PRODUCTION OF RADIATION DESTRUCTANT FROM SPENT BUTYL RUBBERS ON THE LINAC LU-10-20

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Radiation methods of materials modification applied in technological chains can have significant economical and ecological advantages as compared to the established chemical, thermal and mechanical methods. Each year the problems of nature resources economy through the use of production and consumption wastes acquire a more significant value, as it allows to solve also ecological issues along with economical ones. This is mostly acute in relation to polymeric systems based on saturated rubbers, for example butyl rubber (BR) used in tyres industry, as due to their high resistance to the action of oxygen, ozone, solar radiation and bacteria they contaminate the environment for rather a long period. At VNIIEF and KSPU there were carried out experiments on application of electron beams with energy from 6 to 10 MeV for radiation destruction of spent rubber based on butyl rubber. Reclaim is tested in the formulation of initial diaphragm mixture, rubber mixture for producing rubberized fabric, roofing.
PACS numbers: 29.17.+w

1 INTRODUCTION

Radiation methods of materials modification applied in the technological chains, can possess a significant economical and ecological advantages as compared to the established chemical, thermal and mechanical methods [1]. Employment of electron accelerators for these purposes has a number of obvious advantages as compared to the permanent sources of ionizing radiation of Co-60 type. A possibility for selecting a facility in a wide range of powers, particles energy and geometry of irradiation area provides great capabilities from the point of view both optimization of technology and radiation safety.

Economy of nature resources through the use of production and consumption wastes each year acquires a more significant value, as it allows to solve also ecological issues along with economical ones. This is mostly acute in relation to polymeric systems based on saturated rubbers, for example butyl rubber (BR) used in tyres industry, as due to their high resistance to the action of oxygen, ozone, solar radiation and bacteria they contaminate the environment for rather a long period. At the same time BR represents a valuable raw material for reuse.

In RFNC-VNIIEF there are conducted radiation studies for development of promising industry technologies [2], whose application will provide a significant economical effect. One of the facilities for obtaining quasi-stationary fluxes of powerful electron and bremsstrahlung radiation is a linear resonance electron accelerator LU-10-20 [3] with the following parameters:

- Energy of accelerated electrons 7-9 MeV;
- Electron beam power 12 kW;
- Irradiation non-uniformity at the width of 500 mm is not more than 10%.

In the given paper there are presented results of joint studies carried out at VNIIEF and KSPU and related to tyres industry wastes reclamation.

2 METHODS OF OBTAINING RADIATION DESTRUCTANT BUTYL RUBBER BASIS

Radiation destruction of polymers containing a quaternary carbon atom is the most promising method, as due to a high penetrating capability of ionizing radiation it is characterized by the absence of expensive destruction agents, polluted sewage and gas effluents.

The known methods of radiation destruction of spent BR rubbers using the accelerated electrons energy imply preliminary grinding of material into 1 mm size crumbs followed by its shaping into a sheet and irradiation. Such an approach does not give a possibility for realization of a method on a commercial scale due to a low process efficiency limited by the crushing operation [4]. Employment of plane sources of Co-60 gamma-radiation allows to perform destruction of large pieces of material but to provide a uniform irradiation it is necessary to enlarge the surface of sources or arrange material rotation around the source [5]. Besides, a danger of contamination with radioactive materials of working areas also limits the capacity of BR industrial processing.

At VNIIEF and KSPU there were conducted the first experiments on application of electron beams with energies from 6 up to 10 MeV for radiation destruction of spent rubber what will allow:

- to irradiate the material uniformly over the whole volume;
- to simplify the operations of material crushing and averaging;
- to raise the efficiency of the technology facility for

polymeric wastes reclamation;

- to lower the danger of ecology pollution of the surrounding area.

To develop technology of BR radiation destruction, there were manufactured trial batches of devulcanizate from spent diaphragms of ≈50 cm diameter and ≈1 cm thickness at different parameters of radiation action (magnitude and power of the doze absorbed). Diaphragms split in two were placed on platforms of production transportation line and were moved perpendicular to the irradiation zone with the rate of about 10 mm/s. There were processed 4 trial batches of devulcanizate with absorbed exposure dose: 67, 116, 165 and 128 kGr. In the last batch the dose rate was two times higher than that of the preceding ones.

The nonuniformity of samples irradiation which was made up of irregular conveyer movement, instability of accelerator parameters and properties of beam scanning magnet system was less than 15%. System of beam scanning made the main contribution to the nonuniformity of irradiation. Measurements of absorbed dose directly on the irradiated samples were performed with the aid of a color dosimetry film made on the basis of poly-carbonate with phenazine pigment SO PDF 5/150 produced by NIIPIK (Russia).

3 ANALYSIS OF BR DESTRUCTANT PROPERTIES

According to the existing branch standards in Russia the quality of reclaim is regulated by indexes of properties of raw reclaim (the content of volatile matters, ashes and softeners, plasto-elastic properties) and its standard vulcanizates (conditional strength at the tension and elongation at the break). As in the proposed destruction method there are used no softeners, regenerative agents and mineral additives, the content of violate matters, ashes and softeners in the samples was not determined.

On the degree of diaphragm destruction they judged by the magnitude of chloroform extract and equilibrium degree of swelling in toluene.

Properties of trial batches of devulcanizate as a function of the absorbed dose received by diaphragm samples are presented in Fig. 1 and 2.

As one can see from the results presented in Fig. 1 and 2, the degree of swelling, magnitude of chloroform extract and plasticity are increasing as the absorbed dose is growing, and the conditional strength is decreasing at tension. Optimal results are achieved at the exposure dose of 110-120 kGr what agrees with investigations conducted earlier [4, 6]. Without reference to the rate of dose receiving the indexes of devulcanizates turned out practically equal.

When assessing the quality of each reclaim a significant meaning belongs to a characteristics of reclaim sheet taken from refining rollers: density, degree of roughness and surface polishing, presence of hard elastic rubber particles and other foreign insertions in the sheet.

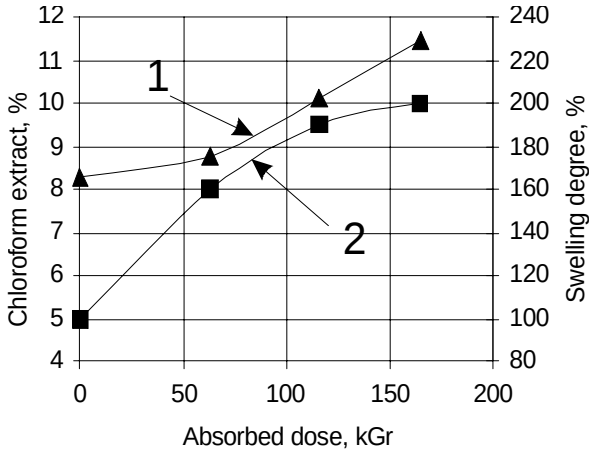

Fig. 1. Dependency of chloroform extract (1) and swelling degree (2) on the absorbed dose.

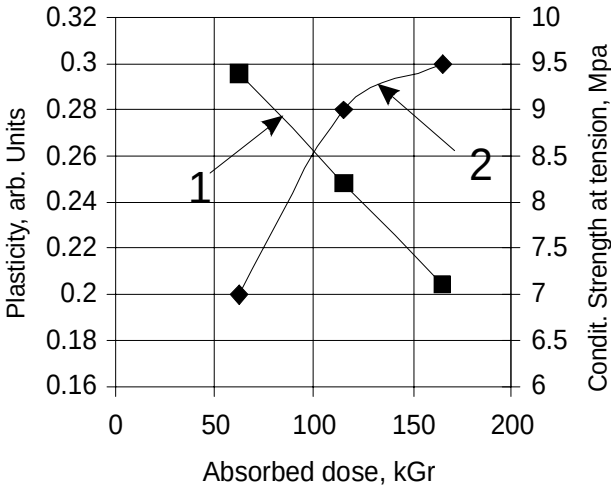

Fig. 2. Dependency of plasticity (1) and conditional strength at tension (2) on the absorbed dose.

To estimate the outward appearance of the sheet of the trial devulcanizate batches, there was used a method recommended in the paper [7]: devulcanizate was mixed with an equal amount of india-rubber, than roved by rollers through a thin clearance and stretched the sheet obtained. The foreign insertions were not noticed even at the minimal irradiation dose of 63 kGr.

When syringing a mixture of 100 devulcanizate mass fractions with 20 mass fractions of rubrax and 50 mass fractions of kaolin there become noticeable non-devulcanizated particles, whose number is decreasing as exposure dose is growing.

4 PRODUCTION OF RECLAIM ON THE BASIS OF RADIATION DESTRUCTANT

To produce butyl reclaim, there was used a batch of radiation destructant of spent diaphragms of "Nizhnekamskshina" join stock company irradiated on the linac LU-10-20 by 135 kGr dose. Destructant represents by a form the halves of initial diaphragms what provides some difficulties at processing. That is why the following operation in production of butyl reclaim are mastication and sheeting on mixing rolls. Plasto-elastic properties of destructant and reclaim are given in Table 1.

Table 1. Plasto-elastic properties of destructant and reclaim

Measures	Destructant	Reclaim
Plasticity, arbitrary units	0.1	0.46
Mildness, arbitrary units	0.32	0.6
Elastic reduction, mm	2.67	1.54

Processing of destructant on rolls leads to material plasticity and mildness what facilitates further reclaim processing. Physics and mechanical measures of pitchy and sulphur vulcanizates on the reclaim basis are given in Table 2.

Table 2. Physics and mechanical measures of vulcanizates

Measures	Sulphur	Pitchy
Conditional strength at tension, MPa	6.8	3.5
Elongation, %	310	500
Residual extension, %	12	20

To estimate the uniformity of the degree of destruction of the obtained reclaim batch, there were selected samples from different parts of briquette and determined measures of plasticity and a number of non-non-flattened particles. A scatter by plasticity did not exceed 5% and the non-flattened particles content was equal for all the samples taken.

5 CONCLUSION

There was irradiated the trial batch of BR wastes. Preliminary laboratory studies of destructant physics and chemical properties showed a capability for its reuse in industry without lowering the item quality.

The reclaim was tested as a formulation of initial diaphragm mixture, rubber mix for manufacturing of rubberized fabric, roofing.

Studies of properties of roofing on the basis of radiation butyl reclaim showed the following:

- Conditional strength at tension, MPa 3.4;
- Relative extension, % 310;
- Residual extension, % 40;
- Product life, years 15;
- Temperature of fragility 60˚C;
- Water absorption, not more than 1%;
- Resistance to ozone (ozone concentration is 10^{-4}%, 168 h, 40˚C) no cracks;
- Resistance to ultra-violet radiation (xenon lamp at 80˚C during 4000 h) no cracks.

The areas of butyl reclaim application are: rubber technical items (rags, plates, spacers, weather strips), roofing of roll and mastic types, sealing and water proofing mastics, anticorrosion colors and rubberized coatings, glue films, rubberized fabric.

The RF Ministry of Health provided a sanitary conclusion according to which the diaphragm radiation butyl reclaim was approved for production, supply, realization and employment on the RF territory.

At present on the basis of data obtained there is being developed a technology of industry radiation reclamation of BR wastes using the electron accelerator with 50 kW power in the volume up to 800 t/year.

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