EXPERIMENTAL DETERMINATION OF THERMAL CHARACTERISTICS OF MUNICIPAL SOLID WASTE

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Abstract. The article is devoted to the experimental study of effective thermal characteristics of municipal solid waste (MSW) wet layer in the drying process. The research is based on the zone method. Series of laboratory experiments was performed. The drying kinetics and temperature curves were obtained on the base of which the kinetic coefficients were determined. We constructed a graph of the kinetic coefficients of the material moisture. The research results can be used for determination the temperature and moisture content fields in the MSW layer during its processing.

1 Introduction

In world practice an overwhelming amount of municipal solid waste (MSW) are taken to landfills. Increased cost of MSW burial and delivering them to the grave sites, a permanent environmental hazards connected with the disposal of large volumes of waste, as well as the difficulty of selection and arrangement of new landfills are stimulating the industrial waste processing as a way takes into account the most requirements of the economy, ecology and resources. Industrial processing provides an integrated approach to addressing disposal, recycling and disposal of waste. It makes it possible to save land resources, to produce of waste new products (heat and electricity), to solve environmental problems. The gradual transition from landfill to industrial processing is the main trend of the solution of solid waste problem in the world.

MSW is a heterogeneous mixture of complex morphological structure, including: food and vegetable waste, paper and textile components, plastic, leather, rubber, wood, ferrous and nonferrous metals, glass, stones, bones.

When considering the entire complex of problems associated with the collection, transportation, disposal and recycling of solid waste in the first place the question of the composition and the properties of this material. If for decision the problem on the collection and transportation of MSW the information on their moisture content and density is sufficient, then for the choice of disposal and utilization method and technology it is necessary to obtain complete information about the morphology and elemental

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composition, including thermal properties of MSW. The morphological structure of MSW is given in Table 1. [1]

Table 1. Morphological composition of MSW in different climatic zones, % by weight.

Component	Climatic zone		
	medium	south	north
Food waste	35…45	40..49	32….39
Paper	32….35	22….30	26..35
Wood	1…2	1…2	2…5
Black scrap metal	3….4	2….3	3….4
Nonferrous scrap metal	0.5….1.5	0.5….1.5	0.5….1.5
Textile	3….5	3….5	4….6
Bones	1…2	1…2	1…2
Glass	2….3	2….3	4….6
Leather, rubber	0.5…1	1	2…3
Stone, stucco	0.5…1	1	1…3
Plastic	3….4	3….6	3….4
Other	1…2	3….4	1…2
Screenings (less than 15 mm)	5….7	6….8	4….6

In world practice for the MSW recycling and disposal are using thermal, chemical, biological and physico-chemical methods. The content in the MSW to 60 - 70% organic (combustible) faction prefers their processing energy efficient thermal methods, where the energy for processing itself can be removed from MSW while producing the new fuel and on the basis of electricity and heat.

2 Statement of the Problem

Thermal processing of solid waste is most often carried out in shaft furnaces (thermal reactors) in which MSW layer sequentially through drying processes and pyrolysis with subsequent gasification of solid carbonaceous residue. Gaseous fuel formed in the processing is removed to the consumer for use in thermal technological process.

Solid waste can be attributed to particulate material, which in the presence of moisture internal require high energy consumption for the drying process. In order to select a rational regime of the reactor it is necessary to determine the temperature field of solid waste layer, drying time raw material and energy costs in the process. Knowledge of these parameters is possible to calculate the speed of charging, the height of the drying zone of the thermal reactor and, therefore, to design it properly.

Determination of MSW layer temperature fields as a multi-porous body, makes it necessary to determine the dependence of its effective heat-physical properties on the moisture content and temperature.

Currently, there are many different methods and techniques for determination of the effective thermal characteristics of the porous bodies [2,3]. As for the solid waste, in literature there are only scattered data obtained based on experimental studies of thermal properties of some individual MSW components [4,5,6].

The purpus of this research is an experimental study of thermal properties of the MSW layer.

3 Experiment and processing

As shown in Table 1, the base components of MSW with the greatest percent in the morphological structure are: food waste, paper (cardboard) and textile, which in the form of moisture due to the material related to the capillary-porous colloidal bodies. To identify the physical picture of the heat and mass transfer in colloidal capillary-porous bodies you need to know the dependence of the thermal coefficients on the physical - chemical properties and moisture content, which is the main factor that determines the thermal properties of moist bodies.

In general, heat and mass transfer process is characterized by variability of physical parameters: temperature and moisture content. In order to determine the material temperature and moisture content dependences of the transfer coefficients we put a series of experiments. In this connection, we used a zonal method which ensures the accuracy of determining the physical characteristics values, acceptable in technical calculations.

Figure 1 shows the experimental setup. The experimental procedure was as follows. The test material (MSW layer sample) was placed in two thin-walled copper cylinder with a diameter of 16 mm and a length of 110 mm. One cylinder is suspended for weighing device, the other – is used for fixing the material temperature change using thermocouples connected to the inverter MBA8. Then cylinders were placed in an insulated pipe, purged with a hot heating medium at a speed of 8 m / s, excluding the external diffusion resistance to vapor transport from the open ends of the sample into the environment. Temperature change over time of the material along the length of the sample and the mass loss are fixed. Thus, the drying kinetics curves and the temperature curves were obtained, from which the effective thermal conductivity coefficient was calculated.
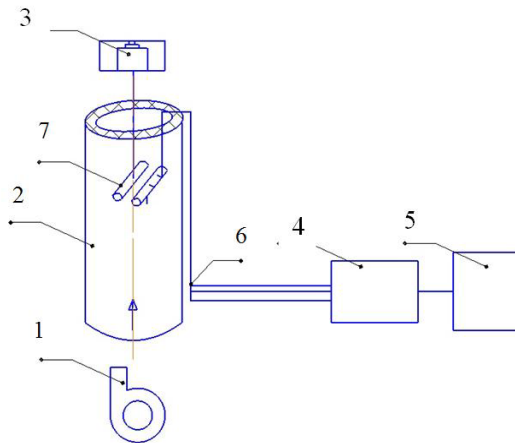

Fig. 1. Schematic of the experimental setup. 1. Air heater; 2. Insulated pipe; 3. Electronic balance; 4. Unit MBA-8; 5. PC; 6. Thermo-couples TCA (c); 7. Samples.

In accordance with the zonal method, the interval of moisture concentration variation in the solid phase $(U_S \div U_E)$ and the temperature $(T_S \div T_E)$ was divided into n zones, each of which assumes a constant thermal conductivity coefficient.

To determine the effective thermal conductivity the zonal method was supplemented by removing the temperature curve. Each temperature curve was divided into n zones corresponding to of kinetics curve zones. For each of the zones T_{S_i} and T_{E_i} were measured and the thermal balance was made:

$$q_i = \frac{m_c \cdot c_c \cdot \Delta T_i + m_M \cdot c_W \cdot \Delta T_i + m_c \cdot \Delta U_i \cdot r}{\Delta \tau_i} \qquad (1)$$

Then, considering that the quantity of heat required to heat up the mass of material, mass of moisture contained in it and evaporate the moisture is supplied by heat conduction through the side surface of the sample, we determined the effective thermal conductivity of moist material in the drying process by the formula:

$$\lambda_i = \frac{q_i \cdot \delta}{F \cdot (T_H - T_{M_i})} \qquad (2)$$

In the equations (1), (2) is indicated: m_c - mass of dry substance in the sample, kg; c_c - heat capacity of dry substance, J/(kg·K); $\Delta T_i = T_{Ei} - T_{Si}$ - temperature change of the material over time $\Delta \tau_i$, ° C; m_M - the mass of moisture in a sample to the time τ_i, kg; c_W - water heat capacity, J/(kg·K); δ − radius of the sample, m; F - the lateral surface of the sample, m^2; $T_H - T_{M_i}$ − the temperature difference between the heating medium and the average temperature of the material in the *i*-th time interval, ° C.

Effective thermal diffusivity was determined by the well-known formula:

$$a_i = \frac{\lambda_i}{c_i \cdot \rho_i} \qquad (3)$$

Specific heat of moist body linearly dependent on the moisture content, was determined on the principle of additive:

$$c_i = c_c(1 - \bar{U}_i) + c_W \cdot \bar{U}_i \qquad (3)$$

The density of the material to be dried was determined by the expression:

$$\rho_i = \rho_c(1 - U_i) + \rho_W \cdot U_i \qquad (4)$$

where in - ρ_W, ρ_c the density of water and dry material respectively.

4 Results and Discussion

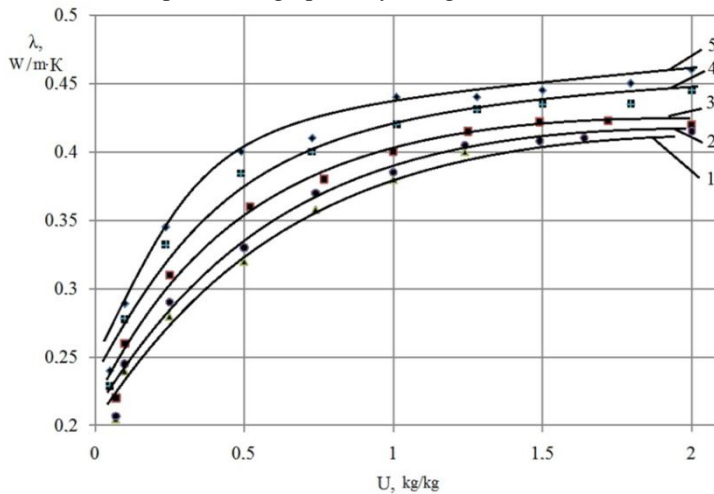The experimental results are presented graphically in fig. 2 - 4.

Fig. 2. Variation of the effective thermal conductivity of MSW during process at temperatures of the drying agent (1– 132°C, 2– 146°C, 3– 157°C, 4– 175°C, 5– 192°C).
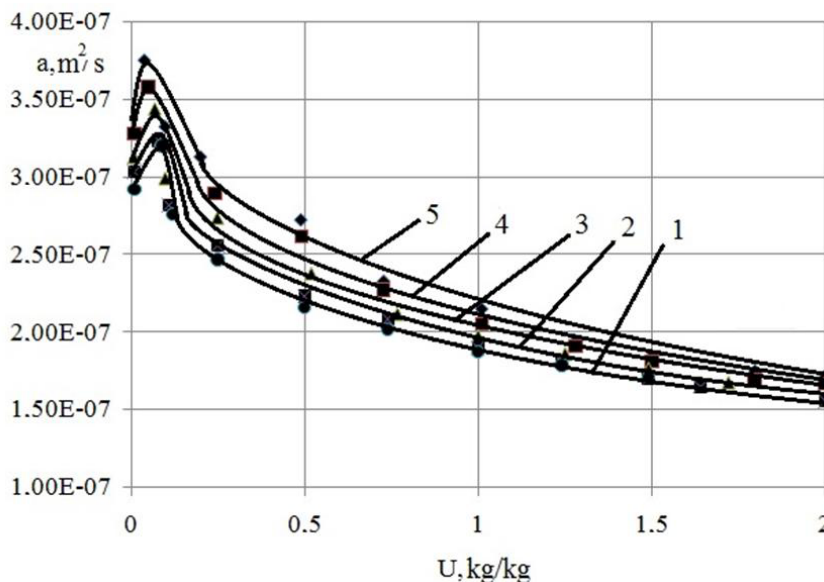
Fig. 3. Variation of the effective thermal diffusivity of MSW during process at temperatures of the drying agent (1– 132°C, 2– 146°C, 3– 157°C, 4– 175°C, 5– 192°C).

5 Conclusion

As a result of the experiments drying kinetics curves and temperature curves were obtained. On the base of the curves effective thermal conductivity and thermal diffusivity of MSW were calculated.

The results of this research can be used to calculate the temperature field and moisture concentrations in the MSW layer during its processing in the thermal reactor.

Acknowledgments

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