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Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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ИЗВЕСТИЯ

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Kazakh national research technical university
named after K. I. Satpayev

ГЕОЛОГИЯ ЖӘНЕ ТЕХНИКАЛЫҚ ҒЫЛЫМДАР СЕРИЯСЫ

♦

СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

♦

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DIRECTIONS OF STUDYING THE PROCESS OXIDES FORMATION OF THE PYROLYSIS OF EKIBASTUS COAL DUST

Abstract. In this article, installations and fire settings for the pyrolysis of coal dust and burning of pyrolysis products with a phase shift of the air supply have been developed and performed. Experiments on the determination of nitrogen oxides in inert and aerial environment have been carried out and the methodic of procedure has been described. The results of the experiment showed that in an inert medium nitrogen oxides are not formed, but in the air medium are suppressed up to three times during the pyrolysis of the Ekibastuz coal dust. Programs have been developed and the calculation of the processes of nitrogen oxides formation during burning of Ekibastuz coal of high concentration on an ECM, taking into account the oxygen concentration, temperature and time, have been carried out. The fire-technical method of suppressing the formation of nitrogen oxides by pyrolysis of fuel with a phase shift of the air supply is proposed in the work, which allows to reduce emissions of nitrogen oxides to the level of modern requirements. Proposed ecological and economic advantages of the method comparing with existing ones.

Key words: nitric oxide, gasification, formation of air, suppression, incineration.

Gasification of solid fuels is used when the target product is a combustible gas. To this end, the fuel is oxidized in such a way as to fully convert its chemical energy into the chemical energy of the gas (i.e. its heat of combustion, which is determined mainly by the presence of CO and H2) [1].

As it is stated [2], the term "synthesis gas" (I.e. gas for chemical synthesis) can be applied only in the second case, therefore the term "generator gas" is proposed as a general name, which will be used further in this paper. In some cases, partial gasification is carried out when, in addition to gas, the desired product is also a solid residue, which in addition to high value can have properties that allow it to be used for chemical production [3].

To study the effect of the shift of combustion processes (SCP) on the formation of nitric oxide, a vertical tubular furnace with electric heating was used (figure 1).

A stainless steel tube with a diameter of 10 mm was installed in the furnace to supply air from below (7). In the fault plane (3) located on the furnace, a system of transverse built-in pipes was suppressed, for supplying argon, air and a gas mixture.

A stream of argon (8), heated in an additional electric furnace (6), was fed into the fault plane. The air was fed into the flow of the gas mixture from the tube by a cross stream. The gas mixture was fed into the by moving in a stainless tube along the axis of the vertical combustion chamber. Dust from Ekibastuz coal (4) was also fed from the feeder through the top of the fault plane.

The time of meeting coal dust heated by argon in a fault plane with air was regulated, taking into account the flow rate of the gas mixture.

By the transverse flow of these streams, the instantaneous mixing of coal dust with a stream of argon and the flow of the gas mixture with air was ensured. Such a mixture of streams created a time delay for the fuel and oxidant to meet.

The ratio of air consumption and the amount of argon in the mixture was regulated by the concentration of oxygen.

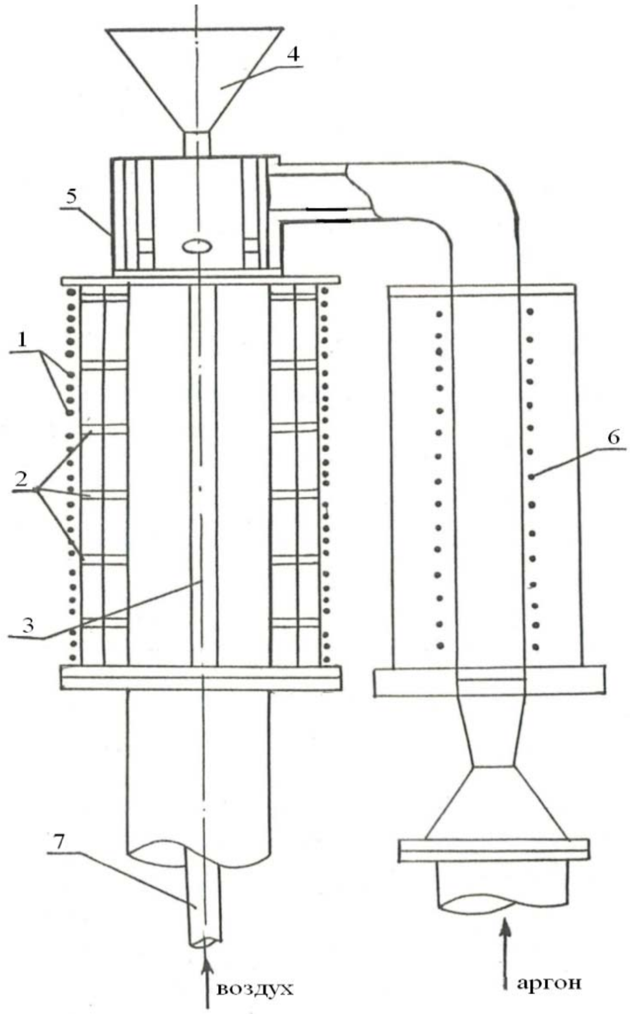

Figure 1 – Scheme of the pilot factory

The adopted experimental procedure, taking into account the furnace size, composition and consumption of the mixture elements, allowed the time for the shift of combustion processes, determination of oxygen concentration (O_2) and furnace temperature.

The experiments were carried out with the dust of Ekibastuz coal of *R* = 18%. The dust consumption in all the experiments was kept constant and composed 0.042 $\frac{g}{s}$. excess air coefficient α = 1,2. The temperature in the furnace varied from 0 to 700 ^{0}C. The oxygen concentration in the furnace was 11%. It was determined using a chromatograph LXM-8MD. Determination of the concentration of nitric oxide was carried out with the help of the "Evdiometer-1" device. The method of running gas analysis is described in [4, 5].

The primary data of the experiments on the effect of SCP time on the formation of nitric oxide: $O_2 = 11\%; \tau = 0; 0.05; 0.1\, s; NO = 220; 160; 83 \frac{mg}{nm^3}$ at the temperature in the furnace 50 ^{0}C and $NO = 146; 113; 98 \frac{mg}{nm^3}$ at the temperature in the furnace 700 ^{0}C. These values are significantly lower than the concentration of nitrogen oxides ($340 - 670 \frac{mg}{nm^3}$) obtained in the gasification of the same coal dust in the air, in the temperature range of 500–900 ^{0}C. The experimental data are in correspond with the experimental data of the All-Russian Thermal Engineering institute and Kazakh Scientific Research

Institute of Power Engineering on suppressing the formation of nitrogen oxides by preliminary heating of the fuel (τ = 0), as well as with the results of calculating the thermal decomposition of the Ekibastuz coal dust, recombination of atomic nitrogen into nitrogen molecules, and the kinetics of fuel nitric oxide formation.

It is shown that nitrogen oxides are not formed in the inert medium, despite the 11.8% oxygen content of in the Ekibastuz coal.

In the literature, the results of research and an attempt to use the decomposition of nitric oxide by carbon, carbon monoxide, and also hydrogen to reduce emissions of nitrogen oxides with flue gases are known.

We conducted experiments to determine the effect of coal dust on the reduction of nitrogen oxide emissions when it is fed into the combustion zone through flue gases. For these experiments, the experimental setup was slightly modified. The flue gases formed in the additional furnace were fed into a vertical furnace into the dust stream of Ekibastuz coal. The dust consumption was $0.133\frac{g}{s}$ approximately equal to the concentration of coal dust in a real combustion furnace ($6.84\frac{g}{nm^3}$). Sampling was carried out at a distance 0.5m from the place where coal dust insertion, which corresponds to the time of arrival 0.29 – 0.3s.

When natural dust is fed into the flue gases, an increase of NO in the content is observed. This can be explained by the interaction of gasification products of coal particles with flue gas oxygen, leading to the additional formation of nitric oxide. Experiments were also conducted with the addition of coke dust into the flue gases obtained by preheating natural coal dust at a temperature 900 ^{0}C.

With the supply of coke dust, the content of nitric oxide in the flue gases decreased from $670-820\frac{mg}{nm^3}$ to $400-460\frac{mg}{nm^3}$.

From this experimental data on the suppression of the formation of nitric oxide by the shift of furnace processes and the reduction of nitric oxide by coke of coal dust to molecular nitrogen, it can be seen that the two independent methods of reducing toxic nitrogen oxide emissions are considered to have good performance potential and can be used in the organization of environmentally friendly burning processes.

Results of analysis and recommendations. The amount of nitrogen released during high-temperature coking depends on the degree of carburization. For coals with a high degree of carburization, the highest temperature is required for the onset of a maximum of nitrogen evolution.

At higher temperatures, the concentration of nitrogen-containing components in volatiles is higher than at low temperatures.

Blair, examining 20 grades of coals and two grades of semi-coke, obtained an empirical expression for determining the mass fraction of the lost nitrogen of fuel as a function of temperature [6]:

$$\psi_N = \frac{0{,}4861\cdot 0.01V^P + 3545\cdot \exp\left(-\frac{85700}{RT}\right)}{1+3545\cdot \exp\left(-\frac{85700}{RT}\right)}$$

Here $R \approx 8{,}3\frac{Дж}{моль\cdot K}$ - the gas constant; V^p – Volatile yield on the working mass,%.

From the above analysis it can be seen that two tendencies can be traced in the construction of mathematical models of calculation. It seems preferable to use simplified schemes - from the equations of total kinetics by introducing refinements into these schemes.

In figure 2, the calculated results are compared with the experimental data [6]. Their coordination is generally satisfactory. Some higher calculated values of nitric oxide formation than in the experimental data are explained by the kinetic nature of the chemical reactions considered in the mathematical model. In fact, this rate of chemical reactions is somewhat slower because of unaccounted factors related to the nature of the organization and the diffusion of the processes of mixture formation. Comparison of the

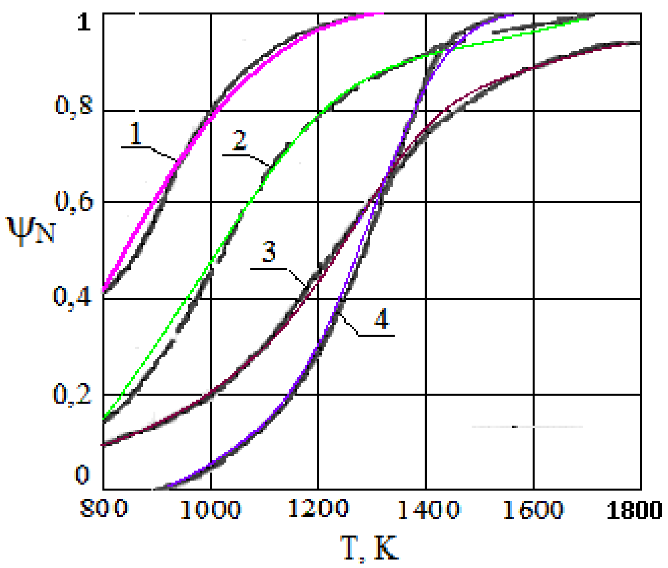

Figure 2 – The degree of gasification of fuel nitrogen depending on the temperature for Ekibastuz coal (calculated and experimental), 1, 2 – T.V. Vilensky, 3 – Pershing, Wendt, 4 – VI. Babiy.

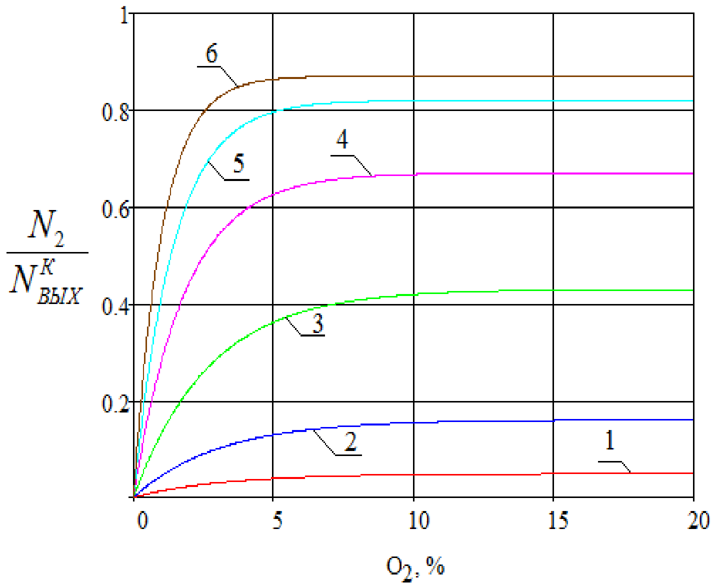

Figure 3 – Recombination of N in N_2 at different curves O_2.
1 – T = 800 K; 2 – T = 1000 K; 3 – T = 1200 K; 4 – T = 1400 K; 5 – T = 1600 K; 6 – T = 1800 K

curves 4,5 and 6 (see figure 3), referring to the same temperature 1200 K, but to different values of the oxygen concentration (3 and 14%) and the coefficient γ(0,67; 0,82; 0,88) taking into account [6] the proportion of nitrogen of the fuel passing into the gas phase. The main calculated curves 1, 2, 3 in Figure 2 have a value γ = 0,26 that occupies an intermediate position between the values of 0,2 and 0.3 indicated in [6] for stone and brown coals, respectively.

Conclusion:

1. The installations and fire settings for the pyrolysis of coal dust and burning of pyrolysis products with a phase shift of the air supply have been developed and performed.

2. Experiments were carried out to determine nitrogen oxides in an inert and air medium using a pyrolytic attachment and describe the experimental procedure using chromatographs LXM-8MD, KhPM-4 and Eudio-meter-1.

It is shown that nitrogen oxides are not formed in an inert medium, despite the oxygen content in the Ekibastuz coal of O_2 = 11,8%.

The content of nitric oxide in the air was $340 \div 670 \frac{mg}{nm^3}$ when the process temperature was changed from 500 to 900 ^{0}C.

The possibility of suppressing the formation of nitrogen oxides up to three times by pyrolysis of the dust of Ekibastuz coal at temperatures of 500÷700 ^{0}C and a shift in the phase of the supply of air for combustion up to 0.1 s.

3. Have been developed programs and the calculation of the processes of nitrogen oxides formation during burning of Ekibastuz coal of high concentration on an ECM, for various values of the oxygen concentration, temperature and time of the process, taking into account the kinematics of formation of fuel oxides of nitrogen.

The results of the calculation are consistent with the known literature data and the first data of the report.

4. A fire-engineering method for suppressing the formation of nitrogen oxides by pyrolysis of fuel with a phase shift of the air supply is proposed, which allows to reduce emissions of nitrogen oxides to the level of modern requirements.

Thus, a decrease in emissions of nitrogen oxides by influencing furnace aerodynamics and conditions of burning can be obtained by the following actions [7-10]:

- burning of fuels at small excess of air or recirculation of the products of combustion in the furnace camera (the greatest effect on decrease in an exit of NO_x is reached at recirculation introduction directly to hot air before torches). However, these methods have limitations, namely:
- considerable complication of ignition of a torch at decrease in the content of oxygen in the burning zone
- temperature increase of an overheat of steam, in connection with a tightening of ignition and burning out of fuels
- some decrease in the completeness of burning out of fuel (increase of loss of heat due to unburnt or emergence of chemical unburnt).

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ЕКІБАСТҰЗ КӨМІРІН ПИРОЛИЗДЕНГЕН КЕЗДЕ АЗОТ ОКСИДІНІҢ ТҮЗУІН ЗЕРТТЕУ ЖӨНІНДЕГІ ЖОЛДАРЫ

Аннотация. Мақалада ауаның ауысуындағы фазаның жылжуымен ыдырау өнімінің жануы және көмір тозаңын ыдырату үшін жанғыш қондырғыны монтаждап және ретке келтіру орындалған. Азот оксидін ауа мен инертті ортада зерттеу бойынша тәжірбие жүргізіліп және тәжірибенің әдісі түсіндірілген. Эксперимент нәтежиесі инертті ортада азот оксиді құрылмайтыныны және ауада Экібастұздық көмір тозаңының ыдырауында үш есеге дейін басым болатынын көрсетті. Программа өңделіп және ЭЕМ-да оттегінің концентрациясы және температурасы мен уақытының есебімен жоғары концентрациялы Екібастұздық көмірдің жануы кезінде азот оксидінің құрылу жүйесі есептелінді. Жұмыста қазіргі талапқа сай азот оксидінің шығындыларын төмендетуге мүмкіндік беретін, ауадағы фазаның жылжуымен жанармайдың ыдырау жолымен құрылған азот оксиді жүйесінің өрт-техника әдісі ұсынылды. Салыстырмалы түрде ұсынылған әдістің экологиялық және экономикалық артылықшылықтары байқалды.

Түйін сөздер: азот оксиді, газдандыру, ауа артықтығы, берілуі, жану.

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ПУТИ ИССЛЕДОВАНИЯ ПРОЦЕССОВ ОБРАЗОВАНИЯ ОКИСИ АЗОТА ПРИ ПИРОЛИЗЕ ПЫЛИ ЭКИБАСТУЗСКОГО УГЛЯ

Аннотация. В статье разработаны и выполнены монтаж и отладка огневых установок для пиролиза угольной пыли и сжигания продуктов пиролиза со сдвигом фазы подвода воздуха. Проведены эксперименты по определению окислов азота в инертной и воздушной средах и описана методика эксперимента. Результаты эксперимента показали, что в инертной среде окислы азота не образуются, а в воздушной среде подавляются до трех раз при пиролизе пыли Экибастузского угля. Разработаны программы и выполнен расчет процессов образования окислов азота при горении Экибастузского угля высокой концентрации на ЭВМ с учетом концентрации кислорода, температуры и времени. В работе предложен огнетехнический метод процесса подавления образования окислов азота путем пиролиза топлива со сдвигом фазы подвода воздуха, что позволяет снизить выбросы окислов азота до уровня современных требований. Отмечены экологические и экономические преимущества предложенного метода по сравнению с существующими.

Ключевые слова: оксид азота, газификация, избытка воздуха, подавление, сжигания.

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