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Cite as: AIP Conference Proceedings **2430**, 090011 (2022); https://doi.org/10.1063/5.0078044
Published Online: 24 January 2022

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Technology of Obtaining Fiber-Filled Shoe Soles

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Abstract. The article discusses the production of fiber-filled shoe soles on the basis of production waste. Resolved: composition and technology have been developed; the study of properties and quality assessment were carried out. In this work, to study the properties of materials, the method of microscopy, methods of studying the physical-mechanical and operational properties were used. As a result of industrial tests, samples of soles were obtained and their properties were tested. Analysis of the data obtained showed that fiber-filled shoe soles have some of the best properties. The area of use of the results is the shoe industry.

INTRODUCTION

Since ancient times, the main material for the sole of shoes was leather, but now its specific weight among the materials of this group is small and significantly inferior to various polymer materials. However, it is impossible to completely displace this material.

In this regard, in the shoe industry, a type of rubber with increased plasticity, made on the basis of rubber with a high content of styrene (up to 80%), is used as a substitute for leather. This type of rubber includes leather-like rubber. This material is similar in properties to natural leather in hardness, thickness, elasticity, but has a higher abrasion resistance, water resistance and significantly better technological properties.

Leather-like materials include all materials with a filler made of fibers that are used for the production of soles. The technology for their production is trivial and is based on the technology for producing rubbers. The technological process of such production consists of the operations shown in Figure 1. Thus, materials of the "relac" type are obtained.

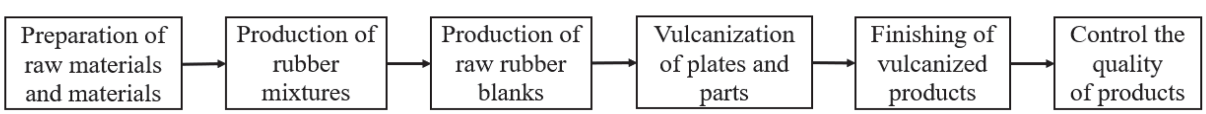

FIGURE 1. Technology for producing leather-like rubbers

The composition of the rubber mixture includes: powdered and resin-like substances, regenerate and rubber. All these materials are subjected to appropriate preparation and processing before being introduced into the mixture.

Next, the rubber is mixed with the other components of the rubber mixtures in accordance with the specified recipe. This operation is most often performed in a rubber mixer [1].

The resulting rubber mixture to increase plasticity is heated by processing on heating rollers for 5-10 minutes at a temperature not exceeding 90° C. To obtain raw rubber blanks, the rubber mixture is calendered with subsequent cutting or cutting of plates and parts of the required shape and size from the calendered tape.

International Conference on Textile and Apparel Innovation (ICTAI 2021)
AIP Conf. Proc. 2430, 090011-1–090011-6; https://doi.org/10.1063/5.0078044
Published by AIP Publishing. 978-0-7354-4175-0/$30.00

Vulcanization of rubber parts for the sole of shoes is carried out by heating the blanks of the rubber mixture in molds placed in the vulcanization press for 5-12 minutes at a vulcanization temperature of 140-170° C [2].

Finished products are checked for quality defects and defects.

The presented technology is not characterized by high efficiency and productivity. A much more efficient production process is the production of pellets and direct injection molding on the tightened upper part of the shoe or the finished sole. In the work [3] injection molding is considered as one of the methods of mechanical processing of polyurethane and polyurethane composites and the production of products based on them.

This work is aimed at obtaining granulate waste polyurethanes and fiber-filled shoe soles on its basis with a given set of physical, mechanical and operational properties.

METHOD USED

Secondary polymer raw materials in the form of waste polyurethane foam (PUF) were used as the main component of the materials. This component is used as the main one due to the fact that most shoes are made on polyurethane soles, a significant amount of which is purchased in the countries of the near and far abroad, since the Republic of Belarus does not have a sufficient raw material resource. In the production of PU soles, waste is invariably generated, which, with appropriate preparation and processing, can again become the raw material for the production of appropriate materials. This concept also appears in the structure and model of waste management for footwear developed by foreign researchers [4–6].

Industrial oil and calcium stearate were used as additional ingredients. As a filler, it is proposed to use the waste obtained as a result of trimming carpets – a polypropylene knop with a fiber length of 2-4 mm (Figure 2).

FIGURE 2. Polypropylene knop

The technology for producing compositions for the sole of shoes with a fibrous filler includes the steps shown in Figure 3.

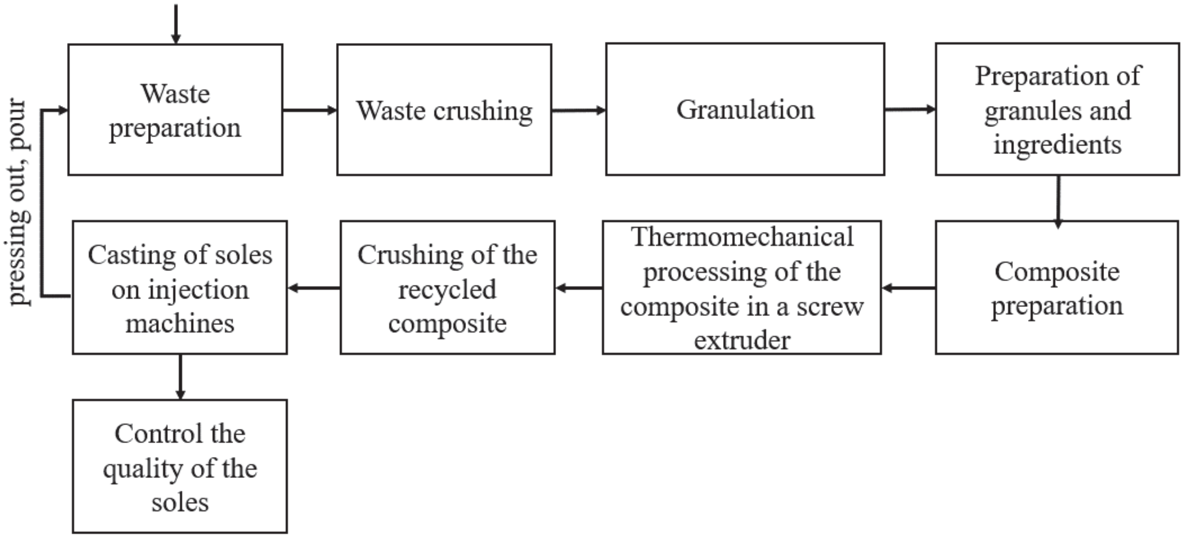

FIGURE 3. Technology for producing compositions for the sole of shoes with a fibrous filler

The waste is sorted by color, there should be no foreign materials and inclusions in the waste, the waste should be dry. The sorted waste is crushed on a rotary-knife type crusher. The crushed waste is mixed with other ingredients using a paddle agitator. Next, the thermomechanical processing of the composite is carried out in a screw extruder. The recycled composite is crushed again in a rotary-knife type crusher. Processing into the product was carried out on a static injection molding unit, which allows to obtain the finished product at temperatures from 140 to 160 ° C. The resulting soles are checked for quality [7–9].

A similar technology is being implemented at an industrial-scale footwear recycling plant set up by the SOEX company and its partners. The technology also includes such steps as shoe shredding, material separation, and granulation. An example of reusing these materials is creating soles [10].

To assess the quality of the obtained shoe soles, the standards applicable to the materials for the sole of the shoes were analyzed. It was found that most of the standards regulate methods for testing rubber. Studies of the physical, mechanical and operational properties of the obtained soles were carried out in accordance with GOST for test methods. Table 1 shows the characteristics of the test methods.

TABLE 1. Test methods

Name of parameter	**Designation**	**Units of measurement**	**Test method**
density	ρ	g/cm^3	GOST 263-75
shore a hardness	H	usl.ed.	GOST 267-73
conditional strength	fp	MPa	GOST 270-75
elongation at break	εp	%	GOST 270-75
relative permanent elongation	Θ	%	GOST 270-75
abrasion resistance	β	J/mm^3	GOST 426-77
bending resistance	N	thousand cycles	GOST ISO 17707-2015

Sampling for testing was carried out in accordance with the requirements of GOST. The sample size was at least 5-6 samples.

RESULTS

Indicators of the physical and mechanical properties of the samples under study are presented in Table 2.

TABLE 2. Physical and mechanical properties of the soles under study

Indicator	Relac	Fiber-filled soles	PU	Leather-like rubbers*
ρ, g/cm^3	1,02–1,06	1,0–1,03	0,8–1,0	no more than 1,1
H, usl.ed.	87–91	81–83	70–90	80–95
fp, MPa	5,0	5,2–5,7	4,0	not less than 5,0
εp, %	175–185	200–205	200	not less than 180
Θ, %	20	18–19	17	no more than 20
β, J/mm^3	2,5–2,9	6,2–6,8	4,5	not less than 2,5
N, thousand	25	30	30	not less than 20

* – according to material standard

The analysis of the data obtained showed that fiber-filled soles have rather close values to the materials used in shoe production, namely, leather-like rubber and primary polyurethane, and significantly exceed the normalized values for similar materials. As can be seen from such indicators as density, hardness and relative residual elongation, the obtained samples correspond to the standardized values of GOST. On average, the obtained samples of soles exceed the standardized values of GOST in terms of conditional strength by 7%, and in terms of elongation at break by 12.5%. In terms of abrasion resistance and resistance to multiple bending, the excess is 2.6 and 1.5 times, respectively.

The quality of the obtained shoe soles was evaluated in comparison with the requirements of GOST for such materials. For a comprehensive quality assessment, we used the "quality polygon", for a visual representation of which the data is displayed in the form of a petal diagram. Figure 4 shows a petal diagram of the relative indicators of the soles of shoes and the "reference".

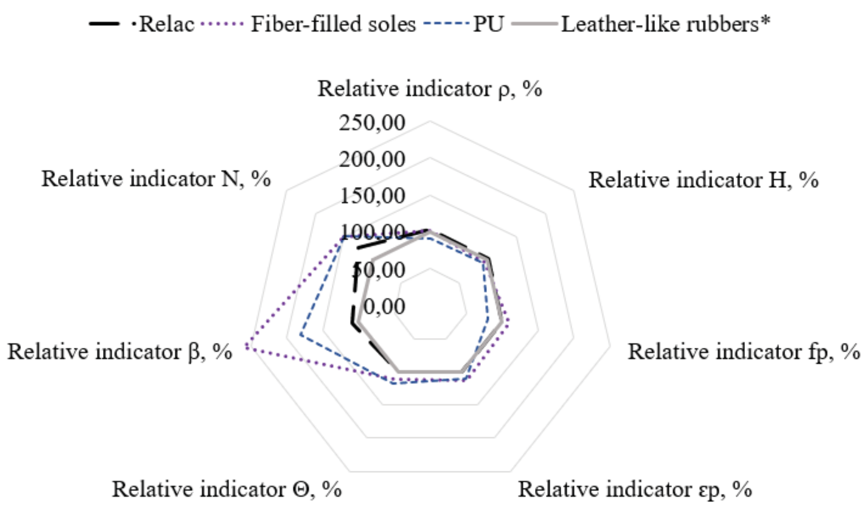

FIGURE 4. Petal diagram of shoe soles

The calculated quality indicators are shown in Table 3.

TABLE 3. Values of integral quality indicators

Indicator	Relac	Fiber-filled soles	PU	Leather-like rubbers*
Area of the petal	30557,5	50079,0	38806,0	27364,1
Quality indicator, %	111,7	183,1	141,8	100,0

Analysis of the data in Table 2 showed that shoe soles obtained from waste according to Figure 2 have the best physical, mechanical and operational properties. In this regard, they can be used for the production of soles of everyday shoes as an alternative to currently used materials, such as "relac".

The diagram of the structure of the obtained fiber-filled shoe soles is shown in Figure 5.

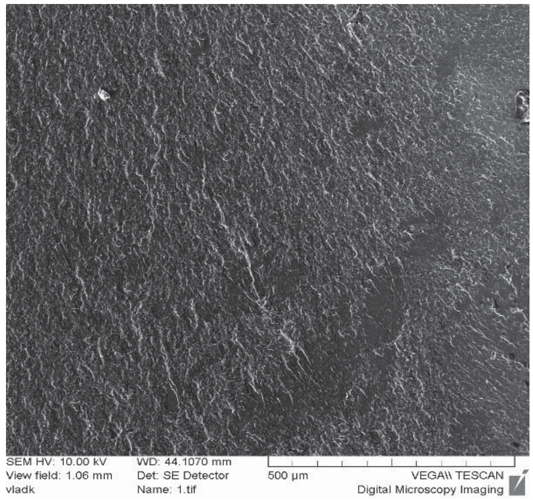

FIGURE 5. The diagram of the structure of the obtained fiber-filled shoe soles

According to Figure 5, it can be seen that the fibers are evenly distributed in the polymer matrix and oriented along, the interface is clearly visible. The fibers in the material are interstructural — chopped, continuous, there are sections of the material itself [11]. The diameter of the fibers is 20 µm, the distance between them is from 0.5 to 3 µm along the fibers and from 3 to 10 µm across the fibers.

The economic feasibility of producing soles using industrial waste is confirmed by calculating the economic effect from replacing leather fiber soles with polyurethane soles with fiber filler, obtained by casting on a MainGroup SP 345-3 machine per 100 pairs and is 250.0 rubles. (≈100 $).

In addition to calculating efficiency, it is important to ensure the competitiveness of the products. The relative level of competitiveness was 1.4, which indicates the superiority of the obtained material in terms of competitiveness.

The scientific significance of the work lies in the development of fiber-filled shoe soles based on granulate of polyurethane waste with a given set of properties.

The developed composition of the fiber-filled composition received a patent for the invention.

The use of polyurethane foam as the main component of waste and fibrous waste as a filler saves primary raw materials and promotes their partial utilization. This work makes it possible to expand the range of materials for shoe sole parts, reduce production costs by replacing primary raw materials with waste, and significantly improve physical, mechanical and operational properties.

CONCLUSION

The analysis of the research results showed that the soles of shoes based on waste have the values of the studied indicators higher than those of soles from primary raw materials. This is confirmed by the assessment of their quality. Thus, it follows that the use of waste allows you to save primary raw materials and contributes to their partial utilization. This work makes it possible to expand the range of materials for the bottom parts of shoes, to reduce the production cost by replacing the primary raw materials with waste, and to significantly increase the physical, mechanical and operational properties.

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