Environmental Considerations of Recycling Polymer and Other Industrial Waste and By-Products

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Abstract

The paper discusses the importance of solving global environmental problems and the ways to improve environmental situation in industrial cities. Recycling and reusing waste generated by various industries is shown to be one of the prospective lines of activities in this respect. The feasibility of using food industry waste as raw materials to synthesize targeted additives for elastomers, which will increase environmental safety of finished rubber goods, is described. The paper shows a prospective way of recycling secondary polymer materials – petrochemical and light industry by-products and waste – into multifunctional additives for rubber products. Oligomers synthesized from petrochemical by-products and waste are suggested to be used as interface coupling agents. An effective method of emulsion rubber modification with multifunctional additives was developed, comprising introduction thereof at the stage of rubber recovery from latex. Particular aspects of the fibre-oligomer additive influence on producing elastomer compositions are determined. Application thereof is found to provide higher performance and environmental safety of emulsion rubber process and also manufacture of vulcanizates with improved properties.

Keywords: ecology, recycling, secondary polymer materials, petrochemical by-products, textile and fat-and-oil industry waste, oligomers, fibrous additives, emulsion rubbers, composites.

INTRODUCTION

At the turn of the new millennium, mankind faced such environmental problems that cannot be solved within an individual state and only joint efforts of the world community can improve the situation. Apart from worsening the quality of life, environment pollution is harmful for human health, particularly for those people who live in large metropolitan areas. Global environmental problems force mankind to reconsider their attitude to the issues of environment protection and management of natural resources. Anthropogenic pollution of the geosphere leads to a disturbance of equilibrium in ecosystems, adversely affects human health resulting in the development of eco-pathologies, particularly in urban residents [1].

For the city of Voronezh, which is one of the fifteen Russian cities with a population of over one million and a major industrial centre, recycling and reusing waste is a pressing environmental problem.

Official data on generation, reuse, treatment, and disposal of industrial and municipal waste in the Russian Federation indicate year-on-year increase in the amount of generated waste and low level of reuse. Hence, there is a big loss of raw materials and utilities and, most importantly, high environment pollution, alienation of considerable areas for landfills, dumps, and other waste disposal facilities. One of the top priorities is to solve the problem of waste recycling. This would both reduce the impact on the biosphere and provide an additional source of goods or energy. Environmental pollution hazards can be reduced by maximizing production recycling of waste. In each region of Russia, there is a certain group of industrial and municipal waste that causes typical environmental problems.

For example, in food industry, vegetable oil refining process is accompanied by generation of high-volume wastes: soapstock, spent diatomite filter powders, bentonite bleaching clays, physical deodorization overheads, deactivated vegetable oil hydrogenation catalysts. These by-products contain various fatty acid derivatives. These types of waste are mainly disposed of to solid waste landfills, which is inefficient both economically and environmentally, since their fatty portions are a valuable raw material for other industries [2]. Fatty wastes are widely used in many countries for the production of mixed fodders for agricultural animals and birds. They are
a source of fatty components, biologically active compounds, and micronutrients, which enables addition thereof to the compound feed formula for laying hens. In European countries such products, due to their relatively high energy intensity, are used as fuel at cement and brick factories. Moreover, the technology of compost production (compound fertilizer) involves the addition of fatty products to plant waste. Another promising direction of fat-and-oil industry waste processing is recycling as raw materials for the synthesis of targeted additives to elastomers, the use of which will increase environmental safety of finished rubber goods [3].

Currently, petro-chemistry is one of the high-volume industries. Crude oil refining and further use of its products in the production of polymer materials lead to generation and accumulation of significant amounts of by-products and waste [4]. Light industry enterprises also generate considerable amounts of textile waste. Petrochemical by-products and textile waste are secondary polymer materials that may contain valuable ingredients. Application of fibrous additives in composites is interesting because their raw material base is almost unlimited. Waste fibres and fibrous materials are formed at various process stages and during their further use. Therefore, it is an important task to look for the most prospective ways of using textile waste generated by light industry enterprises and spent fibre-containing products [5]. Also, technologies based some petrochemical waste have been commercialized to produce oligomers that readily substitute expensive film-forming products in coating compositions and other composites. A promising direction in this respect is the one that will provide an integrated approach to addressing the issue of combined usage of oligomers made on the basis of petrochemical by-products and fibrous material waste to produce multifunctional additives used in the production of rubber goods. Such an integrated approach to processing of these wastes will both optimize waste management and reduce the environmental pressure.

The objective of the study is to recycle secondary polymer materials – various industrial waste – into multifunctional additives and investigation of their potential applications in synthetic rubber manufacturing.

MATERIALS AND METHODS

Commercial SKS-30 ARK styrene-butadiene emulsion rubber latex was chosen as a subject matter of the research. Unmodified styrene-containing oligomer (SCO) synthesized from polybutadiene process by-products and maleic anhydride-modified SCO (MA SCO) were used in the research. Cotton and capron (nylon-6) fibres with a length of 2-10 mm were used as a fibrous additive.

In reference [6], production of composite materials by introduction of fibrous additives into emulsion rubber matrix is reported. However, the studies of the fibrous additive effect on the resulting vulcanize properties suggest that these can be improved through the use of additives with interface coupling agents. On the other hand, studies [7] demonstrated the feasibility of obtaining a time-stable aqueous oligomer-antioxidant dispersion (OAD) based on unmodified and modified SCO. This was the basis for using them as interface coupling agents.

In paper [8] various methods of coupling unmodified and modified SCOs and fibrous additive with emulsion rubber matrix are presented. An effective method was chosen, consisting in pretreatment of fibrous additive with an oligomer at an elevated temperature, followed by the addition of antioxidant, and preparation of aqueous fibre-oligomer-antioxidant dispersion based on the mixture thus produced, and also its further use for emulsion rubber latex coagulation.

This technique of introducing the fibre-oligomer additive (FOA) based on SCO and MA SCO in combination with capron and cotton fibres into latex was used in further studies to produce filled polymer composites based on the emulsion rubber under consideration. For this purpose, FOA was mixed with emulsion rubber latex, and the resulting mixture was coagulated according to a conventional procedure [9] using a 10% by weight aqueous magnesium chloride solution as a coagulating agent and a 1.0-2.0% by weight aqueous sulfuric acid solution as an acidifying agent. Coagulation was carried out at the temperature of 60-65 °C. The resulting rubber crumb was separated from the aqueous phase, washed with warm water, and dehydrated in a drying oven at a temperature of 75-80 °C to a stable mass loss value. The content of oligomers in rubber matrix was maintained at: 20; 40 and 60 kg/tonne rubber; fibrous additives – 5 kg/tonne rubber; antioxidants – according to generally accepted requirements.

RESULTS AND DISCUSSION

Analysis of experimental data showed that additional use of FOA had a positive effect on the process of rubber recovery from latex and lead to a higher rubber crumb yield. This may be attributed both to the additional amount of unmodified and modified SCO and fibrous additives in the produced rubber crumb and to lower rubber loss as fines. At the same time, the additives are fully distributed in the polymer matrix and are not observed in the wastewater. The best distribution of fibrous additive was observed when it was added in combination with MA SCO in the amount of 20-40 kg/tonne rubber. This effect is due to certain physical and chemical processes that take place when cotton fibre is treated with MA SCO oligomer at higher temperatures (100-160 °C), where maleic anhydride reactive groups can react with cellulose to form esters (Fig. 1).
In this case, MA SCO plays the role of an interface coupling agent and enhances adhesion between the fibrous additive and rubber matrix. In the production of emulsion rubbers, antioxidant loss amounts to 30-35%. It was found that introduction of antioxidant in rubber as a component of FOA composition results in a 1.5-fold lower antioxidant loss, which allows fuller and more efficient use of expensive raw materials. Lower antioxidant loss is also confirmed by a higher thermo-oxidative aging resistance of elastomer compositions (Figure 2, a), with all other parameters being maintaining in conformance with the Technical Specifications (TU) requirements (Table 1).
The use of oligomers as interface coupling agents for nonpolar rubber matrix and fibre leads to higher tear strength and dynamic tensile strength of elastomer compositions obtained from emulsion rubber containing multifunctional additives (Fig. 2 b, c).
Table 1: Effect of FOA composition on the properties of rubbers and vulcanizates based on SKS-30 ARK rubber

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SKS-30 ARK TU 38-40355-99</th>
<th>Type of additive (fibre content 5 kg/tonne rubber, FOA 40 kg/tonne rubber)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No additive</td>
<td>OAD</td>
</tr>
<tr>
<td>Mooney viscosity MB 1+4</td>
<td>51±5</td>
<td>55</td>
</tr>
<tr>
<td>(100°C) - rubber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modulus at 300 % elongation, MPa</td>
<td>13.0 min.</td>
<td>13.6</td>
</tr>
<tr>
<td>Tensile strength, MPa</td>
<td>22.0 min.</td>
<td>24.1</td>
</tr>
<tr>
<td>Elongation at break, %</td>
<td>420 min.</td>
<td>520</td>
</tr>
</tbody>
</table>

CONCLUSION

Thus, based on the research carried out, the following conclusions can be drawn:

- At present, prevention and reduction of waste generation are the most pressing tasks. These challenges can be addresses both by the introduction and application of low-waste and resource efficient technologies and equipment and by the use of waste through processing, regeneration, recovery, and recycling, thus reducing their quantities and producing goods and also improving the environment and, hence, increasing the public health level;

- Petrochemical and textile waste and by-products are promising raw materials for manufacturing multifunctional additives used in emulsion rubber technology, which can be further applied for the manufacture of engineering products.

- The use of multifunctional additives obtained on the basis of secondary polymer materials provides both higher process efficiency when producing elastomer compositions and vulcanizates with improved properties and also lower environment pressure.

REFERENCES


