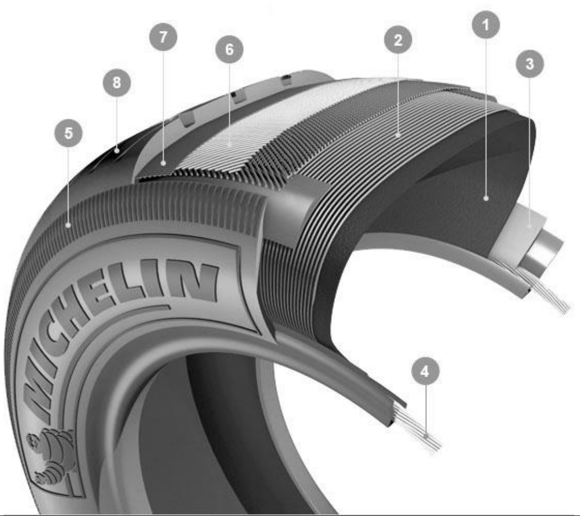
Martina PEZER; Marijana PAVUNC SAMARŽIJA; Ana BARIČEVIĆ; Edita VUJASINOVIĆ; Marija JELČIĆ RUKAVINA & Nina ŠTIRMER

Abstract: *Today textiles hold an important place in our daily life. Textile is not only just beautiful designer goods, bed or tablecloth. Textile has become an integral, if not reinforcing part of rockets, airplanes, cars, skis, sailing boats, kayaks, golf and baseball bats, tyres, heart muscles, blood vessels and new architectural miracles. If one bears in mind exponential population growth and an increase in living standards, it is clear that demand for textile raw materials is growing enormously and that producers of textile fibres are not able to satisfy the need for the adequate textile raw materials in the traditional way. That is why in the area of textile, significant efforts are put in research and development of new, preferably renewable textile raw materials, as well as on new and more comprehensive textile recycling processes and/or recycling of new 21st century materials that contain textiles in its structure or, are based on the textiles such as fibre-reinforced composites. One of such products, which in its structure contains significant amounts of high-performance fibres and may be recyclable are discarded tyres from different transport vehicles. How to get fibrous material from waste vehicles tyres, some of the qualitative characteristics of the obtained recycled textile fibres and recommendation for their reuse are presented in this paper.*

Keywords: *tyres, fibre reinforced composites, waste, recycling, mechanical recycling, reclaimed fibres.*

1. Introduction

Nowadays, through the usage of different technical textiles, textile-containing items become significant part of our everyday routine. One of such items is vehicle tyre. The modern tyre has its origins in the work of three pioneers, Goodyear who discovered vulcanization of rubber in the USA in 1839, RW Thompson, a Scottish engineer, who developed and patented the concept of the pneumatic tyre in 1845, and Dunlop, who in 1888 first used textiles, a canvas fabric, as rubber tyre reinforcement. Early tyres used cotton woven fabric which was later replaced by a unidirectional arrangement of Nylon cords sometimes with a small number of weft threads across them (Figure 1).



1. Inner line - an airtight layer of synthetic rubber	5.Sidewall - protects the side of the tire from impact
2. Carcass Ply - the layer consisting of thin textile fibre cords (or cables) bonded into the rubber	6. Crown plies (or belts) - is made up of very fine, resistant steel cords bonded into the rubber
3. Lower bead area - this is where the rubber tire grips the metal rim	7. Cap ply (or "zero degree" belt) - reinforced nylon based cords embedded in a layer of rubber
4. Beads - ensure an airtight fit and keep the tire properly seated on the rim	8.Tread - provides traction and turning grip for the tire and is designed to resist wear, abrasion and heat

Figure 1: Main parts of the typical radial tyre [3]

Today, the radial tyre contains about 4 to 7 % of its total weight of textile material; cross-ply tyres contain much more, about 21% [1]. Since tyres production in the EU is quite big (approx. 4.5 million tons per year [2]) it seems that something between 90 and 900 thousand tons of textile fibres are required for their production. If one bears in mind exponential population growth and an increase in living standards, environmental protection and energy saving it is clear that producers of textile fibres are not able to satisfy the need for the adequate textile raw materials in the traditional way. That is why in the area of textile, significant efforts are put in research and development of new, preferably renewable textile raw materials, as well as on new and more comprehensive textile recycling processes and/or recycling of items that contain textiles in its structure like e.g. tyres.

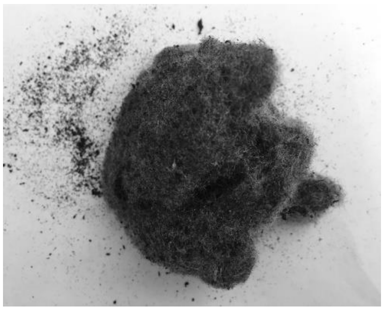
Waste tyres are today major environmental problem because of its slow degradation process in the nature. Disposal of waste tyres have been recognized as a significant problem throughout the world. Landfills of tyres can be dangerous places not only because of the negative impact to environment and the risk of fire, also can laid the groundwork for reproduction of damaging insects and rodents. In addition to the above reasons, the practice of waste tyres disposal on landfills is becoming unacceptable due to the reduction of available places for their disposal. According to the Directive 1999/31/EC [4], any kind of burning waste tyres without recycling energy is prohibited in the European Union. According to Directive, any form of disposal of used tyres in natural environment has been completely banned since 2006 and, following this decision, the quantity of available used tyres has grown considerably. According to statistics from 1992, in the 12 EU countries, 65% of used tyres are dumped in landfills and only 35% is treated in another way. Ten years later, in 2002, the situation has completely changed. In 15 EU countries, 65% of used tyres are recovered, for energy or material purposes, and less than 35% ended up on landfills. Today in these 15 countries, only 5% of waste tyres are disposed on landfills. Low awareness of the population and lack of regulations contribute to poor waste management in other European countries, where the rate of uncontrolled disposal in the environment amounts to 29% of the total quantity of waste tyres [5].

The amount of rubber tyres disposed in Croatia is roughly 15,000 20,000 tons per year [6]. Landfill disposal of worn mobile tires is drastically reduced due to European Directives and the Regulations on disposal of waste tyres issued by Croatian Ministry of Environmental Protection, Physical Planning and Construction in 2006 [7]. Regulations aimed at establishing a system for the collection of waste tyres for recovered in material and energy purposes and environmental protection. In comparison of recovery for energy purposes, the process of mechanical recycling of used tyres does not create additional waste substances and all the products from mechanical recycling are usable without accompanying "negative emissions in the environment". It follows that mechanical process of recycling waste tyres is far more acceptable to environment and nature.

During mechanical recycling, sieve separates the rubber granules and textile fibres released from the wire by vibrating. Steel wire is separated from recycled rubber granules and textile fibres with magnetic separator, and with the conveyor belt disposed in the container for further processing, while mixture of recycled tyre textile fibres (RTTF) and adhering small rubber particles are transported together to the landfill (Figure 1). During the process of mechanical recycling, two types of fibrous material (TYPE 1 and TYPE 2) are obtained and with screw ribbon transported together to the landfill (mixed RTTF).

a.

b.



c.

Figure 1: Recycled Tyre Textile Fibre: a. landfill of RTTF in recycling yard; b. samples of RTTF Type 1 - contains of a large amount of fine and coarse fractions or rubber granules and c. samples of RTTF Type 2 - contains a large amount of fine fraction of rubber granules

In comparison of recovery for energy purposes, the process of mechanical recycling of used tyres does not create additional waste substances and all the products from mechanical recycling are usable without accompanying "negative emissions in the environment".

Many studies have been conducted on the possible use of rubber from worn mobile tyres in a variety of civil and non-civil engineering projects [8-10]. The most common uses of tire rubber are for the production of electricity, incineration in cement kiln as alternative fuel or for the production of secondary rubber composites. As far as civil engineering works are concerned, many efforts have been made towards production of cement based composites such as concrete, road barriers, kerb units and pedestrian blocks in road construction and other geotechnical works [8-12]. Currently, only 5% of recycled waste tyres are used in the field of civil engineering. Possibilities for their application are much higher and considering that the concrete industry aims to find alternative sources of raw materials, which would reduce the negative impact of the production of concrete components on the environment and preserve natural resources. In a scope of wide investigations at the Faculty of Civil Engineering in Zagreb, rubber granules and recycled steel fibres are used in the cement composites and two innovative concrete products were developed in cooperation with industrial partners [9, 12-15].

2. Experimental part

2.1 Methodology

The use of fibres in brittle matrix materials has a long history going back at least 3500 years when sun-baked bricks reinforced with straw were used to build the 57 m high hill of Aqar Quf near Baghdad [16]. In addition, horsehair was used to reinforce masonry mortar and plaster (ACI Committee 544.1R, 1996). After that, asbestos fibres have been used to reinforce cement products, such as roofing sheets, for about 100 years. However, primarily due to health hazards associated with asbestos fibres, alternate fibre types like acrylic, aramid, carbon, nylon, polyester, polyethylene and polypropylene were introduced for the use in the fibre reinforced concrete throughout the past 40 years.

Having in mind that virgin textile fibres are nowadays widely used for different kind of items (from clothes to space rockets) and that fibres production is limited with natural resources (oil, gas etc.) and environment (farmland and rural areas) it becomes clear that recycled textiles will play important role in further sustainable production of textile raw materials e.g. fibres.

Tyre recycling is globally characterized as one of so-called sustainable development activities that uses used products to make new ones, except in the case of contained textile fibres. In order to overcome this problem and to help major Croatian waste vehicle tire recycling company to close its production loop research activities on possibilities of reclaimed fibres usage as cement reinforce or filler have started.

By industrially performed tyre recycling 80% of rubber granules, 15% of recycled steel fibres and 5% of recycled textile fibres with firmly adhered rubber particles were obtained. According to heats of fusion and crystallization determined by differential scanning calorimetry (DSC), the sample consists of 60 % of PET, 25 % of PA 6.6 and 15 % of PBT with a large contribution of rubber granules and a small contribution of steel fibres [13]. Since in the samples of RTTF there is a large amount of rubber granules, there was a need to develop methodology of fibre isolation (Figure 2). After fibre purification, it was found that sample of RTTF Type 1 consists of 15% purified RTTF, 20% contaminated RTTF with rubber and 65% of rubber particles with very short RTTF.

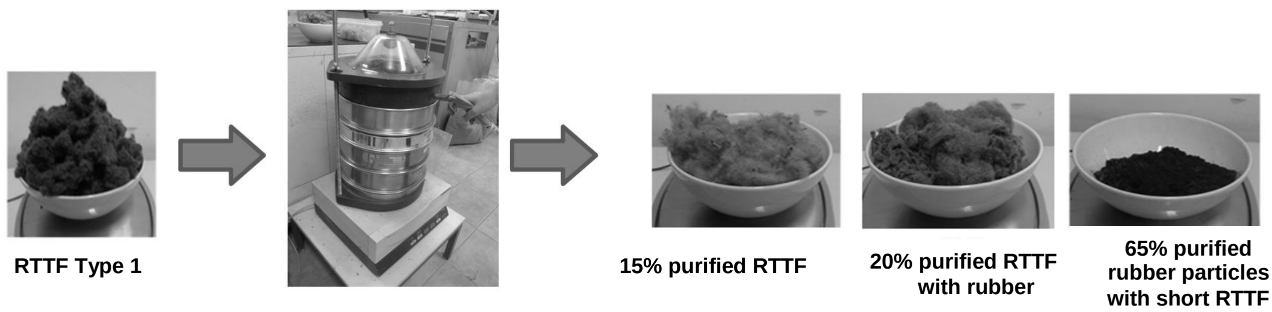


Figure 2: Procedure of RTTF purifying

3. Methods

In order to be able to evaluate usefulness of the obtained textile fibres and their possibilities to replace some virgin textile fibres as concrete reinforcements, objective measurement and evaluation of basic fibre quality parameters are performed (Table 1).

Table1: Methods and procedures used in fibre evaluation

Quality parameter	Test procedure
Raw material content	Microscopically, according to the standard methods for identification of fibres in textiles [17, 18]
Fibre fineness	ISO 137:2015 - determination of fibre diameter by projection microscope method that is suitable for wool fibres in any form and for other fibres of reasonably circular cross-section [19].
Fibre length	ISO 6989:1981 - determination of length and length distribution by measurement of single fibres [20].

4. Results and discussion

Although previously performed tests showed that reclaimed fibres after mechanical recycling of used tyres in Gumiimpex – GRP PLC industrial plant are composed of PES (PET & PBT) and PA 6.6 fibres, new test showed that obtained RTTF have slightly different composition (Figure 3). Such differences in the raw material content of RTTF have their starting point in unknown and not precisely defined types of tyres that are to be recycled in one continuous process, since different tyres (according to their application and producer) have different textile fibres incorporated in them.

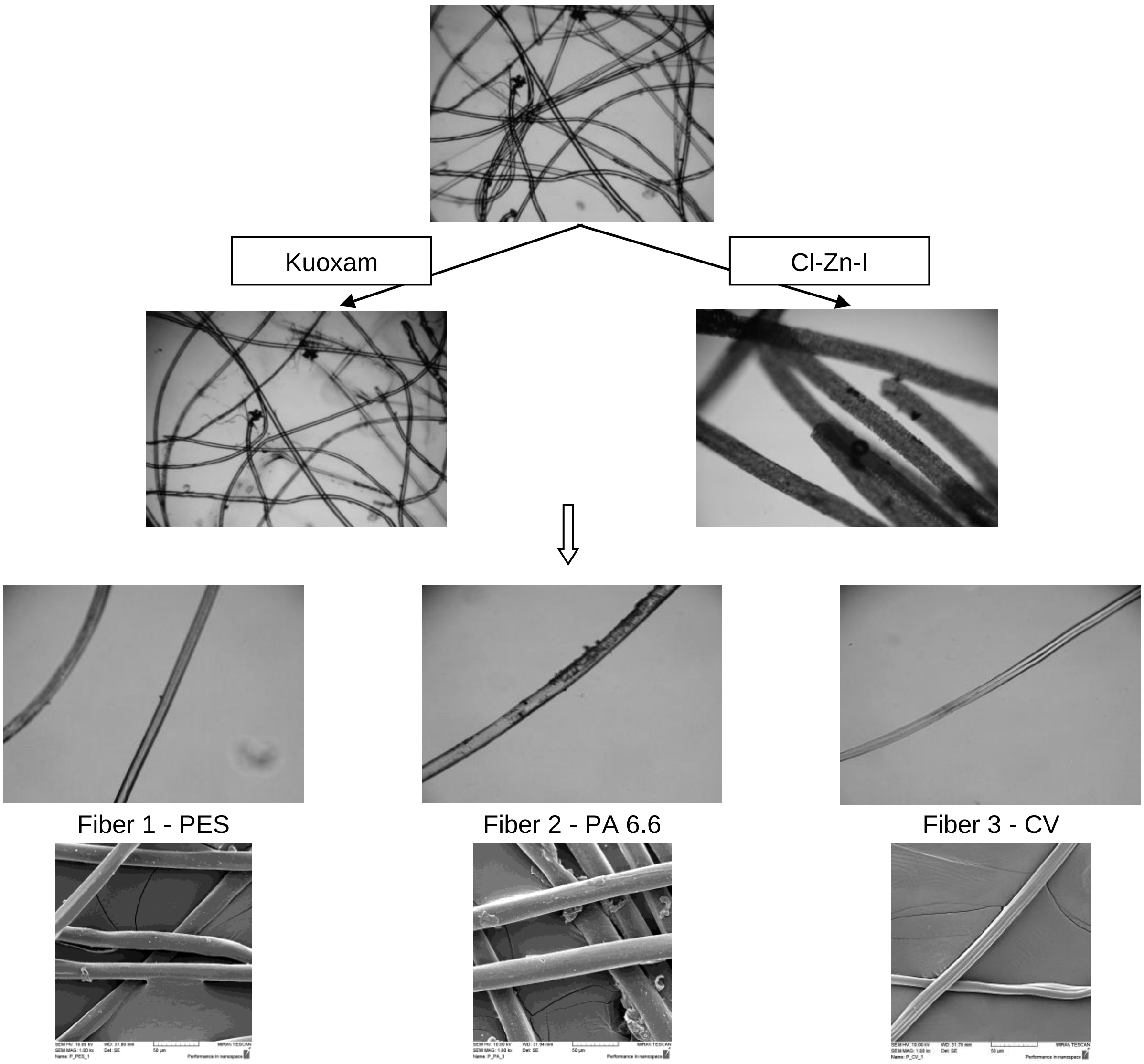


Figure 3: Identification of textile fibres in the sample of RTTF

According to the determined fibre fineness it is obvious that RTTF covers a wide range of fibre`s diameter ranging from 8.0 to 38.0 µm, which is not unexpected since tree different fibres are mixed together, each with its own original variety. Such highly uneven fibrous material will probably pose a difficulty in prediction of its further processing abilities and usefulness as reinforcing fibres. That is why additional fine-tuning of RTTF material might be needed if it is designed for higher demanding purposes. One of such process can be based on fibre density like e.g. de-haring process that is applied on special animal fibres.

Table 2: Fibre fineness

Fineness	Fibre 1 (PES)	Fibre 2 (PA 6.6)	Fibre 3 (CV)
number of performed measurement [-]	500	500	500
minimum [μm]	18.0	26.0	8.0
maximum [μm]	26.0	38.0	18.0
arithmetic mean [μm]	20.2	30.1	12.4
standard deviation [μm]	1.7	2.0	1.8
coefficient of variation [%]	8.4	6.8	14.4
practical error [μm]	±0.15	±0.18	±0.16

Beside fineness, length is another important fibre quality parameter in evaluation of its usability and processability. Based on the results of RTTF fibre length measurement (figure 4) it appears that the majority of fibres in RTTF sample is shorter than required minimal length for further processing in textile yarns. Conferring to this such short staple fibrous material like RTTF might be used in some nonwoven geotextile structures or as a filling fibre.

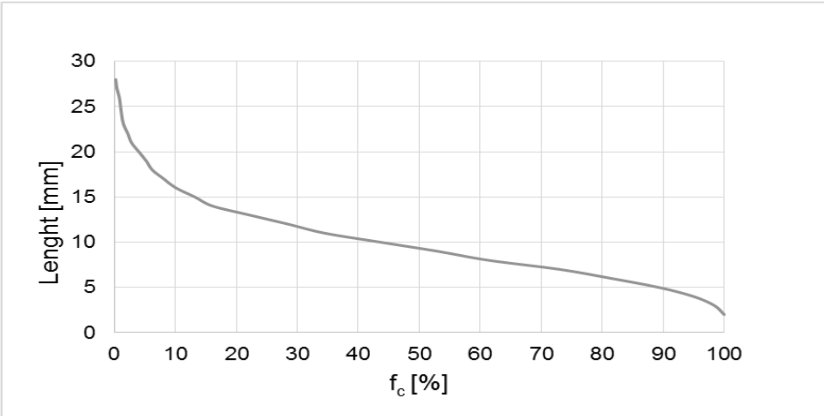


Figure 4: The staple diagram, by number

5. Conclusion

Environmental protection and energy saving are crucial problems in all fields of human activities, especially in production and industry. Sustainable development has become one of the most evident solutions in order to prolong the existence of clean and healthy environment. The 1992 Earth Summit in Rio de Janeiro defined sustainable development as economic activity that is in harmony with the earth's ecosystem [1]. The best way to ensure sustainable development would be to reconcile human needs with the capacity of the planet to cope with the consequences of human activities, or, in other words, to take from the earth as little as possible natural resources and return to the earth as little as possible waste.

As presented research are in scope with previous, it should be continued with work on further purification of RTTF after mechanical recycling of used tyres primarily regarding its composition. Different kind of fibres, and especially when they are reclaimed have different properties like for example moisture content or dimensional stability so, in order to be able to properly define RTTF material quality and usability in designing new 21st century composite material like concrete reinforced with reclaimed textile fibres.

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