THERMAL ANALYSIS OF THE CENOSPHERE OF FLOATING ASHES OF THERMAL POWER PLANTS FOR THE PRODUCTION OF AERATED CONCRETE

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ABSTRACT

The thermal analysis of the cenosphere of floating ashes of thermal power plants for the production of aerated concrete and ways of solving the issues of environmental pollution by ash waste are discussed. The Thermal analysis of the cenosphere of floating ashes from thermal power plants in the city of Ekibastuz, Republic of Kazakhstan is carried out. In this study, much attention was paid to identifying the compliance of the cenosphere of floating ashes from thermal power plants with international standard norms and requirements for the production of aerated concrete. Also, studies were carried out on the thermal decomposition of the floating ash cenosphere.

Keywords: thermal analysis, derivatogram, thermal decomposition, cenospheres of floating ashes, standard norms and requirements, aerated concrete.

INTRODUCTION

Thermography, or thermal analysis, is one of the most common methods for studying the phase composition of materials. Thermography serves to study the composition of mineral raw materials for the production of building materials, to determine the temperature at which physical and chemical transformations occur in materials, and to investigate the hardening of binding components [1]. Thermography is based on the following phenomena: changes in enthalpy, mass, size, and electrical conductivity during heating [2]. The curve recording changes of any property from heating time is called a thermogram. Derivatography is a combination of the two most common thermographic methods: differential thermal analysis and thermogravimetric analysis [3]. Derivatographic analysis is based on the simultaneous measurement of mass and enthalpy of the material during heating. During the analysis of one sample, four curves are simultaneously recorded that characterize the process of thermal transformations of a substance: mass loss (TG), sample temperature rise (T), weight loss rate (DTG), and rate of temperature change (DTA), which reflects the change in enthalpy [3]. The device for taking derivatograms, a derivatograph consists of an infrared reflective oven providing a rapid rise in temperature and a thermostat to set the heating rate [5 - 7, 10]. The main studied raw material, the floating ash of the Ekibastuz TPPs, consists of spherical micro particles similar to luminous non-magnetic cenospheres [4, 8, 9].

The study aimed to analyse and decode the derivatograms of mineral raw materials obtained from the cenosphere of floating ashes of thermal power plants and to determine the possibility of their use for the production of aerated concrete.

EXPERIMENTAL

Methods

During the analysis, the temperature change hatching was recorded automatically, with the distance between two adjacent hatches corresponding to 20^{o}C. To determine the mass of the substance, the mass change hatching was recorded in the TG curve field of the derivatogram, with the distance between two adjacent hatches corresponding to 1 mg.

Test conditions

Device type: D500 Derivatograph. Sample mass: 50 mg. Heating rate: 10°C/min. Device sensitivity: *TG* = 500; *DTA* = 1/10; *DTG* = 1/10.

The procedure for decoding the derivatogram is as following:

- after drawing the baseline on the DTA curve, the peaks were found, the type of effect was determined, and the inflection points at the beginning and the end of the transformation were marked. Then, projecting these points onto the T curve, the temperature of the beginning and the end of the transformation was determined;
- detection of a peak on the DTG curve made it possible to project the top of the peak onto the T curve and determine the true temperature of chemical transformation;
- after determining the mass loss (Δm) of the sample as a result of its thermal decomposition, the content of impurities in the analysed material was calculated according to the TG curve. The value of Δm found from the TG curve was equal to the mass of the volatile product that was released from the sample as a result of a chemical reaction.

During the thermal decomposition, water in the ash cenosphere is evaporated, the organic part is burned to a gaseous state, and the mineral part became crystalline and amorphous. The mineral part of the ash cenosphere was dominated by mullite, which included clay minerals, peat, quartz, feldspar, iron sulphide and hydroxide, calcium and magnesium carbonate. During combustion, clay minerals dehydrated and formed aluminium with a low base and calcium silicate content. Mullite, quartz and feldspar did not change or melt. Calcium and magnesium carbonates decomposed to form CO_2, CaO and MgO. Large CaO and MgO crystals slowly reacted with water after their formation, thus reducing the strength of the binder when ash was added.

RESULTS AND DISCUSSION

Calculation of the transformation activation energy

Activation energy is the excess amount of energy that a molecule must possess for a chemical transformation to begin.

To graphically determine the activation energy, points on the initial branch of the peak of the DTA curve was selected (Fig. 1). For each point, the distance to the baseline (Δt, mm) was measured using a ruler, and the temperature ($t°C$) was determined by projection onto the T curve. The values found are listed in Table 2.

Based on the data obtained (Table 2), a graph was plotted in coordinates ln $\Delta t = 1/T$. The graph represents the slope along which the activation energy E was calculated, kJ mol^{-1}.

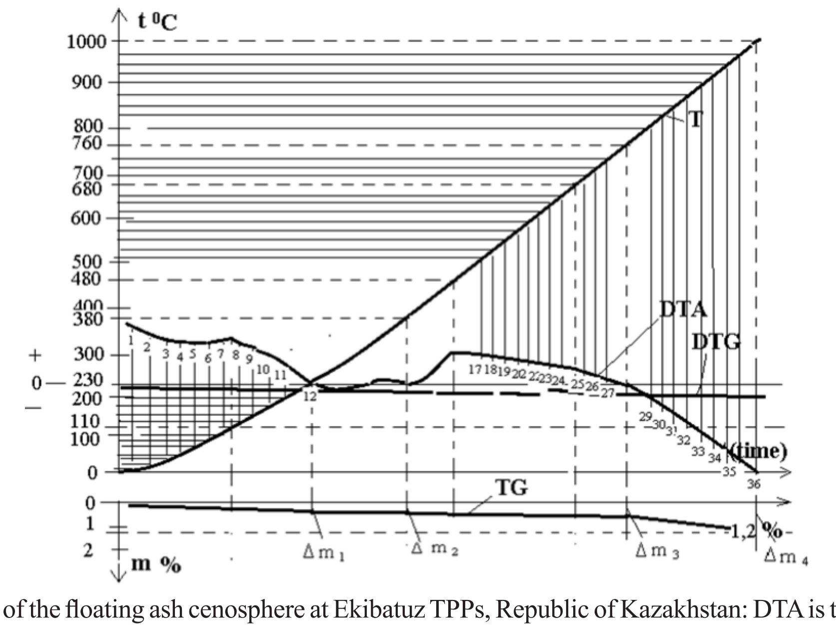

Fig. 1. Derivatogram of the floating ash cenosphere at Ekibatuz TPPs, Republic of Kazakhstan: DTA is the differential curve of thermal stability tests, DTG is the rate of change in mass, TG is the mass change/loss curve, and T is the temperature rise curve.

Table 1. Parameters of thermal decomposition tests.

#	Temperature rise, t, $°C$	Temperature change, Δt, $°C$	Energy effects	Mass loss, Δm (%)	Decomposition of mineral and chemical compounds
1	0–230	230 peak at 110	exotherm	0.40	Evaporation of water, organic compounds, clays, chlorites: Chlorite (clay) $\left[Mg_{5.6}Fe^{2+}{}_{0.5}Al_{0.9}\right]\left[Si_{3.2}Al_{0.8}\right]O_{10}\left(OH\right)_8$
2	230–380	150	No effects	0.40	No decomposition and change
3	380–760	380 peak at 480	exotherm	0.70	Hematite $\left(Fe_2O_3\right)$, magnesium, potassium, calcium carbonates ($MgCO_3$, $CaCO_3$) and hydroxides ($Ca\left(OH\right)_2$, KOH)
4	760–1000	240 peak at 1000	endotherm	1.2	dicsociation magnesium, potassium, calcium carbonates ($MgCO_3$, $CaCO_3$, $Ca\left(OH\right)_2$) and dehydration hydroxides ($Ca\left(OH\right)_2$, KOH)

The energy activity was determined according to the graph on Fig. 2:

$E_1 = R.b_1/a_1 = 0.00831$ *kJ/mol.K.50mm / 65mm = 0.0064 kJ/mol ;*

$E_2 = R.b_2/a_2 = 0.00831$ *kJ/mol.K.50mm / 17mm = 0.0244 kJ/mol ;*

$E_3 = R.b_3/a_3 = 0.00831$ *kJ/mol.K.50mm / 5mm = 0.066 kJ/mol*,

where $R = 0.00831$ *kJ/mol.K* is an absolute gas constant and $b_1, b_2, b_3, a_1, a_2, a_3$ are plotted values in mm.

The derivatogram of the thermal decomposition of floating ashes from Ekibatuz thermal power plants showed the initial temperature of 230°C and heat transfer processes had effects from 0 to 230 and 380 - 760 degrees of heat dissipation (exo) and 760 - 1000 degrees of absorption heat (endo). The corresponding mass loss at these temperatures was 1.2 %. The main crystalline phase of the thermal decomposition product of the silica ash compound was the mullite phase.

CONCLUSIONS

The results of the study the derivatogram did not reveal any restrictions for the use of floating ashes in the production of all types of building materials. The use of floating ashes from thermal power plants is advisable in the production of refractory materials and structures used

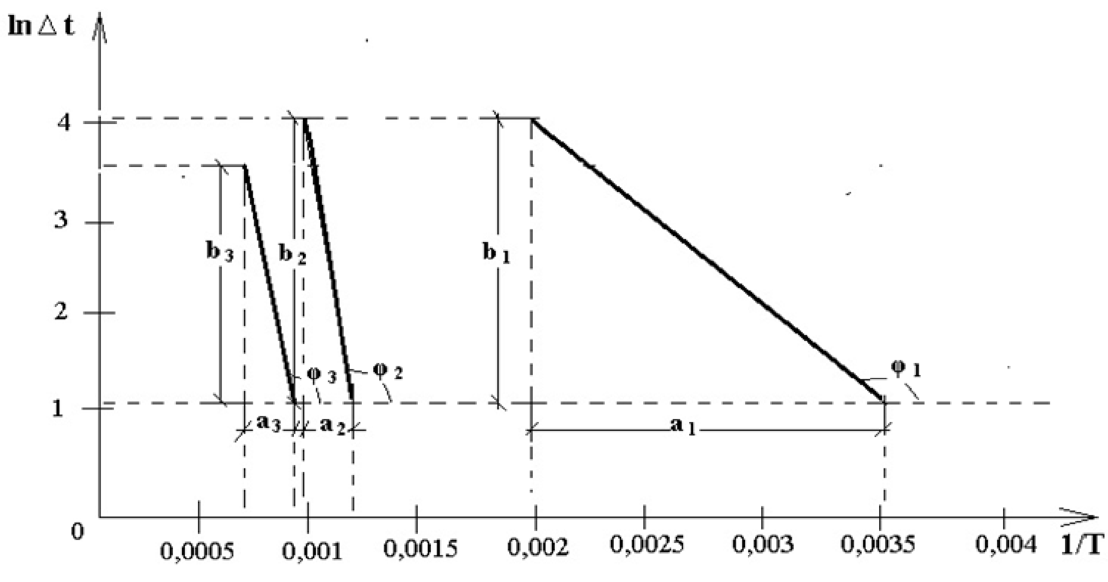

Fig. 2. The energy activity graph.

Table 2. Calculation of the energy activity.

Point number	Δt , mm	t, °C	T, K	$1/T$	ln Δt
exotherm					
1	5	10	283	0.0036	1.09
2	10	20	293	0.0034	2.303
3	15	30	303	0.0033	2.708
4	20	40	313	0.0031	2.996
5	25	60	333	0.0030	3.219
6	30	80	353	0.0028	3.401
7	35	110	383	0.0026	3.555
8	40	125	398	0,0025	3.689
9	45	150	423	0.0023	3.807
10	50	180	453	0.0022	3.912
11	55	208	481	0.0020	4.07
12	60	230	503	0.00198	4.094
exotherm					
17	5	520	793	0.00126	1.09
18	10	538	811	0.00123	2.303
19	15	558	831	0.00120	2.708
20	20	580	853	0.00117	2.996
21	25	600	873	0.001145	3.219
22	30	620	893	0.001119	3.401
23	35	640	913	0.001095	3.555
24	40	680	953	0.00104	3.689
25	45	700	973	0.00102	3.807
26	50	720	993	0.001009	3.912
27	55	740	1013	0.00098	4.07
exotherm					
29	5	800	1073	0,000931	1,09
20	10	820	1093	0,000914	2,303
31	15	842	1115	0.000896	2.708
32	20	870	1143	0.000874	2.996
33	25	888	1161	0.000861	3.219
34	30	918	1191	0.000839	3.401
35	35	950	1223	0.000817	3.555
36	40	1000	1273	0.000785	3.689

in the construction of industrial facilities. The results of the analysis of thermal decomposition of the floating ash cenosphere of Ekibastuz thermal power plants comply with the requirements of the GOST 30108 standard and do not exceed its standard indicators.

The thermal decomposition analysis showed that the floating ash cenosphere was resistant to high temperatures and had a mass loss of 1.2 %, and the final decomposition product consisted of crystalline mullite ($Al2$ [$Al2.4$ $Si1.2$] $O9.66$). Thus, the floating ash cenosphere can be used in the production of refractory aerated concrete.

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