Investigation of the resource potential of the aluminum oxide waste formed during testing and disposal of energy-saturated materials

A N Ponik¹, N Y Karpova¹ and G M Batrakova²

¹Joint-stock company “Research Institute of Polymeric Materials”, JSC "RIPM", Russia, 614101, Perm, Chistopolskaya street, 16,
²Perm National Research Polytechnic University, "PNRPU", Russia, 614990, Perm Region, Perm, Komsomolsky Prospect, 29

E-mail: karpowa.nadezhda2010@yandex.ru

Abstract. Theoretical and experimental investigations of aluminum-containing waste formed during testing and disposal of energy-saturated materials are carried out. Conversion directions of using aluminum oxide are considered. The research results allow us to recommend cleaning products for dust and gas emissions of thermal destruction of energy-saturated materials for use as additives in various types of civilian products.

Introduction

Environmental safety control in the field of waste handling generated in the process of testing and disposal of products of energy-saturated materials is based on the principle of hazardous properties identification and introducing a set of measures aimed at reducing the amount of non-recyclable wastes and placing in the environment only non-recyclable waste residues, identifying the resource potential of waste and its resource-saving.

The priority directions of the state policy in the field of waste management are the maximum use of raw materials; prevention and reduction of waste formation; reduction of the hazard class of waste in the sources of their formation, as well as the introduction of the best available technologies for treatment, disposal and neutralization of waste. The stated directions (changes from December 29, 2014 458-FZ “On Production and Consumption Wastes”) are intended to solve technological, economic, social and organizational issues of low-waste technologies creation in a complex, to combine environmental and economic interests of society in order to ensure sustainable development.

The known mechanisms for reducing the formation and hazard of industrial waste are:
- improvement of technological processes and minimization of waste formation;
- changing the properties of the waste, above all, toxicity, reducing the hazard of subsequent stages of waste management - the processes of temporary storage, transportation, processing, location in the environment (disposal);
- usage of the resource potential of waste components, processing and preparation of market products [1-2].

During one of the technological processes associated with the development, testing and destruction of high-energy systems, large quantities of waste are formed with a high content of aluminum oxide
(Al₂O₃). Waste formed during the process (Figure 1) - alkali metal salts and aluminum oxide can be partially disposed. At present, up to 200 t/year of waste is accumulated at production sites.

The biotesting method was used to investigate waste formed during testing and disposal of energy-saturated materials, and environmental hazard class 4 (low hazardous waste) was established. A certificate was received for this waste and the waste was included in FKKO No. 76511411203 [3, 4].

![Figure 1. Waste from the gas cleaning system of the test stand.](image)

Industrial wastes with a high content of aluminum oxide are considered as high-quality technogenic mineral raw materials with potential for recycling. Taking into account the possibility of release from impurities, dispersed and phase compositions, the directions of use and preparation of market raw materials and products were determined.

To determine the method of using aluminum-containing waste, the theoretical and experimental investigations are carried out.

The low toxic hazard of waste formed on the stand makes it possible to assess its applicability to the production of civilian products.

The following conversion directions for the use of aluminum-containing waste are proposed:

I. As an additive to materials for the soil stabilization in the construction of the subgrade and layers of pavement.
II. As a filler mixed with fireclay sand for the manufacture of refractory materials;
III. As the strengthening additive in cement mixtures, heat-resistant solutions (concrete) and in fired rock materials;
IV. As an additive for fired rock materials (technical ceramics).

**Experiment**

In the first direction, investigations were conducted on the use of aluminum oxide as an additive to materials for soil stabilization in the construction of the subgrade and layers of pavement, and the optimal mixing proportions were determined to give the greatest strength in the following ratio:

- portland cement (grade 300) - 1 part;
- sand - 3 parts;
- aluminum oxide - 2 parts;
- water - 1 part.

This cement-soil mixture was introduced and used in pilot production for the repair of the pavement base. However, the use of such valuable raw materials as a filler in pavements is unpractical.

Therefore, together with the «Orgtekhnstroy» trust, experimental research work was carried out on the use of recyclable Al₂O₃ as an additive in building materials in order to increase their density, water impermeability and frost resistance.

According to the second direction of aluminum oxide usage, the effect of Al₂O₃ on the strength of the hardened composition was evaluated according to the following attributes:

- according to the amount of Al₂O₃ used, depending on the cement consumption;
- according to the influence of the water-cement ratio (W/C) and the heat-humidity conditions (HHC) on the sample structure.
The compositions were formed from a mixture of portland cement mark 300 and river quartz sand with the addition of Al\(_2\)O\(_3\). The consumption of aluminum oxide ranged from 0.125 to 30.0 % by weight of the binder (water / cement (hereinafter referred to as W / C) - 0.5 and 1.0). (Figure 2).

![Figure 2](image-url)

**Figure 2.** The test results of heat-resistant solutions with the addition from 5 to 22 % of aluminum oxide at the different firing temperatures.

The test results of the investigated compositions showed the following:
1. Cement mixtures with natural hardening for 28 days (standard term) and the W/C ratio about 0.5 (dry mixtures compacted by pressing) gave the strength increase from 37 to 64 %;
2. In the compositions with the W/C ratio about 1.0, a stable increase in strength was not obtained;
3. With the natural keeping of the samples for more than 28 days with the ratio W / C = 0.5, the strength increase is 29 % (with the consumption of aluminum oxide - 10%).

In the third direction, the effectiveness of using aluminum oxide as the refractory additive was studied on the formed concrete mixture:
- fireclay powder - 350-450 kg/m\(^3\);
- portland cement (grade 300) - 350-450 kg/m\(^3\);
- aluminum oxide - 5-55 % by weight of cement;
- water - 40-60 % by weight of cement.

The formed mixtures were subjected to firing at the temperature of 1200 °C; at tests of samples, the following results are received:
- the best performance achieved with the content of 35 % Al\(_2\)O\(_3\);
- strength increase with respect to the control sample during firing up to 800 °C was 68.9%.

In the fourth direction of the aluminum oxide application for fired rock materials (technical ceramics) as additives were used: spent catalyst IM 2201, caustic magnesite, perlite sand, and fireclay sand. (Figure 3).

![Figure 3](image-url)

After 7 days of normal curing
After heating to 800 C
After heating to 1200 C

The total amount of refractory additive together with aluminum oxide in all compositions was 16.66 %, while the content of the other components was 83.34%. This ratio was maintained in all compositions. Before firing, all the compositions pressed in a punch with diameter of 50 mm under loads up to 411 kgf/cm\(^2\) and fired. The firing mode was carried out in two stages: firing in a muffle furnace with the temperature rise to 800 and 1200 °C.

A comparative analysis of the results shows that the optimal amount of aluminum oxide content is from 8.3 to 13.3 %. At the same time, on the fireclay sand with the aluminum oxide content of 10.83 %, the maximum compression strength is 629.0 kgf/cm\(^2\), and the strength increase to the control sample was 201 %. The strength increase with respect to the control sample during firing to 800 °C was 68.9 % [5].
**Figure 3.** The test results of artificial fired rock materials based on the Chusovaya’s slag, aluminum oxide and additives.

**Summary**

According to the results of exploratory research, we can distinguish rational areas of use for cleaning products of dust and gas emissions of thermal destruction of energy-saturated materials containing aluminum oxide in the production of building materials, namely, their use as a plasticizing additive to cement systems in the production of ready-mixed concrete and mortar mixes, as well as filler for dry construction mixtures. Also, taking into account the experience of handling this kind of wastes, we can assume a positive effect from their use in the production of high-temperature composites - in ceramic and refractory materials of general construction and special purposes.

Thus, the results of investigations in the above four directions allow us to recommend the cleaning products for dust and gas emissions of thermal destruction of EM for use as additives in the following types of civilian products:

- Refractory materials;
- Cement mixtures;
- Heat-resistant solutions (concretes) and fired rock materials (technical ceramics).

**References.**

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