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FLUIDIZED BED COMBUSTION OF BROWN COAL FROM VRŠANY MINE

Summary. Petrographic analysis can give useful information about the behaviour of brown coal during fluidized bed combustion. The brown coal Vršany mine (the North Bohemian basin) is characterized by reflectance, maceral composition, chemical and mineralogical composition. The chemical composition, optical properties and morphology of particulate emissions (bottom ash, fly ash captured in a cyclone) are determined. Elemental composition of ashes is performed by INAA and Xray emission analysis (PIXE). The experiments of fluidised bed combustion are carried out in two regimes: oxidation and reduction. It was found that composition of fly ash depends on reaction conditions. Samples of fly ash from the second regime of fluidized bed combustion (lower concentration of oxygen) are characterized by higher contents unburnt carbon, sulphur, nitrogen, volatile matter and elements as As, Cd, Zn.

SPALANIE FLUIDALNE WĘGLA BRUNATNEGO Z KOPALNI VRŠANA

Streszczenie. Określono zdolność odbicia światła, skład maceralny, skład chemiczny i mineralogiczny węgla brunatnego z kopalni Vršany (Płn. Czeskie Zagłębie Węgla Brunatnego), poddanego spalaniu w kotle fluidalnym. Określono także skład chemiczny, własności optyczne i morfologię cząstek popiołów, wykorzystując między innymi analizę aktywacji neutronowej, powstałych w trakcie spalania węgla w warunkach utleniających i redukcyjnych.

Introduction

The project „Heavy Metal Emission Flows During Fluidized Bed Combustion of Fossil Fuels“ (Grant Agency of the Czech Republic, Grant No. 104/95/0653) is being solved by co-operation of 3 scientific institutes within the Academy of Sciences of the Czech Republic. Among objectives of the project is the investigation into the composition and morphology of fly ash trapped in the cyclone separator during fluidized bed combustion of brown coal in the oxidation and reduction modes, in dependence on the coal composition and properties.

Experimental

Combustion tests on the coal from the Vršany mine (North Bohemian Brown Coal Basin) were carried out by the Institute of Chemical Processes AS CR, using a pilot-scale boiler 0.1 MW power in the steady-state mode. The equipment and combustion experiments in the oxidation (stoichiometric) and reduction modes have been described by Smolík et al (1996). Coal sample of 500 kg weight was crushed, and the particle size fraction 0.5 - 4.5 mm was separated by sieving. Fly ash was trapped in a cyclone separator, and the submicron particles which failed to be trapped by the cyclone were collected in a low-pressure cascade impactor. The particles from the cyclone were sorted by sieving into particle size fractions < 40μm, 40 - 63μm, 63 - 90μ, 90 - 200μm, and > 200 μm.The coal sample and fly ash fractions from the total magnification 450×. Ash morphology was examined using a total magnification of 300× and 650×. The mineralogical composition of the coal and ash was evaluated by using DRON X-ray diffractograph at the Institute of Geology AS CR. The trace element contents of the coal, ash from the fluidized bed reactor, and the various fractions of the flue ash in the cyclone were determined by neutron activation analysis (NAA) and by measurement of charged particle induced X-ray emission (PIXE) at the Institute of Nuclear Physics AS CR.

Results and disciusion

Coal from the Vršany mine is orthotypic detro-xylitic brown coal (tab. 1 - 5), in which huminite, particularly its maceral ulminite, is the predominating component. The detritic fraction of the coal matter comprises densinite and liptodetrinite, while attrinite is accessorially present. The mineral matter is mostly dispersed throughout the coal matter, separate mineralized positions are rare.The Vršany coal sample contained quartz and kaolinite, in particular. Iron disulfides were rather low and their origin was syngenetic. Framboids and crystals were scarcely dispersed through the coal matter and formed aggregates to a lower extent. Total sulfur was below 1% and over one-half of it was bound in the organic matter (tab. 1). Ash, whose content was A^d = 18%, contained mostly oxides of silicon, aluminium, and iron (tab. 6).

Table 1

Results of technological analysis of Vršany coal

W^a (%)	A^d(%)	T_B (°C)	S_t^d (%)	S_o^d(%)	S_p^d(%)	S_{SO4}^d (%)	Q_s^{daf} (MJ/kg)	V^{daf} (%)
22.11	18.00	1250	0.96	0.65	0.27	0.04	29.43	53.06

Table 2

Results of elemental analysis of Vršany coal

C^{daf} (%)	H^{daf} (%)	N^{daf} (%)	S_o^{daf}(%)	O_d^{daf} (%)
70.96	5.45	1.00	0.80	21.75

Table 3

Petrographic characteristics of Vršany coal (%)

Ro	Huminite	Liptinite	Inertinite	Min.Mater
0.39	65.0	15.6	4.8	14.6

Table 4

Ash composition (%)

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	Mn_3O_4	MgO	CaO	Na_2O	K_2O	P_2O_5	
40.39	2.13	25.97	18.56	0.169	1.74	5.36	0.48	0.72	0.26	3.64

Table 5

Trace element content of coal (in ppm)

As	Br	Cd	Cl	Co	Cr	Mn	Mo	Ni	Sb	Sc	Se	U	V	Zn
1.75	2.81	<14.1	<37.1	8.2	34.9	233	1.7	20.6	0.2	9.0	0.5	1.0	10.8	2.6

The amorphous form of minerals in ashes largely predominates over their crystalline form (Hower et al., 1966, Weiss et al., 1994).Quartz, anhydrite, haematite, and, to a lesser extent, spinelite were present in the ashes examined.

The chemical composition data indicate that the organic matter was more perfectly burnt in the oxidation mode than in the reduction mode (tables 6 and 7). The unburnt fraction in the second experiment increased from 16% to 48% in dependence on the grain size, in contrast to the first experiment during which it did not exceed 5%. In addition to carbon, all the fractions from the second experiment were richer in nitrogen and sulfur.

Table 6

Chemical parameters of ashes from combustion in the oxidation mode

Sample	A^d (%)	C^d (%)	H^d (%)	N^d (%)	S^d(%)	V^d(%)
<40μm	97.17	2.26	0.09	0.01	1.53	2.83
40-63μm	98.03	1.74	0.08	0.04	0.73	1.97
63-90μm	97.77	2.07	0.07	0.06	0.61	2.23
90-200μm	97.08	2.62	0.08	0.05	0.43	2.13
>200μm	94.72	4.67	0.10	0.05	0.29	1.83
popel I	98.22	1.14	0.08	0.06	0.44	1.78

Table 7

Chemical parameters of ashes from combustion in the reduction mode

Sample	A^d (%)	C^d (%)	H^d (%)	N^d (%)	S^d(%)	V^d(%)
<40μm	82.15	16.78	0.22	0.11	5.63	5.60
40-63μm	80.98	18.11	0.31	0.19	5.15	5.15
63-90μm	76.63	22.72	0.32	0.25	4.40	4.40
90-200μm	71.82	25.95	0.30	0.31	4.25	4.25
>200μm	47.23	49.90	0.46	0.48	4.88	4.88
popel II	96.87	2.37	0.00	0.06	3.13	3.13

The micropetrographic evaluation of the ash was based on the morphology, appearance, porosity, and light reflectance of particles of the completely or partly transformed coal matter, whose classification has been proposed by Baily (1993) and by Rosenberg et al. (1996).

Table 8

Micropetrographic parameters of the fly ash and ash emerging from combustion in the oxidation mode (in vol.%)

Sample	Cenosphere	Tenui-network	Crassi-network	Solid	Fragment of macerals	Mineroid
<40μm	0.5	0	7.2	2.0	0	90.3
40-63μm	0.5	2.1	8.3	3.2	0	85.9
63-90μm	0	2.7	7.5	2.7	0	87.1
90-200μm	0	3.3	8.8	1.4	0	86.5
>200μm	0	5.3	11.5	1.0	0	82.2
popel II	0	0	3.0	0.8	0	96.2

Table 9

Micropetrographic parameters of the fly ash and ash emerging from combustion in the reduction mode (in vol.%)

Sample	Cenosphere	Tenui-network	Crassi-network	Solids	Fragment of macerals	Mineroid
<40μm	0.7	5.8	10.5	4.5	1.5	77.0
40-63μm	1.3	6.3	13.1	1.3	1.6	76.4
63-90μm	1.1	9.9	15.1	1.2	2.0	70.7
90-200μm	0	11.0	19.8	1.2	2.2	65.8
>200μm	0	17.9	22.8	1.3	2.3	55.7
popel II	0	0	3,5	0	0	96.5

The unburnt fraction of the organic fly ash matter in the cyclone contained small amounts of crassi- and tenui-cenospheres (tables 8 and 9) The majority of semi-coke particles possess a network texture. The number of both thin-walled (tenui) (fig. 1) and thick-walled (crassi) networks (fig. 2) increases with increasing particle size. The majority of tenui-networks arose probably from the pyrolysis of textinite, ulminite, of densinite, whereas the crassi-networks were the result of pyrolysis attrinite, densinite, ulminite, their mineralized forms, and gelinite. Gelinite, eu-ulminite, and fusinite can be regarded as precursors of the smooth, compact particles („solids"). Coal maceral residues (ulminite, densinite, resinite, fusinite, sclerotinite) were only detected in the fly ash emerging from the reduction combustion. Trace and minority elements such as As, Cd, Cl, Co, Hg, Ni, Pb, and Sn are monitored in ashes for environmental protection reasons (Zamarský, 1994, Querol et al., 1995). In the fly ashe resulting from the fluidized bed combustion of coal from the Vršany site, the highest concentrations of As, Br, Cd, Cl, Co, Cr, Mo, Ni, V, and Zn were found by Schwarz et al. (1996) in the particle size fraction < 40 μm. Higher concentrations of elements, except for Mn, Sc, and U, were identified in the fly ash emerging from combustion in the reduction mode.

Conclusions

The composition and morphology were investigated for 5 particle size fractions of fly ash and ash from the fluidized bed combustion of brown coal from the Vršany mine which, in view of the volume of reserves and quality, is regarded as a prospective raw material for power generation. The results gave evidence that in addition to carbon, also sulfur, nitrogen, and the majority of trace elements concentrate in the solid residue even during imperfect combustion. Noteworthy is the fraction < 40 μm, which is enriched appreciably with the trace elements. If not trapped in the separator completely, such fine particles may become air pollutants.

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Streszczenie

Próbkę węgla brunatnego (500 kg) z kopalni Vršany spalono w palenisku fluidalnym, w warunkach utleniających i redukcyjnych. Powstałe popioły lotne sklasyfikowano w następujących frakcjach: < 40 um, 40-63 um, 63-90 um, 90-200 um, > 200 um. Próbkę węgla oraz popioły poddano analizie petrograficznej i chemiczno-technologicznej, przy wykorzystaniu mikroskopii optycznej, spektroskopii rentgenowskiej i aktywacji neutronowej (NAA).

Analizowany węgiel reprezentuje typ ziemisto-ksylitowy z dominującym udziałem ulminitu oraz densynitu i liptodetrynitu. Charakteryzuje się niskim stopniem uwęglenia (R_o = 3, 39%, V^{daf} = 53,06%), średnią zawartością popiołu (A^d = 18%) i siarki całkowitej (S^d_t = 0,96%). Stwierdzono, że skład chemiczny popiołów lotnych zależny jest od warunków reakcji. Próbki popiołów, pochodzących ze spalania w warunkach niskich zawartości tlenu (redukcyjnych), charakteryzowały się wyższą zawartością niespalonego węgla (C^d = 16,78 ÷ 49,90%, w zależności od frakcji), siarki, azotu, części lotnych i metali: As, Cd, Zn.