**Development of Similarity Criteria for Complex Analysis of the Process of Tearing of Municipal Solid Waste Bags**

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**Abstract.** The criteria for tearing bags used in municipal solid waste processing were established through analysis of existing bag breaker designs, leading to the selection of a prototype design. Data from literature sources and preliminary results from laboratory tests enabled the identification of key indicators that significantly influence the bag-breaking process. Dimensional analysis helped determine these criteria and formulate an equation for the process. The findings will facilitate the development of a prototype bag breaker with optimized parameters.

**Keywords:** municipal solid waste, bag breaker, similarity criteria, key parameters, dimensional analysis

**INTRODUCTION**

The rise in living standards, manufacturers’ pursuit of additional profits through small packaging, and rapid urbanization in developing countries—particularly in nearly all Central Asian republics—have intensified the waste management problem [1]. Currently, the primary waste processing method in these regions is landfilling, which results in the irreversible loss of large quantities of secondary raw materials.

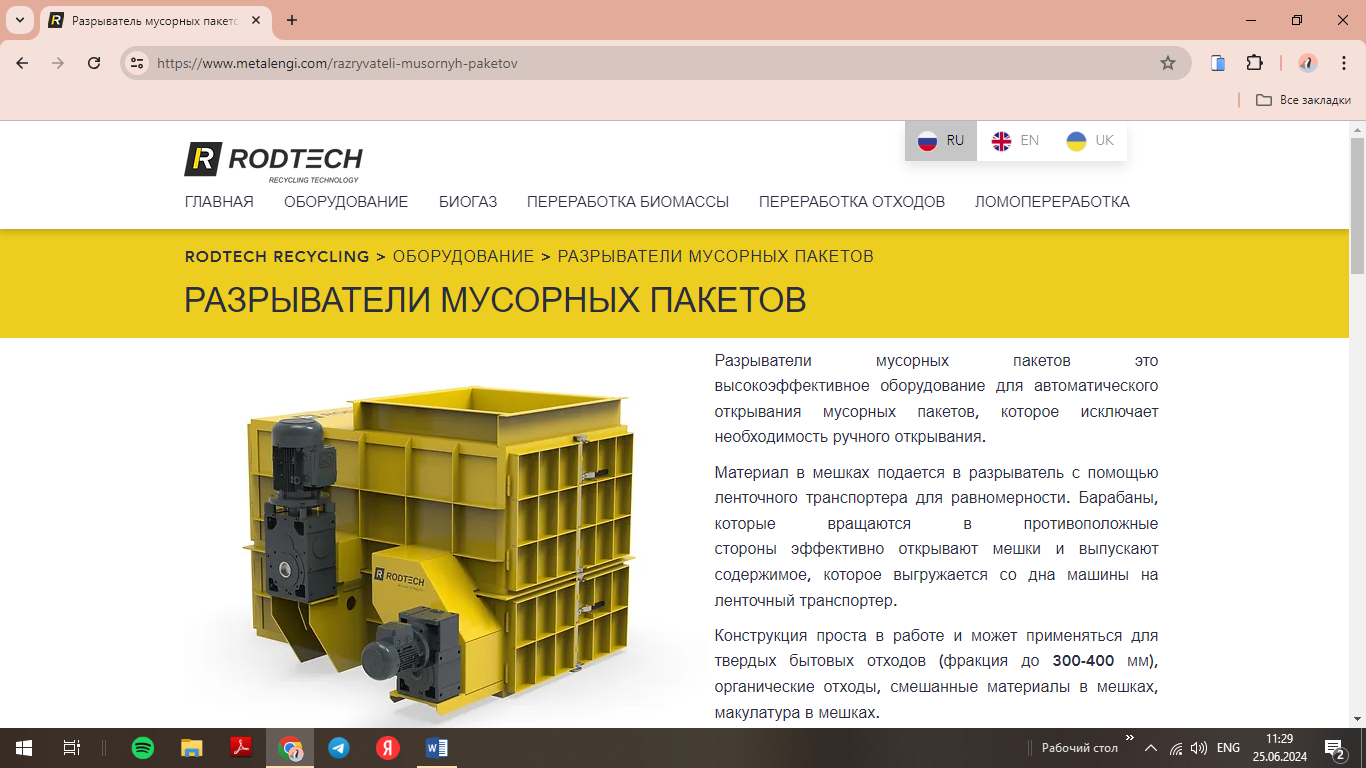
One strategy to improve waste sorting efficiency is to equip sorting complexes with bag breakers designed to accommodate the properties of MSW. Most of the collected and disposed MSW is packaged in polyethylene bags, whose morphological and fractional composition differs from household waste.

Several leading companies produce bag breakers, such as "Sifania-Ekotekhnika” (Republic of Belarus). They have developed a drum-type bag breaker design, shown in **Figure 1** [2]. The key advantage of this equipment is that its tearing knives are made of high-strength steel. According to the company, the knives have a lifespan of 1,000,000 bag tears. However, this device also has disadvantages, including high energy and material consumption [2].



**FIGURE 1.** General view of the bag breakermade by "Sifaniya-Ekotekhnika” (Republic of Belarus**)**

The design of the bag-tearing machine made by the "RODTECH RECYCLING Company, (China) also should be mentioned; it is shown in **FIGURE 2** [3].



**FIGURE 2.** Bag breaker of the "RODTECH RECYCLING Company (China)"

The advantages of this design include:

- long service life of the machine;

- relatively high productivity, compared to the drum-type design;

- the possibility of tearing the bags inside the outer bags;

- the ability to rotate the tearing rolls in the opposite direction;

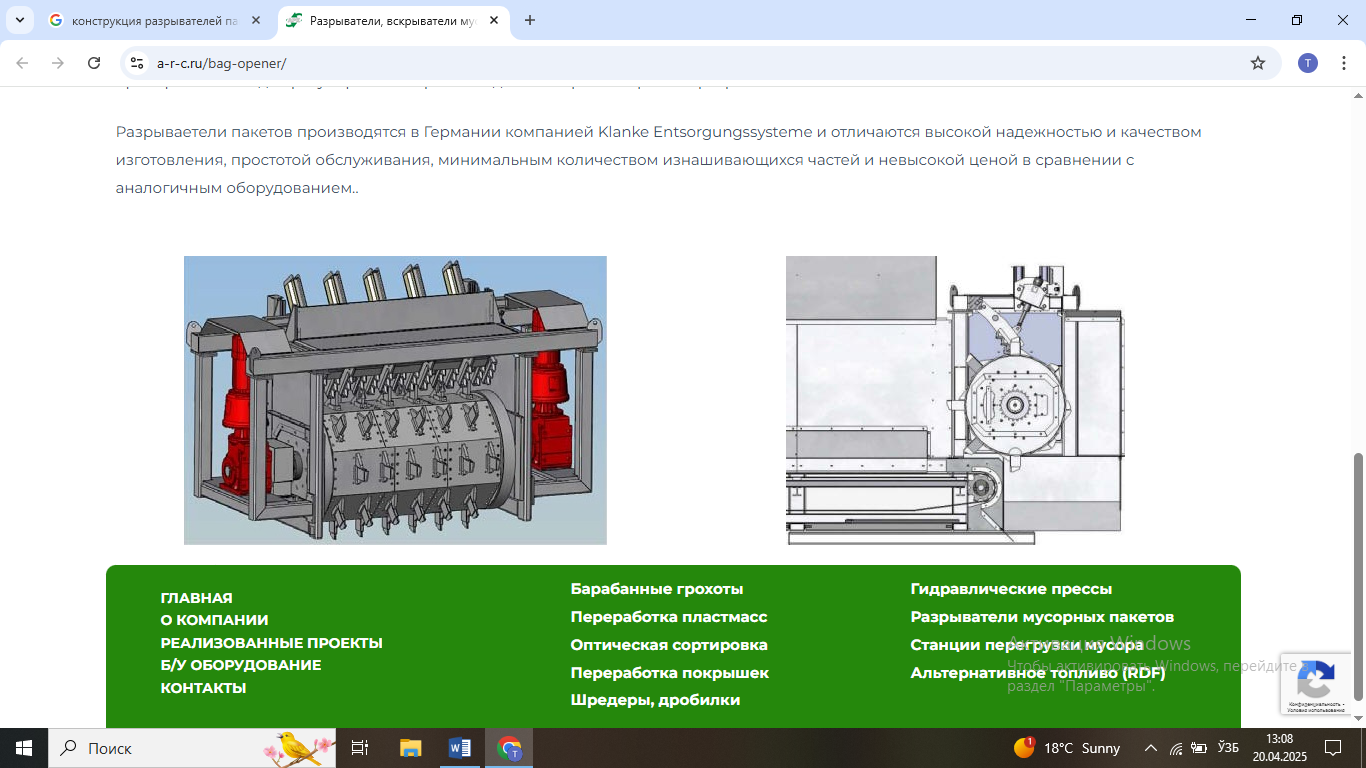
- corrosion resistance;

- ease of maintenance.

In addition, it can be noted that the percentage of bag tearing will be approximately 95%.

Along with advantages, there are some shortcomings. These include the high cost of waste recycling [3].

In the design of the bagbreaker of the "KlankeEntsorgungssysteme Company (Germany)", an interesting solution was applied againstbags sticking to the surface of the knives **FIGURE 3** [4].



**FIGURE 3.** Bag breaker by Klanke Entsorgungssysteme (Germany)

One of the main advantages of this machine is the reciprocating movement of the knives installed on the drum surface. This movement of the knives ensures high-quality cleaning of knives from sticking bags. In addition, several advantages can be noted:

- full automation of the control system;

- the ability to clean the knives from wound bags during movement;

- manufacturing of working parts from wear-resistant materials;

- low cost and ease of maintenance.

The following can be attributed to the disadvantages of the machine:

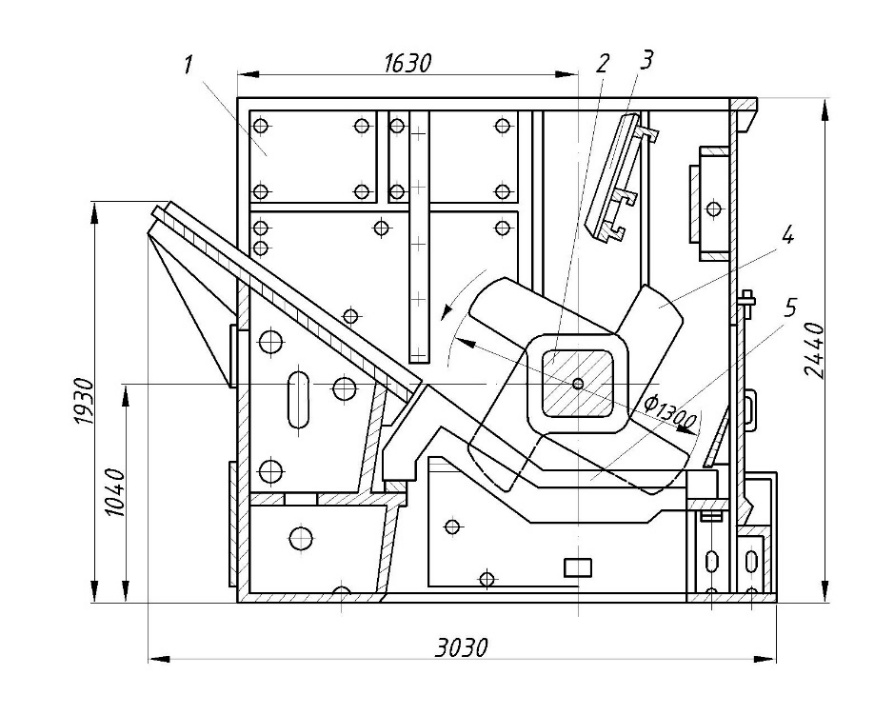
- high cost of the machine;

- low reliability due to the complexity of design;

- low adaptation to changing properties of waste.

The analysis of the advantages and disadvantages of the above-mentioned designs of bag breakers, andthe bag breakers produced by "Netmus (Russia)", "Metal Tech System (USA)", and "COPARM (Italy)" allowed us to select a prototype of the bag breaker design based on the criteria of generalized efficiency, and the quality of the manufactured products. In this case, the quality of the products was assessed notby crushing the components of solid waste located inside the bags [4].

Based on the above data and the requirements for machines of this kind, a prototype of the machine design was selected. A schematic representation of the bag breaker prototype is given in **Figure 4** [5].



**FIGURE 4.** Schematic representation of the prototype of the MSW bag breaker

It should be noted here that scientific developments conducted by scientists from various countries contribute to the improvement ofmachine designs and increase the efficiency of their operation [5].

The studies conducted by V.G. Sister [6] are devoted to the calculation and selection of equipment for waste processing plants and, based on the data obtained, the development of process flow schemes. However, his research did not reflect studies related to the justification of the rational parameters of bag breakers based on their characteristicsand the volumes of waste accumulation.

The studies conducted by L.Ya. Shubov et al. [7] are dedicated to improving innovative systems for waste sorting stations. Effective sorting methods and machines implementing the proposed technologies are substantiated. However, theissues related to the design justification of the bag breaker and the determination of its key parameters were left unsolved in his studies.

A.N. Mirny,in reference [8], considers the issues of separate waste collection and the requirements for machines and mechanisms performing this type of work.

Prof. V.I. Balovnev [9] in his research addressed the issues of choosing special machines with improved indicators based on transportation distance and mass of transported waste. Additionally, he developed a generalized hypothesis of crushing solid materials.

A.M. Gonopolsky et al. [10] studied the issues of choosing and justifying the method for crushing food waste. Rational parameters of crushing machines were determined.

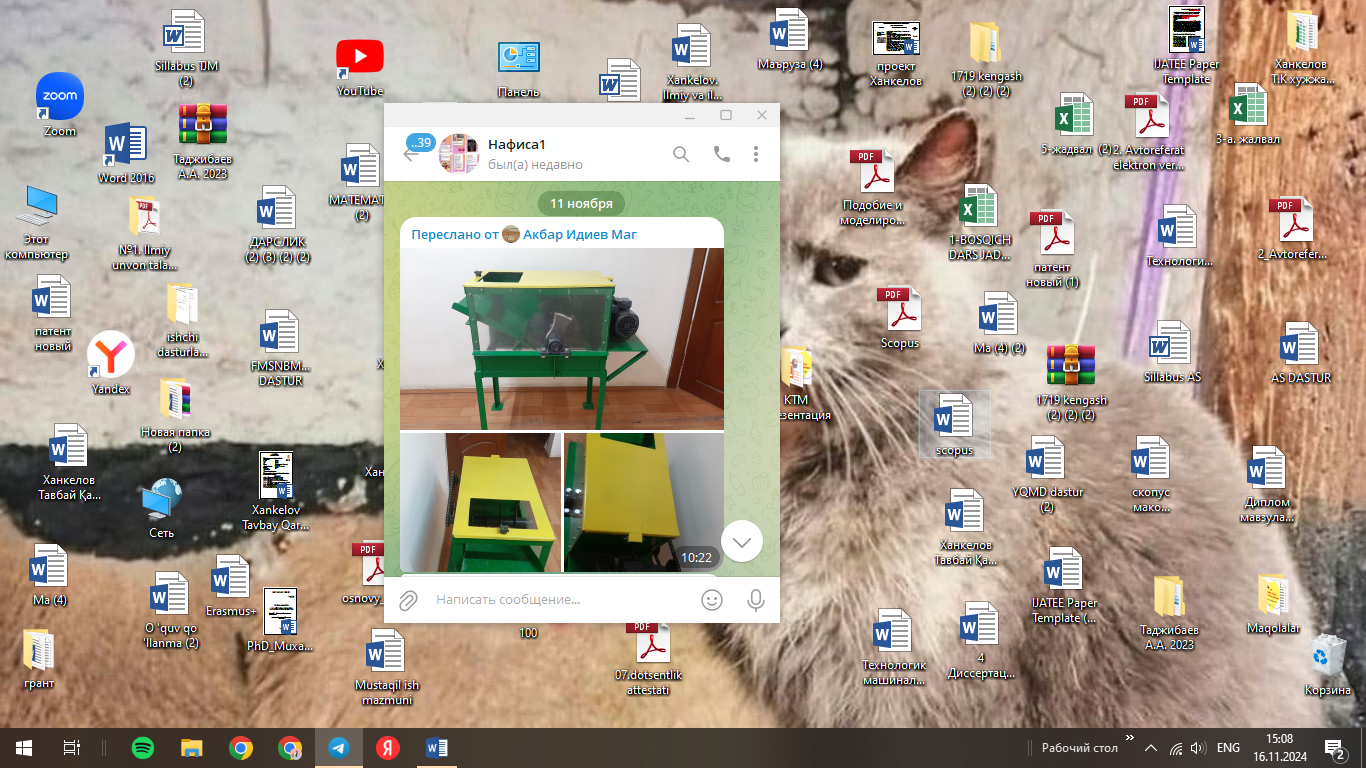
Among domestic scientists, we can mention the studies conducted by T.K. Khankelov et al. [1,11], in which issues related to the development of scientific foundations for MSW crushing and sorting by impact were considered. Laboratory samples of hammer crushers and sorting devices were created, and patents for inventions and utility models for the developed deviceswere received.

**MATERIALS AND METHODS**

It is necessary to apply the methods of physical and mathematical modelingfor a comprehensive analysis of the process of tearing bags and determining the rational values of the key characteristics of the device.

Physical modeling of the processes of crushing, sorting, and tearing bags with waste is justified by the following aspects: first, physical modeling can find an answer to the problem when the studied issue is very complex, which makes it impossible to compose an acceptable analytical dependence for it, otherwise the solution to the designated problem runs into unknown analytical obstacles; second, the above method allows to reduce the costs of implementing experimentsthat serve to study theoretical results [12].

To justify the rational values of the key parameters of MSW bagbreakers, a physical model of the bagbreaker was developed and a series of laboratory experiments were performed. Figure 5 shows the general view of the physical model of the MSW bagbreaker.



**FIGURE 5.** General view of the physical model of the bagbreaker

To determine the factors influencing the tearing process ofbags and their variation intervals, three types of rotor knife designs were developed, shown in Fig. 6.

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**FIGURE 6.** Different designs of rotor knives: a-rectangular knife; b-trapezoid knife; c-axe knife

The analysis of the working process of tearing bags on the physical model of the device allowed us to establish the parameters that significantly affect the tearing. To determine the similarity criteria and compile a criterion equation describing the process of tearing bags, the method of dimensional analysis was used [12].

One of the main parameters showing the efficiency of the bagbreaker is its performance. Below is the functional dependence of the device's performance on the main parameters describing the tearing process in an implicit form:

(1)

where - is the diameter of the bagbreakerroll, m; *n*– is the rotation velocity of thebag breaker roll, s-1; *N*– is the power of the MSW bag breaker drive, kgm2/s3, a– is the size of the grate opening, m; *L*– is the width of the bag breaker roll, m; δ– is the volumetric weight of bags, kg/m3; g– is acceleration of gravity, m/s2.

Let us determine the similarity criteria for this process. In our case, 7 parameters describe the process of bag breaking, 𝑛= 7. We express the units of measurement for seven indicators by three basic units of measurement [12].

The formulas for the dimensions of the above quantities have the following form:

To find similarity criteria, it is necessary to select base quantities with independent dimensions, which include all the main units of measurement. In our case, we will take the following three quantities with independent dimensions:

In this case, we find 7-3=4 similarity criteria. To find criterion , we write the dimension of parameter in the numerator of the fraction, andin the denominator,we write the product of dimensions with yet unknown exponents .

(2)

We determine the exponents by equating the dimensions of the numerator and denominator so that we get a dimensionless complex. So, for: 

Let us introduce dimensions instead of symbols for physical quantities. Then, after raising these quantities to the specified powers, we finally obtain:

(3)

We will get the remaining similarity criteria in the same way. Let us write out the following similarity criteria:

 (4)

–is the similarity criterion that characterizes the ratio of the rotor diameter to the weight of the bag breaker; –is the criterion simplex that expresses the ratio of the rotor length to its diameter; –is the criterion of similarity that characterizes the ratio of the drive power of the bag breaker to the volume forces.

The final criterion equation, describing the tearing process, has the following form:

(5)

Equation (5) is a criterion equation, describing the tearing process, depending on three factors. Criteria, are considered factors and criterion is an optimization parameter.

**CONCLUSIONS**

1. Based on the analysis of existing bag breaker designs, a prototype was selected, and a physical model of the MSW bag breaker was created.

2. To identify the factors that significantly influence the process, a series of single-factor experiments was conducted, resulting in a list of key factors.

3. The similarity criteria system, determined through dimensional analysis, will enable the identification of optimal values for the key parameters that enhance the efficiency of the bag-tearing operation.

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