ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ
Әл-Фараби атындағы Қазақ ұлттық университетінің

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Казахский национальный университет
имени Аль-Фараби

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Al-Farabi Kazakh
National University

SERIES
PHYSICO-MATHEMATICAL

3 (337)

MAY – JUNE 2021

PUBLISHED SINCE JANUARY 1963

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

NAS RK is pleased to announce that News of NAS RK. Series physico-mathematical journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of chemistry and technologies in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of chemical sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Физикалық-математикалық сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын усынады. ҚР ҰҒА Хабарлары. Химия және технология сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді химиялық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия физико-математическая» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Вклю-чение Известия НАН РК в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по химическим наукам для нашего сообщества.

«ҚР ҰҒА Хабарлары. Физика-математикалық сериясы».
ISSN 2518-1726 (Online),
ISSN 2224-346X (Print)

Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 14.02.2018 ж. берілген **№ 16906-Ж** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *физика-математика ғылымдары және ақпараттық техникалар саласындағы басым ғылыми зерттеулерді жариялау.*

Мерзімділігі: жылына 6 рет.
Тиражы: 300
Редакцияның мекен-жайы: *050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19, 272-13-18*
http://www.physico-mathematical.kz/index.php/en/

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Муратбаева көш., 75.

«Известия НАН РК. Серия физика-математическая».
ISSN 2518-1726 (Online),
ISSN 2224-346X (Print)
Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).
Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ 16906-Ж** выданное 14.02.2018 г.
Тематическая направленность: *публикация приоритетных научных исследований в области физико-матема-тических наук и информационных технологий.*

Периодичность: 6 раз в год.
Тираж: 300
Адрес редакции: *050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19, 272-13-18*
http://www.physico-mathematical.kz/index.php/en/

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

News of the National Academy of Sciences of the Republic of Kazakhstan.
Physical-mathematical series.
ISSN 2518-1726 (Online),
ISSN 2224-346X (Print)

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty). The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. 16906-Ж,** issued 14.02.2018

Thematic scope: *publication of priority research in the field of physical and mathematical sciences and information technology.*

Periodicity: 6 times a year.

Circulation: 300

Editorial address: *28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19, 272-13-18, http://www.physico-mathematical.kz/index.php/en/*

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS
OF THENATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
PHYSICO-MATHEMATICAL SERIES
ISSN 1991-346X
Volume 3, Number 337 (2021), 12 – 19 **https://doi.org/10.32014/2021.2518-1726.41**

UDC 536.46:532.517.4
IRSTI 29.03.77; 29.03.85

A.S. Askarova[1-2], S.A. Bolegenova[1-2], A.O. Nugymanova[1], S.A. Bolegenova[2], Z.Kh. Gabitova[1]

[1]Al-Farabi Kazakh National University, Almaty, Kazakhstan
[2]Scientific Research Institute of Experimental and Theoretical Physics of al-Farabi Kazakh National University, Almaty, Kazakhstan
E-mail: bolegenova.symbat@kaznu.kz

NUMERICAL SIMULATION OF HEAT AND MASS TRANSFER PROCESSES DURING THE COMBUSTION OF SOLID FUEL OF DIFFERENT MOISTURE IN COMBUSTION CHAMBERS OF POWER PLANTS

Abstract. In the article, using numerical methods, studies have been conducted to determine the effect of the moisture content of the burnt coal on the characteristics of the heat and mass transfer process. The combustion chamber of the PK-39 boiler of the real energy object of the Republic of Kazakhstan (Aksu TPP) was chosen as the object of the study. Temperature (*T*) and concentration (O_2, *CO*, CO_2) fields were calculated for Ekibastuz coal with working moisture equal to 5, 7, 9 and 11%.It is shown that an increase in the moisture content of coal leads to a decrease in temperature both in the area of the burners and at the outlet from the combustion chamber. The concentrations of oxygen, water and carbon dioxide also decrease with decreasing working moisture along the entire height of the combustion chamber. In the area where the burners are located, with an increase in moisture, the amount of carbon monoxide *CO* formed decreases; however, above the active combustion zone, an increase in moisture leads to a less intense process of afterburning of carbon monoxide *CO* to carbon dioxide CO_2. The results of computational experiments on the combustion of pulverized coal in the combustion chamber of operating power object (boiler PK-39 at Aksu TPP) are compared with experimental data obtained in the course of field experiments carried out directly at the Aksu TPP.

Key words: heat and mass transfer processes, numerical simulation, temperature, concentration, moisture, combustion chamber, oxygen and carbon oxides, environmental protection

Introduction

In the near future, for the sustainable development of the country's thermal power industry, it is necessary to optimize the combustion processes of traditional energy fuel (Kazakh coal), develop and implement "clean" technologies for generating energy in order to protect the environment from harmful gas and dust emissions and ensure the efficiency of power plants. In this regard, studies of the processes of heat and mass transfer that take place in the combustion chambers of industrial boilers when burning coals of high ash content in them are **relevant** today [1-2].

For research of the heat and mass transfer processes occurring in the combustion chamber, that is, directly in the field of physicochemical transformations of fuel and oxidizer molecules into combustion products, due to the difficulty and high cost of carrying out field experiments, as well as due to the lack of accuracy and complexity of constructing fire models, the most **relevant**, and in most cases the optimal are the methods of computer simulation and carrying out computational experiments [3-9] on their basis. Carrying out of computing experiments by means of computer technics now allows to predict with high accuracy the behavior of physicochemical systems that are complex for analytical calculation.

As it is known, coal is supplied to TPPs of various compositions, which sufficiently affects the characteristics of heat and mass transfer. Therefore, the moisture content of Ekibastuz coal, burned in the furnaces of boilers, fluctuates within 5-11%. Variation of percentage of a moisture in fuel leads to variation of thermal and concentration characteristics of the heat and mass transfer process. In this regard, the characteristics of the heat and mass transfer processes (temperature and concentration fields) in the combustion chamber, taking into account the different values of moisture content in the fuel, were investigated below [10-13].

Physical statement of a problem

The combustion chamber of the PK-39 boiler of Aksu TPP, which burns the high-ash Ekibastuz coal, was chosen as a research object for carrying out of computing experiments on research of influence of fuel moisture on the characteristics of heat and mass transfer. Twelve vortex pulverized coal burners located on two tiers of the combustion chamber. Each burner contains one channel with an air mixture and two channels of secondary air.

Figure 1 shows the general scheme of the combustion chamber of the PK-39 boiler at Aksu TPP and its breakdown into elementary volumes for numerical modeling. We have obtained 98.820 elementary volumes with a computational grid measuring 27x61x60. Ekibastuz KSN coal of the “Vostochny” open pit was used as fuel. Table 1 shows the percentage composition of the test coal used in the calculations.

Table 1 – Working composition of Ekibastuz coal with recalculation for different moisture content

W^P	A^P	C^P	H^P	O^P	N^P	S^P
5	41,78	41,98	2,86	6,74	0,82	0,82
7	40,9	41,1	2,8	6,6	0,8	0,8
9	40,02	40,22	2,74	6,46	0,78	0,78
11	39,14	39,33	2,68	6,32	0,77	0,77

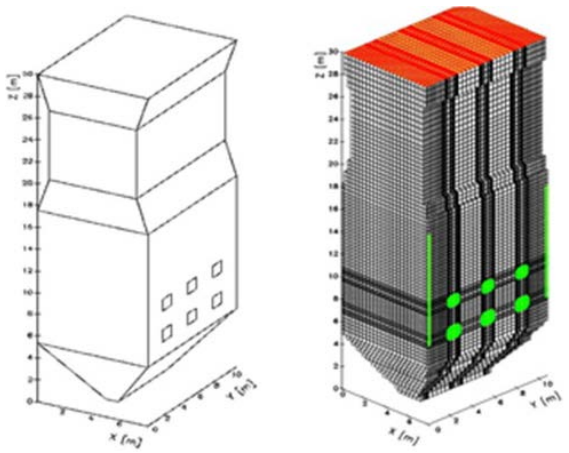

Figure 1 – General scheme of the combustion chamber of the PK-39 boiler at Aksu TPP and its breakdown into elementary volumes

Results

As a result of the performed numerical experiments, the fields of temperature and concentration of carbon oxides (*CO* and CO_2) were obtained throughout the entire combustion chamber of the PK-39 boiler at Aksu TPP.

Figure 2 presents the graph of the distribution of the average temperature values T in each section along the height of the combustion chamber when burning coal of different moisture content and comparison with the experimental data obtained in the course of field experiments carried out directly at the Aksu TPP.

Analysis of the figure shows that the greatest differences between the calculated and experimental data (Figure 2) are observed when a coal flame is ignited.

This can be explained by the unsustainable nature of the combustion process in this area and, accordingly, the difference between the real physical conditions of ignition of the pulverized coal and the mathematical model describing the process of burning fuel in this area. If the percentage of fuel moisture increases from 5% to 11%, the temperature in the area of burners decreases by an average of 300 °C. At the outlet of the combustion chamber, the differences in temperature values decrease and are no more than 35 °C.

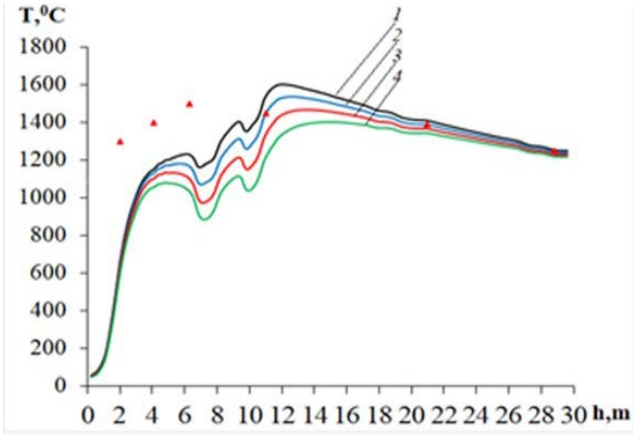

Figure 2 – Distribution of temperature *T* over the height of the combustion chamber when burning coal of different moisture content: 1 – 0%, 2 – 5%, 3 – 7%, 4 – 11%, ▲ – experiment [14-15]

Figure 3 shows the results of a 3D simulation of the combustion process of Ekibastuz coal in the form of temperature distribution in the section of the combustion chamber of the PK-39 boiler of the Aksu TPP, falling on the lower tier of burners. The temperature scale can be used to determine the temperature value at any point of this section. Analysis of the figure shows that with an increase in fuel moisture, the cross-sectional average temperature of the pulverized coal flame decreases, which was previously demonstrated in Figure 2.

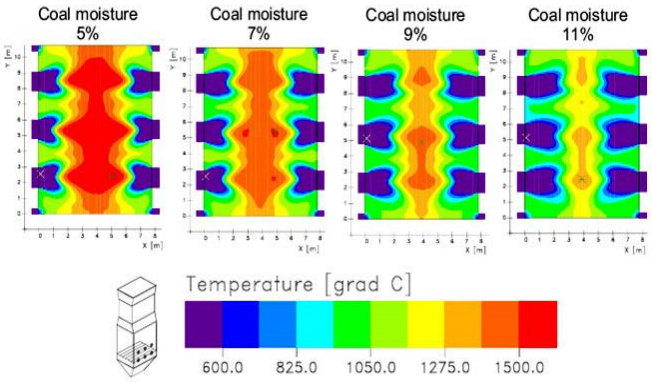

Figure 3 – Distribution of temperature *T* in the section of the lower tier of the burners of the PK-39 boiler during the combustion of Ekibastuz coal of different moisture content

Figure 4 shows the distribution of averages in each section of oxygen concentrations O_2 along the height of the combustion chamber of the PK-39 boiler at the Aksu TPP and comparison with the experimental data obtained directly at the Aksu TPP. It is shown that a decrease in moisture leads to a decrease in the concentration of the oxidant in the combustion chamber, which is probably associated with

a more complete combustion of coal and with a higher consumption of the oxidant (oxygen).

Maximums of O_2 concentration fall on the location of burners and suction, that is, where the air mixture and additional air are supplied. The O_2 concentration reaches its minimum values in the central region, where the pulverized coal flame is located and where the chemical reactions of combustion and oxidation are most intense. At the same time, with an increase in moisture, the oxygen concentration increases, and the minimum shifts to the outlet from the combustion chamber (Figure 4). It can be seen that for 5% moisture, the minimum oxygen concentration is about 0.01 kg/kg, while for 11% moisture it is about 0.06 kg/kg.

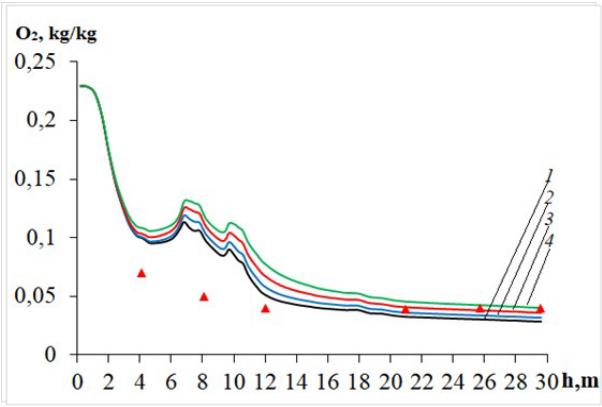

Figure 4 – Distribution of O_2 concentrations over the height of the combustion chamber when burning coal of different moisture content: 1 – 0%, 2 – 5%, 3 – 7%, 4 – 11%, ▲ – experiment [14-15]

Figure 5 shows a graph of the distribution of averages in each section of carbon monoxide *CO* concentrations. The analysis of the figure shows that the formation of the concentration of carbon monoxide CO occurs mainly in the main part of the flame, where its average temperature reaches its maximum values. Moreover, with a decrease in the moisture content in coal, the maximum CO concentration increases and shifts to the area of the burners.

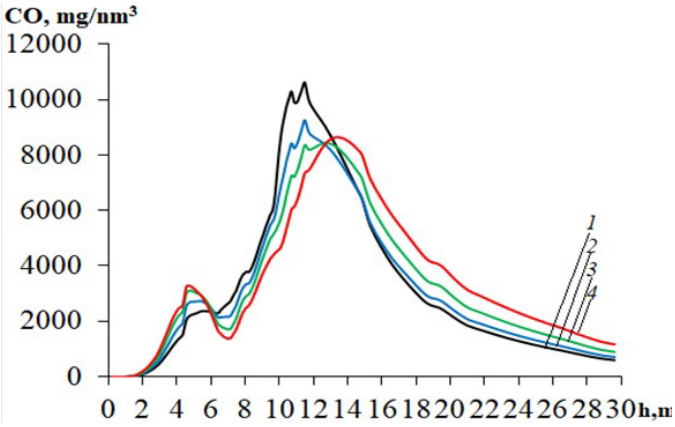

Figure 5 – Distribution of *CO* concentrations over the height of the combustion chamber when burning coal of different moisture content: 1 – 0%, 2 – 5%, 3 – 7%, 4 – 11%

Moving towards the outlet from the furnace, the concentration of carbon monoxide decreases and at the outlet the concentration values for W^P=5% – 614,40 mg/Nm^3; для W^P=7% – 724,52 mg/Nm^3; для W^P=9% – 907,38 mg/Nm^3; для W^P=11% – 1183,05 mg/Nm^3. Thus, an increase in the moisture content of the fuel leads to a decrease in the concentration of carbon monoxide *CO* in the area of active combustion, which coincides with the experimental data given in [14-15]. This can be explained by the fact that at low

temperatures the reaction of the formation of carbon dioxide from carbon of the fuel predominates; however, as the temperature rises, the reaction between coal and the formed carbon dioxide begins to prevail.

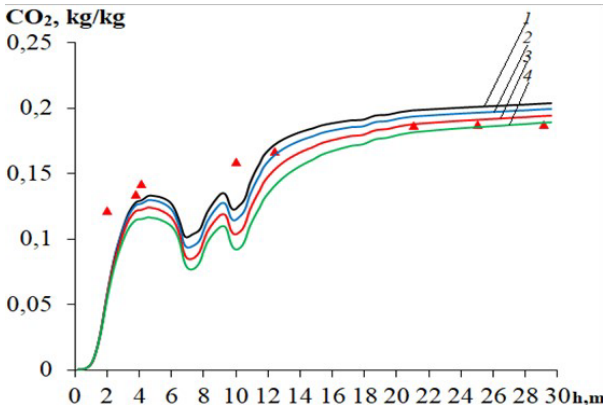

Figure 6 – Distribution of CO_2 concentrations over the height of the combustion chamber when burning coal of different moisture content: 1 – 0%, 2 – 5%, 3 – 7%, 4 – 11%, ▲ – experiment [14-15]

Figure 6 shows the distribution of averages in each section of values of concentration of carbon dioxide CO_2 along the height of the furnace space. It can be seen that an increase in moisture leads to a decrease in the concentration of carbon dioxide, which is associated with the temperature conditions of the process (for example, with an increase in temperature, the reaction of the formation of carbon monoxide *CO* prevails). In addition, this, in turn, creates worse conditions for the reaction associated with the afterburning of *CO* to CO_2.As a result, the value of the concentration of carbon dioxide CO_2 at the outlet of the furnace decreases with increasing moisture content of the fuel.

Here, in Figure 6, the results of an experiment carried out directly at the TPP are plotted [14-15]. We see that the greatest differences in the results of computational and natural experiments are observed in the area of ignition of the combustible mixture, which is associated with the instability of combustion and the difference between the simulated and experimental conditions for the ignition of the air mixture.

In the area of the lower tier burners, the average concentration of carbon dioxide CO2 is for a moisture content of W^P=5% – 0,10364 kg/kg; W^P=7% – 0,0945 kg/kg; W^P=9% – 0,08507 kg/kg; W^P=11% – 0,07707 kg/kg. At the outlet from the combustion chamber, these values increase to 0,2039 kg/kg; 0,19918 kg/kg; 0,19424 kg/kg; 0,18944 kg/kg respectively.

Conclusion

Based on the results of us study, the following conclusions can be drawn:

- It has been shown, that an increase in the moisture content of coal leads to a decrease in temperature both in the area of the burners and at the outlet from the combustion chamber. Oxygen and carbon dioxide concentrations also decrease with decreasing operating moisture along the entire height of the combustion chamber.
- In the area of burners, with increased moisture, the amount of carbon monoxide *CO* produced decreases, but, above the active combustion zone, the increase in moisture leads to a less intensive process of *CO* to CO_2.
- Comparison of the results of numerical modeling with the data of field experiments obtained directly at the operating power plant (TPP) showed good qualitative and good quantitative agreement. Concentrations of harmful substances (*CO*, CO_2) at the outlet from the combustion chamber do not exceed the MPC standards, which were established to control emissions from coal-fired TPPs.

The results obtained will be used to conduct research on further optimization of the combustion of high-ash coal in the furnaces of power plants and to reduce harmful dust and gas emissions into the environment.

Acknowledge: This work has been supported financially by the Ministry of Education and Science of the Republic of Kazakhstan No.AP09261161 and No.AP08857288.

А.С. Аскарова[1-2], С.Ә. Бөлегенова [1-2],
А.О. Нұғыманова[1], С.Ә. Бөлегенова[2], З.Х. Габитова[1]
[1]Әл-Фараби атындағы ҚазҰУ, Алматы, Қазақстан;
[2] Эксперименталдық және теориялық физиканың ғылыми-зерттеу институты,
Алматы, Қазақстан
E-mail: bolegenova.symbat@kaznu.kz

ЭНЕРГЕТИКАЛЫҚ ҚОНДЫРҒЫЛАРДЫҢ ЖАНУ КАМЕРАЛАРЫНДА ӘР ТҮРЛІ ЫЛҒАЛДЫЛЫҚТАҒЫ ҚАТТЫ ОТЫНДЫ ЖАҒУ КЕЗІНДЕГІ ЖЫЛУ-МАССА АЛМАСУ ПРОЦЕСТЕРІН САНДЫҚ МОДЕЛЬДЕУ

Аннотация. Бұл мақалада сандық әдістерді қолдана отырып, көмір ылғалдылығының жылу мен масса алмасу процесінің сипаттамаларына әсерін анықтау үшін зерттеулер жүргізілді. Зерттелетін нысан ретінде Екібастұз көмірінде жұмыс істейтін Ақсу электр станциясында (Ақсу қ., Қазақстан) орнатылған ПК-39 бу қазандығының жағу камерасы таңдалды.

Екібастұз көміріне арналған жұмыс ылғалдылығы 5, 7, 9 және 11% - ға тең температуралық (Т) және концентрациялық (O_2, CO, CO_2) алқаптар есептелді. Көмір ылғалдылығының жоғарылауы қыздырғыштардың орналасу аймағында да, жану камерасының шығысында да температураның төмендеуіне әкелетіні көрсетілген. Оттегі, су және көмірқышқыл газының концентрациясы жану кеңістігінің бүкіл биіктігі бойынша жұмыс ылғалының төмендеуімен азаяды. Ылғалдылықтың жоғарылауымен қыздырғыш құрылғылардың орналасуы аймағында пайда болған CO көміртегі тотығының мөлшері азаяды, алайда белсенді жану аймағынан жоғары ылғалдылықтың жоғарылауы CO көміртегі тотығының CO_2 көмірқышқыл газына дейін аз қарқынды жану процесіне әкеледі. Жұмыс істеп тұрған энергетикалық объектінің от жағу камерасында (Ақсу ЖЭС ПК-39 қазандығы) тозаң-көмір отынын жағу бойынша есептеу эксперименттерінің нәтижелері тікелей Ақсу ЖЭС-те жүргізілген заттай эксперименттер барысында алынған эксперименттік деректермен салыстырылды.

Түйін сөздер: жылу және масса алмасу процестері, сандық модельдеу, температура, концентрация, ылғалдылық, жану камерасы, оттегі және көміртегі оксидтері, қоршаған ортаны қорғау.

А.С. Аскарова[1-2], Болегенова С.А.[1-2],
А.О. Нұғыманова[1], С.А. Болегенова[2], З.Х. Габитова[1]
[1]Казахский национальный университет имени аль-Фараби, Алматы, Казахстан;
[2] Научно-исследовательский институт экспериментальной и теоретической физики,
Алматы, Казахстан
E-mail: bolegenova.symbat@kaznu.kz

ЧИСЛЕННОЕ МОДЕЛИРОВАНИЕ ПРОЦЕССОВ ТЕПЛОМАССОПЕРЕНОСА ПРИ ГОРЕНИИ ТВЕРДОГО ТОПЛИВА РАЗЛИЧНОЙ ВЛАЖНОСТИ В КАМЕРАХ СГОРАНИЯ ЭНЕРГЕТИЧЕСКИХ УСТАНОВОК

Аннотация. В статье с применением численных методов проведены исследования, позволяющие определить влияние влажности сжигаемого угля на характеристики процесса тепломассопереноса. В качестве исследуемого объекта была выбрана топочная камера парового котла ПК-39, установленного на Аксуской электростанции (г. Аксу, Казахстан), работающая на Экибастузском угле. Общая установленная мощность электростанции – 2450 МВт. На электростанции работают 8 энергоблоков (паровых котлов) ПК-39 номинальной мощностью 300 и 325 МВт. В топочной камере котла ПК-39 установлено 12 вихревых пылеугольных горелок, расположенных на двух ярусах. Каждая горелка содержит один канал с подаваемой аэросмесью и два канала вторичного воздуха.

Были рассчитаны температурные (T) и концентрационные (O_2, CO, CO_2) поля для

экибастузского угля с рабочей влажностью, равной 5, 7, 9 и 11%. Показано, что увеличение влажности угля приводит к уменьшению температуры как в области расположения горелок, так и на выходе из топочной камеры. Концентрации кислорода, воды и диоксида углерода также уменьшаются с уменьшением рабочей влаги по всей высоте топочного пространства. В области расположения горелочных устройств с увеличением влажности количество образуемого монооксида углерода *CO* снижается, однако выше зоны активного горения увеличение влажности приводит к менее интенсивному процессу догорания оксида углерода *CO* до диоксида углерода CO_2. Результаты вычислительных экспериментов по сжиганию пылеугольного топлива в топочной камере действующего энергетического объекта (котел ПК-39 Аксуской ТЭС) сравнены с экспериментальными данными, полученными в ходе натурных экспериментов, проведенных непосредственно на Аксуской ТЭС.

Ключевые слова: процессы тепломассопереноса, численное моделирование, температура, концентрация, влажность, камера сгорания, оксиды кислорода и углерода, защита окружающей среды

Information about authors:

Askarova Aliya - Doctor of Physical and Mathematical Sciences, Professor, Head of the Laboratory for Simulation of Heat and Mass Transfer, al-Farabi Kazakh National University. The author made a significant contribution to the concept and design of the research, data acquisition or their analysis and interpretation. The author approved the final version of the article before submitting it for publication, https://orcid.org/0000-0003-1797-1463

Bolegenova Saltanat – Doctor of Physics and Mathematics, Professor, Head of the Department of Thermophysics and Technical Physics, al-Farabi Kazakh National University. The author made a significant contribution to the concept and design of the research, data acquisition or their analysis and interpretation. The author approved the final version of the article before submitting it for publication. https://orcid.org/0000-0001-5001-7773

Nugymanova Aizhan – PhD student, Senior Lecturer, Department of Thermal Physics and Technical Physics, al-Farabi Kazakh National University. The author made a significant contribution to the concept and design of the research, data acquisition or their analysis and interpretation. https://orcid.org/0000-0003-0393-5672

Bolegenova Symbat – PhD, deputy dean for educational, methodical and educational work Al-Farabi Kazakh National University. The author has written the first version of the article or its critical review for important intellectual content.E-mail: Symbat.bolegenova@kaznu.kz, https://orcid.org/0000-0003-1061-6733

Gabitova Zarina – PhD, Senior Lecturer, Department of Thermal Physics and Technical Physics, al-Farabi Kazakh National University. The author made a significant contribution to the concept and design of the research, data acquisition or their analysis and interpretation, https://orcid.org/0000-0001-8412-0525

REFERENCES

[1] Askarova A, Bolegenova S, Maximov V, Bekmukhamet A, Gabitova Z, Beketayeva M (2014) Control harmful emissions concentration into the atmosphere of megacities of Kazakhstan Republic. International conference on Future Information Engineering, Beijing, Peoples China, 10:252-258. DOI: 10.1016/j.ieri.2014.09.085.

[2] Askarova AS, Bolegenova SA, Maximov VYu, Bekmukhamet A (2012) Mathematical simulation of pulverized coal in combustion chamber. Proceedings of 20th International Congress of Chemical and Process Engineering CHISA, 25-29 August 2012. Procedia Engineering, Prague, Czech Republic, 42:1150-1156. DOI:10.1016/j.proeng.2012.07.507.

[3] Muller H (1992) Numerische Berechnung dreidimensionaler turbulenter Strömungen in Dampferzeugern mit Wärmeübergang und chemischen Reaktionen am Beispiel des SNCR–Verfahrens und der Kohleverbrennung. Fortschritt–Berichte VDI–Verlag, 6(268):158. (in German).

[4] Muller H, Schiller A (1994) Prediction of combustion and pollutant formation in coal fired furnaces. Proceedings of 6th Int. Conference on Combustion and Heat Technics. Ungarn, 45-52.

[5] Magda A, Magda SI, Strelow M, Muller H, Leithner R (2011) CFD modelling of ash deposits in coal-fired power plants. Proceedings of International Conference on Heat Exchanger Fouling and Cleaning. Crete Island, Greece, 301-308.

[6] Muller M, Scheffknecht G, Lemp O, Leithner R, Strelow M, Epple B (2012) Prediction of slagging and fouling of furnaces and heat exchanger surfaces in boilers by simulation. VGB PowerTech, 92(11):44-49.

[7] Leithner R, Epple B etc (2012) Simulation von Kraftwerken und Feuerungen. Springer-Verlag Vienna, 810.

[8] Leithner R, etc, (2016) Computational modeling of heat and mass transfer processes in combustion chamber at power plant of Kazakhstan. Proceedings of 20th International Conference on Circuits, Systems, Communications and Computers (CSCC 2016) MATEC Web of Conferences 76(06001):5. DOI:10.1051/matecconf/20167606001.

[9] Vockrodt S, Müller H, Hoppe A, Leithner R (2002) Einsatz von CFD-Simulationen zur Optimierung von Braunkohlefeuerungen. Proceedings of 9th conference on boiler technology. Szczyrk, German, 565-569.

[10] Kurose R, Tsuji H, Makino H (2001) Effects of moisture in coal on pulverized coal combustion characteristics. Fuel, 80(10):1457-1465. DOI:10.1016/S0016-2361(01)00019-9

[11] Liang XY, Wang DM (2003) Effects of moisture on spontaneous combustion of coal. Journal of Liaoning Technical University, 22(4):472-474.

[12] Clemens AH, Matheson TW (1996) The role of moisture in the self-heating of low-rank coals. Fuel, 75:891–895.

[13] Arisoy A, Akgun F (1994) Modelling of spontaneous combustion of coal with moisture content included. Fuel, 73:281-286.

[14] Алияров Б.К. Освоение сжигания экибастузского угля на тепловых электростанциях. – Алматы: Гылым, 1996. – 272 с.

[15] Разработка и внедрение вихревых трехканальных горелок на котлах ПК–39–2 Ермаковской ГРЭС: отчет (заключительный) /КазНИИЭ: рук. Алияров Б.К.; испол. Устименко Б.П., Бухман М. – Алматы, 1991. – 59 с. – № ГР 01910010550. 01910010550.

МАЗМҰНЫ-СОДЕРЖАНИЕ-CONTENTS

Publication Ethics and Publication Malpractice
in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see **http://www.elsevier.com/publishingethics** and **http://www.elsevier.com/journal-authors/ethics**.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see **http://www.elsevier.com/postingpolicy**), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (**http://publicationethics.org/files/u2/New_Code.pdf**). To verify originality, your article may be checked by the Cross Check originality detection service **http://www.elsevier.com/editors/plagdetect**.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

(Правила оформления статьи для публикации в журнале смотреть на сайтах:

www:nauka-nanrk.kz

http://physics-mathematics.kz/index.php/en/archive

ISSN 2518-1726 (Online), ISSN 1991-346X (Print)

Редакторы: *М.С. Ахметова, Р.Ж. Мрзабаева, Д.С. Аленов*
Верстка на компьютере *В.С. Зикирбаева*

Подписано в печать 12.06.2021.
Формат 60x881/8. Бумага офсетная. Печать – ризограф.
11 п.л. Тираж 300. Заказ 3.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-18, 272-13-19