Short Communication

Research into the Usefulness of Ash from the Co-Combustion of Lignite and Biomass in Mining Technologies

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Abstract

Biomass is a kind of fuel that is more and more often used in the energy industry. It supplements coal and allows it to meet the requirements of producing "green" energy and limit CO_2 or sulphur emissions. Research refers to the ash originated from the combustion of the lignite with and without the wood biomass in the CFB boiler. This article shows the results of research into physical-chemical properties of fly ash obtained from the combustion of the lignite with and without the wood biomass (wood pellet). The possibilities of the use of this ash include in suspension technologies widely used in coal mines.

Keywords: biomass, co-combustion, fly ash, suspension technology

Introduction

Over the years the market for combustion by-products (CBP) has been constantly changing. It touches both the widening of the range of the fuels used and the direction and amount of the ash used in the cement and building industries, as well as in the road industry [1-4]. Coal mines, one of the major mass recipients of fly ash [5-7], have experienced the temporary difficulties with access to the chosen types of ash, especially the most wanted ones showing the best binding properties, and at the same time the oversupply of CBP in power plants located within further from coal mines. Another important aspect of the changes is the constant widening of the fuel range used in power plants (biomass, waste fuels, sewage sludge) [8].

The addition of biomass is justified by both the reduction of gas pollution and the necessity of the share in 'green energy,' as well as the possibility of obtaining the additional funds, but also in some cases the quality of the fuel [9, 10].

The type of co-combusted biomass is mainly determined by the existence of the agriculture and wood industry in the area, the farms of energy plants, and the cost of transportation. Among the frequently co-combusted biomass are: wood, wood chips, bark, straw, olive mill cake, and sunflower husks [11-14].

The properties of fly ash from co-combustion depend greatly on the burning conditions (the kind of boiler, temperature of burning), the amount and chemical composition of the ash from coal and biomass, as well as the share of the biomass in the mixture with coal [12, 15].

The article shows the comparative results of two fly ash from coal combustion in the CFB (circulating fluidized bed) boiler. In the first case the lignite was the only fuel, in the second one 8% of the fuel mass was made by wood biomass pellet.

The aim of the research was to determine the differences of properties among different ash and the suspensions made of them in order to use them in mining technologies, mainly for filling underground voids and sealing and caulking of gob (breaking down zone) resulting from coal exploitation.

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Experimental Procedures

The tested samples of fly ash have been obtained from lignite burning in the CFB boiler – designated PT, and from co-combustion of lignite with the biomass (wood pellet in the amount of 8%) in the same type of boiler – designated PTB. The grain composition was marked with the use of laser diffraction with the application of analysette 22 made by Fritsch. The specific density has been measured by the pycnometry method with the use of a helium pycnometer micrometrics multivolume pycnometer.

For testing the properties of suspensions we prepared ash-water mixtures having variable weight proportions of ash and water. The methods used for the tests have been chosen according to the Polish standard PN-G-11011:1998 "Materials for solidified backfill and gob caulking. Requirements and tests."

In the first part of the tests concerning the suspensions in the liquid state the following tests were carried out: density, fluidity, the content of the supernatant water, the rheological properties. The latter tests were made by the use of the rotary viscometer made by Rheotest, and Bingham rheological model was adopted for the analysis.

The second part of the tests included the determination of the suspension binding time, after 28 days of their seasoning the determination of the uniaxial compressive strength and soakability after 24-hour seasoning in water surroundings.

Results and Discussion

The specific densities of the tested ash differ slightly: for the PT ash from the lignite combustion in the CFB boiler it reached 2.32 Mg/m^3, whereas for the PTB ash from co-combustion it reached 2.45 Mg/m^3. The significant differences in the grain composition can be noticed within both tested ashes. The content of the grains smaller than 0.1 mm reached 43.6% for the PT ash and 62.2% for the PTB ash.

The properties of ash-water suspensions in the liquid state made of PT and PTB fly ash are shown in Table 1. The results of the research show undoubtedly that the suspensions of similar properties made from the two analyzed ashes differ significantly in the content of the solid parts. For the PT ash the mass ratio of the ash to water (a/w) reached 0.55:1, letting us prepare the suspension of the fluidity to 300 mm, which is the highest limit for mining technologies. The suspensions from the PTB ash to reach the mentioned fluidity should be prepared with the mass ratio a/w above 0.8:1. In the case of the supernatant water the situation was similar: for the same value a/w the suspensions made of PT show the lower value of the supernatant water. Although in both cases the fluidity and the amount of the supernatant water were observed as smaller for the higher values of a/w, the course of the changes differed. It appears that the same fluidity of the suspensions from PTB ash show lower value of the supernatant water. The practical meaning of this feature is that for the suspensions of the same amount of the supernatant water (e.g. remains in gob), the suspensions from the PTB ash will show the lower flow resistance and better abilities to gob penetration.

The amount of the supernatant water is one of the properties thoroughly described in the PN-G-11011:1998, meeting the requirements allows us to use the suspensions for gob caulking or to solidified backfill. In the first case the amount of the supernatant water cannot be more than 15%, in the second case 7%. Among the analyzed suspensions, a few fulfill both criteria.

The results of research on the rheological properties of suspensions are shown as flow curves, and in case of the Bingham model – the straight line for which plastic viscosity is a directional factor, and the yield stress is a value they reach for the zero shear rate. The rheological properties categorize the suspensions as liquids. They let us determine the flow resistance during pipeline transportation, and the abilities of the flow and penetration of the gob. A good example here can be the flow curve for the suspensions: PTB (0.9:1), PT (0.6:1), PTB (1.15:1), PT (0.75:1) (Fig. 1). This shows the similarities of many suspensions made from different ash of different proportions a/w.

The properties on the seasoned suspensions covered specify the setting time, while with the suspensions seasoned for a period of 28 days include uniaxial compression strength (Rc) and soakability (Table 1).

The findings for seasoned suspensions show the possibility to obtain a suspension of short binding times, but for the suspensions with the proportion a/w higher than 0.7:1 in the case of PT ash and the proportion a/w higher than 0.95:1 in the case of the PTB ash. The tested suspensions differ significantly in the resistance to uniaxial compression. The higher values of Rc have been obtained for the suspensions made of the PTB ash, even when the a/w proportions were the same. The soakability of the suspensions from the PT ash was practically independent from the a/w proportion, and oscillated within 42-55%. The suspensions from the PTB ash showed lower characteristics of soakability.

In two cases (suspensions of a/w= 0.8:1 and a/w=0.9:1) the requirements for the solidified backfill were fulfilled, but at the same time the suspensions do not meet the requirements of the amount of the supernatant water. None of the analyzed samples was collapsed after 24-hours in water.

Conclusions

The ash used for the tests and which were the components of the tested suspensions, were taken from the CFB boilers after the combustion of lignite or co-combustion of lignite with 8% of wood biomass. The tests were conducted according to the Polish standard PN-G-11011:1998 in order to find the possibility of using this type of material in mining technologies.

The obtained results allow us to say that for both types of ash it is possible to prepare suspensions meeting the requirements of the standard mentioned above for the materials for gob caulking. However, in the case of pollution leachability we observed an exceed of the limit require-

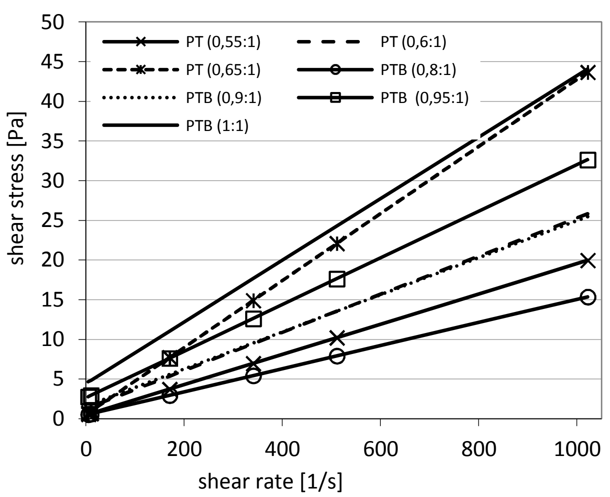
Table 1. The properties of ash-water suspensions from PT and PTB ash.

The weight ratio of fly ash to water a/w	Density [Mg/m³]	Fluidity [mm]	Amount of supernatant water [%]	Bingham rheological model		Setting time [day]		Uniaxial compressive strength (Rc) [MPa]	Soakability (collapsing behaviour) [%]
				Plastic viscosity [Pa s]	Yield stress [Pa]	beginning	end		
The suspensions of PT ash from lignite combustion									
0.55	1.25	295	18.8	0.0191	0.47	3.0	10.0	0.12	42.85
0.60	1.27	280	17.3	0.0240	1.28	3.0	9.0	0.16	54.55
0.65	1.28	240	15.6	0.0422	0.53	3.0	9.0	0.21	50.00
0.70	1.29	220	12.7	0.0454	3.49	2.0	5.0	0.26	50.00
0.75	1.32	190	8.7	0.0943	7.14	2.0	4.0	0.38	51.82
0.80	1.34	180	6.3	0.1161	9.38	2.0	4.0	0.51	53.57
0.90	1.39	155	5.9	0.1455	18.91	2.0	3.0	0.63	48.48
The suspensions of PTB ash from co-combustion of lignite and biomass									
0.80	1.33	320	16.2	0.0146	0.47	2.0	6.0	0.66	15.38
0.90	1.38	280	11.8	0.0234	1.61	2.0	5.0	0.68	17.07
0.95	1.38	270	7.1	0.0294	2.63	2.0	5.0	0.59	47.32
1.00	1.43	245	4.8	0.0388	4.45	2.0	5.0	0.74	36.75
1.05	1.44	230	4.4	0.0461	6.22	1.0	2.0	0.71	33.64
1.10	1.46	200	2.4	0.0718	10.20	1.0	2.0	0.65	45.38
1.15	1.46	180	0.0	0.0902	13.43	1.0	2.0	0.9	39.19

ments of the sulfur content and the pH index. On the other hand these features do not exclude the materials from use in mines. They should be analyzed individually, according to the place of the suspension appliance.

The obtained results reveal the significant differences within the properties of suspensions made of ash from lignite combustion (PT), and co-combustion of lignite and 8% of biomass (PTB). The differences were bigger than it might have been estimated knowing only the amount of the added fuel of another type. The suspensions based on the ash of type PT in a/w proportion 0.7:1 could be used for gob caulking. This allows binding the great amount of highly salted water. The suspensions made of PTB ash show high values in the uniaxial compression (above 1.0 MPa) after 28 days of seasoning.

This can indicate the possibility of good quality binding in the mixtures made of different wastes after the sedimentation processes.



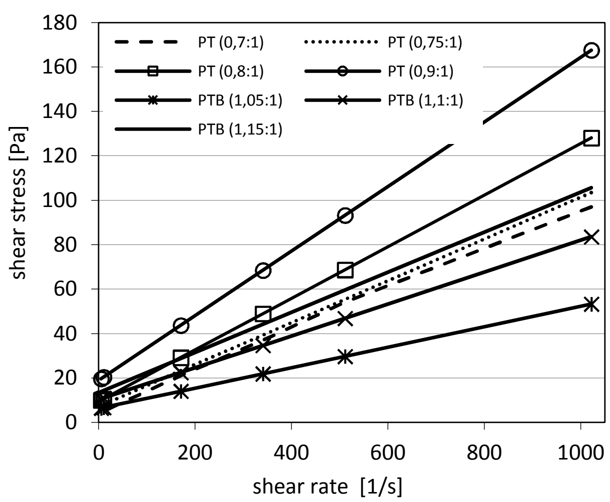


Fig. 1. The flow curves acc. to the Bingham model for the suspensions made of PT and PTB ash.

The general conclusion from the conducted research for the recipients using both these kind of wastes and other ones coming from the coal combustion is that even the smallest addition of the fuel of different type (e.g. biomass) can change the properties of the used suspensions. To increase the effectiveness of suspensions used in fire prevention, for example, of necessity is proper knowledge on their properties, and the influence of different factors on them.

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