Experimental studies of ignition of a 5 MW semi-industrial installation in Ekibastuz coal using electrochemical activation technology

A P Burdukov, E B Butakov, and G V Chernova
Kutateladze Institute of Thermophysics SB RAS, Novosibirsk, Russia

E-mail: chernova@itp.nsc.ru

Abstract. This work uses a high-frequency electrochemical ignition device that generates high-frequency cold plasma arcs that ionize the oxidizer, which contributes to the multiple acceleration of thermochemical transformations of carbon-containing solid fuels and wastes, and, consequently, to a more complete rapid burning out of the torch. Coal fuel research was carried out at the CDPP-2 station in the city of Ekibastuz, and experiments were conducted on the ignition and combustion of coal fuels using a high-frequency electrochemical ignition device. After the coal fuel was supplied to the street swirler, the combustion chamber was heated for 4 minutes, after reaching 500 °C, the coal burned in the autothermal regime. These results will be used to design a pilot burner at the station in Ekibastuz, Kazakhstan.

1. Introduction
Coal is the most common energy fuel in the world. Despite the long period of its use in thermal power engineering, the difficulties in its efficient and clean combustion arise due to deterioration of its consumer qualities. The bulk of produced coal is used in the energy sector, although a significant portion of it is used in chemistry, metallurgy and other industries.

Russia is the largest coal power; one-third of the world's resources are concentrated in its interior. At the same time, the quality of coals supplied to the power plants, is getting worse. At that, combustion of low-grade coals in boiler installations causes significant difficulties related to coal flame ignition, stabilization of its combustion, and fuel burnout at simultaneous reduction of environmental performance of the power plants [1].

Many researchers consider plasma methods of flaring of coal and waste products of their processing for the needs of power engineering, metallurgy and the chemical industry, using electric power in the form of low-temperature plasma, as promising in comparison with traditional fire methods [3 - 6]. Practical realization of plasma processes of coal processing is possible, as follows from [1, 2, 9], using plasma jet reactors [8] or combined electric arc reactors [7, 8]. A high-voltage alternating current plasmatron is a special case of electrothermochemical processing of coal dust. In this area, extensive studies have been carried out and high-voltage multi-electrode plasmatrons have been developed [10]. The essence of thermochemical preparation of fuel consists in heating under a deficit of oxygen of the flow of a pulverized coal mixture in a special chamber to a temperature higher than the autoignition temperature of a given coal. At the same time, there is an almost complete release of volatile and possibly partial combustion and / or gasification of coal carbon. As a result, at
the exit from the thermochemical fuel preparation chamber into the furnace, the resulting fuel mixture or high-reactive two-component fuel (gas + coke residue) ignites when mixed with secondary air and stably burns without using a second type of high-reaction fuel to stabilize the flame. Heating of the air mixture, which is a slurry of coal particles in the air in the thermal preparation chamber, can be carried out by burning a gaseous, liquid or solid fuel, by an electric arc plasma or by another method of supplying thermal energy. The technology of heat treatment must ensure reliable operation when using coals of various qualities (with different ash content, humidity and volatiles output).

The main purpose of the work is to study the ignition and combustion of Ekibastuz coal using electrochemical activation without additional pilot fuels.

These studies are of great interest for "large", as well as industrial energy, where the average efficiency of using fuels does not exceed 60%. Carrying out work to create optimal combustion technologies for electrochemical activated solid fuels, as well as burner device designs, allows us to achieve a new level of energy use of the most common coal fuels.

2. Experimental setup and procedure

The experiments were carried out on a large fire stand with a thermal power of 5 MW. The technological scheme of the fire stand is shown in Figure 1. The technical composition of coal is as follows (mass %, dry): moisture Wrl – 8, ash Ar - 38.1, volatile content - 25, sulfur Sdl - 0.7, net calorific value Qp – 17.56 MJ/kg. The main units and auxiliary systems of the fire stand are functionally related as follows. Screw feeder of coal dust with a frequency converter with a capacity of up to 290 kg/h. The pulverized coal is ignited by a electrochemical fuel device Figure 2.

Figure 1. Technological scheme of the stand 5 MWt.

Ignition and combustion of pulverized coal is realized in three-section reaction chamber with the total length of 1510 mm and inner diameter of 315 mm, lined inside with a refractory material. Pulverized coal afterburning occurs in the lined combustion chamber with the diameter of 1000 mm and length of 2800 mm. The combustion products are mixed into the atmosphere cyclone and exhauster.
Gas composition along the reaction chamber was measured by the optical-absorption gas analyzer at three points; temperature is measured in the same cross-sections of the chamber by the platinum-platinum-rhodium thermocouples. The flow rate of supplied air was obtained by the metering orifices and rotameters. The coefficient of air excess in the reaction chamber was 0.5.

3. Results and discussion
Experiments were carried out with constant fuel flow rate (210 kg/h), air excess ratio (0.5), and ignition electrochemical fuel device power (10 kW). The results of experimental studies on ignition and combustion of coal after its grinding in a mill-disintegrator are illustrated in Figure 3:

When coal passed through the electrochemical fuel system, ignition and heating of the dust-air flow to a temperature of 600°C were observed, but when moving along the furnace, the temperature did not drop and combustion was observed. For 400 seconds, the muffle furnace walls were heated slowly from 24°C to 350°C, which is due to the low reactivity of Ekibastuz coal fuel. Later on, from 400°C, combustion progressed along the length of the combustion chamber and a considerable temperature increase occurred up to 1400°C. Thus, using the electrochemical fuel device power 10 kW, it was
possible to ignite and subsequently melt the 5 MW burner at the low-grade coal obtained at the Ekibastuz station.

4. Conclusion
As a result of experimental study, new data on the effect of electrovchemical activation of coal fuel on the reactivity of fuel were obtained. Experimental data on the combustion and gasification of coal fuel crushed at highly stressed mills were obtained at 5 MW thermal furnace.

During the research, important experimental information was obtained that can be used for development of energy systems and devices without burning fuel oil and stabilizing the combustion of boilers from pulverized coal, as well as schemes and technical solutions necessary to replace highly reactive fuels with a electrochemically activated coal at industrial power plants.

The obtained results objectively allowed 1) to evaluate the technical and economic feasibility of introducing a system without fuel oil ignition, 2) to organize a system without fuel oil ignition applying electrochemically activated coal dust obtained from coals used on boilers (Station No. 2B of Ekibastuz).

Acknowledgements
Research results modernization of the experimental stand were obtained within the framework of the state assignment for the IT SB RAS, research results coal combustion was funded by RFBR according to the research project № 18-38-00416

References
[1] Chernetskiy M.Yu., Burdukov A.P., Butakov E.B., Anufriev I.S., Strizhak P.A. Using Ignition of Coal Dust Produced by Different Types of Mechanical Treatment under Conditions of Rapid Heating // Combustion, Explosion, and Shock Waves. 2016. V. 52, No 3. P. 326–328
[2] Burdukov A.P., Butakov E.B., Popov V.I., Chernetskiy M.Y., Chernetskaya N.S. The use of mechanically activated micronized coal in thermal power engineering // Thermal Science. – 2016. - V. 20. - P. s23-s33.
[3] Burdukov A.P., Popov V.I., Chernova G.V., Chernetskiy M.Yu., Dekterev A.A., Chernetskaya N.S., Markova V.M., Churashev V.N., Yusupov T.S. Development of the technology of using mechanically activated microgrounded coals for firing and lighting of coal boilers of acting thermal power stations // Thermal Engineering. – 2013. – №60(12). – P. 889-894.
[4] Messerle, V.E., Ustimenko, A.B., Karpenko, Y.E., Chernetskiy, M.Y., Dektev, A.A., Filimonov, S.A. Modeling and full-scale tests of vortex plasma–fuel systems for igniting high-ash power plant coal // Thermal Engineering (English translation of Teploenergetika). – 2015. – № 62 (6). – P. 442-451.
[5] Burdukov A.P., Popov V.I., Chernetskiy M.Yu., Dekterev A.A., Hanjalić K. Mechanical activation of micronized coal: prospects for new combustion applications // Applied Thermal Engineering. – 2014. - V. 74 – P. 174-181.
[6] Reason I. Get oil and gas out of pulverized-coal firing // Power. - 1983. - P. 111-113.
[7] Gerasimov G.Ya., Makarov V.N. Kinetics of formation of nitrogen oxides in the combustion of ulcerized fuel // Heat transfer in steam generators // Proceedings of the All-Union Conference. Novosibirsk: ITF SB AS USSR. - 1988. - P. 242-246.
[8] Pfender E. Thermal Plasma Technology: Where Do We Stand and Where Are We Going? // Plasma Chemistry and Plasma Processing. - 1999. - V.19. - P. 1-31.
[9] Zhukov MF, Karpenko EI, Peregovud VS, Buyantuev S.L., Messerle V.E. Plasma non-oil firing of boilers and stabilization of combustion of a pulverized-coal torch (Low-temperature plasma, Vol. 16) / Ed. VE Messerle and VS Peregovuda .- Novosibirsk: "Science" Sib. Publishing company of RAS, 1995. 304 p.
[10] Engelst VS, Desyatkov GA, Musin NU, Saychenko NA Savings of fuel oil with plasma illumination in pulverized-coal boilers // Problems of energy saving: Tez. doc. All-Union.
scientific-practical. Conf. - Kiev, 1991. – V. 1. – P. 57. - 58.