Domestic Solid Waste Crusher

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Abstract *The article gives an analysis of the types of collection and transportation of municipal solid waste, as well as the impact of the type of waste collection on the design of the crusher. In addition, the methods and methods, as well as the principles of the work of crushers for grinding food waste, are analyzed. The questions of determining and substantiating the basic parameters of a hammer mill using the basic principles of the theory of similarity and modeling are considered. To compile the criterion equation, the dimensional analysis method was used.*

Keywords: *separate, mixed, municipal solid waste, processing, organic waste, rotor, hammer, crusher, abrasion, similarity theory.*

i. INTRODUCTION

An increase in population, rapid urbanization, booming The processing of municipal solid waste (MSW) is a widespread problem in both urban and rural areas of many developed and developing countries of the world.

Currently, solid waste arising in the process of human life, as well as production waste, have become the main reasons for the negative impact on the environment and human health. Solving the problems of processing solid waste should be financially sustainable, technically feasible, socially and legally acceptable, as well as environmentally friendly [1, p1275-1276]. Organic components, in particular, food waste, referring to the number of biological waste according to [2, pp.1-2., 3, pp.11-12] make up from about 25 to 40 percent of the total mass of waste. The value of which varies significantly depending on the time of year, the level of income of the population, lifestyle, etc. Fundamental in solving the problem of processing solid waste is a separate type of waste collection and transportation system, to which most EU countries have moved [4, p. 41–42]. Separate waste collection has a number of undeniable advantages. With a separate method of collection and transportation, the components of solid waste are pre-sorted, which eliminates the need for preparatory sorting. In addition, with a separate collection and transportation method, the waste constituents retain their original form, which favorably affects the quality of secondary raw materials, and with mixed collection and transportation, the waste constituents mixing with food waste become unusable and thereby increase the negative environmental impact of the waste. In this regard, the Chinese government's pilot program is interesting; in 2000, the government selected eight pilot cities, including Shanghai, to study the mechanisms for sorting solid waste. To advance this pilot program, a series of administrative regulations and policies have been developed at both the national and local levels. Selected as a pilot city, the Shanghai government has included waste management as a municipal practice. In addition, incentive and education programs have also been introduced. The local government, together with the Bank of China, began introducing a Green Account for households. Waste sorting led to points in the bill that could be exchanged for everyday goods, such as milk, shampoo, etc., or deducted for utility bills [5,1275-1276]. Sorted, for example, food waste can serve as food for livestock, and the remaining waste from another container as secondary raw materials for industry [6,74-75]. With such separate processing, the damage caused by landfills to the environment is reduced, the amount of stored waste at landfills is reduced, and the number of vehicles is involved

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Shipping's waste in landfills.

ii. MATHERIALS AND METHODS

Due to the mixed waste collection that is used in such a region as Uzbekistan, the problem of processing food waste is significantly complicated, due to the mixing of food waste with other components. Unfortunately, at this stage it is quite difficult to organize separate waste collection everywhere. The reason for this is not only the unpreparedness of the population, but also the lack of appropriate living conditions and technical support, as well as the absence of garbage chutes [7, pp.20-21]. Therefore, their disposal is one of the urgent problems of ensuring the environmental safety of the population. There are many ways of processing (disposal) of solid waste, but among them there are the most common such as: incineration; pyrolysis; recycling in waste processing plants; storage at landfills.

But, with any method of processing waste, its crushing is a nodal link. Shredded waste is better sorted, better compacted, and also better burned. Many different designs of crushers are used for grinding waste, such as: jaw; conical; roll; toothed; hammer; rotary etc.

But, the creation of effective crushers for the processing of household waste causes considerable difficulties, since the waste is a conglomerate that is very diverse in physical and mechanical properties, containing fibrous inclusions (paper, wood, leather, rubber), brittle components (glass, stone), plastic, ferrous and non-ferrous metals, as well as organic (food) waste.

The development and creation of crushers intended for grinding wastes close in terms of their physical and mechanical properties is relevant, as crushers designed to grind all components of the waste are very energy-intensive, and the output product is unsuitable due to the presence of harmful impurities in it.

Therefore, as indicated above, very strict requirements must be imposed on these crushers in terms of energy intensity and material consumption, as well as the cost of production per unit of output [8, pp.53-54].

One of the promising ways to handle organic waste is to grind it in water to form a pulp [9, pp.45-46] and then remove it through sewer networks to sewage treatment plants for domestic wastewater.

But, the constraining reason for introducing the above method of waste management into the waste recycling system in multi-apartment buildings of Uzbekistan is that the apartments in these houses are not equipped with such crushers. In addition, in the Decree of the President of the Republic of Uzbekistan dated April 17, 2019, No.-4291 "On approval of the strategy for solid waste management in the Republic of Uzbekistan for the period 2019-2028," it is not provided to equip apartment buildings with crushers [10, pp.1- 59].

And, also, these crushers are characterized by a very high specific energy consumption, as well as the high cost of waste processing.

Another disadvantage of this method is the lost organic components, which could serve as raw materials for industry and agriculture.

The disadvantages of serial grinders with knife and cam cutting devices [11, pp.1-12, 12, pp1-15, 13, pp. 1-6] is: the impossibility of processing fiber, fat and film waste of plant and animal origin, large bone waste, etc., the formation of embankments in pipelines from the grinder to the sewer network.

But, from the point of view of low energy and material intensity indicators, hammer crushers are most suitable for processing organic waste [14, pp. 288-289]. The use of a hammer mill for grinding organic components of waste is relevant not only because of low indicators for energy and material consumption, but also for the following reasons: firstly, the amount of incoming waste to landfills is reduced; secondly, the number of vehicles involved in the transportation of waste will be significantly reduced; thirdly, subject to the relevant requirements, crushed municipal solid waste can serve as raw materials for production, for example, for the production of compost. In addition, it is

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important to note that by reducing the amount of waste disposed of, the life of the landfill is extended, as well as the saving of land resources used for backfilling, which in turn affects the cost of waste disposal.

iii. EXPERIMENTAL RESULTS

Based on the results of experimental studies to determine the physical properties of the components of solid waste in the places of their collection and transportation [15, pp.11-12], as well as a priori information, a prototype design was selected and on the basis of this a physical model of the design of a hammer mill was developed and investigated. General view and structural diagram of the hammer crusher is shown in Figure 1.

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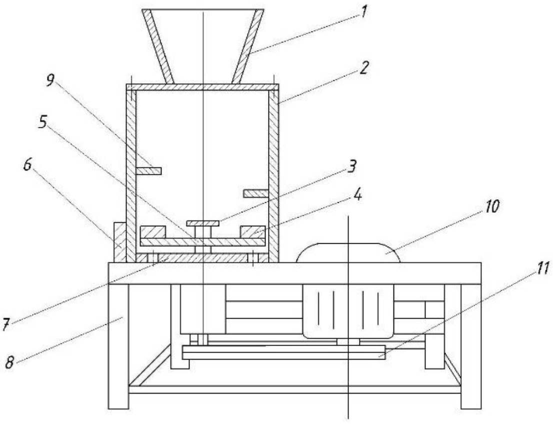

Fig. 1. Hammer mill

a) a general view of the hammer crusher, b) the design of the hammer crusher. 1-hopper; 2-working camera; 3-knife rotating; 4-hammer; 5-rotor; 6 - side grate; 7-lower grate; 8-frame crusher; 9-knife motionless; 10-electric motor; 11- V-belt.

Hammer crusher works as follows. The waste coming to the grinding falls into the loading hopper 1. Then the waste enters the working chamber 2, where it is accelerated to a speed equal to the nominal speed of the electric motor 10, due to the creation of air pressure through the hammer 4.

Accelerated waste to a nominal speed of rotation of the electric motor 10, is crushed due to the impact of the waste with knives 9 rigidly welded to the walls of the working chamber 2. In addition, the waste is crushed by impacting with the grate 5. The sharpened ends of the rotating rotors 5 contribute to the efficient grinding of waste.

Fibrous and film wastes are crushed by erasing between the lower part of the rotor 5 and the bottom of the working chamber 2. By erasing the waste passes through the grate 7 located on the bottom of the working chamber.

To study the influence of the shape and size of the crusher hammer (Fig. 2), as well as the number of knives installed on the inner wall of the crusher working chamber on the crushing efficiency, a series of preliminary experiments were carried out.

a) b) c)

Figure 2. Designs of rotors with various hammers

a) straight hammers located along the axis of the rotor; b) hammers located at an angle of 45 degrees to the axis of the rotor; c) paraboloid hammers.

An analysis of the influence of existing factors on the process of grinding waste and establishing criteria-based dependencies on the basis of use was carried out by compiling relations from dimensionless complexes based on the methods of similarity theory and dimensions using the –theorem [16, pp. 30-31; 17, pp. 31-32].

Thus, the process of crushing waste can be characterized by the following functional dependence.

$$F\ (d,\ D,\ L,\ l,\ \omega,\ N,\ \mathrm{d}_0,\ m, Q,\ g,\ E,\ \mu,\ \alpha,\ \rho) = 0\ ,\ (1)$$

Where

d-linear size of the waste before grinding, m; D-diameter of the rotor, m;

L is the rotor length, m; l-linear size of the rotor hammer m; ω-rotor speed, s^{-1}; N-power of the crusher drive, W; d_0-linear dimensions of the waste after grinding, m; g-acceleration of gravity, m / s2; E-modulus of elasticity of waste, N / m2; μ - Poisson's ratio; α-angle sharpening of a rotating knife degree; ρ-density of waste, kg / m3; m is the mass of the hammer, kg; Q - feed waste kg / h;

Using the method of zero dimensions with independent variables D, N, ω, we obtain the following equation:

$$\frac{d_0}{D} = \hat{O}\left(\frac{\mathrm{d}}{\mathrm{D}};\frac{L}{D};\frac{l}{D};\frac{D\omega^2 Q}{N};\frac{g}{D\omega^2};\frac{mD^2\omega^3}{N};\frac{D^3\omega E}{N};\frac{D^5\omega^3\rho}{N}\right)\ (2)$$

In order to comply with similar conditions in two crushers, the relevant criteria must have the same values. In this case:

$$\ddot{I}_1 = \frac{d_0}{D} = idem;\ \ddot{I}_2 = \frac{d}{D} = idem;\ \ddot{I}_3 = \frac{L}{D} = idem;\ \ddot{I}_4 = \frac{l}{D} = idem;\ \ddot{I}_5 = \frac{D\omega^2 Q}{N} = idem;$$

$$\ddot{I}_6 = \frac{g}{D\omega^2} = idem;\ \ddot{I}_7 = \frac{mD\omega^3}{N} = idem;\ \ddot{I}_8 = \frac{D^3\omega E}{N} = idem;\ \ddot{I}_9 = \frac{D^5\omega^3\rho}{N} = idem.\ (3)$$

Finding Φ is generally difficult. It is possible to search for individual particular dependencies that are of the greatest interest, for example, the efficiency of grinding waste from the power of the crusher

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$$\frac{d_0}{D} = \hat{O}_1(\frac{mD\omega^3}{N}) \text{ , (4)}$$

Assuming in a first approximation a proportional dependence, we have:

$$\frac{d_0}{D} = k_1 \frac{mD\omega^3}{N} \Rightarrow d_0 = k_1 \frac{mD^2\omega^3}{N} \text{ , (5)}$$

From staging experiments, for certain values of the frequency of rotation of the electric motor, you can find the value of:

$$\hat{e}_1 = 1.6 \div 3$$

From relation (5), we can construct the dependence of the fineness of fractions of crushed waste on engine power (Fig. 3):

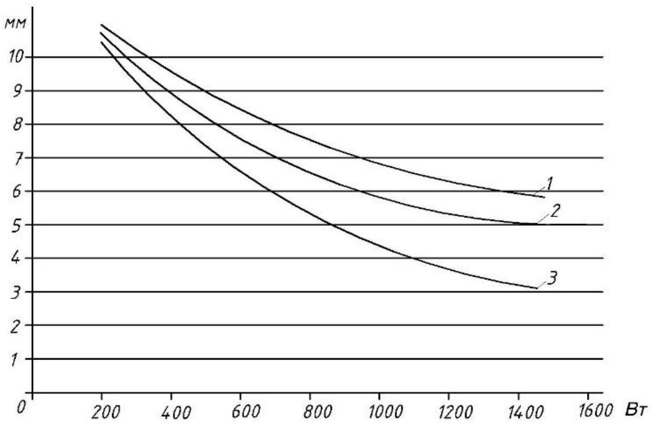

Fig. 3: Dependence of the size of fractions of crushed waste on the electric motor power at various rotational speeds: 1 - at an electric motor rotation speed, n = 750 rpm, 2 - at an electric motor rotation frequency, n = 1000 rpm, 3 - at a frequency rotation of the electric motor, n = 1500 rpm.

Analysis of the graphs presented in Fig. 3. shows that an increase in engine power has a positive effect on the grinding of waste. In addition, increasing the speed of the electric motor also contributes to efficient grinding.

Also of interest is the dependence of the size of the fractions of crushed waste on the supply of waste to the working chamber.

From the $\ddot{I}_1$ criteria and $\ddot{I}_5$ can also be found:

$$\frac{d_0}{D} = \hat{O}(\frac{D\omega^2 Q}{N}), \text{ (6)}$$

In the same way, you can find the ratio between the particle size fractions of crushed waste from the feed:

$$d_0 = \hat{e}_2 \frac{D^2\omega^2 Q}{N} \text{ (7)}$$

From staged experiments, for certain values of the frequency of rotation of the electric motor, taking into account relation (7), one can find the value of the coefficient:

$$\hat{e}_2 = 0.25 \div 4$$

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From relation (7), we can construct the dependence of the fineness of fractions of crushed waste on the supply (Fig. 4):

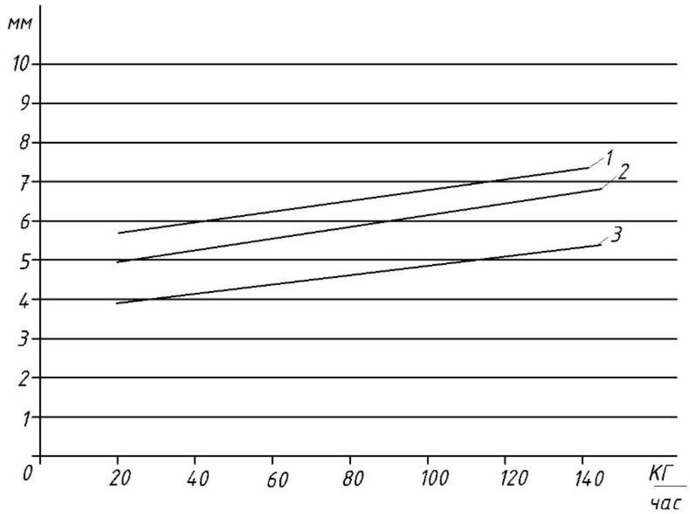

Fig. 4. The dependence of the size of the fractions of crushed waste from the feed at various values of the electric motor power: 1-at electric motor power, N = 750 W; 2-at electric motor power, N = 1000 W; 3-with electric motor power, N = 1500 W.

An analysis of the graphs presented in Fig. 4 shows that with an increase in the waste supply, the average value of the crushed waste increases, which in turn adversely affects the quality of the compost. On the other hand, the greater the engine power, the lower the average diameter of the crushed waste, but the opposite is the increase in energy consumption.

In addition, when conducting this one-factor experiment, a feed rate of 20 kg / h was taken as the lower limit of waste supply, and 140 kg / hour as the upper limit.

iv. CONCLUSION

Based on the results of the studies, it can be concluded that in order to achieve optimal working conditions of the physical model of a hammer mill, it is necessary that the main parameters have the following values:

- the rotor diameter is 260 - 270 mm (with a working chamber diameter of 300 mm);
-blades should be straight: blade width 55 ÷ 65 mm, blade height 20 ÷ 25 mm;
- frequency of rotation of the electric motor 1500 rpm;
- the number of knives on the inner wall of the working chamber should be 2-3 pieces;
- dimensions of the grate: width 270 ÷ 300 mm, height 90 ÷ 110 mm;
- grate diameter 18 ÷ 20 mm.

v. REFERENCES

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