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The Study of the Electric Potential of the Torch from Underburning of Fuel in Steam Boilers

Anatoliy ZUBAREV[1,a], Alexander NIKIFOROV[2,b] and Evgeniy PRIKHODKO[3,c]

[1]Flat 175, house 5, Naberezhnaya str., Pavlodar, Kazakhstan

[2]Flat 25, house 38, Kirova str., Pavlodar, Kazakhstan

[3]Flat 55, house 177/1, Lomova str., Pavlodar, Kazakhstan

[a]ef_teplo@psu.kz, [b]aleke4599@mail.ru, [c]john1380@mail.ru

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Abstract. The article presents the results of the industrial testings of the control sensor designed to check the completeness of fuel combustion in dependence with the magnitude of the electric potential. It is shown that is possible to control the underburning of fuel with the help of boilers according to the electric potential of the torch.

Introduction

The generation of electricity in thermal power plants (TPP) in the Republic of Kazakhstan is mainly based on the combustion of the organic solid fuel of Ekibastuz and Karaganda coal fields. The usage of electron-ion phenomena accompanying the process of burning fossil fuels allows to quickly control the combustion process in the electric potential of the torch, which makes it possible to determine the functional relationship between the parameters characterizing the combustion process and its electric potential (φ):

$$q_4 = f_1 (\varphi) \quad (1)$$

In the case of liquid or gaseous fuel combustion, the interest is the interconnection between the electric potential and the chemical incompleteness of the combustion (q_3), i.e.:

$$q_3 = f_2 (\varphi) \quad (2)$$

The complexity of the mechanism of fuel combustion and its mathematical description predetermined the method of research - physical modeling. It is one of the methods of measuring the electric potential of the flame based on the occurrence of a potential difference across the charge resistance included between the electrodes without applying an external emf [1, 2]. Taking into consideration that the magnitude of this potential difference is proportional to the concentration of the charged particles produced in the combustion process, it can be assumed that it reaches its maximum when the sum of q_3 and q_4 is minimal.

The Results of the Industrial Testings

In pursuance of the approved program, the change of the magnitude of the mechanical underburning q_4 was normally achieved by adjusting the airflow coefficient α for a boiler as a whole according to the excess of oxygen in the combustion products ΔO_2. Thus, for BKZ 420-140 the change in the airflow rate α = var was carried out in two ways:

1) The number of revolutions of the raw coal feeder npsu = var from 750 to 900 rev / min;
2) The flow rate of secondary air in a group ranging from 50 to 100% every 10 minutes.

The graphical interpretation of $\varphi = f_3 (\alpha)$ for BKZ-420-140 during burning Ekibastuz coal is shown in Fig. 1.

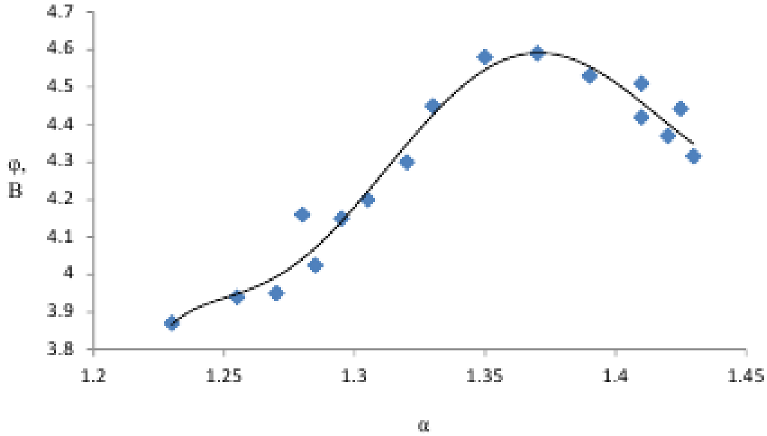


Figure 1. The effect of the airflow rate to the electric potential of the flame from the combustion of coal in the furnace of Ekibastuz BKZ-420-140.

The availability of extremum corresponds to the optimal ratio of airflow (α_{opt}) which is recommended by the regime chart, and the minimal mechanical underburning q_{4min}. The conducted industrial tests of the system for continuous and efficient control of the mechanical underburning of fuel actually confirmed the connection of the electric potential φ and the mechanical underburning q_4. The change of the boiler load quantity was carried out in steam from 100% to 60%.

The ash content was varied in the range 34% - 56% for the working masses. For this purpose there were formed railway trains which transported coal with specified ash content from different coal mines. The results of that industrial multifactorial experiment during burning Ekibastuz coal with different ash content in the combustion chamber of the boiler BKZ 420-140 are shown in Fig.2.

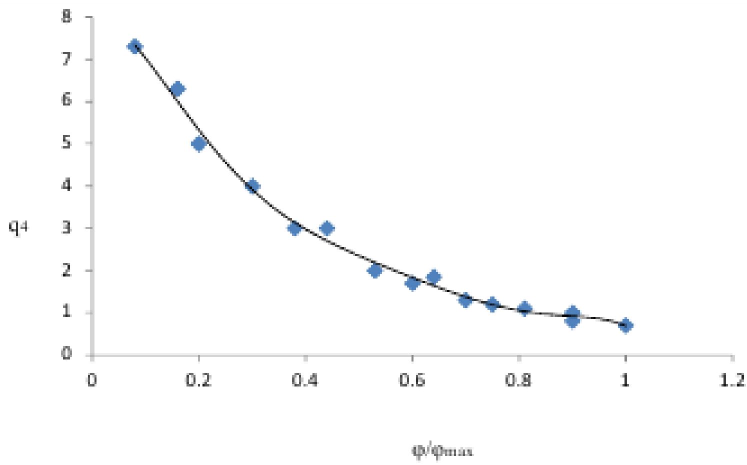
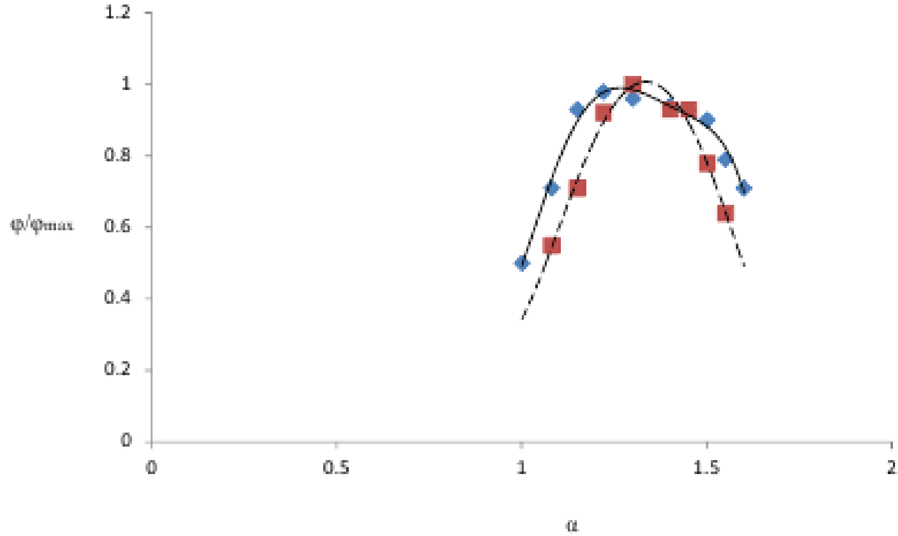


Figure 2. The dependence of the mechanical under burning of fuel on the relative magnitude of the electric potential of the torch.

Fig. 2 demonstrates that regardless of the thermal load quantity of the boiler unit, φ / φ_{max} reaches its maximum value when q_4 = min for this type of a combustion unit and the type of combustion. The industrial tests of the quality control system of pulverized coal combustion according to the electric potential of the flame on the boilers P-57 and P-67 during burning, respectively, Ekibastuz and Berezovsk coals, practically confirmed the general laws of $\varphi = f_3(\alpha)$ and $\varphi = \psi(q_4)$. However, the comparative analysis of the experimental curves $\varphi = f_3(\alpha)$ for the slit burners of the boiler P-67 BGRES-1 and the swirl burners of the boiler P-57 EGRES-1, shown in Figure 3, reveals the different magnitudes of the relativity of the change in φ / φ_{max} depending on the airflow coefficient α.



1 – for the coal of Berezovsk coal deposits;
2 – for the coal of Ekibastuz coal deposits

Figure 3. The changes in the relative magnitude of the potential of the torch in dependence with the airflow rate.

In the meantime, Fig. 3 displays that the maximum value of the relative magnitude of the potential of the flame from the combustion of coal species is determined by α value in the range from 1.2 to 1.4.

Moreover, there were conducted some testings of the flame control system for the electrical potential of the flame during the ignition process of BKZ 420-140. Its kindling was carried out with fuel oil. The tests were fulfilled on an industrial boiler with six burning devices, on three of which, next to the nozzles there had been installed uncooled probes for measuring the electric potential.

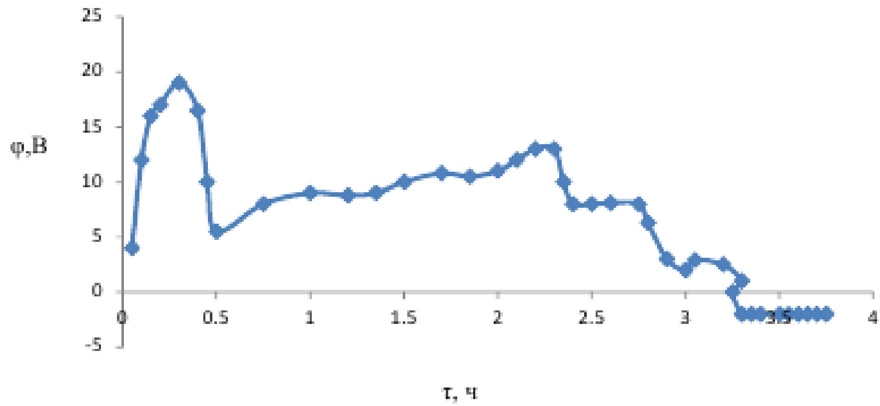


Figure 4. The change of the potential of the flame during the ignition of the boiler.

In Fig. 4, the change of the sign of the potential from positive to negative occurs due to switching on the coal-pulverization systems and switching off the liquid fuel supply in the period of reaching a steady mode. During the combustion of liquid fuels, the fluctuations in the magnitude of the electric potential correspond to the successive connection of the fuel oil nozzles, as well as to the instability of supply and combustion processes of fuel oil.

On the basis of the experimental data, one can judge on the ability to control the kindling regime of the boilers according to the electric potential of the torch of each burning device and through the averaged signal about the boiler as a whole. The error in the measurement of the electrical potential of the torch in the industrial experiment did not exceed 5%.

Conclusions

1. The use of electron-ion phenomena accompanying the process of burning oil and coal fuels in the furnaces of the boilers, enables rapid and continuous monitoring of the combustion quality according to the magnitude of the mechanical incomplete combustion of fuel, both for the individual burning device and the boiler as a whole.
2. According to the maximum magnitude of the electric potential φ_{max}, it is possible to adjust and optimize the fuel-air ratio in the process of changes in the load quantity of the boiler or its fuel quality.
3. It is possible to control the ignition mode of the boiler (based on the electric potential of the torch) in the same way as it was fulfilled during the transition from the combustion of liquid fuel to solid fuel.

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