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Experimental investigation of ash behavior and emissions during combustion of Bosnian coal and biomass

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Abstract

This paper presents results of experimental research into the ash behavior of different Bosnian coal types and biomass fired in an *electrically heated entrained pulverized fuel flow experimental reactor*. The results are derived from a series of tests performed under a range of temperature and air conditions for the fuel test matrix. In essence, the experimental reactor comprises a 3 m length alumina–silicate ceramic tube, where combustion takes place, surrounded by SiC stick-type electric heaters and three-layer insulation. The temperature of the reaction zone is controlled by a programmable logic controller (PLC) with thyristor units for each of the heating zones, allowing the process temperature to be varied at will across the range from ambient to 1560 °C.

The methodology is based on the evaluation of ash deposits formed in the experimental reactor during the tests. Test points, reflecting the different types of ash deposits, are plotted against appropriate fuel indicators onto graphic diagrams. Emissions of NO_x and SO_2 are also measured under different ambient conditions—at different temperatures and air distributions—to determine the emission figures for the fuels being tested.

The results for six different fuels are presented, namely two single coals, two coal blends, and two coal–biomass blends. The results obtained support the thesis that the appropriate ambient conditions for combustion of coals and biomass can be recognized and recorded in this way.

Keywords: Combustion; Coal; Biomass; Reactor; Ash behavior; Ash deposits; Emission

1. Introduction

Environmental issues significantly influence trends in coal consumption today. The improvement of existing and introduction of new and more advanced combustion technologies in coal-fired systems are necessary to increase efficiency and improve environmental performance. The power system of Bosnia and Herzegovina is based on coal, but its coal-based power plants are less performing than those in developed countries. The problems are largely related to domestic coal combustion. However, Bosnia and Herzegovina is rich in coal. Recent estimates suggest exploitable coal reserves of 3.8 billion tonnes (geological coal reserves are 8.5 billion tonnes), of which 60% is lignite and 40% is brown coal (in heating value terms, Bosnian brown coal is similar to subbituminous coal). Taking into account future consumption rates estimated, coal reserves in Bosnia and Herzegovina should last for some 150–200 years. Approximately, 80% of coal produced in Bosnia and Herzegovina goes to four existing coal-based power plants, with a total capacity of 2000 MW_e. The construction of 1500 MW_e of additional capacity in new coal-based power plants at different locations of Bosnia and Herzegovina is planned by 2011. Fig. 1 provides a map of coalmines in Bosnia and Herzegovina.

The characteristics of Bosnian lignite and brown coal vary widely from one coal basin to another and even between different coalmines within the same coal basin. Generally, Bosnian coals are low-rank coals, with a high CaO content in the ash, high sulfur content, and a low net calorific value [1]. The calorific values of Bosnian coals range between 7 and 21 MJ/kg.

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Research into specific problems of the combustion of domestic coals at Sarajevo University's Mechanical Engineering Faculty endeavors to produce a reliable database of Bosnian coal behavior, with the emphasis on ash deposition characteristics and pollutant emissions under different ambient conditions. The aim is to improve the sustainability of coal-based electricity generation in Bosnia and Herzegovina, responding to the demands of a liberalized energy market. Co-combustion of domestic coal and biomass—predominantly wood residues, is also being tested. This aspect of the research aims to facilitate co-combustion in the power plants, allowing further reduction of carbon dioxide emissions and improving energy efficiency [2].

The research here presented therefore represents a precondition for the adoption of clean coal technologies in Bosnia and Herzegovina.

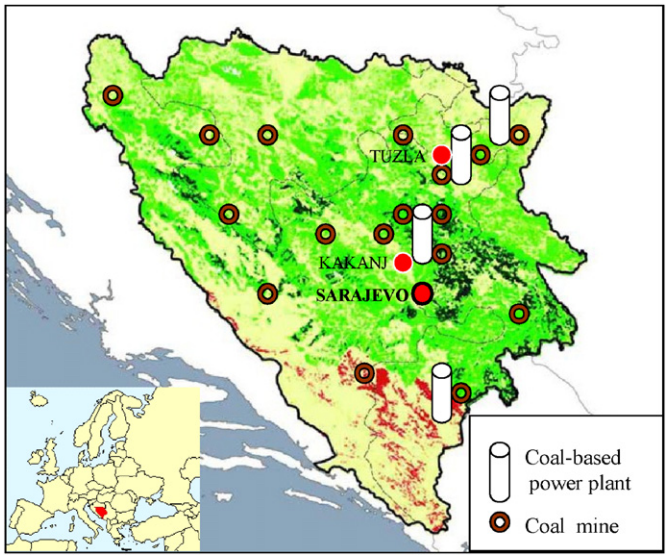

Fig. 1. Map of coalmines of Bosnia and Herzegovina.

2. Fuel test matrix

Fourteen domestic single-coal types and their blends were submitted to laboratory ash analysis and Ash Fusibility Test (AFT). Six fuels were also tested using an experimental reactor. The fuels tested were: two single coals, namely *Dubrave* lignite and *Kakanj* brown coal, two coal blends used at operational thermal power plants, namely the *Tuzla TPP blend* and *the Kakanj TPP blend*, and two coal–biomass blends, namely *Kakanj* brown coal and uncontaminated wood residue (*spruce sawdust*) mixed at 93:7 and 80:20 weight ratio. This is so called *fuel test matrix* [2].

Spruce saw dust was sampled from a sawmill placed near the Kakanj coal-based power plant in Middle Bosnia (Fig. 1), where the timber cut from the surrounding woods undergoes primary processing. Proximate and ultimate analyses of the fuel test matrix are given in Table 1, while Table 2 shows the data for AFT and the chemical composition of the ash from the fuels tested. Table 3 summarizes the data on the ash chemical composition and AFT of the ash deposits from co-firing tests. Comparison of the data for the different fuels reveals a number of differences between the coal and the biomass tested. The ash content in the Kakanj brown coal is high at 41.43% per mass, while for the spruce sawdust it is only 0.26%. This fact seriously

Table 1
Proximate and ultimate analysis of the test fuels and spruce sawdust

	Test fuel[a]						
	K	D	M1	M2	S	K93S7	K80S20
Type of fuel	Brown coal	Lignite	Coal blend	Coal blend	Biomass spruce	Fuel blend	Fuel blend
Proximate analysis (%), as-received/*DAF*							
Moisture	13.4/0.00	30.4/0.00	12.99	35.34	11.2/0.00	11.29	11.28
Ash	41.1/0.00	30.3/0.00	35.30	20.55	0.26/0.00	38.55	33.20
Volatiles	25.0/54.9	25.3/64.4	28.74	25.46	75.5/85.3	29.35	35.80
Fixed C	20.5/45.1	14.0/35.6	22.97	19.32	13.0/14.7	20.81	19.72
Combustible	45.5/100	39.3/100	51.72	44.78	88.5/100	50.17	55.53
Ultimate analysis (%), as-received/*DAF*							
Carbon	33.8/74.3	27.0/68.7	38.65	31.84	38.9/44.0	35.38	35.87
Hydrogen	2.7/5.9	2.3/5.9	2.86	2.55	7.4/8.3	3.10	3.70
Sulfur	2.3/5.0	0.77/1.9	2.51	0.94	0.33/0.37	2.14	1.89
Nitrogen	0.92/2.0	0.46/1.2	0.98	0.60	0.33/0.37	0.92	0.83
Oxygen	6.8/14.9	9.3/23.5	7.81	8.60	41.6/47.0	9.45	13.95
Calorific value (kJ/kg), as-received/*DAF*							
Gross	13490/–	10520/–	14753	11603	17386/19.636	13763	14269
Net	12657/–	8859/–	13864	10265	15612/17923	12864	13248

[a]Test fuels: K—Kakanj, D—Dubrave, M1—TPP Kakanj blend, M2—TPP Tuzla blend, S—biomass spruce sawdust, K93S7—Kakanj:Spruce = 93:7 (%, w/w), K80S20—Kakanj:Spruce = 80:20 (%, w/w).