Increase of recycling efficiency of domestic waste of preliminary preparation of their dispersed fraction

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Abstract
Paper is devoted to efficiency increase of preparation process of dispersed fraction of domestic waste for the subsequent recycling by thermal methods. Necessity of preliminary preparation of dispersed fraction of domestic waste is proved. It is suggested to derive fine fraction from the total mass of the stored domestic waste and to expose them to preliminary preparation for increase of efficiency of their recycling.

Physical and mechanical properties of dispersed waste mixture are studied. The experimental researches of efficiency of granulation processes by such methods as pelletizing, granulation by compression and granulation in fluidized layer are conducted.
Dependence of the granules size on waste humidity and the gas flow rate for fluidisation is theoretically established and experimentally confirmed. Necessity of cyclic delivery of binder solution with regular intervals for providing of stationary operating mode of granulation of dispersed fraction of domestic waste in the device with fluidized layer of discontinuous operation is also theoretically established and experimentally proved.
The studied features of granulation of dispersed fraction of domestic waste by different methods will allow simplifying of choice of method and means of preliminary preparation of dispersed waste for different existing types of their recovery. Technology of heat treatment in chamber furnaces is considered as the most effective and ecologically rational method of recovery. The appropriate corrective amendments, which increase efficiency of such processing, are introduced in the existing technology of waste recycling in chamber furnaces on the basis of the conducted researches of methods of preliminary preparation of dispersed fraction.
Key words: DOMESTIC WASTE, DISPERSED FRACTION, RECOVERY, PRELIMINARY PREPARATION, GRANULATION, PELLETIZING, COMPACTION, FLUIDISATION, HEAT TREATMENT, CHAMBER FURNACE

Annually, in Ukraine about 15 million t of domestic waste are stored, and only about 10% of them are recycled and recovered. At present, more than 2 billion t of domestic waste are accumulated in the territory of Ukraine [1]. In the country, there are about 4 thousands registered and relatively equipped landfill sides [2]. At that, places of unapproved stocking of unassorted domestic waste are spontaneously formed near each settlement irrespective of its size. According to data of 2015, in Ukraine the area occupied by such waste is more than 2% of the whole territory of the country. The huge areas, which could be rationally used by reserved fund and are demanded in agriculture or city agglomerations, now are buried under layer of garbage and continue to be exposed to pollution and poisoning.

Despite the growing size of the problem, not enough attention is paid to it. The majority of known decisions are directed to separate collection of garbage, separation of valuable components, reduction of waste production in general and implementation of non-waste technologies [3]. However, there is open problem of reduction of territories of unapproved stocking of waste formed under the conditions of unseparable collection of garbage which is the reason of accumulation of dangerous chemicals, harmful bacteria and viruses of dangerous diseases.

Dispersed fraction of unassorted waste (the size of particles is up to 1 mm) as a part of the stored waste poses the greatest ecological danger. It is should be noticed that both organic and inorganic dispersed components pose specific danger. The organic dispersed component of waste contains toxic, chemically and biologically dangerous substances. Process of decay of organic component is followed by separation of methane-containing gas mixture that leads to frequent ignitions and fires in places of unapproved stocking of waste [4]. The inorganic dispersed component of waste in course of reversal process becomes the reason of arch formation in bunkers, sticking, hanging of particles, hard driving or blocking of moving elements of processing mechanisms, reduces efficiency of recovery process and reliability of recovery equipment. The ratio of organic and inorganic dispersed components in the stored waste is specific to each separate stored waste. Because of impossibility of division of organic and inorganic dispersible components of waste, such compound of dispersible waste becomes the main problem of scale industrial recycling of the stored waste. The compound of organic and inorganic dispersed fraction of waste does not undergo sorting, possesses complex rheological properties and represents the most ecologically dangerous component of waste in places of stocking. Fine particles of waste are spread quicker in reservoirs, penetrate into the soil simpler, are oxidized and dissolved more actively. Initially when stocking domestic waste, the fine component is about 10% of the whole waste.

Results of the conducted researches allowed establishing that under the influence of climatic factors and biochemical processes of decay in places of stocking, the fractional composition of waste is changed, at that, the share of ecologically aggressive fine fraction increases within 10 years from 7-10% to 70-80%.

Physical and mechanical properties of dispersed fraction of the stored waste located in different climatic and environmental conditions, such as non-uniform morphological composition, humidity – 30 - 75%, bulk density – 300-350 kg/m^3, true density of mixture ≈ 1660 kg/m^3, do not allow implementation of scale industrial processing by any of the known thermal methods due to agglomerating of dispersible waste into warm and gas proof mass that determines necessity of preliminary preparation before processing. On the basis of experimental studies, it was suggested to derive the fine fraction of domestic waste from the total mass of stored waste and to expose them to preliminary preparation for increase of processing efficiency.

In this regard, the relevant scientific task is creation of technological basis for recovery of domestic waste on industrial basis and safe processing of their ecologically aggressive fine component by grounding of rational processes and parameters of granulation providing control of fractional and moist composition of the obtained product.

It was experimentally confirmed that processing of dispersed unassorted waste is possible in case of restriction of minimum fineness of processed material and humidity control that provides stabilizing in general of physical and mechanical properties of dispersed fraction. It is possible to achieve it in the course of material granulation. Granulation is formation of particles of material (granules) of the given fineness, shape and with the given properties. Process of granulation implies both grinding of large lumpy material and combining of fine particles of material. In the paper, the second case of granulation is considered.

The industry applies several methods of combining of fine materials into granules. The most widespread methods of granulation are different types of compaction, pelletizing of dispersed mass in the rotating devices and granulation in fluidized layer.

Granulation of dispersed fraction of domestic waste by method of pelletizing was studied by disk-shaped laboratory installation.

It was established that the stable pelletizing and formation of granules from dispersed waste can be observed only in case of achievement of relative humidity of 50% (in the presence of solution binding in material – 40 … 45%) by material. At that, free movement of particles on working surface of the device was possible in case of humidity of material no more than 35%. Therefore, material moistening and adding of binding solution should take place in course of granulation.

In case of granulation by pelletizing, granules with diameter of 5-10 mm were obtained. The average bulk density was about 400 kg/m^3, and did not depend on the size of formed granules. Distribution of granules-pellets strength corresponds to the classical theory of solid particles and is uniformly reduced with growth of the relative size of particles. Granules-pellets of dispersible waste were of brittle structure and were crumbled in the course of applied load. Mean value of strength of granules of dispersed fraction of waste obtained by pelletizing was about 0.04 MPa. Necessary time of pelletizing for obtaining granules of disperse phase of waste with such properties is 45-50 min.

Compression processing was considered as the stage of preliminary preparation of dispersed fraction of domestic waste for further processing. Compaction of dispersed material differs from other methods of granulation and more precisely guarantees such properties of finished products as size, shape, density etc [5].

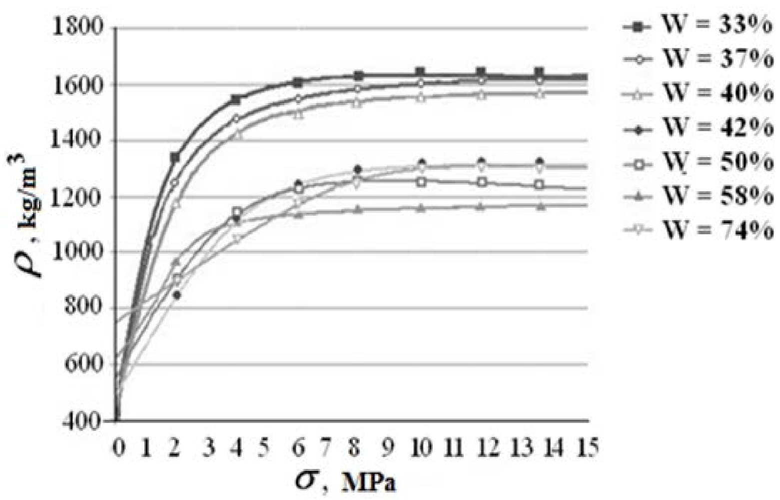
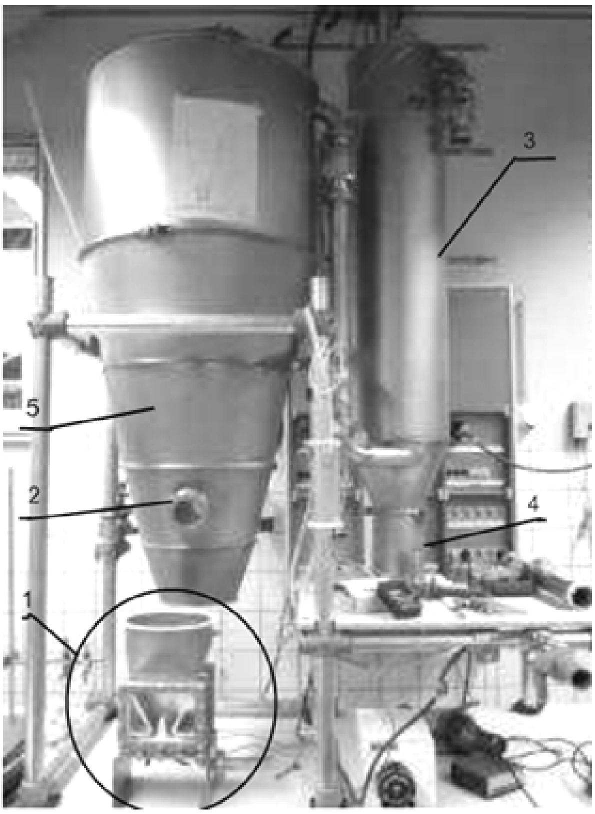


Figure 1. Compression curves of compaction of dispersed fraction of waste of various humidity (developed by the author)

The experimental researches on compaction of dispersed fraction of domestic waste were conducted on the special instrument for compression tests of Donetsk National Technical University. On the basis of compression tests of the studied material, compression curves of compaction process of dispersed fraction of waste for tests of various humidity (Figure 1) were built.

From diagrams of growth of briquettes bulk density in case of pressure increment of compaction, it is possible to draw a conclusion that effective compaction of dispersed fraction of domestic waste is possible in case of humidity up to 40% inclusive. The use of more wet raw materials for compaction will lead to formation of less dense and less solid briquettes that will be reflected in efficiency of further operation. Therefore, when compaction of dispersed material, which humidity exceeds 40%, there is necessity of preliminary drying.



1 - feed part of machine; 2 - observation window; 3 - vertical forcing pipe; 4 - filter; 5 - operating zone of machine

Figure 2. The granulator device of discontinuous operation with fluidized layer of German Technical University Hamburg University of Technology (TUHH) of institute of Solid process engineering and particle technology (SPE)

Granulation in fluidized layer is a process in case of which particles of the solid static mass interact and integrate into larger granules. This static mass under the influence of gas flow passes into pseudostate similar to a state of liquid mass.

In relation to domestic waste, such type of preliminary preparation is applied for the first time. It was experimentally established that granulation of small-sized fractions of domestic waste in fluidized layer possess a row of advantages comparing with other methods of granulation. This approach makes it possible to solve several main problems of recycling of dispersed waste simultaneously; namely, the possibility of drying by fluidizing gas makes it simpler to use excessively humid material, and continuity and closeness of process reduce negative impact of dangerous wastes on people and environment. Isolation of such process and circularity of flow motion of fluidizing gas allows isolating and catching the majority of harmful and dangerous substances [6].

The experimental researches of granulation in the machine with fluidized layer were conducted on laboratory installation of discontinuous operation (Figure 2).

Process of granulation in the device fluidized by layer differs from other methods of granulation by rather complex hardware basis and large number of controlled parameters [7]. On the one hand, it complicates control of this process making certain demands to the equipment, material and operator. On the other hand, a large number of controlled parameters makes it possible to control granulation process deeply and in details that in turn gives the chance to process complex granular masses [8]. Non-identified dispersed fraction of waste can be also referred to such material.

For providing of dispersed and humidity conditions of product, parameters of supply of fluidizing gas in the granulator device were established experimentally; stable fluidizing of dispersed fraction of waste with the relative humidity 20… 40% is provided in case of air flow in the range of 80 … 100 m^3/h.

The granules obtained in consequence of this process tended to regular spherical shape and were of the small size ($d_{eku} \approx 3.099$ mm). Such size of material particles allows providing necessary level of gasification and sufficient amount of contact sintering points. The granules obtained by fluidizing also possess high level of porosity (≈ 63%), hence, providing the particle with big response surface necessary for efficient involvement in chemical processes (Figure 3).

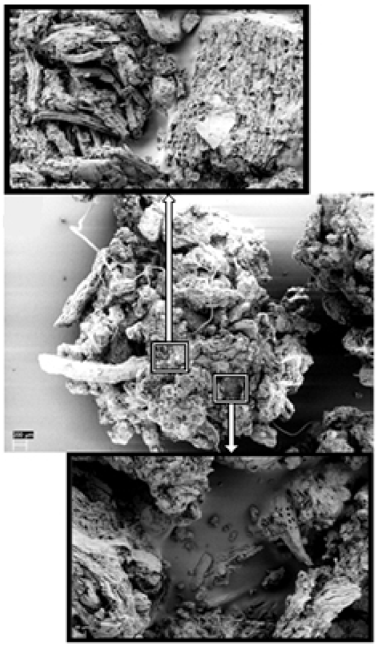


Figure 3. The granule of dispersed waste obtained in the device with fluidized layer. Pictures of REM x50 and x500 (developed by the author)

It was experimentally established that for support of the stable mode of fluidizing of dispersed fraction of waste, it is necessary to use material with the relative humidity no more than 25…35%. Humidity necessary for stable fluidizing can be achieved by means of preliminary atmospheric drying.

For regulation of granulation process of bulk in the device with fluidized layer, an important role is played by such parameters as fluidizing gas flow, current humidity of material and size of granules. The amount of moisture in material affects adhesive power conducing aggregation of material particles, and thereby, increase in the size of granules. The fluidizing gas flow provides suspension of particles conducing their intensive interaction and, thereby, granulation. At the same time, fluidizing gas flow dries up the liquid on particles surface reducing humidity of material. The size of particles increases with increase in humidity, however, particles of the bigger size for suspension require greater air flow.

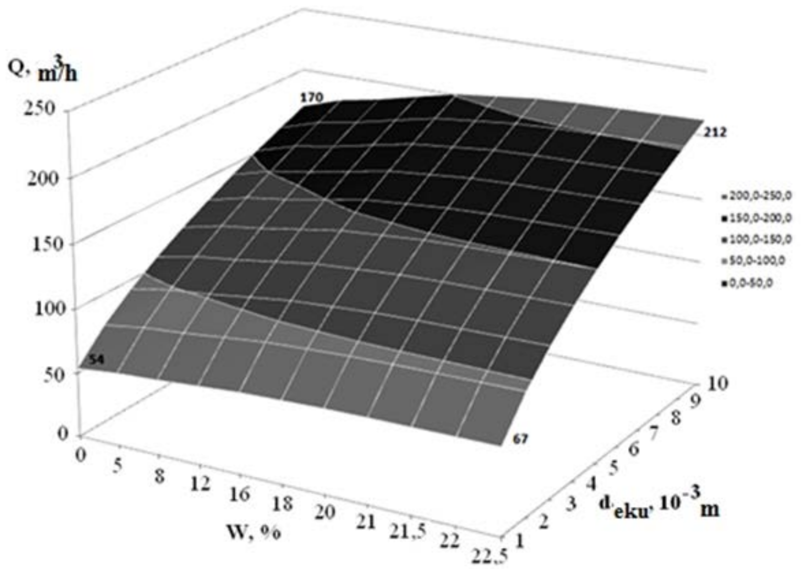
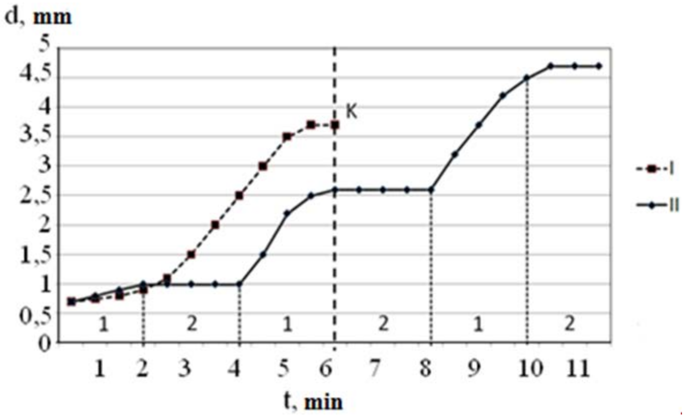


Figure 4. Dependence of process parameters of fluidizing in case of granulation of dispersed fraction of domestic waste (developed by the author)

It was theoretically established and experimentally proved the mutual logarithmic dependence of the size of granules (d_{eku}) on humidity of domestic waste (W) and gas flow (Q) on fluidizing (Figure 4). Such dependence is characteristic of the range of humidity of material of 0 … 25% and the gas flow of 80 … 100 m^3/h in the device of volume ≈3 m^3 .

Also necessity of cyclic delivery of solution of binding material with uniform intervals of delivery was proved experimentally. It allows prevention of unwanted aggregation of particles of dispersed fraction of waste, accumulation of material and drops of binding solution on walls of operating device, and also provides uniform drying of particles in the course of granulation and, respectively, formation of solid granule (Figure 5).

Parameters of supply cyclicity of binding for obtaining optimum strength of granules, in case of which the ratio between supply period of binding liquid and idle fluidizing is 1:1-1:1.2 in average at total duration of intervals of 1.5-2.5 minutes for general time of granulation till 20 minutes, are established.



I – diagram of particles growth in fluidized layer with continuous feed of binding; K –line of critical sticking of material in case of continuous feed binding, granulation process stop; II - diagram of growth of particles with cyclic delivery of binding with an interval of two minutes;
1 – fluidizing stage with supply of binding; 2 – fluidizing stage without supply of binding

Figure 5. Dynamics of increase in the size of granules in fluidized layer in case of continuous and cyclic feed of binding with uniform intervals

Table. Results of granulation of dispersed fraction of waste by different methods

Basic equipment of granulation	Plate granulator	Stamp press	Fluidized layer
Average equivalent diameter of particles, mm	7,5	*Fixed value*	3,099
Granule strength, MPa	0,034	0,3	0,26
Duration of granulation process, min	45…50	5…7	10…12
Necessity of further drying	*Yes*	*No*	*Yes*

High level of strength of agglomerates formed in the granulator with fluidized layer, their high density and low finale humidity allow application of these granules in many processing diagrams. As an example of recovery of dispersed fraction of waste, the technology of thermolysis-energetic recuperation developed by Donetsk National Technical University (Figure 6) is considered [9].

The following principles are the basis for technology of thermo-recuperation:

1) Technology basis is thermolysis of organic part of waste.

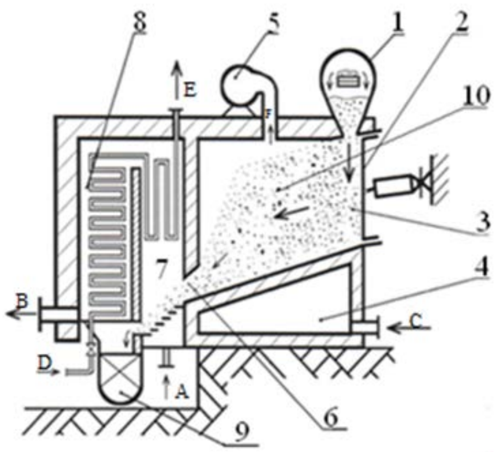
2) Large scale of industrial plants and high technology productivity. Possibility of use of the existing hardware basis of coke-chemical enterprises.

3) Complex nature of recycling. Recovery of organic component, volatile product entrapment, thermal energy obtaining.

4) Recovery of unassorted organic waste. Compounding of mixtures of industrial and domestic solid and liquid wastes.

5) Controllability and flexibility of processes.

6) Complete tightness of the thermolysis equipment, complete cycle of processing, and consequently, high level of ecological safety.



1 - system of charging; 2 – pressing and pushing device; 3 - thermolysis furnace; 4 - heating system of furnace; 5 - system of volatile discharge; 6 - inclined passage; 7 - fire chamber; 8 - boiler unit; 9 - system of ash disposal; 10 - material sintering zone
A - air supply in fire chamber; B - furnace gases for purification; C – supply of gas and air for heating of the furnace; D - water supply in boiler unit; E - discharge of steam to the turbine; F - discharge of chemical products for recycling

Figure 6. Schematic diagram of installation of thermolysis-energetic recuperation of waste [9]

Fundamental distinguish of this technology from other thermal methods of processing is division of heat-carrying agent and processed weight that leads to the minimum formation of volatiles containing dioxines [10]. At the same time, the volatile components, which are formed during thermolysis, are less polluted than when burning, inasmuch as the process is carried with compacting of the initial raw materials. It is provided with repressing of bulk mass of waste after charging in the furnace in the course of its layered sintering that almost completely excludes formation of dust fractions in gas products.

Recovery of waste by coking puts certain requirements to material. It is theoretically justified and experimentally proved that by analogy with coke-chemical production, thermolysis of waste particles is possible only at certain granulometric composition of particle with the size <1 mm - 25-27%, 1-3 mm - 40-45%,> 3 mm - 28-35%. It is caused by certain ratio of large and small-sized particles of material for achievement of the maximum bulk density, which is conductive to the better sintering, at the same time providing sufficient gasification of material during thermolysis. The size of granules of dispersed fraction of waste obtained in case of granulation in the device with fluidized layer ($d_{eku} \approx 3$ mm) is comparable to the necessary size of furnace charge for effective sintering in chamber furnaces, and allows providing of necessary level of gasification and enough contact sintering points. Thus, it is possible to draw a conclusion that the granules of dispersed fraction of domestic waste obtained in case of granulation in the device with fluidized layer are suitable for their further processing by thermal methods including in technology of thermal-recuperation in chamber furnaces. The granules of dispersible fraction of waste obtained in fluidized layer can be also used as the component in carbon furnace charge without coke quality loss. Efficiency of such processing was experimentally confirmed on the hardware basis of PJSC "Avdeevka Coke Plant".

The preliminary evaluation of economic effect of such recycling method application under the conditions of our state has shown the following results:

- the cost of industrial complex of productivity on the initial raw materials of 2 mil. tons per year is 20 mil. c.u.;
- construction period – 1.5-2 years;
- profit of the project – 8-10 mil. c.u./ year;
- payback period – 2-3 years.

Practical implementation of this technology is supposed to be on platforms and with use of infrastructure and personnel of the existing coke-chemical plants allowing application their potential. Thus, relevant scientific problem of creation of technological basis for elimination of stored waste on an industrial basis and safe recycling of their ecologically aggressive fine components due to grounding of rational processes and parameters of granulation providing control of fractional and moist composition of the obtained product is solved in the paper.

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