22nd International Conference
ENGINEERING MECHANICS 2016
Svratka, Czech Republic, 9 – 12 May 2016

ANALYSIS OF INNOVATIVE METHODS FOR CAR TIRE COMMINUTION

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Abstract: *This paper deals with an analysis of two innovative methods for tire recycling: high pressure method – Waterjet and mechanical method Rotarex Fast&Easy. Both methods have been developed on the basis of earlier patents. In the Waterjet method the particles of rubber separate from the tread by means of high pressure water jets flowing out from a water spray head. The mechanical method is based on milling of blocked tires.*

Keywords: tire recycling, tire comminution, Waterjet method, Rotarex Fast&Easy method

1. Introduction

Although used car tires have always been an ecological issue, currently we are able to cope successfully with it. Legal norms introduced by the European Union have encouraged the member states to start dealing with the problem of used car tire management. According to the available norms, as many as 75% of manufactured tires are supposed to be recycled in some way or another which is the responsibility of the manufacturers. The cheapest way to manage used car tires is the so called energy recovery, that is burning. Contrary to common beliefs it is environment friendly and generates relatively little contamination. It allows to obtain large amounts of heat as its energy value 32 GJ/Mg and is similar to energy value of coal. Burning is carried out in high temperature furnaces, power plants, and paper mills, guaranteeing small pollution. The number of tires which undergo burning accounts approximately for 60-75% of tires intended for recycling. The remaining tires have to be reused in a different way. This is the so called material recycling which involves obtaining rubber granulate from tires.
There are two industrial methods for obtaining granulate from tires: cryogenic and mechanical methods.

Briefly speaking, a cryogenic method involves freezing tires down to temperature equal to -85°C, and then breaking the frozen tire into tiny parts. This technology is being introduced into new companies. Mechanical methods (cost of a company is very expensive) involve comminution of tires as required into granulate with particles of 150 μm do 0,8 mm and more. In order to achieve the final effect it is necessary to perform a few operations of comminution.

The above mentioned operations are accompanied by separation of rubber from wires and textile parts of the tire. The most commonly used method is the mechanical one. The disadvantage of all the mechanical methods is that the granulate contains parts of wire that has not been caught by magnets.

2. New innovative methods for tire comminution

In search of more effective methods for tire utilization, new solutions are being constantly created. The number of patents connected with this area is quite impressive. Unfortunately, most of them will never be analyzed or implemented.

This paper presents two new methods for tire utilization which have been developed at the University of Science and Technology Bydgoszcz and Hydrapress Sp. z o.o. company also from Bydgoszcz. The first water based method is called “Waterjet” solution and it was developed at the University as part of the

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Ministry Development Project. The authors of this paper were involved in this Project. The second method “Rotarex Fast&Easy Method” was developed on the basis of a patent of Hydrapress Sp. z o.o. company, and the authors of this paper belonged to the project team.

2.1. Waterjet method

The authors of this paper started research on tire decomposition by using the high pressure method with application of a patent in 2004 entitled “Tire Utilization Method” and a subsequent patent in 2010. On this basis another patent application has been submitted (Holka&Jarzyna, 2010), whose operation principle is presented in figure 1.

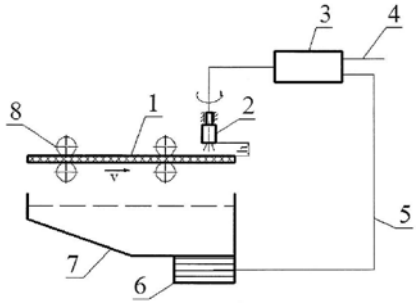

Fig. 1: Scheme of tire utilization by Waterjet method: 1-tire, 2-rotary head, 3-pump, 4-water supply system, 5- technological system for secondary circulation, 6-set of filters , 7-tank, 8- driving rollers

In this method water which after compression is directed to at least one rotary head equipped with at least two nozzles is fed to the respective device, generating high pressure, from where it continuously or cyclically hits the tire surface separating rubber and textile parts from the metal mesh. After removal of rubber and metal parts from a tire, the wastes with water flow down to the tank. Thanks to the secondary circulation the water is resupplied to the pump. Before recycling tires were cut and flattened. During the process a tire moves with v velocity under a water spray head. Velocity of the move and the distance between the head and the tire need to be adjusted to the pump parameters, the type of tire, and the assumed efficiency of the process.

Experimental tests were supposed to find out whether the proposed method can be an alternative for currently used methods (especially mechanical comminution) and how steel wires are separated from the remaining materials of the tire. A special test stand was built to be used for all experimental tests, fig. 2.

Fig. 2: Overall view if the test stand *Fig. 3: A view of a tire after Waterjet method application*

The results of experimental tests after application of single water jets as well as a three nozzle head have confirmed that complete separation of steel wires from the remaining materials is possible, fig. 3.

Another important issue is the size of particles after the process. Relevant measurements were performed with the use of a microscope equipped with an ocular with a scale, calibrated by means of a 1 mm long model and a scale of 0,01 mm. The measurement was made using x80 zoom. Specimens were random taken from comminuted rubber and maximum sizes of particles were determined for each view. A division row was developed on the basis of this population which was featured by variability range (difference in measurement results) $R=a_{max}-a_{min}=688,2+9,3=688,2$ µm and arithmetic mean of measurement results $\bar{a}=146$ µm. Moreover, the average square deviation was determined for s=139,8 µm as well as a mean error of the mean value $\bar{s}=8,82\,\mu m$.Value ranges for n=251 of measurements, for probability value level p=0,95 were $131,91<E(a)<160,95\,\mu m$. In figure 4 there is a histogram of the division row of rubber particles (Holka&Jarzyna, 2011).

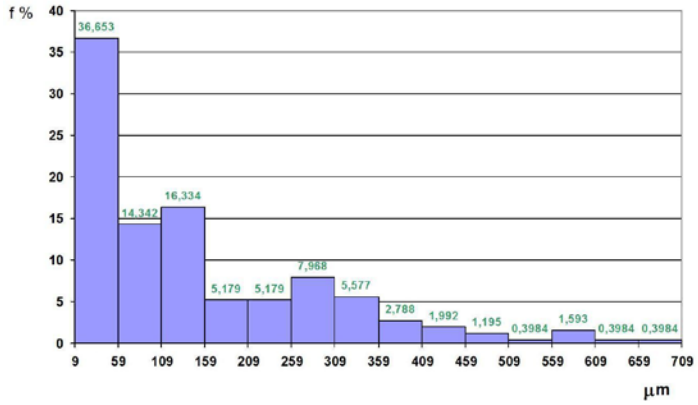

Fig. 4: Histogram of the division row of rubber particle dimensions (non-modal row)

Fig. 5: Overall view of a three nozzle spray head

The water spray head is an important element of the test stand, fig. 5. The head consists of three nozzles mounted at certain angles. A proper choice of nozzles facilitates penetration of the jet into the rubber turning the head simultaneously. Thus, the nozzles shift by translational and rotary motion leaving the wires clean.

Conclusions for Waterjet method

a) The tests have revealed that the method can be used in industrial conditions as an alternative for mechanical comminution methods.

b) Application of high pressure water jets (min. 200 MPa), enables total separation of steel wires from the remaining materials. The obtained rubber is characterized by high degree of disintegration and does not contain wires.

c) Utilization of a bigger number of spray nozzles allows simultaneous treatment of a tire throughout its width.

d) Due to small dimensions of the device and its mobility it can be used it in tire collection points.

2.2. Rotarex Fast&Easy method

This technology uses a tool for milling in the form of a special quick rotating head patented by a company from Jarocin: RBB-STAL SA, (P.392203, 2010 (fig. 6).

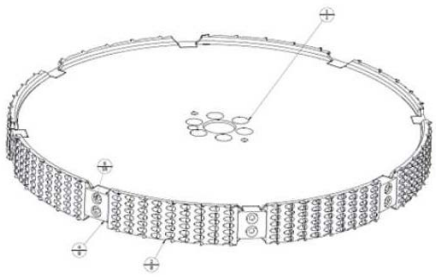

Fig. 6: Milling head (Holka&Wełnowski, 2012)

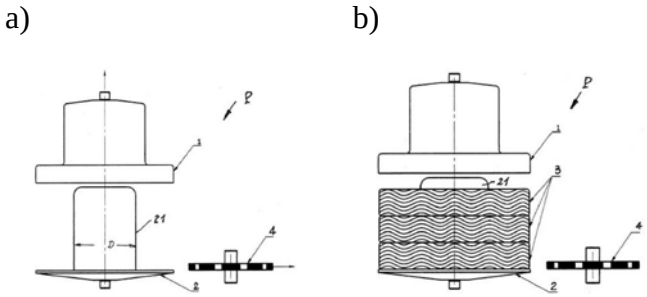

Fig. 7: Device for tire recycling: a) device without tires, b) device with tires; 1-upper plate of the press , 2-lower table of the press, 3-tires, 4 – machining disk , 21 – guiding roll, P - press (Wełnowski, 2012)

Being in possession of a good milling tool, engineers from Hydrapress Sp. z o.o. company applied for a patent entitled (Wełnowski, 2012). The scheme of the device operation is presented in fig. 7. Comminution of tires by the presented method involves compression of tires stapled between the upper and the lower plate of the press (fig. 7b) in a special device (fig. 7a). The tires compressed to a given degree are set into rotary motion by means of the upper and lower plate sets. They are exposed to a

rotating machining disk until complete disintegration of the compressed tires. The disk of the tool is fixed proportionally and is slidingly in relation to the upper and lower rotary axes of the plates. A guiding roll with a conical end protrudes from the lower plate (Wełnowski, 2012).

Patent description contains the idea of the machine operation. The real machine is somewhat different than the description, fig. 8.

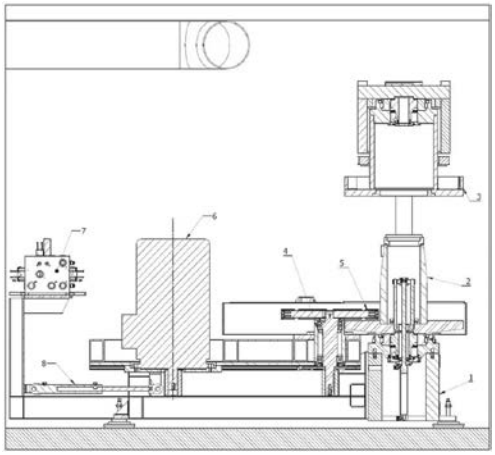

Fig. 8: Machine for mechanical tire recycling ; 1-body, 2-table with an arbor , 3-press bed, 4-spindle , 5-millig disk , 6-motor , 7- hydraulic block, 8-press actuator (Holka&Wełnowski, 2012)

In the considered method the height of compressed tires is equal to the height of the mill and machining can be performed concurrently and backwardly. Tests are being performed in order to determine optimal parameters of the machining. One of the most important issue will be to determine the obtained granulate size in the function of the tire and mill rotation and in the function of the feed.

The considered machine is a mechatronic one which combines numerous innovative technological solutions in the field of mechanics, hydraulics, pneumatics, electronic control, ergonomics and OHS. Its spindle and drive plates are powered electrically and hydraulically with smooth control of pressure force, compressing module and feed of the whole spindle. It is characterized by the following technical parameters: arrangement of operation: vertical, operation modes: manual, automatic, CNC control: controller FACET (Holka&Wełnowski, 2012).

3. Conclusions

1. It should be noted that the companies which deal with traditional recycling are stationary ones due to big size of their equipment. Thus they have one big disadvantage. If their efficiency is high the surrounding area soon becomes devoid of tires and in order to maintain continuity of production the tires have to be supplied from more and more distant places which has a negative impact on the company profits. Waterjet machines and Rotarex Fast&Easy are relatively small which makes them easy to transport. A complete device Rotarex Fast&Easy with the whole tooling can be placed in a portable container.

2. Waterjet method produces rubber particles which are free from contamination with metal. Besides, like in the Fast&Easy method it is a mobile system, that is, due to its small size it can be transported to a given location or increase the company efficiency through installation of a new station.

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