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NEW TECHNOLOGY OF DRY BENEFICATION OF FLY ASH FROM COAL POWER PLANTS USING APPLIED MINERALOGY TECHNIQUES

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The existence of environmental and strategic need to process dumps and slagheaps of coal mining enterprises of Russia and foreign countries results in reviewing the potential of using fly ash as a technogenic mineral resource. Comprehensive studies of substance composition of fly ash from coal power plants make it possible to define rational further ways of utilizing that mineral resource substantiating the scheme of its technological secondary processing. In view of the numerous environmental problems stemming from the techniques of wet benefication and processing of that mineral resource, a technology is suggested of dry cleaning of fly ash from thermal coal power plants.

Studies were carried out using a number of samples of fly ash from various power plants. The suggested criteria are used to discriminate the compounds of fly ash and quantitative and qualitative composition of particulate matter is assessed. Studies of substance composition of fly ash samples has demonstrated that the concentration of non-combusted carbon in them varies from 5 to 20 %. The principal technological procedure of cleansing in our studies was a combination of magnetic and electric separation of ash in the state of vibrational pseudo-liquefaction. It enables one to increase the throughput capacity and selectivity of the cleansing process significantly. In the result of such cleansing a stable mineral fraction is produced that contains 0.5-2.5 % of carbon, so that the purified mineral fraction can be used as a construction binding agent.

Key words: applied mineralogy of fly ash, qualitative and quantitative composition of fly ash, recycling, vibrational pseudo-liquefaction.

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Introduction. The global practice of power generation at thermal power pants occurs as flame combustion of finely grinded coal. However, when proceeding from bulk to dust level flame combustion the share of furnace slag formed drops while the share of fly ash carried away from the furnace increases. The constantly growing areas of ash dumps bring about reversible environmental problems that entail significant changes in the natural balance of environmental systems.

The principal mineral phase of fly ash of thermal power plants (TPP) is a promising binding substance for construction industry, however impurities of non-combusted coal that vary from 3 to 20 % prevent its effective recycling [6, 7, 16]. For stable use of fly ash as a universal binding agent the content of "non-combustion" according to Russian standards should not exceed 3 % [8].

Using wet technologies for recycling of TPP fly ash to separate its non-combusted coal results in the apparent effect of hydration of the principal inorganic (mineral) part of fly ash, hence to the loss of its binding properties that may only be recovered via expensive calcination [10]. Therefore an attempt was undertaken within the scope of the current study to develop a new technological procedure for benefication of coal TPP fly ash using dry enrichment techniques. Such techniques include electric and magnetic separation that use significant differences in electric conductivity and magnetic perception of coal and magnetite hematite spheres associated with it from those of inorganic mineral components of fly ash. Specifics of the suggested technology consists in intensifying the process of electric and magnetic benefication of fly ash due to involvement of the effect of vibration pseudo-liquefaction [1-4].

In their state of rest the particles of bulk material are in permanent contact with each other, and their mutual position does not change then [12-14]. Vibration forcing of moderate intensity may produce forces in the layer of substance that overcome static friction between the particles which would result in continuous mutual displacement of such particles. With further strengthening of vibration even the gravity force may be exceeded, so that the particles of bulk material will be "swarming" above the vibrating surface. In other words, vibration forcing of various intensity may bring bulk materials into the quasi-aggregate state of "granular liquid" and "granular gas" [15].

Using the effect of pseudo liquefaction makes it possible to proceed from separation in a thin layer to separation in bulk material, thus more than doubling the process selectivity and productivity [14].

The end products of such technology of fly ash recycling is raw material for construction industry and the energy containing fraction sent for new combustion [11].

Particularities of fly ash qualitative and quantitative composition. As for substantive and grain composition of ash and slags coming to ash dumps, they depend on the mineral composition and quality of coal fuel, design of boiler furnaces, operational conditions for the boilers (steam load, uniformity of the combustion process and its combustion temperature in the furnace), the system of preparation and feed of

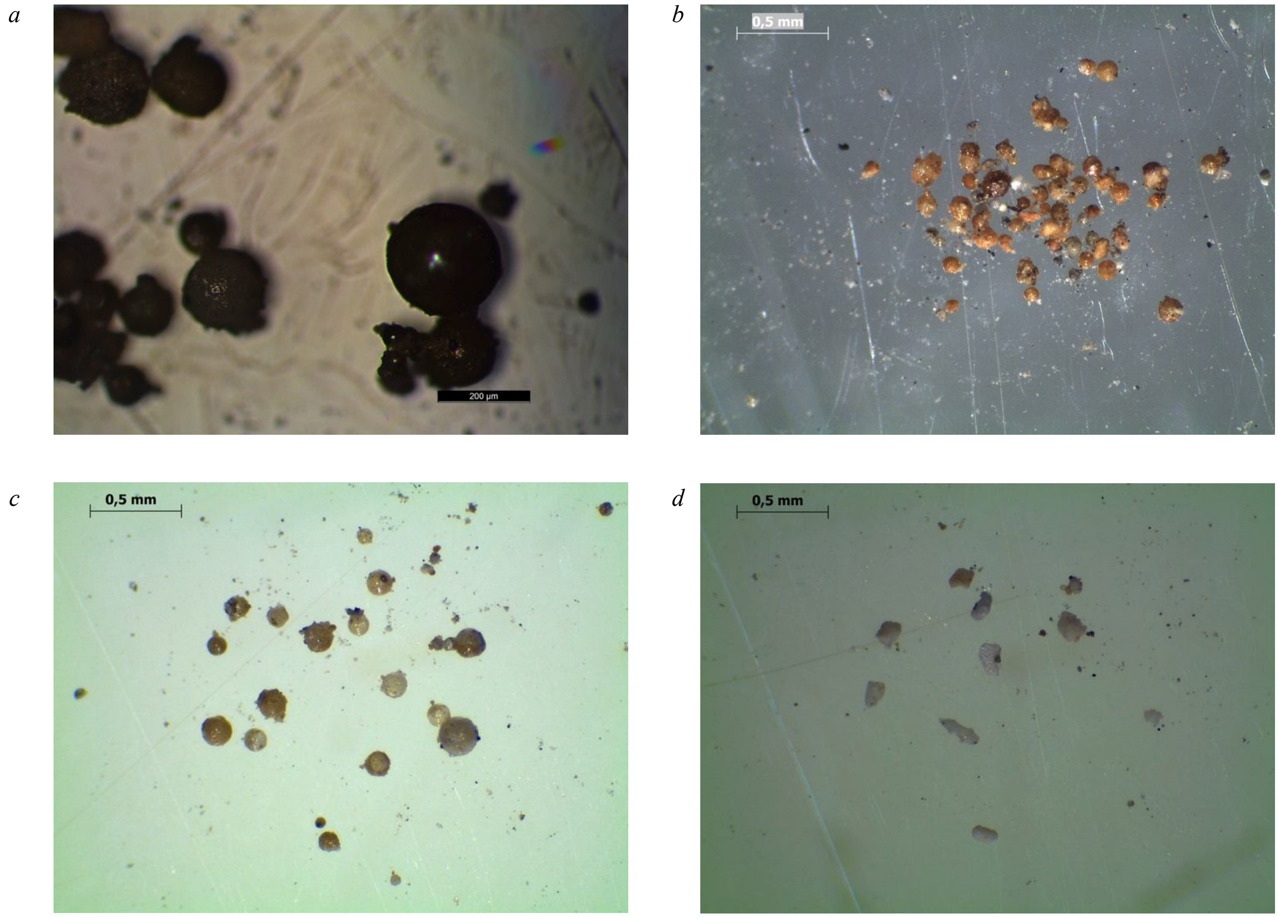

Fig. 1. Examples of separation of particles of fly ash according to qualitative criteria: *a* – aggregate magnetite-hematite spheres with "non-combustion" coal particle; *b* – honey-red spheres; *c* – transparent and light-grey siliceous spheres; *d* – agglomerated particles of quartz glass of irregular shape and glassy shine

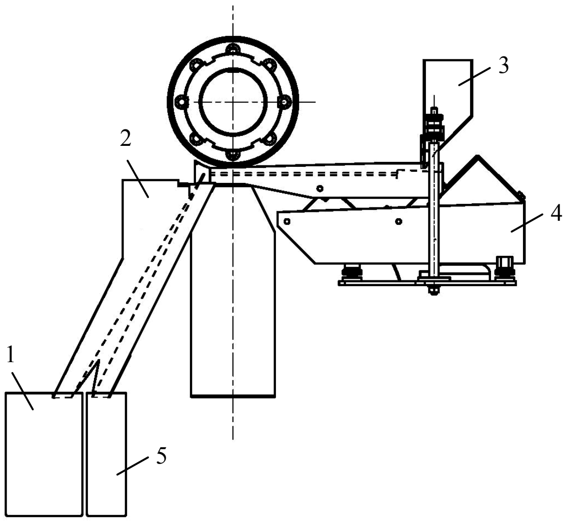

Fig. 2. Layout of the facility for electromagnetic separation in vibro-liquefaction state

1, 5 – product receptacles; 2 – chute; 3 – hopper; 4 – electric vibration feeder

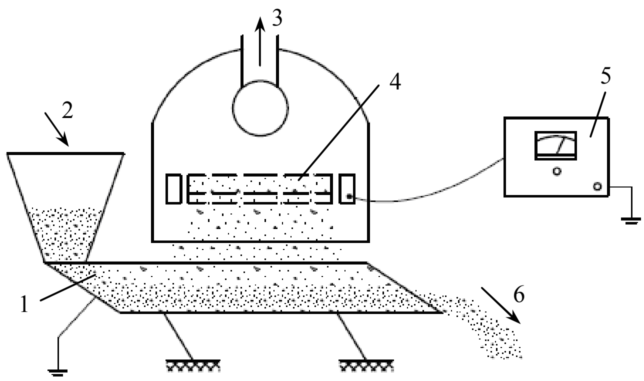

Fig. 3. Facility layout for electric separation in vibro-liquefaction state

1 – vibration feeder; 2 – feeder; 3 – electrically conducting product; 4 – high tension mesh electrode; 5 – high tension source; 6 – non-conducting product

coal dust for combustion (type and operational state and the number of mills operating); facilities feeding the slag to the system of hydraulic slag removal (HSR)[8, 9].

In the course of coal combustion in TPP power facilities light fraction of fly ash is formed that consists of particles of different density, composition and structure [6]. Our study subjects were the four samples of fly ash from thermal power plants situated in different regions of the RF.

These samples present fly ash that forms in TPP furnaces in the course of combustion of dust state coal. It should be specified that such a definition does not cover fly ash formed during combustion of combustible shales, their delivery and use following the respective regulatory technical documentation.

Particle content in various types of ash, mass %

Particle type	Fly ash sample			
	1st	2nd	3rd	4-th
Acc.	15-20	5-8	10	10-15
WS	40-45	80	60	10
RS	15	8	5-7	10-15
MHS	5-8	2-5	4-6	8-12
QG	10	5	8-10	15
CA	15	2	10	40
Major glassy products	0	0	5	10

To study substance composition of fly ash products were obtained of enriching two different classes of particle sizes that belong to two different stages of benefication: 0-0.63 and 0.04-0.63 mm. The first class (0-0.63 mm) is a product of common sieve separation into different size ranges during which all the particles larger than–0.63 mm were removed from it. The second class (0.04-0.63 mm) is a product of another stage of separation into different sizes, and in its course all the particles smaller than –0.04 mm in size were removed and two stages of magnetic separation and one stage of electromagnetic separation followed.

In the course of microscopic studies particles of fly ash were graded according to their morphologic and physical-optical characteristics to identify the following types of particles (Fig. 1): non-combusted coal particles (CP), white microspheres (WS), red spheres (RS), magnetite-hematite spheres (MHS), agglomerated particles of quartz glass (QG), composite agglomerates (CA).

Quantitative characteristics of fly ash composition are presented in the Table.

By way of an example Fig. 1 demonstrates microphotographs of particles from fly ash sample No. 1, their size varying from 0.005 to 0.1 mm. As for its qualitative composition the predominant substance is quartz globules and aggregates (about 55 %). Smaller amounts in approximately equal proportions are presented by mixed quartz-mica ("red") and carbonaceous silicate globules (15-20 %). Besides, agglomerates of carbonaceous silicate are found (approximately 20 %), their average size varying within 0.01 to 0.1 mm.

Designing technological solutions for Dry benefication of TPP fly ash in pseudo-liquefaction State. When studying samples of fly ash, three significant mineralogical and technological features were identified:

– carbon particles usually form agglomerates with magnetite-hematite spheres;

– carbon particles are characterized by large sixes in comparison with other particles of bulk mass;

– the principal mass of silicates is presented by glassified and non-glassified alumosilicates.

Accounting for these features, the solution of the problem of extracting carbon particles from dry fly ash is seen as a combination of dry separation into different sizes with further separation by magnetic and electrical properties of the particles in their pseudo-liquefaction state (Figs.2-5).

Following the above a combined technology was designed for benefication of dry TPP fly ash that includes the following basic elements: sieving

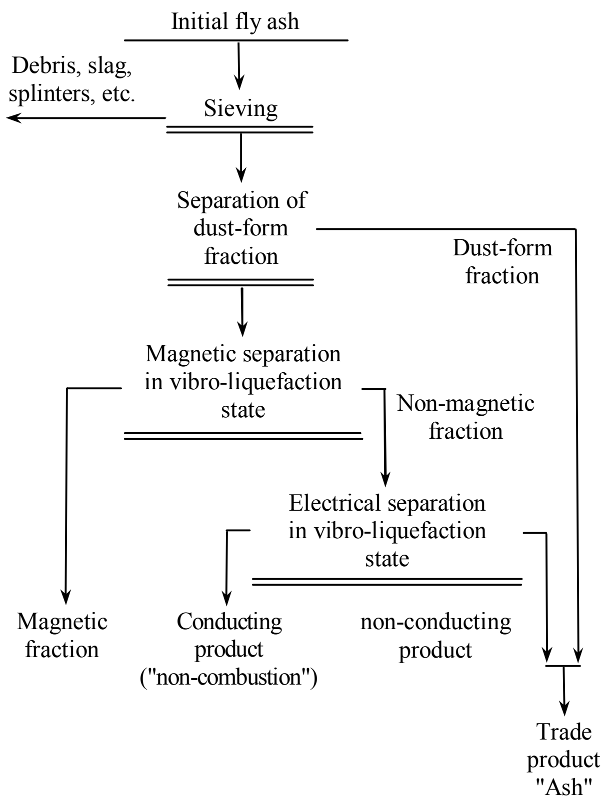

Fig. 4. Process Flow Chart of Dry Benefication of TPP Fly Ash in Pseudo-Liquefaction State

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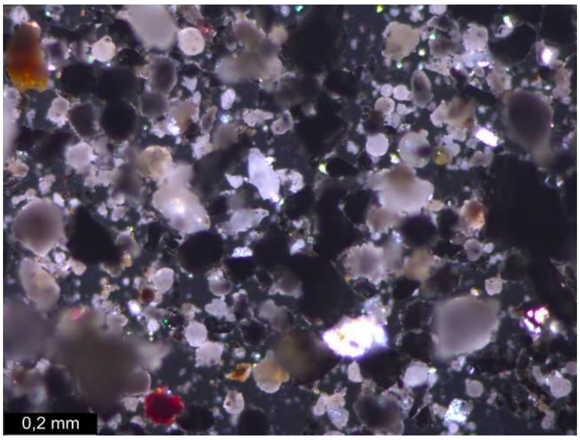
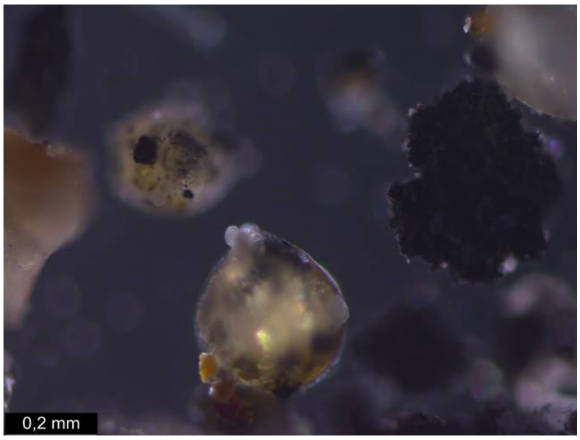
a  b 

Fig. 5. Products of benefication of fly ash sample No. 1: a – silicate fraction; b – carbonaceous silicate aggregates and carbonaceous silicate globules

to remove slag and major foreign inclusions; dry classification of throughput product in its pseudo-liquefied state to separate dust-form fraction that contains no "non-combusted" material; magnetic separation of the +40 μm fraction in its pseudo-liquefied state to extract agglomerates of coal particle with magnetite-hematite spheres and other magnetic inclusions and then electric separation of non-magnetic fraction in its pseudo-liquefied state where the residual coal particles are extracted into the conducting product. The non-conducting product is merged with dust-form particulate fraction –40 μm which is the trade product of carbonaceous particle content not exceeding 3 %.

In the course of technological tests which followed the scheme presented in Fig. 4 to process all the samples of fly ash mineral fractions were obtained with carbon content of 0.5-2.5 %. During the process about 3-8 % of mineral component of the initial fly ash is transferred to carbon product. Particle sizes vary between 0.005 and 0.1 mm. As for its qualitative composition the predominant substance is quartz globules and aggregates (about 55 %). Mixed quartz-mica ("red") and carbonaceous-silicate globules are present in smaller amount but approximately even proportions (15-20 %). Also, agglomerates of carbonaceous silicate composition are present to about 20 %, their average size varying between 0.01 to 0.1 mm.

Conclusion. Studying the composition and physical properties of dry fly ash demonstrated that coal particles form agglomerates with magnetite-hematite spheres most often and typically are of larger sizes as compared to other particles of the bulk mineral mass. Besides, fly ash is of extremely low bulk density and a unique conditional internal friction factor which is close to unit. Starting from these data a combine technology was developed of enriching TPP dry fly ash that includes magnetic and electric separation in vibro-liquefied state making it possible to produce a stable trade product containing less than 3 % of carbonaceous particles. Thus it can be used as a universal binding agent in construction industry.

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