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БАЯНДАМАЛАРЫ

ДОКЛАДЫ

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РЕСПУБЛИКИ КАЗАХСТАН

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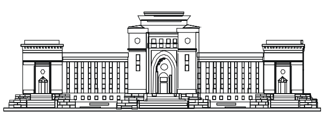

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INVESTIGATION OF AERODYNAMICS AND HEAT AND MASS TRANSFER IN THE COMBUSTION CHAMBERS OF THE BOILERS PK-39 AND BKZ-160

Abstract. Scientific researches in the field of development of new and improvement of existing technologies to improve the combustion of low grade fuels that reduce emissions of pollutants and at the same time improve the main indicators of energy complexes represent considerable interest for thermal power industry in the Republic of Kazakhstan. The development of such methods and improving coal combustion processes, along with alternative ways of organizing its combustion process (plasma thermochemical preparation, with the use of technology overfire air and the technology mechanism of selective and non-catalytic reduction of nitrogen oxide emissions) is currently the most urgent for the entire energy complex.
Keywords: combustion, combustion chamber, plasma-fuel systems, numerical modeling.

Many experimental and analytical studies are carried out under simplified conditions, which differ from the real heating conditions of the process flow. For example, many of them are carried out under the conditions of combustion of large particles when they are incinerated in a medium with large excess of air. Some researchers have assumed that the temperature of the medium does not change during combustion, and combustion takes place in one of the limiting regimes: kinetic or diffuse. This simplification of the combustion process distorts its essence and does not allow us to clarify the aerodynamics and heat exchange occurring in a real combustion chamber [1].

When the solid fuel burns in a pulverized state, turbulent heat transfer processes, masses of reacting components and their interaction products take place in the combustion chamber. Such processes are described by equations based on the laws of conservation of mass and momentum. For reactive flows, in which heat transfer processes and chemical reactions occur, it is necessary to further solve the energy conservation equation and add the equation of conservation of the mixture components or the conservation equation for the mixture fractions and their variations. Turbulence is described by transport equations for turbulent characteristics [2-5].

This system of basic equations of the mathematical model used in the present work to describe the processes of turbulent heat and mass transfer during the combustion of solid fuel in the pulverized state (pulverized-coal torch), is as follows [2]:

The equation of continuity or the law of conservation of mass in a differential form is written in the form:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}\left(\rho u_i\right) = 0\,, \tag{1}$$

where the first term describes the flow nonstationarity, the second term represents convective transfer.

Law of conservation of momentum:

$$\frac{\partial}{\partial \tau}\left(\rho u_i\right) = -\frac{\partial}{\partial x_j}\left(\rho u_i u_j\right) + \frac{\partial}{\partial x_j}\left(\tau_{i,j}\right) - \frac{\partial p}{\partial x_j} + \rho f_i\,, \tag{2}$$

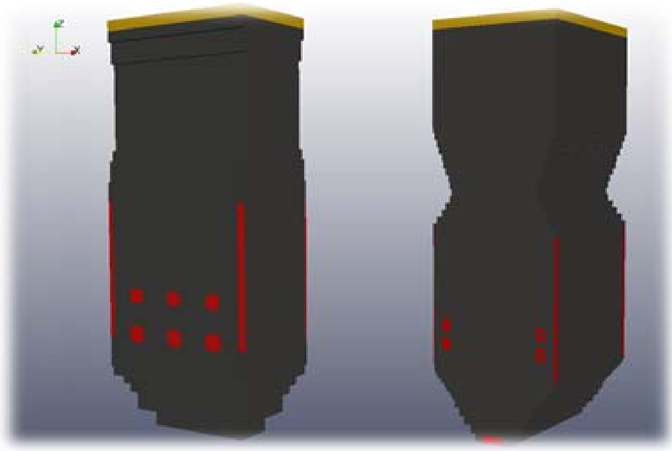
where f_i – mass force; $\tau_{i,j}$ – stress tensor.

Energy equation:

$$\frac{\partial}{\partial t}(\rho h) = -\frac{\partial}{\partial x_i}(\rho u_i h) - \frac{\partial q_i^{res}}{\partial x_j} + \frac{\partial P}{\partial t} + u_i \frac{\partial P}{\partial x_i} + \tau_{ij}\frac{\partial u_j}{\partial x_i} + S_h \quad (3)$$

Plasma thermochemical preparation of coal for combustion consists in heating by a plasma torch with an oxygen deficit of the flow of the pulverized coal mixture in a special chamber to the temperature higher than the autoignition temperature of this coal. In this case, there is an almost complete release of volatile substances and partial combustion and gasification of coal carbon. As a result, the obtained fuel mixture or the highly reactive two-component fuel, consisting of combustible gas and coke residue, is ignited when mixed with secondary air and steadily burns without the use of a reserve high-reaction fuel (fuel oil or natural gas) to stabilize the pulverized-coal flare even in a cold furnace. The use of different types of burners does not cause differences in the mechanism of plasma thermochemical preparation of coal for combustion. The use of PTS makes it possible to exclude fuel oil from the fuel balance of CHP, traditionally used to kindle boilers [6-8].

The process of plasma thermochemical preparation of fuel for combustion is carried out in PTS. The plasma torch is installed on the lined channel of the air mixture of the burner, which is converted into PTS and installed directly into the combustion chamber [7, 8]. Figure 1 presents a general view of the furnace chambers of the PK-39 boilers of the Aksuiskaya SDPP and BKZ-160 of Almaty CHP-3 equipped with plasma-fuel systems.



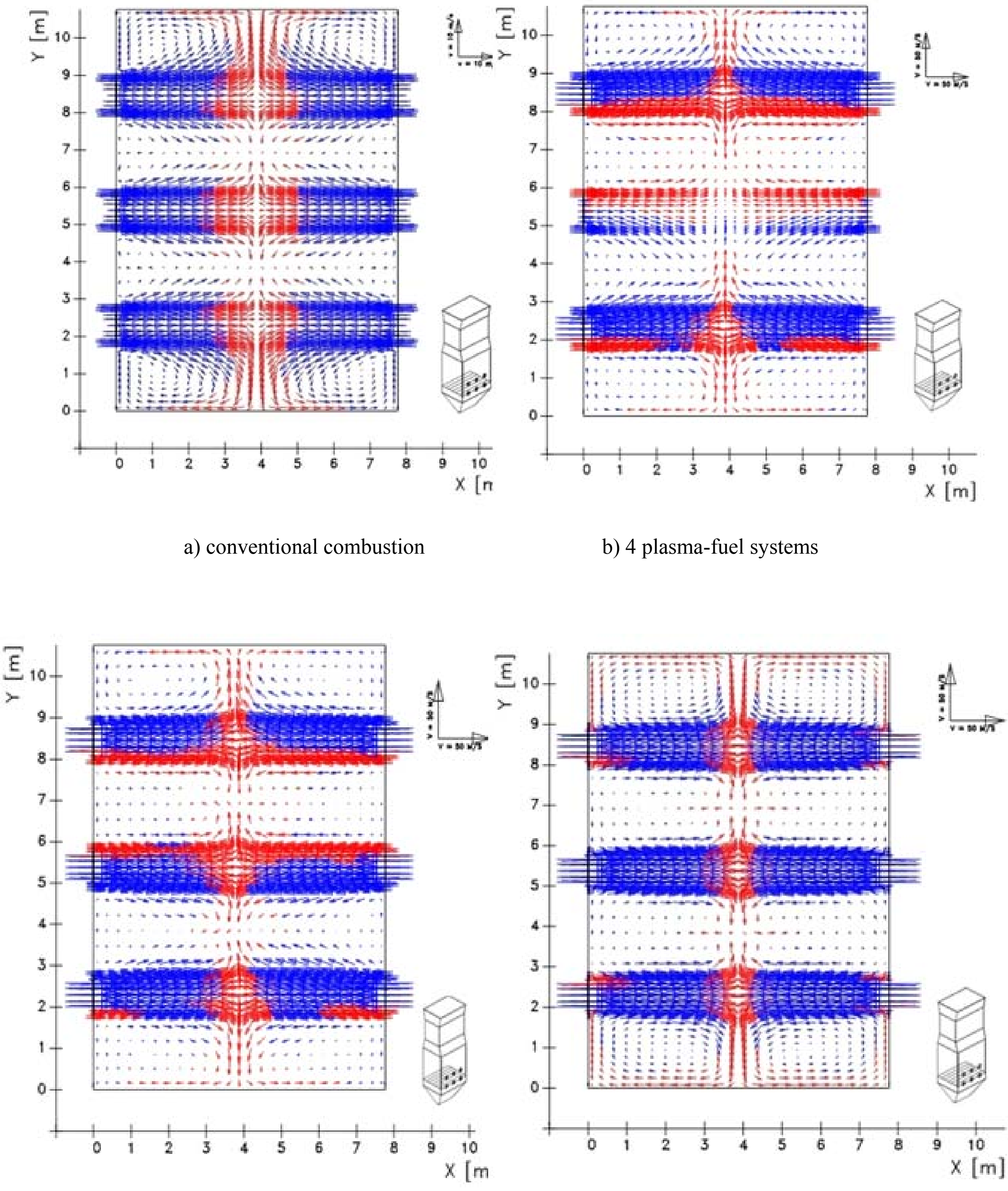
a) PK-39 of the Aksuiskaya SDPP; b) BKZ-160 of Almaty CHP-3

Figure 1 – General view of furnace chambers of boilers equipped with plasmatrons

Figures 2 and 3 show the field of the full-velocity vector in the combustion chamber in the cross section of the burners for each of the investigated cases, for the boilers PK-39 and BKZ-160.

Analysis of figure 2 shows that with increasing number of thermochemically activated flows (4, 6, 12 plasma torches), the core of the flame is shifted to the center of symmetry of the combustion chamber. At the point of collision of opposing flows, the dynamic head is transformed into static pressure as a result of braking. Under the action of the resulting pressure drop, the total flow spreads up and down with increased velocities. When impact opposite torches and the turbulence of the streams, mass and heat transfer is accelerated to a large extent, while the mixture-forming and heating amplification intensify the combustion process.

Figure 3 indicates a significant difference between the two investigated cases. In Figure 3b, the pulverized coal streams, flowing into the furnace through conventional burners and through plasma-fuel systems, are clearly visible. Thus, in the furnace chamber, the flows of the two-component high-reaction fuel gasified by plasma activation are propagated in accordance with the laws of aerodynamics and are the thermal source for the air mixture delivered through burners not equipped with plasma ignition systems.



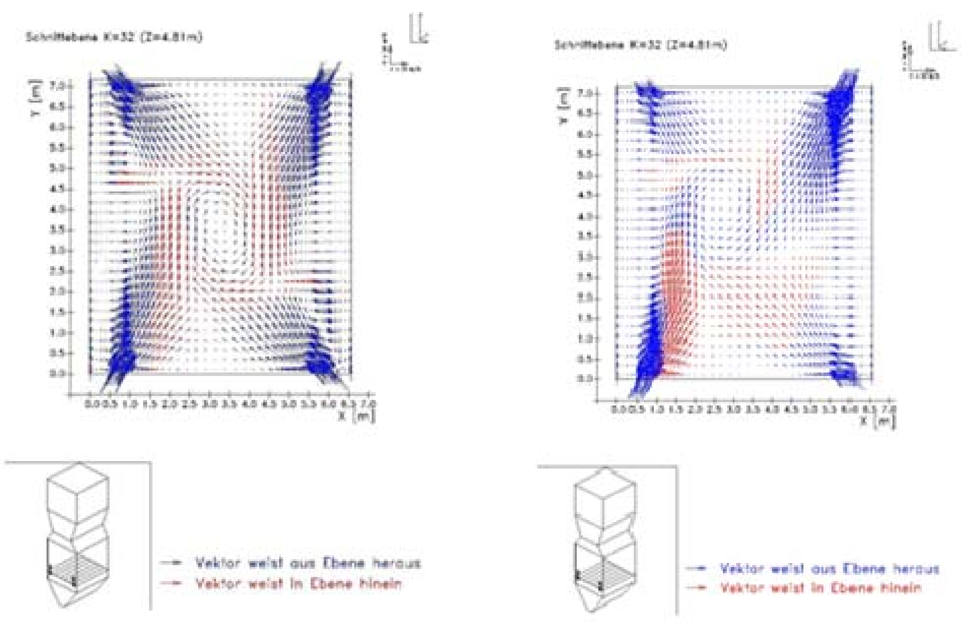
a) conventional combustion

b) 4 plasma-fuel systems

c) 6 plasma-fuel systems

d) 12 plasma-fuel systems

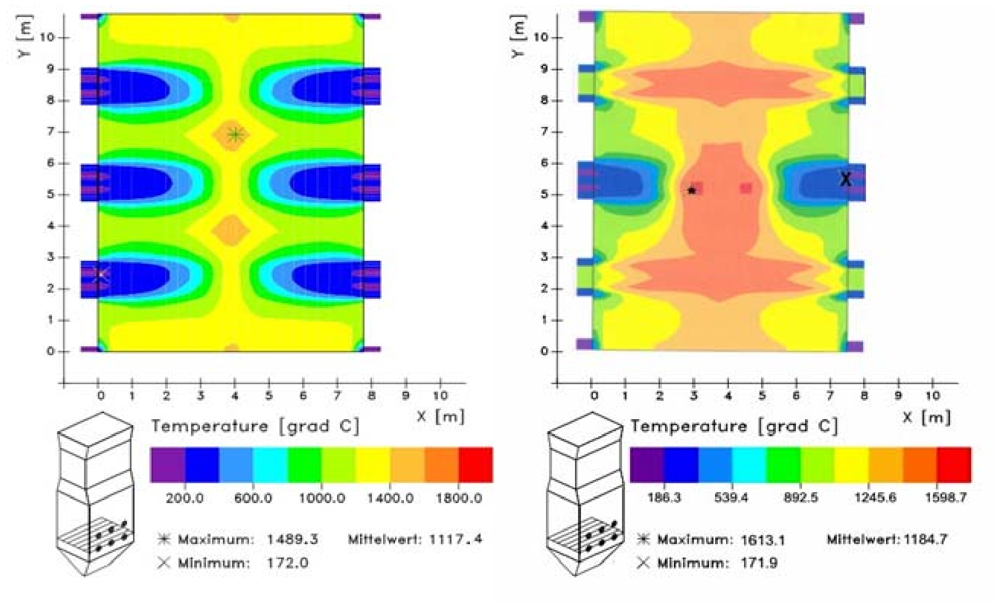
Figure 2 – The field of the full-velocity vector in the section of burners
of the combustion chamber of the boiler PK-39 of Aksuyskaya SDPP



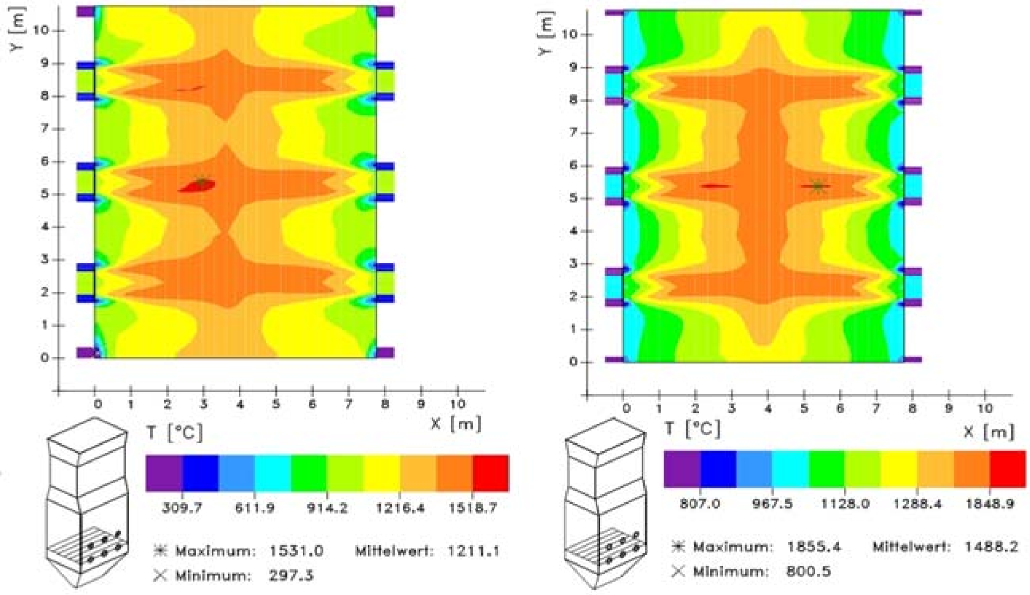
a) conventional combustion b) 2 plasma-fuel systems

Figure 3 – Distribution of the full-velocity vector in the location of the burners of the combustion chamber of the boiler BKZ-160 of Almaty CHP-3

It can be noted (Figure 4) that, compared with the conventional pulverized coal flow, the average temperature in the plane of the burner cross-section for the PK-39 boiler increases with the number of thermochemically activated streams and amounts to: 1117 ºC - without activation; 4 activated streams – 1185 ºC; 6 – 1211 °C; 12 – 1488 °C.

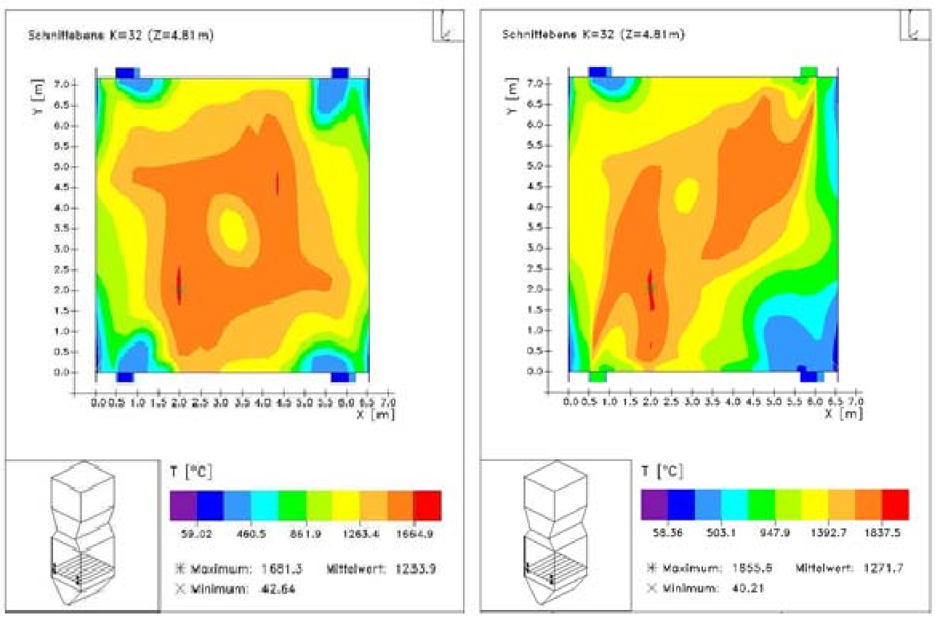


a) conventional combustion b) 3 plasma-fuel systems



c) 6 plasma-fuel systems d) 12 plasma-fuel systems

Figure 4 – Temperature field in the plane of the burner section of the lower stage of the furnace chamber of PK-39 boiler of Aksuiskaya SDPP



a) conventional combustion b) 2 plasma-fuel systems

Figure 5 – Temperature distribution in the area of the burner devices arrangement in the lower stage of the furnace chamber of the BKZ-160 boiler of Almaty CHP -3

Analysis of figure 5 shows that, in comparison with the use of conventional pulverized coal flow, the average temperature in the plane of the section of burners with thermochemically activated flows increases and amounts to: 1234 ºC - without activation, and 1272 ºC - for two activated flows in the lower stage of the burners.

On the basis of the foregoing, it can be concluded that for all boilers under study the process of plasma activation of the combustion of the air mixture leads to an increase in the temperature in the area of installation of burners. At the same time, with an increase in the number of installed plasma-fuel systems, the combustion front is shifted to the location of plasma activation systems of coal flows.

This can be explained, first of all, by the fact that during the plasma activation of the pulverized coal stream, volatile substances are released before entering the combustion chamber, carbon is oxidized, which leads to partial gasification of the fuel. The released volatile and gasification products begin to react with the oxygen present in the primary air, in turn, further releasing heat and further heating the reacting stream of pulverized coal particles, the products of combustion of volatile and gasification of the coke residue (carbon).

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ПК-39 ЖӘНЕ БКЗ-160 ҚАЗАНДЫҚТАРЫНЫҢ ЖАНУ КАМЕРАЛАРЫНЫҢ АЭРОДИНАМИКАСЫ МЕН ЖЫЛУ МАССА АЛМАСУЫН ЗЕРТТЕУ

Аннотация. Атмосфераға бөлінетін зиянды қалдықтардың мөлшерін кемітетін және энергетикалық кешендердің негізгі көрсеткіштерін бірмезгілде жоғарылататын төменгі сұрыпты отындардың жануын жақсартуға қатысты жаңа технологияларды жасау және ағымдағы түрлерін жетілдіру облысындағы ғылыми зерттеулер Қазақстан Республикасының жылуэнергетика саласы үшін айтарлықтай қызығушылық тудырып отыр. Осындай әдістерді жобалау және жану процесін ұйымдастырудың балама түрлерін қолдана отырып, көмірді жағу процесін жетілдіру (өткір үрлеу технологиясы мен азот тотықтарының қалдықтарын селективті каталитикалық емес кеміту механизмі технологиясын қолдана отырып, плазмалық термохимиялық әзірлеу) қазіргі уақытта барша энергетикалық кешен үшін өзекті болып отыр.

Түйін сөздер: жану, жану камерасы, плазма-отын жүйелері, сандық модельдеу.

А. С. Аскарова, С. А. Болегенова, С. А. Болегенова, В. Ю. Максимов, Ш. С. Оспанова

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ИССЛЕДОВАНИЕ АЭРОДИНАМИКИ И ТЕПЛОМАССООБМЕНА В ТОПОЧНЫХ КАМЕРАХ КОТЛОВ ПК-39 И БКЗ-160

Аннотация. Научные исследования в области разработки новых и совершенствования существующих технологий по улучшению горения низкосортных топлив, которые обеспечивают снижение выбросов в атмосферу загрязняющих веществ и одновременно улучшают основные показатели энергетических комплексов, представляют значительный интерес для теплоэнергетической отрасли Республики Казахстан. Разработка таких методов и совершенствование процессов горения угля наряду с использованием альтернативных способов организации процесса его сжигания (плазменная термохимическая подготовка, с применением технологии острого дутья и технологии использования механизма селективного и некаталитического снижения выбросов оксидов азота) является в настоящее время наиболее актуальным для всего энергетического комплекса.

Ключевые слова: горение, топочная камера, плазменно-топливные системы, численное моделирование.

CONTENT

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