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MATHEMATICAL PROCESSING OF INDUSTRIAL EXPERIMENT RESULTS BASED ON INFRASOUND TO IMPROVE THE ECONOMIC EFFICIENCY OF THERMAL POWER PLANTS

The paper offers a new method of dust and gas emissions data processing at thermal energy plants. This method allows to increase the economic efficiency of thermal power complex by reducing the payments penalty for emissions into the atmosphere. The resulting mathematical model can be used as a basis for the development of an automated process control system of low-frequency acoustics of gas and dust flow.

Keywords: *infrasonic exposure; dust and gas treatment process; factor analysis; regression analysis.*

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МАТЕМАТИЧНА ОБРОБКА РЕЗУЛЬТАТІВ ВИРОБНИЧОГО ЕКСПЕРИМЕНТУ З ВИКОРИСТАННЯМ ІНФРАЗВУКУ ДЛЯ ПІДВИЩЕННЯ ЕКОНОМІЧНОЇ ЕФЕКТИВНОСТІ ТЕПЛОВИХ ЕЛЕКТРОСТАНЦІЙ

У статті запропоновано новий метод обробки даних про викиди газів та пилу на теплових енергетичних об'єктах. Даний метод дозволяє підвищити економічну ефективність теплового енергетичного комплексу за рахунок зменшення штрафних виплат за викиди в атмосферу. Описана математична модель може бути використана як основа для розробки автоматизованої системи управління технологічним процесом низькочастотних акустичних потоків газу та пилу.

Ключові слова: *інфразвукова дія; процес пило- та газоочищення; факторний аналіз; регресійний аналіз.*

Форм. 1. Рис. 3. Літ. 14.

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МАТЕМАТИЧЕСКАЯ ОБРАБОТКА РЕЗУЛЬТАТОВ ПРОИЗВОДСТВЕННОГО ЭКСПЕРИМЕНТА С ПРИМЕНЕНИЕМ ИНФРАЗВУКА ДЛЯ ПОВЫШЕНИЯ ЭКОНОМИЧЕСКОЙ ЭФФЕКТИВНОСТИ ТЕПЛОВЫХ ЭЛЕКТРОСТАНЦИЙ

В статье предложен новый метод обработки данных о выбросах газа и пыли на тепловых энергетических объектах. Данный метод позволяет повысить экономическую эффективность теплового энергетического комплекса за счет уменьшения штрафных выплат за выбросы в атмосферу. Представленная математическая модель может быть использована в качестве основы для разработки автоматизированной системы управления технологическим процессом низкочастотных акустических газовых потоков и пыли.

Ключевые слова: *инфразвуковое воздействие; процесс пыле- и газоочистки; факторный анализ; регрессионный анализ.*

Problem statement. In recent decades, the objectives of environmental protection have become one of the most important issues to be addressed by the mankind.

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Particular attention of the international community is paid to air pollution prevention. Its protection from harmful effects of various factors is regulated by legislation.

There are many methods, techniques and devices for emissions treatment from polluting components of the production cycle. Scientists around the world look for new methods and techniques that reduce air pollution with emissions. They try to discover new properties of well-known structures and create new solutions of the relevant problems on this basis.

Water is one of the main structures of the world that surrounds us from birth (Rassadkin, 2008).

The structure of water is very mobile. Compounds of molecules split every billionth of a second. However water has stable order zones – clusters. They can be compared with lattice. When one water molecule leaves such lattice, another comes in its place. Molecules leave – the lattice remains. How strict record is possible in a volatile environment? This is due to the cluster memory. New information means new cluster, a new record in water.

This world is a collection of countless waves and vibrations. In the boundless ocean of microscopic and giant rhythms, everything vibrates – space, matter, but they vibrate with different frequency (Khorbenko, 1986; Elpiner, 1973). Exposing water to different types of waves, we can change the properties of water and use it to address the urgent problems of modern industry, including dust and gas treatment.

Recent research and publications analysis. The following scientists were engaged in the analysis of dust and gas treatment problem – Y.S. Drugov et al. (1984), A.P. Klimenko et al. (1980), S.I. Lugovskiy and G.K. Dymchuk (1991), E.P. Mednikov (1963), S.B. Stark (1983), V. Straus (1981), V.N. Uzhov (1959), K. Wark and S.M. Warner (1980).

O.A. Kazakov (1999) can be called the pioneer of infrasonic exposure on water structure in Kazakhstan. He concentrated on the use of infrasound in medicine. New idea has stirred interest in East Kazakhstan, and the scientists of East Kazakhstan State Technical University have been conducted a research on infrasonic exposure on thermal power complex facilities in order to reduce emissions of harmful nitrogen oxides (NO_x), sulfur (SO_2), carbon monoxide (CO) and ash particulates.

Unresolved issues. Existing methods and equipment for decontamination of harmful gas components do not provide a 100% treatment of emissions due to high costs of equipment, significant expenses on reconstruction and maintenance, high costs of chemical agents. Therefore, this paper suggests a new infrasonic method of dust and gas collection.

The purpose of this study is a mathematical analysis of the experimental results of infrasound exposure on dust and gas flow to automate the process of dust and gas treatment at thermal power facilities.

Key research findings. Kazakhstan electricity basis is a thermal power complex with the total capacity of 16,733 MW. Currently, the share of thermal power accounts for 42% of the total emissions of air pollutants from stationary sources. In accordance with the Resolution of Government of the Republic of Kazakhstan No. 1232 as of December 14, 2007, all newly introduced and existing TPP boilers should have reduced pollutant emissions into the atmosphere since 01.01.2013.

Traditional technology of particulate (chamber) coal combustion prevails in the power industry of Kazakhstan, and it is essential to increase efficiency and "environmental friendliness" of this technology. The main emphasis in this should be placed on dust and gas treatment of flue gas outside boilers.

Experimental and industrial testing of infrasonic exposure on reduction of harmful substance emissions into the atmosphere with flue gases was carried out in August-October 2013 in the boiler and the turbine plant of LLP "NPP Sogrinskaya TPP".

Boiler No. 2 was exposed to sonic waves of low frequency on flue gas dust and gas flow carried on.

For heat generation, in the boiler room there were 3 steam boilers BKZ-160-100fb installed with steam generating capacity of 160 t/h each. The fuel used is coal from the field "Karazhyra" of LLP "Karazhyra LTD" and the coal mine "Maikubensky" of Shoptykolskoe field.

The combustion of the fuel releases nitrogen oxides, sulfur dioxide, carbon dioxide, inorganic dust with SiO_2 content of 70–20%.

Pollutants emission into the atmosphere is carried out after the pre-treatment:

Boiler No. 1 – 3 Venturi scrubbers.

Boiler No. 2 – consistently emulsifier of the 2nd generation and 3 Venturi scrubbers.

Boiler No. 3 – emulsifier of the 2nd generation (at an installation stage).

During fuel combustion, dust and gas flow produced in the boiler is sequentially treated in the emulsifier – Venturi scrubbers and then is emitted to the atmosphere through exhauster and pipe. Thus, before emulsifier and exhauster, pollutants concentrations were measured with Testo 350 M: nitrogen oxides (NO_x) and sulfur (SO_2), carbon monoxide (CO), as determined by dust emissions. Then, in the upper zone of the emulsifier, infrasonic radiation with the frequency up to 30 Hz was supplied in gases intensively washed with water by means of IFS-1 device. After infrasonic exposure, pollutants concentrations in flue gases were remeasured.

The obtained measurement results indicate that the exposure of sound waves of low frequency on the flow of flue gases from the operating boiler unit with the most efficient frequency of 30 Hz results in lowering the concentrations of hazardous substances:

- SO_2 – by 5.4%;
- NO_x – by 0.22%;
- CO_2 – by 3.95%;
- dust content – by 15.16%.

Data analysis shows that with infrasonic exposure on dust and gas flow dust particles grow by more than twice, increasing the efficiency of dust and gas treatment. Thus, there is a reduction in the emission of harmful gases into the atmosphere.

S.V. Surkov and O.N. Tsabiev (2003) considered the movement of dust particles in gas flows. As a result of their study, the mathematical models of dust particles movement were obtained on the basis of the secondary flow models. Using the Stoke's formula, Klyachko's formula, Navier-Stokes equations by their numerical integration the mathematical model that enables predicting the deposition of particles in the suspension carrying flows of square and rectangular gas flues was obtained. The model suggested by S.V. Surkov is well agreed with experimental data.

Near the corners of the gas flue, there is an increase in the concentration of particulate matter in connection with the occurrence of secondary flows and particle deceleration. This allows us offering the rectangular flue for subsonic dust and gas treatment unit. The curve of suspension carrying flow velocity in round and rectangular flues given in this work indicates the indisputable advisability of such a solution. This conclusion is confirmed by the path of movement of particulates obtained in experiments on round and rectangular flues.

On the basis of these experiments, we prepared a table of data with factorial signs – infrasonic exposure time (min), exposure frequency (Hz), effective signs – dust content (g/m^3), the concentration of harmful gas components SO_2, NO_x, NO_2, CO_2 (mg/m^3).

Obtained experimental data were processed by methods of mathematical and applied statistics. Correlation and regression analysis was performed using the Statistica software. The best approximation will be achieved by using the following linear function:

$$y = a_0 + a_1 x_1 + a_2 x_2, \quad (1)$$

where y – the value of pollutant concentration; x_1 – infrasonic exposure time; x_2 – infrasonic frequency radiation; a_0, a_1, a_2 – model parametres.

Figures 1–3 show the results of calculations for the paired coefficients of correlation, regression analysis on the basis of NO_x efficiency. Figure 2 contains the values of the regression equation and regression coefficients. On the basis of the determination coefficient, F-criteria we may conclude on the quality of the models obtained.

Correlations (1.sta)
Marked correlations are significant at p < ,05000
N=144 (Casewise deletion of missing data)

Variable	Время	Частота	NOx
Время	1,00	-0,00	-0,09
Частота	-0,00	1,00	-0,19
NOx	-0,09	-0,19	1,00

Figure 1. **Paired correlation coefficients (efficiency sign – NO_x),** *developed by the authors*

Multiple Regression Results: 1.sta

Multiple Regression Results

Dependent: NOx Multiple R = ,20641917 F = 3,137616
R?= ,04260887 df = 2,141
No. of cases: 144 adjusted R?= ,02902886 p = ,046430
Standard error of estimate:23,055636553
Intercept: 307,96180556 Std.Error: 13,85471 t(141) = 22,228 p = 0,0000

Время beta=-,09 Частота beta=-,19

Figure 2. **Regression analysis results (efficiency sign – NO_x),** *developed by the authors*

Regression Summary for Dependent Variable: NOx (1.sta)
R= ,20641917 R?= ,04260887 Adjusted R?= ,02902886
F(2,141)=3,1376 p<,04643 Std.Error of estimate: 23,056

N=144	Beta	Std.Err. of Beta	B	Std.Err. of B	t(141)	p-level
Intercept			307,9618	13,85471	22,22795	0,000000
Время	-0,087910	0,082402	-0,1674	0,15687	-1,06685	0,287862
Частота	-0,186764	0,082402	-1,0667	0,47062	-2,26651	0,024942

Figure 3. **Normal probability plot (efficiency sign – NO_x),** *developed by the authors*

An important part of the regression analysis is the analysis of residues (residues are the differences between the observed values of the dependent variable and those of its values predicted by the regression model). The results of normality of residuals distribution using normal probability plots are shown in Figure 3.

Similar results were obtained for other types of controlled impurities, namely CO_2, SO_2 and dust particles (fly ash).

Conclusions. Application of infrasound exposure to the water used in the process of wet dust and gas treatment will reduce the emission of substances, most harmful for human health.

Mathematical processing of the experimental results obtained proves the quality of the selected mathematical models.

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Стаття надійшла до редакції 17.06.2014.