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Plasma Application for Coal Combustion Activation

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This paper is about a problem of effective and environmental friendly pulverized coals incineration. Coal is one of the main energy resources of the 21st century. Today all over the world fraction of coal in the fuel balance of thermal power plants increases. For example, in the USA the fraction of coal-fired thermal power plants in electrical power producing is more than 57% [1], and in Kazakhstan it is about 85%. Moreover, the rank of power coals is decreasing everywhere. It leads to the difficulties of its ignition and incineration and simultaneous environmental pollution increase. In order to improve the efficiency of coal combustion new plasma-fuel system for thermal power plants is developed. It is pulverised coal burner equipped with arc plasmatron. It provides fuel oil-free start up of pulverised coal fired boilers, flame stabilization, and as a consequence, the simultaneous decrease of unburned carbon and nitrogen oxides formation due to two-stage combustion [2]. Plasma-fuel systems procedure is based on plasma thermochemical activation of coal for burning. It consists in arc plasma heating of air-fuel mixture up to the temperature of coal devolatilization and carbon residue partial gasification. By that be initial coal high or low rank from air-coal mixture hot combustible gas and highly-reacting coke residue is obtained. When mixture with secondary air at furnace it can be ignited and burn stably without use of fuel oil or natural gas traditionally used for boilers start up and low-rank coals flame stabilization. Plasma-fuel systems have been tested at 26 power boilers having steam-productivity from 75 to 670 t/h and equipped with different type of pulverized coal burners [3]. While testing plasma-coal systems the coals of all ranks, such as brown, black, anthracite and their mixtures were incinerated. Volatile content of them was in the range from 4 to 50%, the ash content varied from 15 to 48%, and heat of combustion was in the interval from 11700 to 25100 kJ/kg. The use of plasma-fuel systems at thermal power plants decreases the unburned carbon by 40-50%, nitrogen oxides by 50-60%, and carbon dioxide emissions can be reduced by 1-2%. The obtained results allow formulating the main principles of plasma-coal systems design for their subsequent industrial use.

Received results allowed formulating the main principles of design of plasma-fuel systems for their industrial use. Plasma coal ignition is based on electro-thermochemical preparation of fuels for incineration, as a result a two-component high-reactive fuel is formed (combustible gas + coke residue). Figure 1 presents this feature [4].

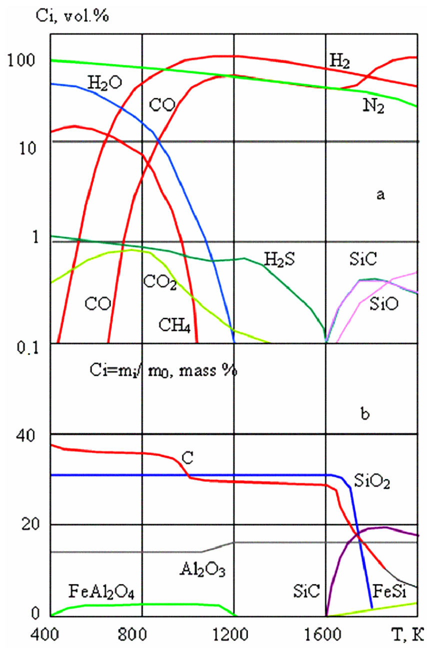

Figure 1. Composition of gas (a) and condensed (b) phases of two-component high-reactive fuel, where m_i is the i-component mass, m_0 is air-fuel mixture mass.

It follows from Fig. 1, concentration of combustible components (CO + H_2 +CH_4) are increased with an increase of process temperature, reaching 50-70% of gas phase (T=900-1200K). This encourages their intensive self-ignition at mixing with major fuel-air mixture. Oxide concentrations (H_2O + CO_2) decrease by 0.1% with temperature increase. The process consists in heating of small part of fuel-air mixture by arc plasma up to the temperature of complete yield of volatiles and partial gasification of coke residue. By this from the smaller part of fuel-air mixture, having come through arc discharge zone (independently on the quality of initial coal) a high-reactive two-component fuel is produced, this fuel can ignite the major flow of fuel-air mixture at mixing with it and stabilize flame burning process.

By combination of the tested technologies new plasma-energy technologies for fuel utilization efficiency improvement and reduction of harmful dust-gas emissions in engineering may be developed.

Figure 2 shows plasmatron and scheme of its mounting onto pulverized coal burner. Plasmatron is the main element of the plasma-fuel system. It is hot plasma generator. It consists of copper water-cooled electrodes (cathode and anode). Plasma forming gas is air blown through the electrodes. Plasmatron power is varied from 100 to 350 kW and geometrical sizes are the following: the height is 0.4-0.5 m, diameter is 0.2-0.25 m and the weight is 25-30 kg.

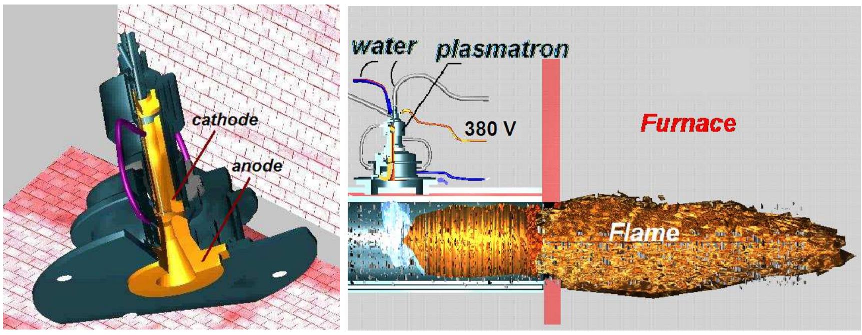

Figure 2. Plasmatron and scheme of its mounting onto direct flow pulverized coal burner.

Coal particles of 50-100 μm initial size in plasma-fuel system undergo heat shock. As a result they are crushed into fragments; each fragment is of a size of 5-10 μm. This leads to intensive devolatilization (CO, CO_2, H_2, N_2, CH_4, C_6H_6 and others) and 3-4 times accelerates the process of oxidation of fuel combustibles.

Plasma technologies are tested in industrial and test bench conditions for all types of power generating coals (shale, brown coal, black coal and anthracite), characteristics of which are given in Table 1 [6]. Volatile yield varied from 4 to 50%, ash – from 15 to 80 %, combustion heat – from 1600 to 6200 kcal/kg.

The plasma-fuel systems have been used successfully at 26 pulverized coal boilers at 15 thermal power plants (Russia, Kazakhstan, Korea, Ukraine, Slovakia, Mongolia and China) with the steam productivity from 75 to 670 tons per hour since 1994. The boilers are fitted with different systems of pulverised coal preparation (such as the direct pulverised coal injection and systems with pulverised coal hopper). Total more than 70 plasma-fuel systems were mounted and tested on the boilers.

For example Fig. 3 illustrates a diagram of arrangement of BKZ-420 boiler burners with two systems of plasma ignition of pulverized coal at the Ulan-Bator TPP-4. All eight boilers of the power plant were equipped with plasma-fuel systems for fuel oil free boiler starting up. The temperature of the two pulverised-coal flames which are 7 to 8 meters in length is 1100 to 1150 ^{O}C.

Table 1. Thermotechnical characteristics of coals.

Coal Type	W^w	A^d	V^d	$Q^w{}_l$ **(kcal/kg)**
Brown	25-35	15-20	35-50	3000-3800
Shale	40-50	75-80	48-50	1600-2000
Black	5-12	20-45	15-40	4000-5000
Anthracite	5-8	25-35	4-10	4300-6200
Coal mixture	10.4	48.5	38.2	3150

(Note on abbreviations: W^w = moisture content per the working mass; A^d = ash content per the dry mass; V^d = yield of volatiles per the dry mass; $Q^w{}_l$ = the lowest combustion heat per the working mass)

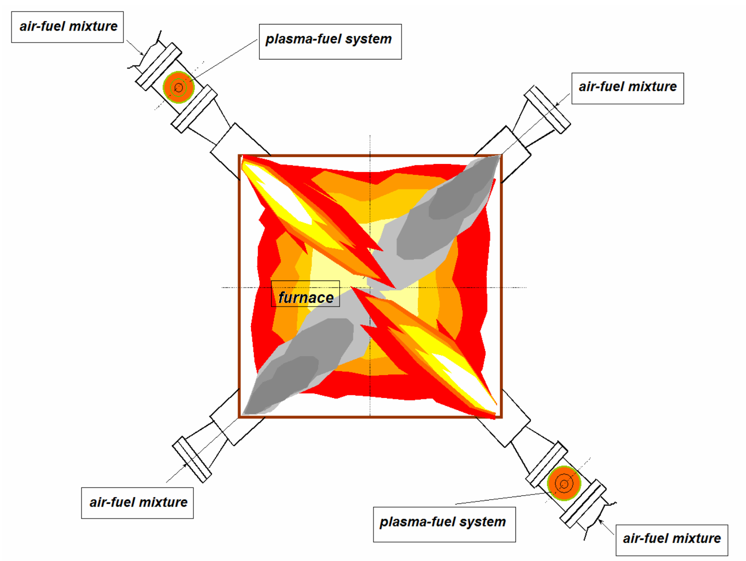

Figure 3. Diagram of mounting of burners onto the boiler with 420 t/h steam productivity equipped with the plasma-fuel systems ignition the air-fuel mixture at the Ulan-Bator thermal power plant 4 (Mongolia).

Figure 4 presents results of experiments on NO_X emission reduction and decrease of unburned carbon at plasma ignition of coals. It is seen from the figure, that when a plasmatron operates (in a regime of plasma stabilization of a flame), NO_X emissions are reduced twice, amounts of unburned carbon are reduced 4 times. One of the reasons for increasing the fuel reaction ability, which provides decrease of amounts of unburned carbon, is a heat explosion of coal particles at their interaction with arc plasma.

Figure 5 shows an experimental dependence of electric power specific expenditures on a plasmatron vs. coal volatiles content for different thermal power plants.

Thus plasma-fuel systems improve coal combustion and increase ecological and economical efficiency of coal use for the replacement of gas and fuel oil in fuel balance of thermal power plants.

Acknowledgments

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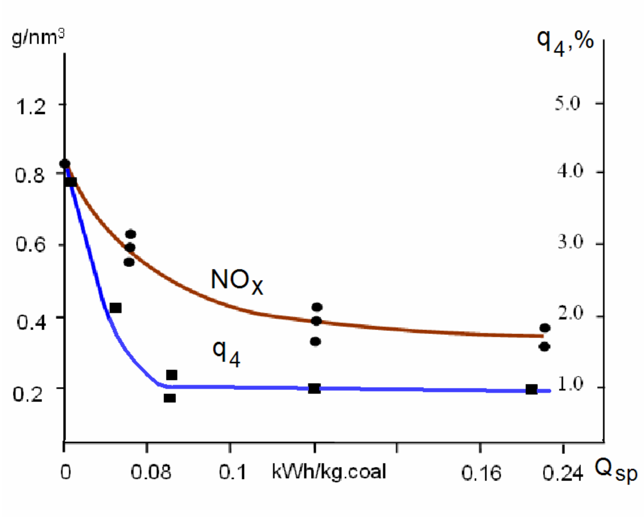

Figure 4. Reduction NO_X formation and unburned carbon (q_4) versus specific energy consumption (Q_{SP}) for plasmatron.

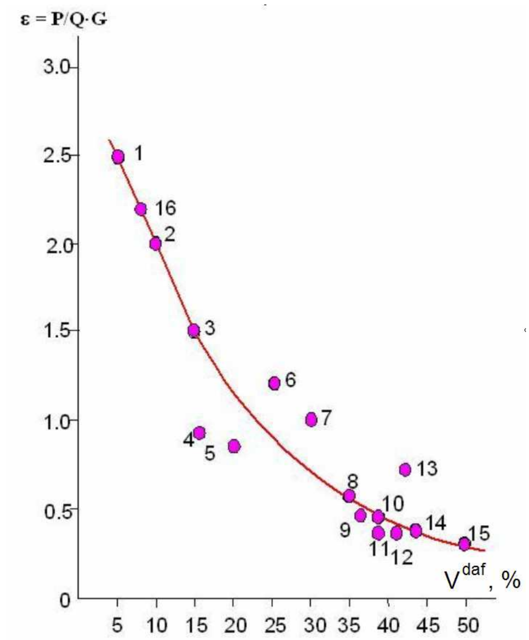

Figure 5. Experimental dependence of relative electric consumption of a plasmatron from a yield of ignited coal volatiles at different thermal power plants: 1 – Northern Korea; 2, 12 – Ukraine; 3 – China; 4, 5, 8, 10, 11, 15 – Russia; 6 – Kazakhstan; 7 – USA; 13 – Mongolia; 14 – Kirghizia; 15 – Estonia; 16 – Slovakia; P – electric power of a plasmatron; Q – coal calorific value; G – coal consumption through a muffle with plasmatron.

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