МРНТИ 29.27.51 https://doi.org/10.18321/cpc22(3)179-186

Modeling and experiments on plasma ignition of Ekibastuz coal in the form of dust

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ABSTRACT

Due to the low cost of coal and the fact that it is readily available in most parts of the world, coal is a convenient fuel source. Despite the inefficiency of the systems when it comes to converting heat energy into electricity, new technologies are necessary in order to improve their efficiency. In contrast to traditional methods of starting-up boilers and stabilizing combustion, plasma ignition and combustion stabilization (PICS) of pulverized coal flames offers an effective and sustainable alternative to the use of fuel oil or gas. This technology involves heating the air-coal mixture with electric arc plasma until the coal devolatilizes and the coke residue partially gasifies. Consequently, low-rank coal is converted into a highly reactive two-component fuel (HRTF) consisting of combustible gas and coke residue. For these processes in a plasma-coal burner (PCB) using Ekibastuz coal in the form of dust, a kinetic analysis was conducted using the PlasmaKinTherm program. Modeling the kinetics of PICS of pulverized fuel allowed changes in temperature, velocity, and concentration to be determined along the length of a PCB. The composition, degree of carbon gasification, and temperature of a stable coal-dust flame were determined using plasma ignition of solid fuel. Based on the comparison between experimental and calculated data, it was found that the results were satisfactory.

Keywords: low-rank coal, plasma ignition, combustion stabilization, high reactive two-component fuel, plasma-coal burner, kinetic modeling, experiment

1. Introduction

Chemical changes, pressure, and heat compacted decayed plant material into a solid form, which is coal. Coal can be converted into electricity using a variety of conversion methods [1]. Coal has been the main source of electricity generation worldwide for the last three decades. There are 2,435 coal-fired power plants operating in the world as of July 2023, with China home to nearly half of all coal-fired power plants [2, 3].

Coal is one of the most dense energy sources available, producing as much electricity as 1,927 kilowatt-hours per metric ton. Clean coal involves washing the coal before it is burned and removing pollutants such as sulfur dioxide from its emissions. New ‘clean coal’ technologies are being developed to overcome the harm caused by coal consumption, and allow coal use to remain economically competitive despite the high cost of achieving low emissions, and eventually ‘near-zero’ emissions [4, 5].

Kazakhstan has considerable coal reserves, but 90% of the coal balance at thermal power plants is high-ash Ekibastuz coal, which has a high moisture content and increases transportation costs, CO_2 emissions, and spontaneous combustion as a result of storage.

Low-rank coal presents a number of challenges when burned in traditional boilers and pulverized coal combustion systems. New technologies are being developed to ensure efficient coal combustion and environmental protection [6, 7]. Currently, nature security and energy conservation require the selection of the most successful technological and scientific achievements [8-10].

Pulverized coal combustion technologies using plasma guns can accelerate coal devolatilization and ignition within a short period of time, resulting in minimal environmental impact [11]. One of these

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Дата поступления: 18 июня 2024 г.

technologies is the PCB (plasma-coal burner), which uses plasma to ignite and stabilize the flame on pulverized coal. This technology utilizes a process of thermochemical fuel preparation for combustion, known as PICS (Plasma ignition and combustion stabilization) [12].

2. Materials and methods

2.1. Materials

In this study, PICS was evaluated on HRTF production for low-rank Ekibastuz steam coal at temperatures between 300 and 2000 K and at a pressure of 0.101 MPa. There were three different concentrations of coal dust and air investigated, and the optimal ratios were 0.6 kg/kg (1000 kg coal per 1667 kg air), 0.7 kg/kg (1000 kg coal per 1429 kg air), and 0.8 kg/kg (1000 kg coal per 1250 kg air). Ekibastuz coal contains 40% ash, 24% volatile yield, 5.8% moisture, and 16,700 kJ/kg of calorific value. There is a softening temperature of 1523 K for ash.

An analysis of coal dust by sieve indicates that coal dust has a fractional composition. According to the analysis, the average coal particle size is 60 microns [12-14].

2.2. Methods

2.2.1. Kinetic methodology

Thermodynamic models can estimate HRTF composition and carbon gasification based on the temperature of the PICS process [15]. Because it does not take into account important parameters such as the process time and the time required for the reagents to move through the PCB, it does not provide a comprehensive understanding of the thermal and dynamic processes that occur when two-phase reacting flows interact with plasma sources. PICS cannot be implemented without knowing the PCB configuration and dimensions. A kinetic model of the PICS process was generated using PlasmaKinTherm for this purpose [13].

2.2.2. Experiment

As shown in Fig. 1, PICS experiments were conducted using a direct flow PCB. There is a pipe installed within the cylindrical section of the PICS chamber (8). At the entrance to the chamber, there is a plasma torch (7). In the PCB channel, coal dust from the hopper (3) is mixed with air from the centrifugal fan (1), at a rate of 15 meters per second, in order to create a mixture of air and coal dust. The mixture of air and coal enters the plasma torch (7) where it meets the plasma jet created by the nozzle, which is the anode. Plasma jets are formed by blowing plasma-forming gases between electrodes, which are then heated. In the vicinity of the anode cut, the plasma jet reaches a temperature of 5000 K [13]. During the experiment, a direct-flow PCB with a diameter of 0.15 meters and a length of 3 m was examined. A plasma torch with a nominal electrical output of 100 kW was used to conduct the experiments on low-rank Ekibastuz coal. Coal dust was sieved and the fractional content was determined. In this experiment, coal and air were consumed at rates of 1000 kg/h and 1430 kg/h respectively. The air-coal mixture was heated to a temperature of 300 K. It was found that the plasma torch provided 80 kW of power at 85 percent efficiency, resulting in the release of 68 kW of power. During the experiment, the direct current plasma torch's power was determined by measuring the current (I) and voltage (U) on the arc (P=U*I). A water-cooled cathode and anode were calorimetered in order to determine the efficiency of the plasma torch [12].

3. Results and discussion

The concentration of coal dust in the aeromixture was investigated in relation to velocity, temperature, and composition of the PICS products. For coal dust concentrations in the aeromixture of 0.6, 0.7, and 0.8 kg/kg, ignition and combustion processes were calculated. A summary of the results can be found in Fig. 2-4. According to the figures, the abscissa axis X represents the distance along the PCB axis.

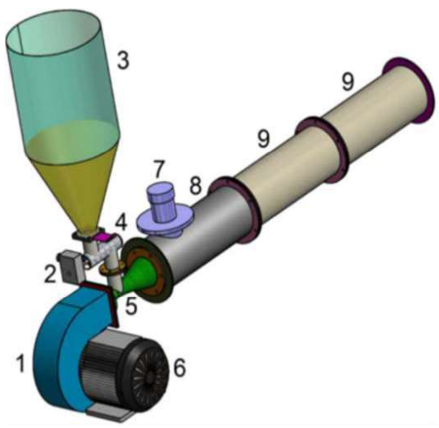
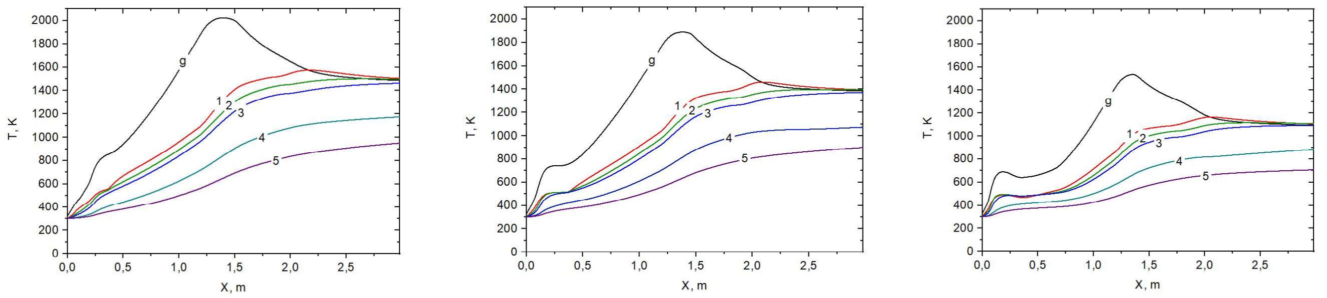


Fig. 1. Scheme of plasma-coal burner: 1 – air supply centrifugal fan; 2 – drive motor for auger feeder; 3 – hopper for coal dust; 4 – batcher for coal dust; 5 – confuser-diffuser nozzle; 6 – drive motor for fan; 7 – plasma torch; 8 – pipe-lined section for the plasma torch; 9 – PICS chamber lined section.



(a) (b) (c)

Fig. 3. Changes in the velocity of coal fractions and the gas phase at coal dust concentrations in the air mixture increase μ=0.6 (a), 0.7 (b) and 0.8 (c) along the length of the PCB: 1–5 – size fractions of coal particles, g – gas.

From Fig. 2 (a), it can be seen that a maximum gas temperature of 1751 °C is sufficient to heat and ignite the coal particles within the PCB at μ=0.6 kg/kg. There is an increase in the temperature of the gas and coal particles as the length of the PCB increases. Approximately 1.4 m in length, the gas temperature passes through a maximum (T_g = 1751 °C), while the particle temperatures do not reach a maximum along the entire channel length (X = 3 m), except at a length of 2.18 m (1301 °C), where the maximum temperature of the smallest fraction of 10 microns is reached. It was observed that the gas temperature (1214 °C) at the burner outlet is significantly lower than the coal temperatures of 10 microns (1230 °C) and 20 microns (1225 °C), and that the difference between the temperature of the gas and particles at the PCB outlet is significant, increasing as coal fractions 3 to 5 increase in size: 1190 °C, 900 °C, and 677 °C, respectively. When larger coal particles are heated, they are heated more slowly than small coal particles, which results in a reduced amount of heat being released due to the oxidation process of carbon. It is important to note that the temperature of fraction 1 at the outlet of the PCB is 16 °C higher than that of the gas, which is associated with the oxidation of carbon on the particle surface.

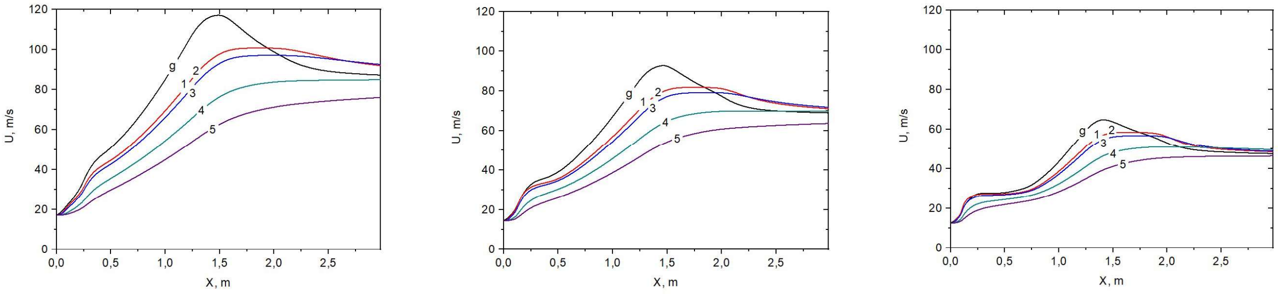
The thermal equilibrium of coal particles and gas on the length of the PCB (3 m) at a coal dust concentration of 0.6 kg/kg was observed with sizes of 10 and 30 μm (curves g, 1, 2, respectively) is already established at the exit from the PCB. As described previously, the velocity curves are qualitatively similar when coal dust concentrations are 0.7 kg/kg and 0.8 kg/kg (Fig. 2 (b) and 2 (c)).

The coal particles and gas accelerate along the PCB length from 17.1 m/s to their maximum velocities when there is a concentration of 0.6 kg/kg of coal dust in the air mixture, as shown in Fig. 3 (a). At a channel length of 1.5 m, it provides a peak gas velocity of 117.2 m/s. A decrease in speed occurs at the PCB outlet, where it decreases to 87.3 m/s. It should be noted that, with the exception of fraction 1, there is no extreme point in the velocity curves of coal particles accelerated by gas over the PCB length considered. A PCB length of 1.86 meters results in a maximum velocity of 100.9 m/s for coal particles in fraction 1. As for the coal particles of the other fractions, they had maximum velocities at the PCB outlet of 97.2, 97.2, 85.0, and 76.2 m/s, respectively (curves 2–5). Regardless of fraction size, PCB's coal particles and gas velocities are much higher than existing pulverized coal burners' air mixture velocities (normally 20–30 m/s).

It is important to note that dynamic equilibrium between coal particles and gas is not achieved over the measured PCB length (3 m) at 0.6 kg/kg coal dust concentration, despite the tendency for gas and particle velocity velocities to converge. It appears that dynamic equilibrium is observed at the outlet of the PCB at 0.7 and 0.8 kg/kg coal dust concentrations (Fig. 3 (b) and 3 (c)), for gas and fractions of sizes between 10 and 100 μm (curves 6, 1, 2, 3 and 4).

Based on different coal dust concentrations in the air mixture, Fig. 4 displays the gas phase compositions along the length of the PCB. Carbon dioxide (CO_2) and water vapor (H_2O) concentrations within the PCB are not greater than 14%, whereas oxygen (O_2) and nitrogen (N_2) concentrations are similar to those in the original air.

There are small extremes in concentration curves at the beginning of the channel (0.2–0.5 m): 0.1% for hydrogen and 0.64% for carbon dioxide. Similarly, nitrogen monoxide (NO) and atomic oxygen (O) concentrations are extreme in this area. There are small extremes in concentration curves at the beginning of the channel (0.2–0.5 m): 0.1% for hydrogen and 0.64% for carbon dioxide. Similarly, nitrogen monoxide (NO) and atomic oxygen (O)



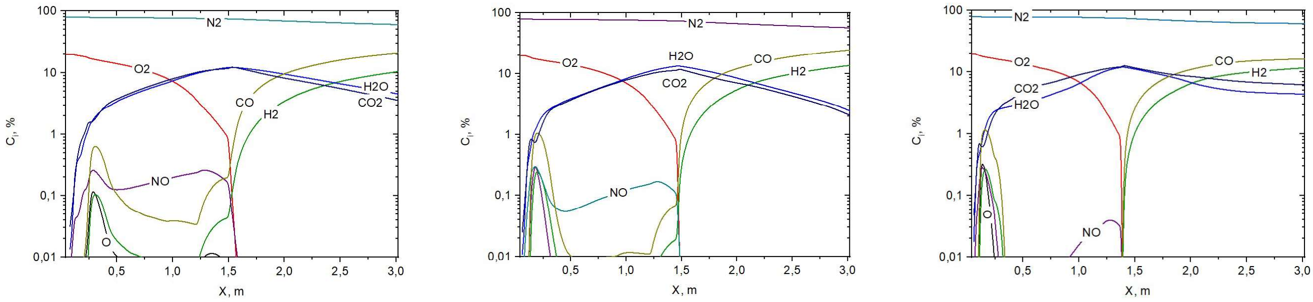
(a) (b) (c)

Fig. 3. Changes in the velocity of coal fractions and the gas phase at coal dust concentrations in the air mixture increase μ=0.6 (a), 0.7 (b) and 0.8 (c) along the length of the PCB: 1–5 – size fractions of coal particles, g – gas.

concentrations are extreme in this area. Arrhenius' equation (6) describes the release of coal volatiles, while the laws of chemical thermodynamics describe the oxidation of coal volatiles in the gas phase. As a result, the following are the extreme values of the specified components at the beginning of the experiment. There are small extremes in concentration curves at the beginning of the channel (0.2–0.5 m): 0.1% for hydrogen and 0.64% for carbon dioxide. Similarly, nitrogen monoxide (NO) and atomic oxygen (O) concentrations are extreme in this area. Arrhenius' equation (6) describes the release of coal volatiles, while the laws of chemical thermodynamics describe the oxidation of coal volatiles in the gas phase. As a result, the following are the extreme values of the specified components at the beginning of the experiment (Fig. 4 (a)). Due to the low temperature at the initial section of the channel (Fig. 1), the oxidation reactions of the released volatiles may not be completed. A rise in temperature in the channel causes a subsequent increase in combustible component concentrations, reaching a maximum of 31.3% at the PCB outlet.

Concentrations of PICS products behave qualitatively similarly at other concentrations of the aeromixture (Fig. 4(b) and 4(c)). There is a complex relationship between the concentrations of combustible components (CO and H_2) along the length of the PCB.

A range of objectives were pursued in this experiment, including the ignition of the air-coal mixture using plasma, the formation of a stable HRTF torch at the PCB outlet, determining the temperature and composition of the HRTF torch, and a comparison between the experimental results and the calculations. In the case of an 80 kW plasma torch, a stable air-plasma jet was obtained. There were 1.43 and 1 t/h of air and coal dust consumed by PCB, or 0.7 kg/kg of Ekibastuz coal dust in the mixture of air and coal dust. As a result of these conditions, the HRTF torch was able to ignite and burn in open air. HRTF torches burn more efficiently in an organized secondary air supply than when they are ignited and burned in an open air environment. In order to determine the length of the HRTF torch, it is necessary to consider the length of the PCB, which is 3 m. The torch is estimated to be approximately 4–5 m in length. As shown in Table 4, the results of bench studies of PICS are compared with those of calculation-based studies. For comparison, the corresponding initial



(a) (b) (c)

Fig. 4. Changes in the composition of the gas phase along the length of the PCB as coal dust concentrations in the air mixture increase μ=0.6 (a), 0.7 (b) and 0.8 (c).

Table 1. Evaluation of the relationship between experimental and calculated PICS parameters for Ekibastuz coal

1	μ	T_{HRTF}	CO	H_2	CO_2	N_2	Method
2	0.7	1450	27.8	9.3	2.2	60.7	Experiment
3	0.6	1487	20.85	10.42	3.64	60.46	Calcualtion
4	0.7	1384	24.5	13.6	2.16	57.2	Calcualtion
5	0.8	1094	16.33	11.6	6.22	61.47	Calcualtion

data, comprised of coal consumption, plasma torch power, dust concentration in the air-coal mixture, and PCB geometric parameters, were used for computation and experiment. Observations indicate that the HRTF temperature (1455 K) showed a deviation that does not exceed more than 5% from the calculated temperature. In the gas phase, combustible substances ($CO + H_2$) concentration is 37.1%, which differs from the calculation value of 3%. In the experiment, H_2 concentration is 9.3%, while in the calculation it is 13.6%, resulting in a discrepancy of 46%. There was a change in the concentration of CO_2 and N_2 by 2.2% and 60.7%, respectively, whereas the calculated concentration of the components was 2.16 and 57.2%, respectively. In the case of CO_2, there is a 2% discrepancy between the computation and experiment, while in the case of N_2, there is a 6% discrepancy. In terms of the key characteristics of the PICS process, only 14% difference exists between computed and experimental values. In comparison with the experimental results (μ=0.7), the remaining concentrations 0.6 and 0.8 showed a 22 and 56% difference. Hence, PlasmaKinTherm proves its suitability for application in engineering calculations of PCBs, with the mathematical model itself capturing the fundamental principles of PICS (Table 1).

Based on the results of kinetic modeling of PICS processes, the optimal concentration of coal dust in the aeromixture was determined to be μ=0.7. This value of dust concentration in the aeromixture was selected using two criteria: achieving the maximum total concentration of combustible components in the gas phase at the minimum PICS temperature. As can be seen from Table 1, the maximum concentration of combustible components (38.1%) is achieved at a minimum process temperature of 1384 K and a coal dust concentration in the aeromixture of 0.7. At μ=0.6, the concentration of combustible components is 31.27% at a temperature of 1487 K, which is 103 degrees higher than at μ=0.7. A higher process temperature leads to increased specific energy consumption for PICS and increases the likelihood of slagging of the plasma-coal burner [14]. At μ=0.8, the concentration of combustible components is lower and amounts to 27.93% at a temperature of 1094 K. Thus, for the experiment, the concentration of dust in the aeromixture was chosen to be μ=0.7 kg/kg.

4. Conclusion

With the assistance of the PlasmaKinTherm program, the kinetic process of PICS in the PCB was simulated. Through this investigation, it was possible to identify variations in temperature, velocity, and concentration of HRTF components along the length of the PCB. Experimental studies of PICS processes were subsequently informed by these variations. A temperature of 1384 K is reached upon exit from the PCB, and the HRTF contains 38.1% synthesis gas. As a result, the HRTF ignites successfully.

In order to investigate the feasibility of using plasma to ignite low-rank Ekibastuz coal, experiments were conducted. A high-temperature torch was produced by the plasma-coal burner at its outlet. It was also determined that the composition of the HRTF torch was as important as its temperature.

There is a relatively small difference (14%) between the computed and experimental values for the main indicators of the PICS process under the same conditions, whereas other concentrations of 0.6 and 0.8 showed differences of 22 and 56%, respectively. These results demonstrate the suitability of PlasmaKinTherm for PCB engineering calculations, while the mathematical model itself reflects PICS fundamental principles.

There was an acceptable convergence between the computed and experimental data in this study. This makes PlasmaKinTherm a useful tool for PCB engineering computations.

Acknowledgments

This work was supported by the Ministry of Science and Higher Education of the Republic of Kazakhstan [Grants No. AP22687016 and No. BR24992915].

References

[1]. Coal Facts // Canada, Natural Resources. – 2017. – 6 October. https://natural-resources.canada.ca/our-natural-resources/minerals-mining/mining-data-statistics-and-analysis/minerals-metals-facts/coal-facts/20071.

[2]. Coal energy industry worldwide // Statista. – 2024. https://www.statista.com/topics/3255/coal-energy-industry-worldwide/#statisticChapter

[3]. Stanway D. China’s Energy-Security Push Drives up Fossil-Fuel Approvals, Greenpeace Research Shows // Reuters. – 2023. – 3 August. www.reuters.com/business/energy/chinas-energy-security-push-drives-up-fossil-fuel-approvals-research-2023-08-03/

[4]. What’s the Role of Coal Consumption in Energy Production? // Just Energy. – 2023. – 24 January. https://justenergy.com/blog/coal-consumption-in-energy/

[5]. ‘Clean Coal’ Technologies, Carbon Capture & Sequestration // World Nuclear Association. – 2021. – 16 November. https://world-nuclear.org/information-library/energy-and-the-environment/clean-coal-technologies

[6]. Rao Z., Zhao Y., Huang C., Duan C., He J. Recent developments in drying and dewatering for low rank coals // In Progress in Energy and Combustion Science. – 2015. –Vol. 46. – P. 1-11

[7]. Сулейменов К.А., Каспиев А.Г., Исмаилов А.Д. Экспериментальные установки лаборатории ‘чистые угольные технологии’ Назарбаев Университет // Nu.edu.kz. ЧУ Nazarbayev University Research and Innovation System; АО Самрук-Энерго. – 2020.

[8]. Bolegenova S., Askarova A., Ospanova S., Zhumagaliyeva S., Makanova A., Aldiyarova A., Nurmukhanova A., Idrissova G. Technology of reducing greenhouse gas emissions for decarbonization and decreasing anthropogenic pressure on the environment // Physical Sciences and Technology. – 2024. – Vol. 11(1-2).

[9]. Bolegenova S., Askarova A., Slavinskaya N., Ospanova S., Maxutkhanova A., Aldiyarova A., Yerbosynov D. Statistical modeling of spray formation, combustion, and evaporation of liquid fuel droplets // Physical Sciences and Technology. – 2022. – Vol. 9(3-4). – P. 69-82.

[10]. Bolegenova S., Askarova A., Ospanova S., Pilipenko N., Shortanbayeva Z., Aldiyarova A. Simulation of atomization and ignition of high-pressure jet stream // Recent Contributions to Physics. – 2023. – Vol. 86(3). – P. 67-76.

[11]. Shen T., Song M., Huang Y., Zhu R., Li Z., Yu Q., Lu P., Wang M. The effectiveness of a novel coal-igniting-fuel technology and application in a direct current burner // Fuel. – 2021. – P. 306.

[12]. Messerle V., Orynbasar M. Ecological efficiency of utilization solid fuel plasma technology // Combustion and Plasma Chemistry. – 2021. – Vol. 19(4). – P. 289-298.

[13]. Messerle V.E., Mossé A.L., Orynbasar M.N. Plasma Ignition of Solid Fuel: Mathematical Simulation and Experiment // J Eng Phys Thermophy. – 2024. – Vol. 97. – P. 116-125.

[14]. Мессерле В.Е., Устименко А.Б. Плазменное воспламенение и горение твердого топлива. (Научно-технические основы). – Saarbrucken, Germany: Palmarium Academic Publishing, 2012. – 404 с.

[15]. Messerle V., Lavrichshev O., Ustimenko A. Numerical and experimental studies of the plasma-thermal processing of ash and slag waste // Recent Contributions to Physics. – 2023. – Vol. 85(2). – P. 42-48.

References

[1]. Canada, Natural Resources, 6 Oct. (2017) Coal Facts. https://natural-resources.canada.ca/our-natural-resources/minerals-mining/mining-data-statistics-and-analysis/minerals-metals-facts/coal-facts/20071.

[2]. Statista (2024) Coal energy industry worldwide. https://www.statista.com/topics/3255/coal-energy-industry-worldwide/#statisticChapter

[3]. Reuters, 3 Aug. (2023) Stanway D, China’s Energy-Security Push Drives up Fossil-Fuel Approvals, Greenpeace Research Shows www.reuters.com/business/energy/chinas-energy-security-push-drives-up-fossil-fuel-approvals-research-2023-08-03/

[4]. Just Energy, 24 Jan. (2023) What’s the Role of Coal Consumption in Energy Production?. https://justenergy.com/blog/coal-consumption-in-energy/

[5]. World Nuclear Association, 16 Nov. (2021) ‘Clean Coal’ Technologies, Carbon Capture & Sequestration. https://world-nuclear.org/information-library/energy-and-the-environment/clean-coal-technologies

[6]. Rao Z, Zhao Y, Huang C, Duan C, He J (2015) In Progress in Energy and Combustion Science 46: 1-11. https://doi.org/10.1016/j.pecs.2014.09.001

[7]. Suleymenov KA, Kaspiev AG, Ismailov AD (2020) Nu.edu.kz. ЧУ Nazarbayev University Research and Innovation System; АО Samruk-Energo. http://nur.nu.edu.kz/handle/123456789/4957

[8]. Bolegenova S, Askarova A, Ospanova S, Zhumagaliyeva S, Makanova A, Aldiyarova A, Nurmukhanova A, Idrissova G (2024) Physical Sciences and Technology 11(1-2). https://doi.org/10.26577/phst2024v11i1a8

[9]. Bolegenova S, Askarova A, Slavinskaya N, Ospanova S, Maxutkhanova A, Aldiyarova

A, Yerbosynov D (2022) Physical Sciences and Technology 9(3-4): 69-82. https://doi.org/10.26577/phst.2022.v9.i2.09

[10]. Bolegenova S, Askarova A, Ospanova S , Pilipenko N, Shortanbayeva Z, Aldiyarova A (2023) Rec.Contr.Phys. 86(3): 67-76. https://doi.org/10.26577/RCPh.2023.v86.i3.08

[11]. Shen T, Song M, Huang Y, Zhu R, Li Z, Yu Q, Lu P, Wang M (2021) Fuel: 306. https://doi.org/10.1016/j.fuel.2021.121503

[12]. Messerle V, Orynbasar M (2021) Combustion and Plasma Chemistry 19(4): 289-298. https://doi.org/10.18321/cpc466

[13]. Messerle VE, Mossé AL, Orynbasar MN (2024) J Eng Phys Thermophy 97: 116-125. https://doi.org/10.1007/s10891-024-02874-6

[14]. Messerle VE, Ustimenko AB (2012) Plasma ignition and combustion of solid fuel. [Plazmennoe vosplamenenie i gorenie tverdogo topliva] Palmarium Academic Publishing, Saarbrucken, Germany. ISBN: 978-3-8473-9845-5

[15]. Messerle V, Lavrichshev O, Ustimenko A (2023) Rec.Contr.Phys 85(2): 42-48. https://doi.org/10.26577/RCPh.2023.v85.i2.07

Моделирование и эксперименты по плазменному воспламенению Экибастузского угля в виде пыли

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АННОТАЦИЯ

Благодаря низкой стоимости угля и его доступности в большинстве регионов мира уголь является удобным источником топлива. Несмотря на неэффективность систем при преобразовании тепловой энергии в электроэнергию, необходимы новые технологии для повышения их эффективности. В отличие от традиционных методов запуска котлов и стабилизации горения плазменное воспламенение и стабилизация горения (ПВСГ) пылеугольного пламени предлагает эффективную и устойчивую альтернативу использованию мазута или газа. Эта технология заключается в нагреве аэросмеси плазмой электрической дуги до тех пор, пока уголь не улетучится, а коксовый остаток частично не газифицируется. В результате низкосортный уголь преобразуется в высокореакционное двухкомпонентное топливо (ВРДТ), состоящее из горючего газа и коксового остатка. Для этих процессов в плазменно-угольной горелке (ПУГ) с использованием Экибастузского угля в виде пыли был проведен кинетический анализ с использованием программы PlasmaKinTherm. Моделирование кинетики ПВСГ пылевидного топлива позволило определить изменения температуры, скорости и концентрации по длине ПУГ. Состав, степень газификации углерода и температура устойчивого пылеугольного пламени были определены с использованием плазменного воспламенения твердого топлива. На основе сравнения экспериментальных и расчетных данных установлено, что результаты являются удовлетворительными.

Ключевые слова: низкосортный уголь, плазменное зажигание, стабилизация горения, высокореактивное двухкомпонентное топливо, плазменно-угольная горелка, кинетическое моделирование, эксперимент

Екібастұз көмірінің шаң түрінде плазмалық тұтануы бойынша модельдеу және тәжірибелер

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АННОТАЦИЯ

Көмірдің төмен құнына және оның әлемнің көптеген аймақтарында болуына байланысты көмір қолайлы отын көзі болып табылады. Жылу энергиясын электр энергиясына айналдыру жүйелерінің тиімсіздігіне қарамастан, олардың тиімділігін арттыру үшін жаңа технологиялар қажет. Дәстүрлі қазандықты іске қосу және жануды тұрақтандыру әдістерінен айырмашылығы, ұнтақталған көмір жалынының плазмалық тұтану және жануды тұрақтандыру (ПТЖТ) мазут немесе газды пайдаланудан тиімді және тұрақты баламасын ұсынады. Бұл технология ауа қоспасын электр доғалы плазмамен көмір буланып, кокс қалдығы ішінара газданғанша қыздырудан тұрады. Осының нәтижесінде төмен сұрыпты көмір жанғыш газ мен кокс қалдықтарынан тұратын жоғары реактивті екі компонентті отынға (ЖРЕО) айналады. Екібастұз көмірін шаң түрінде пайдаланатын плазмалық көмір оттығында (ПКО) осы процестер үшін PlasmaKinTherm бағдарламасы арқылы кинетикалық талдау жүргізілді. ПТЖТ ұнтақталған отынның кинетикасын модельдеу ПТЖТ ұзындығы бойынша температураның, жылдамдықтың және концентрацияның өзгеруін анықтауға мүмкіндік берді. Тұрақты ұнтақ көмір жалынының құрамы, газдану дәрежесі және температурасы қатты отынның плазмалық тұтануы арқылы анықталды. Эксперименттік және есептелген мәліметтерді салыстыру негізінде нәтижелердің қанағаттанарлық екені анықталды.

Түйін сөздер: төмен разрядты көмір, плазмалық тұтану, жануды тұрақтандыру, жоғары реактивті екі компонентті отын, плазмалық көмір оттығы, кинетикалық модельдеу, тәжірибе