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Analysis of chemical composition and physical and mechanical properties of power plant ash for its further processing

I.V. Frolova [a]*, V.V. Tikhonov [a], A.P. Poltoranina [a], K.Y. Cherkashina [a], Fu Shuangcheng[b]

[a] *Department of Chemical Engineering, National Research Tomsk Polytechnic University, Lenin avenue, 30, Tomsk, 634050, Russia*
[b] *School of mechanical engineering, Changzhou University, 213164, Changzhou P.R., China*

Abstract

The results of the study of ash of Tomsk Power Plant 2 (Toms, Russia) are represented. The grain size composition of ash and distribution of main oxides among fractions have been determined. Physical and mechanical properties and quality indices of ash have been investigated. It has been established that ash of Tomsk Power Plant 2 is referred to a latent active group of cindery waste and can be used as a binding material, in fly ash aggregate productions and in highway engineering.

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Keywords: ash, cindery waste, grain size composition; physical and mechanical properties; aggregate density

1. Introduction

Nowadays, a part of worldwide electric power generated by coal combustion is about 20% [1]. Along with electric power about 500 million tons of cindery waste is produced and its utilization is a very complicated problem. Thus, solution of this problem allows:

- decreasing adverse impact on the environment. Discharge of water that is used for cindery waste transportation pollutes basins and destroys their microclimate. Ash disposal areas not only occupy and contaminate huge agricultural areas but also pollute air even more than chimneys.

* Corresponding author. Irina V. Frolova. Tel.: +8-903-953-6312.
E-mail address: fiv.08@mail.ru

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- developing resource-saving and environmentally friendly technologies. Cindery waste has wide prospects because it is a valuable raw material for other productions. Technologies developed on the base of physical and chemical properties of cindery waste are able to solve problems which deal with lack of constructional materials, improvement of biological features of agricultural areas and ability to produce more economically efficient products.

In some European countries (the Netherlands, Denmark) complete utilization of cindery waste is a tradition supported by the government and legislated by the documents. The majority of the developed countries utilize 70-95 % of cindery waste[2]. A huge quantity of ash disposal areas is formed in the Russian Federation currently, where about 1.5 billions of cindery waste is stored. These ash disposal areas occupy approximately 22 thousand hectares. Unfortunately, only 5-13% of this cindery waste is utilized [3]; it is planned to increase utilization up to 30-50 % until 2020 and to 60-80 % until 2030. Therefore, investigation of utilization methods is a topical and practically interesting issue.

2. Results and discussion

The object of the research is ashes of Tomsk Power Plant 2 operating on Kuzbass coal. Huge ash dumps were collected during the station activity; these dumps are valuable for the further production usage. Ash was sampled from the dump according to the requirements from RD 34.09.603-88.

According to the macroscopic analysis dump ash is a dark gray dispersed material that boils under the action of hydrochloric acid. The main feature of ash composition is prevalence of a glassy substance in the form of spheres. Their light-gray surface is fritted, unruffled and glossy. Some spheres have white or brownish white color. The majority of the spheres have a bubble structure (hollow inside); the rest are compact-grained. While grinding spheres disintegrate and give a homogeneous fine-grained mixture.

The important characteristic of dispersed materials is their grain size composition, which depends on such factors as operating conditions of a boiler installation, furnace construction, coal feed and coal pulverization system. In this work screen analysis from GOST 9758-77 was applied for grain size composition determination. The results are given in Figure 1.

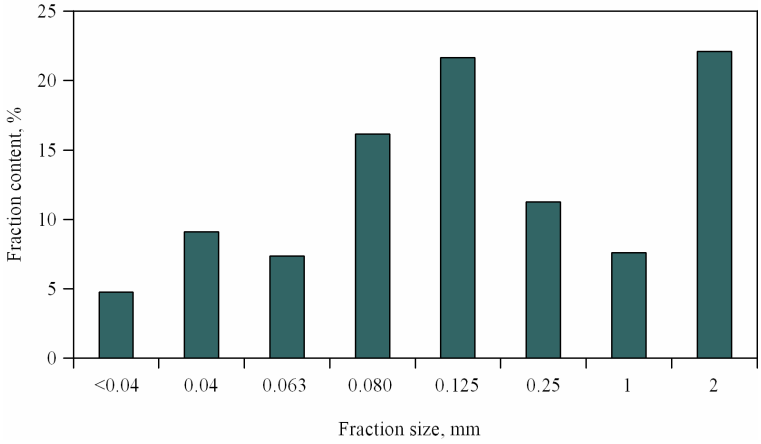

Fig.1. Histogram of grain size distribution

Figure 1 shows that ash is a polydispersed material. According to RD 34.09.603-88 one of the important steps of ash utilization is material classification, which is based on more typical quality indices, such as:

- basicity index (hydraulic module) Mo is a ratio of basic oxide sum to acid oxide sum;
- silica index Mc is a ratio of silica oxide reacting with the other oxides to the sum of aluminium and iron oxides;
- quality index (hydraulic activity) K.

Contents of basic oxides, which are necessary for calculation of cindery waste quality indices, are determined by atomic emission spectroscopy. The results are shown in Table 1.

Loss on ignition is approximately 7wt. % and caused by availability of coke and particles of coal that are not burned down. These particles of coal in the presence of moisture are known to be easily oxidized, thus increasing in volume up to 15% and even more. Therefore, the high content of loss on ignition of ashes is undesirable[4,5].

Calculated values of silica (Mc) and basicity (Mo) indices as well as hydraulic activity (K) show the ratio of main components and allow referring ash of Tomsk Power Plant 2, according to its chemical composition, to active, latent active or inert group. This classification of waste is offered by UralVTI research institute[6] and presented in Table 2.

Table 1. Fraction quality indices of ash of Tomsk power plant 2

Fraction size, mm	Oxide content, wt.%									Mo	Mc	K
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	SiO_2	TiO_2	LOI			
+1	16.47	6.44	13.93	0.90	1.26	0.48	59.26	0.68	0.59	0.12	1.95	0.40
-1 +0.25	12.92	6.18	12.47	0.82	1.22	0.48	53.86	0.65	11.41	0.13	2.12	0.37
-0.25 +0.125	10.63	6.18	21.06	0.75	1.33	0.51	52.80	0.51	6.23	0.14	1.67	0.34
-0.125 +0.08	6.20	4.09	26.98	0.49	1.10	0.33	34.84	0.32	25.65	0.15	1.05	0.32
-0.08 +0.063	5.69	516	48.19	0.45	1.87	0.35	31.94	0.35	6.01	0.21	0.59	0.39
-0.063 +0.04	6.22	5.13	42.51	0.51	1.71	0.40	31.70	0.39	11.44	0.20	0.65	0.41
< 0.04	11.57	5.68	20.58	0.75	1.63	1.06	54.96	0.64	3.13	0.34	1.71	0.34

Table 2. Classification of waste of solid fuel combustion

Chemical properties		Cindery waste		
		Active	Latent active	Inert
Quality indices	M_0	0.5-2.8	0.1-0.5	<0.1
	M_c	1.5-7.8	1.4-3.6	1.3-3.2
	K	1.0-3.6	0.5-1.3	0.4-0.9
	$CaO_{общ}$	20-60	5-20	0.5-5
Field of application		Local binding agent and products on its base, self-hardening material, highway engineering.	It requires hardening enhancement. Production of biding materials hardening in the presence of activators at a high temperature. Highway engineering.	Raw material for fly ash aggregate and brick production. Highway engineering. Technogenic soil.

Analysis of the data has shown that fractions with a grain size from 0.08 to 1 mm can be referred to a latent active group of cindery waste; it allows using these fractions as a local binding agent and products on its base (wide range of building and heat insulating materials) and also in highway engineering. Fractions with a grain size of less than 0.08 mm can be referred to an inert group of cindery waste; it allows using these fractions in fly ash aggregate and brick production.

Besides, it is known that a high value of the basicity index leads to better binding properties of the material and higher strength during solidifying. A high value of the silica index means that the material would bind and solidify slowly, but nevertheless its strength would increase in time. Special additives and an admixture of caustic limestone, which is responsible for ability of the material to solidify faster and stronger, may control hydraulic activity and CaO content [7].

The physical and mechanical properties of ash of Tomsk Power Plant 2 are determined by standard techniques[8] and presented in Table 3. The material was used full-sized to determine the aggregative specific gravity and it was ground to the powder to evaluate the pycnometric specific gravity. The determination of these two quantities of ash and slag material is based on the fact that particles of ash and slag possess closed pores; therefore, pycnometric and aggregate specific gravity are not equal.

Table 3. Physical and mechanical properties of ash of Tomsk power plant 2

Fraction size, mm	Pycnometric specific gravity, g/cm^3	Bulk density, kg/m^3	Aggregative specific gravity, g/cm^3	Specific surface area, cm^2/g
+ 1	2.3212	941.2	2.0014	2822
-1 + 0.25	2.3943	894.1	2.0182	2834
-0.25 + 0.125	2.4035	882.35	2.3901	3288
-0.125 + 0.08	2.4151	1088.23	2.4017	3971
-0.08 + 0.063	2.4197	1411.76	2.4103	5056
-0.063 + 0.04	2.5243	1382.35	2.5215	5776
< 0.04	2.5252	1264.71	2.5249	5795

As Table 3 shows, aggregative specific gravity of particles is less than specific gravity of a substance which forms its particle. The difference between aggregative and pycnometric specific gravity is the higher, the larger this particle is. Increasing of aggregative specific gravity of fine fractions is caused by content variety of magnetic components[9]. The higher the content of magnetic components, the higher the value of aggregative specific gravity is[10] . These data should be considered when evaluating the possibility of extracting the individual components of ash and slag mixtures and choosing a processing method.

3. Conclusion

The grain size composition has been determined, physical and mechanical properties and main quality indices of ash have been investigated. It is shown that fractions with a grain size from 0.08 to 1 mm can be referred to a latent active group of cindery waste that allows using these fractions as an autoclaved binding agent and products on its base (wide range of constructional materials) and in highway engineering as well. Fractions with a grain size of less than 0.08 mm can be referred to an inert group of cindery waste that allows using these fractions in fly ash aggregate and brick production. Besides, high ferrous oxide content in cindery materials allows considering that ash of Tomsk power plant 2 is a prospect raw material for extraction useful ferriferous products which have a wide range of application from filler for concrete to catalysts.

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References

1. Delitsyn L.M., Vlasov A.S. The necessity of new approaches for the usage of thermal power plant coal ash. *Thermal Engineering* 2010; **3**: 49-55.
2. Fursov V.V., Balyura M. V. Studying of properties of thermal power plant ash and cindery waste for the construction purposes. *Tractates of the International Geotechnical Engineering Conference "Urban development and geotechnical construction"*. SPb., 2008, **4**: 673-7.
3. Schelokov Y. M. *Ecological problems of energy-intensive industries: handbook*. M.: Heat; 2008.
4. Volzhensky A.V., Ivanov I.A., Vinogradov B. N. *Usage of ash and cindery waste in the production of construction materials*. Stroyizdat; 1984.
5. Putilin E. I., Tsvetkov B.C. *Application of fly ash and cindery waste mixtures in highway engineering*. Federal State Unitary Enterprise «Soyuzdornii»; 2003.
6. Panteleev V. G., Larina E. A., Melentyev V.A. *The composition and properties of thermal power plants ash and cindery waste: Reference book*. Energoizdat, Leningr.div.; 1985.
7. Itskovich S.M., Chumakov L.D., Bazhenov Y.M. *Technology of aggregate concrete: Handbook for the architect university speciality "Construction products and designs"*. Higher school; 1991.
8. Krasheninnikova N.S., Erdman S.V., Korobochkin V.V., Frolova I.V. *Chemical technology of inorganic substances: Laboratory course*. Tomsk: Publishing house TPU; 2004.

9. Anshits A.G., Kondratenko E.V., Fomenko E.V., Anshits N.N., Sharonova O.M., Nizov V. A., Kovalev A. M., Bayukov O.A., Solanov A.N. Extraction of magnetic fractions of constant composition from ash and researching of their physical and chemical properties. *Chemistry for sustainable development* 1999;**2**:31-6
10. Vinogradov B.N., Vysotskaya O.B. Methods of ash quality assessments. *Solid fuel chemistry* 1990;**4**:139-143.