Research of coal combustion in low-temperature fluidized bed with reduction of nitrogen oxides emission

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***Abstract* – This paper is devoted to the solving task of low quality coal combustion in low-temperature fluidized bed with reduction of nitrogen oxide emissions.**

Key words – low-temperature fluidized bed (LTFB), cannel coal (CC), anthracite culm (AC), nitrogen oxides.

I. Introduction

In accordance with the objectives of the President of Ukraine by the Government was developed a Program of modernization of municipal heat supply of Ukraine in 2013-2014. Over the 3 year period, Ukraine has to reduce the consumption of natural gas for heat production by around 50%, or 4.2 billion m3. A promising method is the ability to use local low quality fuels for heat and hot water supply systems by its combustion in a fluidized bed. Combustion in a fluidized bed is different from the traditional combustion by high energy efficiency of fuel combustion, low emissions of air pollutants with allowance to used low quality fuel (brown coal, slate, peat and coal waste product) and biomass fuels (sawdust, rice husk and pre-dried sugar cane bagasse) [1]. However, implementation technology of fuel combustion in the fluidized bed is a demand to addition research including method of furnace ignition, the operation mode of furnace with LTFB for different type of fuel, evaluation of quantitative characteristic of the emissions [2].

II. Scientific research

For scientific research of fuel combustion in LTFB in the laboratory of Institute of Thermal Physics of NAS of Ukraine ware developed laboratory bench (with 59 mm diameters of finance chamber) and laboratory system with furnace model (with the metric of finance chamber – 300 x 300 mm) for fuel combustion in the LTFB.

The scheme of the laboratory system with the furnace model is provided in Fig. 1.

The laboratory system with the furnace model for a fuel combustion in the LTFB works as follows: first, on fire grate (16), placed solid fuel. Fuel filling into the bunker for fuel supply carries out (2) and by screw for fuel supply (13) served in the furnace (1). Then include air blower (14) and smoke exhauster (10) and open the cold water supply valve to the heat exchanger (4). By flowmeters determine water flow. By thermometers installed in heat exchanger determine the temperature input and outgoing water from the heat exchanger. Fuel ignition is realized by a gas burner or with the solid fuel ignition. Determine the amount of fuel (natural gas, charcoal) consumed for the ignition. Passing through the heat exchanger reduces the temperature of the flue gases and through the gas pipe (5) go into the two channel centrifugal filter (6), in which the flue gas cleaning process is realized.

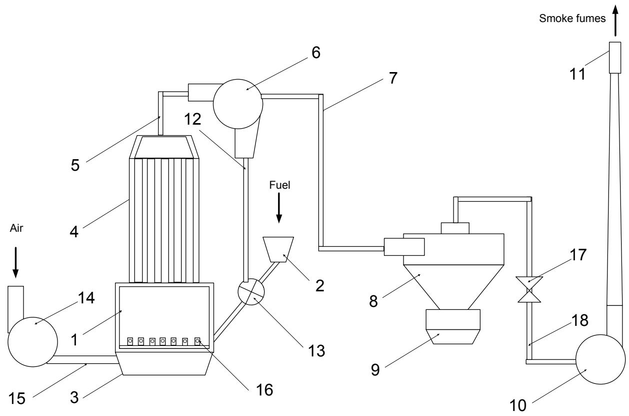

Fig. 1. The laboratory system with the furnace model for a fuel combustion in the LTFB

Where:

1) Boiler furnace with fire grate; 2) Bunker for fuel supply; 3) Bunker for slag; 4) Heat exchanger; 5) Gas pipe after the boiler; 6) Two channel centrifugal filter; 7) Gas pipe after two channel centrifugal filter; 8) Six channel centrifugal filter; 9) Bunker for slag; 10) Smoke exhaust; 11) Smokestack; 12) Pipe for slag returning into the furnace; 13) Screw for fuel supply; 14) Air pump; 15) Pipe for fuel supply; 16) Mitriform grating; 17) Valve 18) Gas pipe after six channel centrifugal filter

After centrifugal filter flue gases by the gas pipe (7) come into the six channel centrifugal filter where the flue gas re-cleaning process is realized. Ash and particulate matter go into the bunker for slag (9). After realized of experiments a volume, mass of ash that fell into the bunker is measured.

Cleaned flue gases after centrifugal filter come through the gas pipe (16) using the smoke exhaust (10) in the smokestack (11). Flue gas flow is regulated valve (9) is smoke exhaust.

III. Research on combustion of low-quality coal in the LTFB

Research on combustion of low-quality coal in the LTFB furnace realized to determine the efficiency of solid fuel combustion in boiler furnaces of small capacity.

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During experiments determined the aerodynamic mode of combustion at different temperatures.

Dependences of comparison of grid resistance and the FB at the rate of air mixtures of chamotte and cannel coal at temperatures of 288 and 1123 K show that the same fluidization velocities (w), the grid resistance and FB (P) with the temperature of 1123 K in average 0.8 times lower than the grid resistance and FB with temperatures 288 K. Bed height (H) with temperature of 1123 K higher on average in twice than height of the bed with temperature of 288 K (Fig. 2).

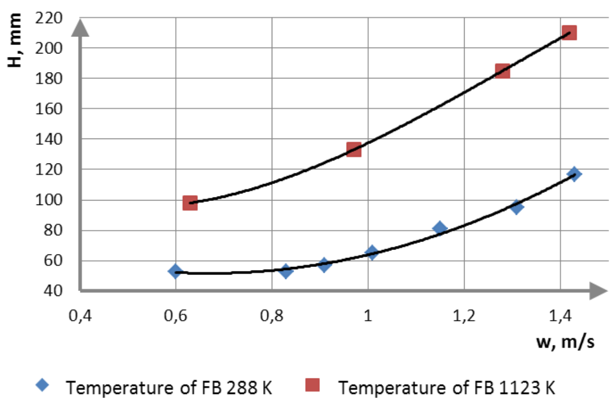

Fig. 2. Dependences of fluidized bed higher from air rate

To determine the temperature modes of cannel coal combustion at the laboratory bench were realized experiments in accordance with the scheme: periodically added inert material in the combustion chamber, which is heated up to the temperature of 1237 K by combustion of propane-butane mixture. Then the gas supply stop and periodically served portions of coal. There is a sharp drop in temperature, and then out volatiles and coal begins to burn. The temperature rises to 1173 K and then again decreases to 1073 K, where it is necessary to re-backfill of coal to prevent fading. Increasing of air rate by combustion of cannel coal requires increasing the feeding coal frequency and accordingly increases the heat capacity (Fig. 3).

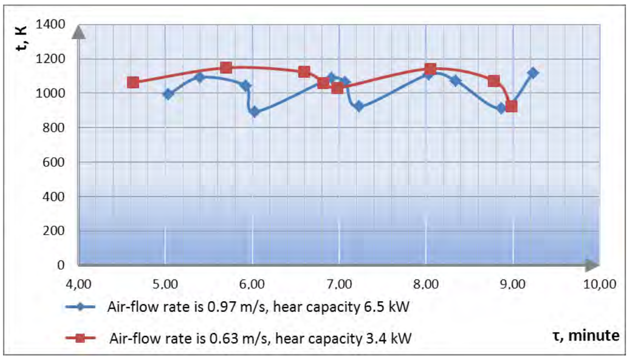

Fig. 3. Dependence of temperature from time

In the firing furnace model of LTFB was combusted anthracite culm with particle size of 0-6 mm. During inception was used sand that heated by the burner that worked at the liquefied gas. After furnace was heating over a period of 20-30 min. Gas flow was gradually reduced and in the fluidized bed of sand and then anthracite coal was added. During 2.5-3 kg / h anthracite consumption in fluidized bed temperature reaches 1123-1223 K. Increasing of the temperature to 1273 – 1323 K was led to the formation of small local caking that easily destructible by particles of fluidized bed, at 1393-1423 K strong caking of ash was formed and fluidization raised.

In some places, gas jet was burst out and channel creation was monitored. The experiments found that the fluidized bed of anthracite reliably operates at 1123-1223 K, the minimum permissible temperature of 1033 K. Lowering of its bed leads to erratic work of the furnace and the end of the coal combustion.

In experiments with the high-ash anthracite slug was observed stable combustion in the temperature range 1173-1223 K with the consumption of slug 10 kg / h and an additional supply of natural gas with productivity 0.7 m3/hr. Airflow consumption was 25-30 m3., temperature variations in the bed not exceeded ± 5 K. When the amount of ash in the volume of fluidized bed reaches 50% of the total amount, slagging of the furnace begins at the temperature 1223 K. Attenuation of the combustion process of high-ash anthracite culm in the fluidized bed is probably due to the net calorific value of fuel and a high proportion of non-combustible ballast that input into the bed.

In the fluidized bed the coal particles combustion process is significantly intensifying in comparison with a bed combustion, since the access of oxygen to the surface of the particles is higher than to particles of coal that burns a bed method. Ability to combusted the shredded fuel makes this combustion process similar to combustion in the pulverized-coal furnace with the advantage of the regulated time staying of coal particles in the fluidized bed. It can not be done in pulverized-coal furnaces. The prolonged presence of small particles of coal in the furnace enables to reduce mechanical underburning of carbon in fuel particles. Especially valuable is the possibility of deep burning-out of carbon in high-ash particles at relatively low temperatures equal to 1123 – 1223 K.

The results of experiments on combustion of coal particles in a fluidized bed of sand showed that at the temperature within the 1073-1173 K rate of particles combustion is determined mainly by the velocity of the oxygen mass transfer. The convective oxygen mass transfer is very small for particles of coal less than 3 mm but it becomes significant for particles larger size.

The realized experiments on combustion of CC and AC particles in a fluidized bed showed that the

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temperature of the particles of coal that is burning higher on 100-180 K than the temperature of inert particles.

IV. Formation of nitrogen oxides during combustion of low-grade coal

Restoration of NOx in the high temperature zone at the combustion of coal is determined by the interaction of carbonaceous substances (volatile or coke particles). On the degree of NOx recovery affects the particle size of coal, pyrolysis temperature, the temperature of the flue gases. [3].

Determined that at the combustion of nazarivskoho, bakunskoho and orsha-borodinskogo coal, the final concentration of NOx in the flue gases is determined by the velocity of ignition and burning-out of volatile substances [4]. The amount of throw out NOx is inversely proportional to the reduced moisture content of fuel combusted at the equivalent circuits of combustion. The effective measures are that reduce the intensity of the process in the activity zone of burner jet.

Based on the research of stages of coal combustion in a fluidized bed determined that the concentration of NOx is higher near by the air-separating grate. Along a height of the bed it is reduced from 1000 to 200 mg / kg. This is because the largest proportion of the fuel nitrogen is released in an area that's rich with oxygen, since in this area the surface temperature of the particles is higher than the temperature of the medium.

Experimental data on the effect of oxygen content in the flue gas at the NOx emissions indicated that at the content with 9-10% of O2, emissions is equal to 300, while 7% – no more than 215 g / GJ. The formation of nitrogen oxides depends on the temperature of the bed and increases on 0.005 g/m3 with an increase of temperature at 1 K. the formation of nitrogen oxides in a fluidized bed in a small degree depends on the correlation of fuel and air in comparison with pulverized coal combustion [5].

The dependence of content of nitrogen oxides on the temperature of the bed is presented at the Fig. 4. Experiments showed that a significant increase in the concentration of NOx is occurred at the temperature increases ranging from 1200 K.

Outlet of NOx during combustion of coal in fluidized bed, depends on the oxygen content in the flue gases and the process temperature. According to the papers [6, 7], with increasing oxygen content in the flue gases from 1 to 10%, NOx level increased in 3 – 6 times, and in the range of 1-3% of oxygen content, NOx outlet does not depend on the type of coal. At higher oxygen content in the flue gas, rate of NOx formation during combustion of black coal is higher than for anthracite, and for oxygen content in the 9-10% this exceed is 60-70% [7].

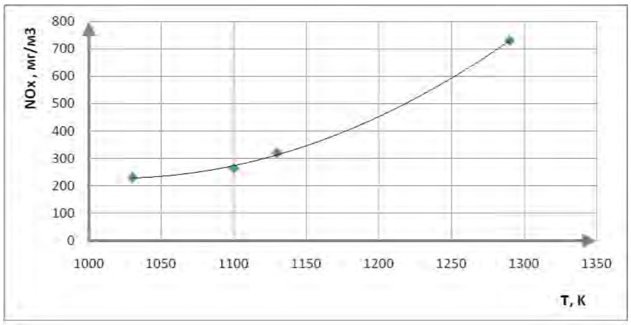

Fig. 4. The dependence of content of nitrogen oxides on the temperature of the bed

Conclusion

During realization of experimental research on combustion of solid fuels was determined that at low temperatures (1183 – 1223 K for AC and 1023 – 1123 for CC) fluidized bed virtually eliminates the possibility of formation of oxides from atmospheric nitrogen, a significant increase in the concentration of NOx occurs with increasing of temperature from 1200 K. Therefore, this technology is environmentally friendly as compared with traditional combustion of solid fuels, and corresponds to European standards for emissions.

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