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METODE RECIKLAŽE OTPADNIH PNEUMATIKA U BOSNI I HERCEGOVINI I OKRUŽENJU

METHODS OF WASTE TIRE RECYCLING IN BOSNIA AND HERZEGOVINA AND IN THE REGION

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Stručni članak

Sažetak: *Tematski obrađena materija ovog rada imala je za cilj postaknuti javnost, faktore odlučivanja na nivou Bosne i Hercegovine o nužnosti primjene standarda i metoda s aspekta zbrinjavanja otpadnih pneumatika, a samim tim upoznati sudionike ovog projekta o načinima, metodama i mogućnostima zbrinjavanja otpadnih pneumatika. U ovom radu dat je akcenat na reciklažu kao ekološki prihvatljiv način zbrinjavanja ove vrste otpada.*

Ključne riječi: *granulat, otpad, otpadni pneumatici, reciklaža*

Professional paper

Abstract: *The purpose of this paper is to encourage the public and decision-makers at the level of Bosnia and Herzegovina to consider the necessity of applying standards and methods from the standpoint of waste tire disposal, and to familiarize participants of this project with the ways, methods and possibilities of waste tire disposal. This paper focuses on recycling as an ecologically acceptable way of disposing this kind of waste.*

Key words: *granules, waste, waste tires, recycling*

1. INTRODUCTION

Rapid industrial development directly influences the existence of large amounts of waste, which obliges every developing country to set up the optimal strategy for waste management.

The framework for the European policy for waste management is contained in the resolution of the EU Council pertaining to the Strategy for Waste Management (97/C76/01) that is based on the formerly valid framework Waste Directive (75/442/EEC) and other European regulations in the area of waste management.

There are three key European principles:

- Prevention of waste formation – for the purpose of preserving nature and resources waste formation must be minimized and avoided wherever possible,
- Recycling and reusage – if waste formation cannot be prevented, it should be reused or recycled or used in the energy recovery process,
- Improvement of the final disposal and monitoring – in cases when waste cannot be reused, it should be treated and adequately disposed or burnt. Both of these methods require monitoring due to them potentially causing hazardous environmental damage.

2. PROCESS OF RUBBER FORMATION

Materials that at room temperature and subjected to ductility strain may at least double their length without remaining deformations upon the strain are defined as elastomers. Such materials are very often defined using the term rubber. The most important property of these materials is a high level of elasticity. In order for a material to be highly elastic, intermolecular bonds must not be too strong and crystallites must not be formed.

Properties of elastomers depend on:

- properties of the main polymer chains,
- intermolecular bonds between polymer chains and
- the amount of covalent bonds of polymer chain atoms.

In the production of elastomers we differ between obtaining rubber from natural rubber in vulcanization process and from synthetic rubber.

Natural rubber may be found in nature in the colloid of the rubber tree. In the vulcanization process that is carried out under pressure at the temperature of 150°C, the properties of natural rubber adapt to the needs of increased strength and elasticity.

Synthetic rubber has found its usage after the Second World War and today its properties are as good as the ones of the natural rubber. Raw materials for the

production of synthetic rubber are coal, limestone, potatoes and crude oil.

According to the application, several groups of products obtained by elastomer processing may be distinguished:

- Tires (road and professional vehicles, bicycles, motorcycles etc.),
- Technical products (panels, seals, pipes, profiles, insulators etc.),
- Other products (footwear, office and school supplies, medical equipment, sports equipment etc.).

3. RUBBER PRODUCTS

The production and sales of rubber products in the world have experienced a mild increase in the last couple of years. In the period between 2004 and 2008 annual increase amounting to 6.7 % may be observed [1].

As the production of new tire products increases, the amount of worn tire products increases as well. Such products represent a specific kind of waste.

It is estimated that in the EU countries around 250,000,000 waste tires accumulate every year, while in the Eastern Europe, North America, South America, Asia and in the Middle East the annual amount equals around 1,000,000,000. Over the years additional amounts of tires are added to these numbers, billions of which are stored or buried at landfills, and uncountable millions found in illegal locations, warehouses and fields around the world, which is shown in Figure 1 [2].

It is estimated that in Bosnia and Herzegovina 13 to 17 thousand tons of worn tires of various sorts accumulate every year.

Waste tires may easily be collected, processed and a new value may be created from them. Tires may be a significant alternative material in the production of certain new rubber products and in obtaining various forms of energy.

Figure 1. Waste tires

Developed countries apply Waste Management Strategies in order to define various methods of tire disposal.

The most frequently applied methods in the EU countries are:

- mechanical recycling (cryogenic crushing, mechanical crushing etc.),
- thermal recycling (incineration in blast furnaces, cement factories etc.),
- chemical recycling (pyrolysis).

New values obtained by recycling of tires are often used as valuable raw materials and their usage contributes to sustainable development [3].

Bosnia and Herzegovina today has two factories dealing with waste tires, one of which applies the process of mechanical recycling, and the other one with the process of chemical recycling. Although there are still no regulations on managing this sort of waste, Bosnia and Herzegovina has a strategy at the level of its entities based on which this sort of waste is defined.

4. MECHANICAL RECYCLING OF WASTE TIRES

Mechanical recycling of waste tires is a procedure that allows for the separation of components from tires in an environmentally-friendly manner. In this process rubber is separated in the way that 60 % refers to rubber granules, 35 % to steel wires and 5 % to canvas, whereat the environment suffers no harmful effects [4].

According to the applied technology and the temperature of the mechanical crushing process, two basic crushing methods may be differentiated:

- cryogenic crushing and
- mechanical crushing.

Currently in Europe and therefore also in our region the process of mechanical crushing is most widely applied.

Figure 2 shows the structure of a classical tire.

Figure 2. Tire structure

4.1. Recycling of waste tires by cryogenic crushing

In the process of cryogenic crushing the tire is first frozen by using liquid nitrogen to reach the temperature between -80 °C and -100°C. At this temperature rubber becomes so brittle that it may relatively easily be cut at

the cutting plant. It is even easier to separate textile and metal parts from the rubber ones. Disadvantage of this process are high energy demands, manipulation problems and relatively high costs. The output product (granules) has a high production price and, along with this, the main properties of rubber are altered.

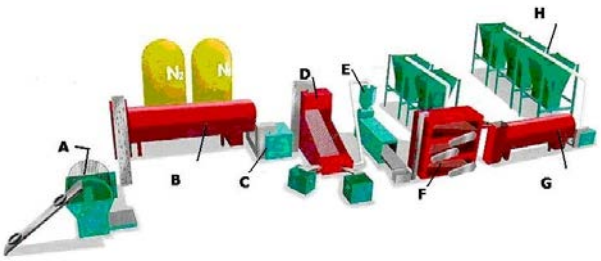

Figure 3. System of cryogenic tire recycling

A schematic representation of cryogenic waste tire recycling is shown in Figure 3. In this process tires are crushed in the crusher (A) up to the size of around 50 mm and transported to the cooling tunnel (B), where they are cooled by liquid nitrogen. In the mill (C) fractions are reduced from 0.4 mm to 0.6 mm, and at the mill exit steel, textile and dust particles (D) are removed.

Thereafter the granules are dried (E) and separated according to the grain size (F). The process continues with secondary crushing (G) and storing of granules (H) [3].

4.2. Recycling of waste tires by applying the mechanical crushing method

The process of mechanical crushing is carried out at the external temperature. In this way structure homogeneity and process stability are assured. Working temperature is achieved by internal friction in mills.

There is a difference between granules of tires for passenger cars and the ones for freight vehicles. In freight vehicle tires, steel threads may have diameter up to 8 mm, so it is necessary to remove them previously in order to prolong the life span of cutters and the whole crushing line. Steel threads are removed by cutting the tires along their length.

Upon removing steel threads tires are put into the machine – crusher with toothed cylinders moving in opposite directions, where they are crushed to small pieces with dimensions of 4 x 5 cm, as shown in Figure 4.

Figure 4. Toothed cylinders

The main products of mechanical processing are rubber granules of various fraction sizes, rubber dust, cut out steel wire and textile [2].

A schematic representation of the mechanical recycling of tires is shown in Figure 5.

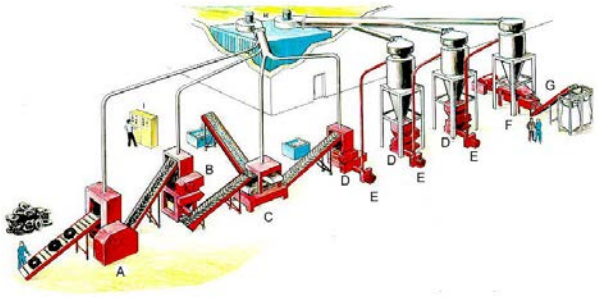

Figure 5. System of mechanical recycling of waste tires

Input crusher (A) chops up the material. Granulator (B) fragments rubber pieces and provides for total separation of mixed material, so steel and textile are sucked out by exhausters (H), i.e. over a magnetic line (C). Further process involves milling for obtaining the desired size of granules (D) [5].

5. RECYCLING TIRES BY APPLYING THE PYROLYSIS PROCEDURE

Pyrolysis is based on thermal separation of molecules with bonds between carbon and hydrogen being preserved [3].

Processes are carried out at higher temperatures in the reactor and in vacuum.

Certain ingredients are separated by condensation, while others are obtained by physical-chemical processes. The quality and amount of output products depend on the type of technology and pyrolysis conditions. Chopped up waste tires in rotational circular furnaces (reactors) are transformed into gases influenced by high temperatures and in vacuum. Gas produced in this manner is transferred to the next system part, where solid fractions are separated. The gas gradually cools, pressure is altered and it transforms into a liquid. Pyrolytic gas that is created in this process is used as source of thermal energy and, in the case of realizing a cogeneration unit, as a source of electrical energy, so the plant practically produces a certain amount of required energy by itself [6].

Along with pyrolytic gas, significant products are ashes, pyrolytic oil, heavy oils, alkane-containing oils, benzene-containing oils, metal and steel swarf.

Rubber waste is a raw material with a high content of carbon. During pyrolysis rubber degrades to simpler carbohydrates with simples bonds and inorganic matter. Cooling of the gas leads to the condensation of the liquid that has the following properties:

- light oil that may be used as heating oil or diesel fuel,
- medium oil with properties suitable for producing lubricants, and
- heavy oil for producing carbon fibers.

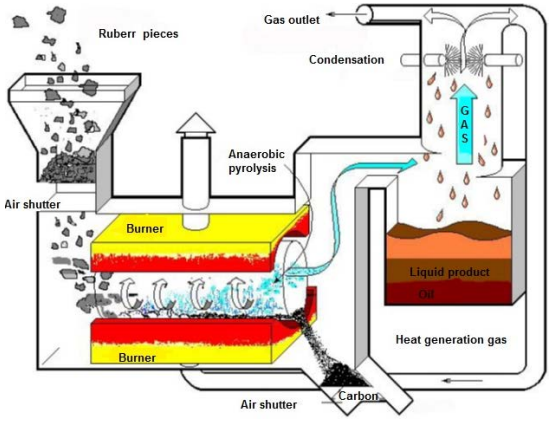

Figure 6. Pyrolysis procedure

Fragmented waste tires in reactors transform in gaseous state influenced by high temperature and without the presence of air. The gas obtained in this way transfers into the next part of the operative system, where solid matter is separated. The gas gradually cools, the pressure is altered and it transforms into a liquid [7]. The pyrolysis process is shown in Figure 6.

In the following figure a schematic representation of the pyrolysis process at the company SGI d.o.o. Sarajevo is shown.

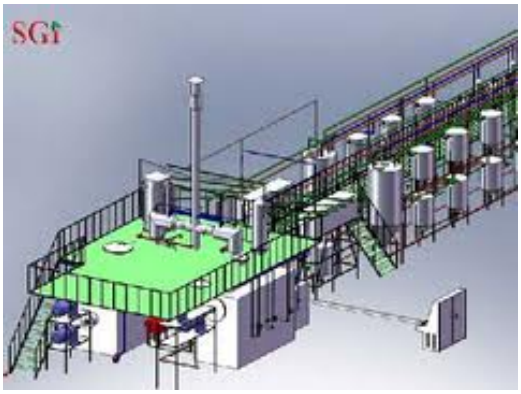

Figure 7. Production layout at the plant SGI d.o.o. Sarajevo

6. EXAMPLES OF RECYCLING IN THE NEIGHBOURING COUNTRIES AND IN BOSNIA AND HERZEGOVINA

There are no accurate data regarding the amount of rubber waste, which primarily involves waste tires, in the Republic of Serbia. It is estimated that it amounts up to 30,000 tons per year, based on the information on the amount of vehicles in the Republic of Serbia. A certain amount of waste tires, around 7,000 tons ends up at the cement factory "Holcim Srbija" in Novi Popovac in the vicinity of Paraćin, where they are used as alternative fuel. The company ECO – Recycling from Novi Sad is one of the largest processing facilities of waste tires in the Republic of Serbia. With its expanded capacities it can process up to 46,000 tons per year. Figure 8 represents a part of the plant at the factory ECO – Recycling doo Novi Sad.

Figure 8. Recycling plant Novi Sad

In the Republic of Croatia systematic disposal of waste tires is carried out according to the Regulations of the Ministry of the Republic of Croatia, which refers to the whole system, starting from collecting and transporting to recycling tires. Today there are around 30,000 tons of waste tires in the Republic of Croatia.

The concession for the disposal of this sort of waste is held by several companies, and the disposal is carried out by incineration at the cement factory (up to 7,000 tons per year), while the largest part of processed by Gumiimpex d.o.o. Varaždin in the process of mechanical recycling, Figure 9.

Figure 9. Plants Gumiimpex d.o.o. Varaždin

In Bosnia and Herzegovina the amounts equal between 13,000 and 17,000 tons per year with the increase of up to 50 % for the amounts that have accrued at illegal landfills in the last ten years.

In Bosnia and Herzegovina environment and ecology are constitutionally governed by entities, which makes the functioning itself more complex. The Ministry of Environment and Ecology of Bosnia and Herzegovina passed the Strategy on Waste Disposal and Management 2012 – 2017, by which it defined relevant parameters and guidelines for waste management. It is expected that additional regulations are to be passed soon, which would define the management of waste accrued due to waste tires.

In the meantime in Bosnia and Herzegovina two plants for the disposal of waste tires have been opened, one of which at the recycling plant using the pyrolysis procedure for obtaining of fuel at the company SGI d.o.o. Sarajevo, and the second at the mechanical recycling plant of the company OS Petrol d.o.o. Srebrenik with the capacity amounting up to 100 tons a day.

Figure 10. The plant SGI d.o.o. Sarajevo

7. APPLICATION OF PRODUCTS OBTAINED BY RECYCLING

Thanks to contemporary modern technologies that have developed in the last ten years in the area of recycling waste tires, and primarily thanks to technologies for mechanical recycling of waste tires, there is a wide range of application of recycled rubber products.

In industrial production the greatest application is the one of rubber granules of various fractions, as shown in Figure 11.

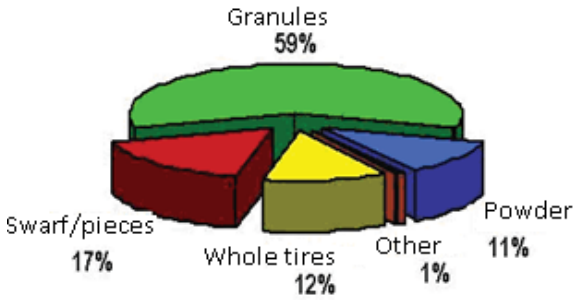

Figure 11. Content of fractions in recycling

The resulting products can be used in industry for the manufacturing of floor coverings, floors of sports fields, children's playgrounds, barn floors, warehouses etc. In the construction industry rubber granules have wide application in the production of sound and insulating barriers, in civil engineering they represent a quality admixture to asphalt and concrete in order to improve their properties.

First of all it is important to emphasize that the usage of recycled products leads to satisfying the conditions of alternative energy sources, i.e. the recycling of waste tires represents renewable sources, whereby new value is created.

Rubber granules, as the most important product of mechanical recycling today, is produced in several fractions, which affects its further application, so there are:

- GG 00 05, refers to granules sized from 0.0 to 0.5 mm, which represents the rubber powder that is widely used in the footwear industry, sports equipment, insulation material for coating cables, automotive parts, pigments, inks, porous asphalt binder materials, coatings and sealants.

Figure 12. Rubber granules 00 05

- GG 05 20, refers to granules sized from 0.5 to 2.0 mm, which represents rubber granules which are widely used in the production of barn floors, floor tiles, roofs, floors of sports fields, rubber asphalt, speed bumps etc.

Figure 13. Rubber granules 05 20

- GG 20 35, refers to granules sized from 2.0 to 3.5 mm, which represents rubber granules which are widely used in the construction industry as light fills in general civil engineering, drainage systems, construction of sidewalks, construction and maintenance of landfills, pillars for supporting bridges and agricultural products.

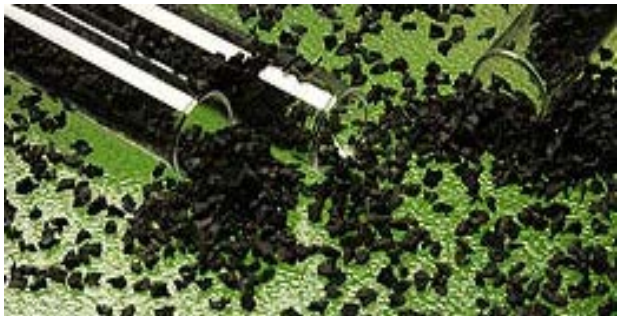

Figure 14. Rubber granules 20 35

- GB xx xx, is available in various sizes and is obtained from mechanically shredded tires, which are split into unequal parts sized from 5 to 300 mm, and the most common applications are in the construction of embankments, drainage systems, thermal insulation, sound barriers, landfill construction, temporary roads, etc.

Figure 15. Rubber granules xx xx

It may be concluded that due to physical properties of the tire, such as non-toxicity, biodegradability, shape, mass and elasticity, waste tires are classified in a wide range of potential applicants for the formation of a new product, which meets the requirements of sustainability.

8. CONCLUSION

Non-selective disposal of used car tires and generally used products made of rubber to sanitary landfills, or in the worst case, to illegal landfills represents a serious problem for human health and for the safety of the environment. It is estimated that in developed countries one waste tire per capita is produced each year, with the tendency of growth. At recycling centers, whether applying mechanical recycling by crushing or by pyrolysis, it is possible to recycle worn tires in an environmentally-friendly way, by means of which new value is created, and the ecological aspect of disposing this kind of waste is not raised as question at the same time.

In the EU there have existed legal regulations for a long time, which regulate the way and procedures related to the disposal of waste tires. In Bosnia and Herzegovina legal documents for regulating this area are in the finalization process.

The pyrolysis process for this type of waste is very effective and that in the combination with recycling plastics it constitutes a compact system that, using a simple line, has a capacity of about 10,000 tons of plastic and tires annually, while on the other hand there is mechanical crushing which has a much greater capacity.

In Bosnia and Herzegovina the two plants were self-initiated without regulations that would regulate this area. Without regulations and ordinances governed by ministries at the entity level, it is very difficult to believe that these plants are cost-effective and efficient. This reflects primarily in the high prices of equipment, transport systems to recycling centers, waste collection and sorting system on the one hand, and the prices of the products obtained on the other hand.

The financial supplement to recycling production is complemented by environmental taxes paid by citizens as ultimate consumers of each product. A positive example of such functioning is present in the Republic of Croatia, where precise legislation governs the area, accompanied by regulations and concessionaires in this area, whereby ecological tax is regulated for each new tire that is produced in or imported to the Republic of Croatia, as well as for its management, which ultimately represents an incentive both for the Concessionaire carrying out the recycling, as well as for the authorized collector and the authorized transporter. In Bosnia and Herzegovina a more serious approach to this problem is required with the aim to develop awareness among citizens about the problem of waste disposal, but also to encourage the implementation of economic programs for the establishment of a company for organized collection of waste tires that would be handed over to authorized recycling centers.

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