Processing of household solid waste for heat treatment

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Abstract. The production of alternative fuels is a promising direction in the development of energy. Nowadays, in science the technology of heat treatment of various materials, including household solid waste is used. In order to obtain an alternative type of fuel from waste, the technology of heat treatment of raw materials without access to oxygen – thermolysis is used. Under the influence of low temperatures (400–500ºC) and without access to oxygen, the material decomposes into several components: water, gas, fuel oil and dark heating oil. To ensure the correct operation of such a line, it is required to supply finely divided raw materials to form the required plug in the loading zone from raw materials. Moreover, raw material should not be homogeneous. It is known that a mixture of rubber and paper gives cleaner results during heat treatment. To ensure proper operation and obtain the desired mixed raw materials, a rotary centrifugal unit with a complex dynamic effect on the material was developed. Calculations and studies showed that such a grinder design is capable of qualitatively grinding raw materials and mixing it in the right proportions. Small dimensions and a design solution in the form of a single rotor with several mechanisms of action on the material allow reducing energy consumption for grinding. The practical value of the paper is in the creation of an improved design of a rotary centrifugal unit on the basis of theoretical and experimental studies. It increases the productivity and quality of the resulting mixture. The results of the study can be used in the industry of waste processing plants.

1 Introduction

Any processing of household solid waste (HSW) is inextricably linked with grinding. The need to obtain raw materials with high dispersion is explained by the fact that due to their increased reactivity, the technical application is economically and technologically more profitable than that of coarse materials [1-3].

However, the grinding of large particles of waste is one of the most energy-intensive operations for the disposal of municipal solid waste. To ensure uninterrupted grinding of HSW, preliminary sorting of the components is required. For grinding various garbage, it is necessary to have appropriate equipment. Thus, for glass, a hammer mill is required, an aggregate with a cutting nature of the impact on the material is necessary for plastic and rubber. After sorting of household solid waste, non- recyclable waste called "tails" remains. These wastes are sent to landfills where they are buried. This option for the disposal of HSW adversely affects the environment. Today, the team of authors of researchers of BSTU named after V.G. Shukhov and engineering and technical workers of Ecotrans LLC are being carried out scientific and technical developments and the introduction of resource-energy-saving technology and special equipment for low-temperature thermolysis of organic waste into actual production [3б 5].

For the correct operation of the thermolysis line, a grinding unit with a complex dynamic effect on materials is required, which is able to grind raw material and mix it with the required additives. Such grinding units are rotary centrifugal units, which have a relatively high specific productivity, low energy consumption, small dimensions and the ability to grind material with natural moisture [6, 7].

The purpose of this study is to develop a fundamentally new design of the grinder based on the analysis of known rotary grinding equipment, determine the rational modes of the grinding process and calculate its main design and technological parameters.

2 Materials and methods

In order to increase the efficiency of the grinding process of raw materials and productivity, the authors developed a rotary centrifugal unit with a horizontal rotor and a fan impeller for mixing crushed raw materials with additional materials.

A rotary-centrifugal unit with a complex dynamic effect on a material is a device that is used to process and transform materials by influencing them with a rotating rotor and centrifugal force [8].

The principle of operation of such an installation is that the material is subjected to dynamic action, which consists of several components. First, the rotor of the installation rotates at speed, creating a centrifugal force

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that acts on the material, pushing it away from the center and pushing it towards the walls of the installation. This allows for mixing and mixing of materials, as well as crushing and grinding them.

Additionally, the installation has a mechanism for supplying additional materials to create a complex effect on the material. For example, you can supply the installation with various reagents and additives that can change the properties of the material, enhance the mixing process, change its texture, etc [9, 10].

The simultaneous action of centrifugal force, rotor rotation and the addition of additional components allows you to create various dynamic processes in the material, which can be useful in the production of various products such as chemicals, food additives and many others.

The grinder contains a cylindrical body (5), in which there is a rotor (8), mounted on a shaft (2), passing through the entire body and fixed in bearing supports (3). The working rotor consists of a screw nozzle (6), which provides continuous support of the material into the grinding chamber, the working rotor has cutting edges on its plane (8) and there is a gear ring (7) on the inner surface of the housing, which provides a cutting effect on the material, then a fan impeller (10) is fixed on the shaft (2) to remove the finished material and mix it with additives. The retaining cover (9) provides different dispersion of the material. The shaft is driven by a pulley (1) and a belt drive.

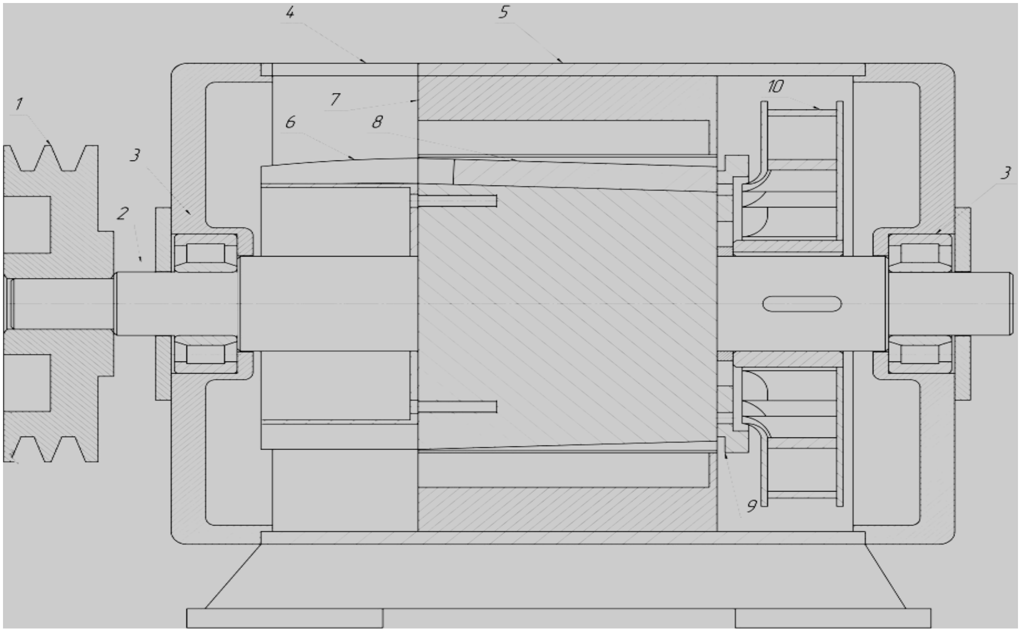

Fig. 1. Rotary centrifugal unit with a horizontal rotor

Fig. 2. Laboratory installation of a rotary centrifugal unit

3 Results and Discussion

A grinding unit (Figure 1) works as follows. The crushed raw material from the feed hopper is fed into the loading chamber, where the screw nozzle (6) is located. It is designed for continuous supply of material to the grinding chamber, if necessary, the nozzle can be supplemented with a cutting nozzle. Next, the raw material is fed into the grinding chamber, where it is exposed to a cylindrical rotor with a cutting edge (8) and the inner toothed surface of the housing (7). The inclined location of the cutting edge provides a cutting effect on the raw material, which in turn reduces energy consumption for grinding. Further, the material is pulled into the mixing chamber with the help of the impeller (10) and unloaded for transportation. The presence of the impeller is due to the fact that fine dust is formed in the grinding chamber, which makes grinding difficult. The structure of the unloading impeller can be selected according to the type of material to be ground. The dispersion of the material is controlled by the size of the gap between the spacer plate (9) and the holes between the cutting edges of the rotor.

One of the main characteristics of the studied unit is performance. Taking into account that the unit consists of several chambers, it is possible to say that the overall performance of the unit will be the sum of the performance of the grinding and mixing chambers. It is necessary to note that the performance of the grinding chamber must be less than the mixing chamber, otherwise a blockage will form: $Q_{ch.} \leq Q_{\text{mix}}$[2].

The performance of the grinding chamber is calculated according to the following formula:

$$Q_{ch.} = l \cdot b \cdot h \cdot z \cdot \rho \cdot n \cdot k_{\varphi} \cdot k_{\lambda} \cdot \cos\cos\alpha\,, \quad (1)$$

where l, b, h – respectively, the length, width and height of the grooves of the rotor, m; z – the number of grooves of the rotor, 8–12 pieces; ρ – bulk density of the crushed material, kg/m$^{3;}$ n – rotor speed, min$^{-1;}$ α – angle of inclination of the cutting grooves to the rotor axis, 5–7 degrees; k_{φ} – 0.65–0.75; k_{λ} – coefficient taking into account the outlet gap of the grinding part of the unit, 0.01–0.03.

The performance of the mixing chamber is characterized by the volume of the displaced flow per unit time:

$$Q_{\text{mix}} = \mu \cdot S_{blade} \cdot U_{\varphi} \cdot k \cdot z, \quad (2)$$

where U_{φ} is the peripheral speed of the center of the working surface of the blade, m/s, S_{blade} is the area of the working surface of the blade, m$^{2;}$ μ – weight concentration of the material in the air flow, kg/kg μ = 4 kg/kg; k – coefficient taking into account the nature of the motion of the polydisperse phase in the mixing chamber, k = 0.05–0.08 [2].

Thus, during the analytical studies, the authors developed a method to determine the performance of a rotary centrifugal unit with two chambers for influencing the material. The installation of a fan impeller facilitates the grinding process and the implementation of the mixing process in the unit. The experimental studies were carried out using a laboratory setup (Figure 2) in BSTU named after V.G. Shukhov.

In order to test the feasibility of grinding the “tails”, the authors analyzed the composition of household solid waste. The results are presented in Table 1.

Table 1. Composition of household solid waste

Name of waste	Quantity, %
Metal	42
Paper	37.9
Plastic	8.4
"Tails"	6.3
Glass Food waste	2.9 2
Other waste	1.4

The experimental work also showed that the performance of the developed rotary-centrifugal installation with a complex dynamic effect on the material depends on several factors.

The performance of the installation depends on the power and efficiency of the engine, as well as on the quality and reliability of the drive system, which ensures the rotation of the rotor and the transmission of dynamic forces to the material.

The performance of the installation also depends on the correct settings and selection of the optimal operating mode, which allows you to achieve the best results when processing material.

The rotary centrifugal unit can be configured and optimized to work with different types of materials. Productivity depends on the type and properties of the material being processed, as well as on the method of its preparation and pre-treatment.

The technical condition of the installation and its maintenance are of decisive importance. Regular technical inspection, maintenance and replacement of worn parts and components help maintain high plant performance.

The performance of a rotary centrifugal plant can be greatly improved by the experience and skill of the operator who can properly set up and control the material processing process.

These factors are important for optimizing the performance of a rotary-centrifugal plant with a complex dynamic effect on the material and allow achieving the best results in material processing.

During the analysis, it was found that 6.3% (4.4 million tons per year) of the total mass (70 million tons per year) is sent for disposal of non-recyclable waste. According to the trend in the development of technologies for the disposal of solid waste, a part of the non-recyclable waste can be prepared for further thermolysis disposal, which allows avoiding landfills harmful to the environment and obtaining useful materials: heating oil, black carbon, water [11-13].

4 Conclusion

1. According to the results of the analysis of the trend in the development of technology of grinding various materials, the authors proposed a new design of a rotary grinder with a horizontal rotor and a fan impeller.

2. A method for the calculation of the performance of the grinder was obtained, taking into account the operation of two chambers of mechanical action on the material simultaneously.
3. The experiments were carried out grinding of various materials in a laboratory setting.
4. The experimental studies were carried out in order to determine the optimal parameters of the grinding process.
5. The analysis of the composition of HSW and the analysis of the feasibility of buried waste processing was carried out.

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