Plasma ignition of dust-coal flame

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ABSTRACT

One of the promising power engineering technologies is the plasma thermochemical preparation of pulverized coal to burning using plasma-fuel systems (PFS). This technology allows increasing the efficiency of fuel use and environmental indicators of thermal power plants, as well as eliminating the use of fuel oil, traditionally used to start-up the boilers and stabilize the combustion of a pulverized coal flame. This paper presents the results of numerical experiments on ignition of pulverized coal in PFS. PFS is designed for fuel oil-free start-up of the boilers and stabilization of pulverized coal flame, and represents a pulverized coal burner equipped with plasma torch. Via PlasmaKinTherm software which combines kinetic and thermodynamic methods of calculating the processes of motion, heating, thermochemical transformations and fuel mixture ignition in the volume of PFS, impact of the power of the plasma torch and ash content of coal onto efficiency of fuel mixture ignition have been determined. Also one of the main regime parameters of PFS providing ignition of the fuel is concentration of coal dust in the fuel mixture which can vary within a wide range. Therefore, conditions for fuel mixture ignition in PFS have been investigated, depending on the concentration of coal in the fuel mixture in the range from 0.4 to 1.8 kg of coal per 1 kg of air. Calculations were performed for cylindrical PFS of 0.2 m diameter and 2 m of length at fixed consumption of coal (1000 kg/h) and the plasma torch power (60 kW) for three values of coal ash content (20, 40 and 70%). The basic regularities of the process of plasma thermochemical preparation of fuel for burning were revealed.

Keywords: coal, fuel mixture, plasma, ignition, numerical experiment.

Introduction

At present, around 41% of electrical and thermal energy in the world is produced at coal-fired thermal power plants (TPP) [1]. By 2035 the share of solid fuels in power generation will be 28% [2]. Such a high share of the use of solid fuels in the energy sector requires the development of energy-efficient and environmentally friendly technologies.

There are new technologies for processing of organic materials, including local fuels and energy resources, for example plasma-assisted fuel processing technology [3–5]. One of the promising technologies is the plasma thermochemical preparation of pulverized coal to burning (PTPCB) [6-8] using plasma-fuel systems (PFS), the most common scheme of which is shown in Fig. 1. PTPCB technology allows increasing the efficiency of fuel use and environmental indicators of TPP, as well as complete eliminating the use of fuel oil, traditionally used to start-up the boilers and stabilize the combustion of a pulverized coal flame. However, carrying out full-scale tests of PFS, which are complex heat and electrotechnical systems, is characterized by high cost and labor costs, despite their external simplicity. The technology of PTPCB consists in heating the fuel mixture (coal dust + air) by electric arc plasma to a temperature of devolatilization and partial gasification of coke. Thus, a highly reactive two-component fuel (combustible gas + coke residue) of the specified composition is obtained from the original coal in the PFS. When it is mixed with air in the furnace of the boiler, the two-component fuel ignites and burns steadily without the additional highly reactive fuel (fuel oi or gas) traditionally used for starting-up the boilers and to stabilize the combustion of the pulverized-coal flame.

In contrast to the known studies of plasma ignition of coals in the combustion chamber [9, 10] and fuel-fired preparation of solid fuel to burning [10–12], PTPCB is conducted in the volume of PFS when plasma flame, having temperature of 5000-6000 °C, effects on air-

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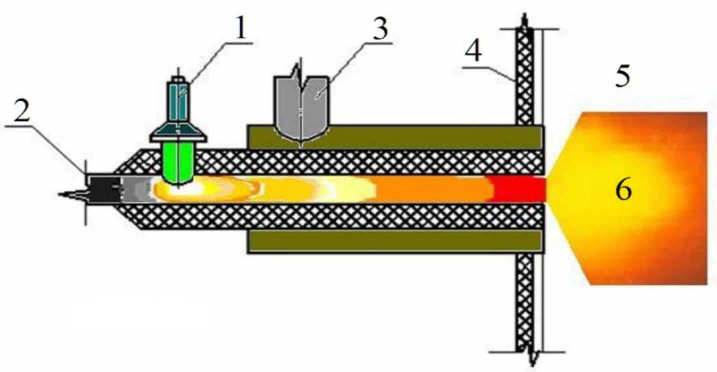

Fig. 1. Scheme of the direct-flow PFS: 1 – plasma torch, 2 – fuel mixture, 3 – secondary air 4 – wall of the boiler furnace, 5 – furnace of the boiler, 6 – flame of highly reactive two-component fuel.

fuel mixture directly [13, 14]. Application of plasma allows accelerating processes of the thermochemical transformation of solid fuel and oxidizer significantly. This paper is devoted to solving the urgent problem of numerical modeling PTPCB processes for the selection of optimal regime parameters of the PFS. The application of physical and mathematical models of heat-mass transfer processes and thermochemical transformations of fuel and oxidant in the PFS and the computer program that implements them is necessary for the design of the PFS.

There are a number of mathematical models, which, along with the experimental results can be used to characterize the processes of ignition and combustion of fuel [15, 16]. All of them are characterized by an extremely simplified model of the interaction of the flow of cold fuel mixture (T = 20-30 °C) with plasma flame. Offered in a number of studies mathematical models result in qualitatively and quantitatively reliable results through the appropriate choice of process parameters, but they are too time-consuming to carry out parametric numerical analysis required when designing specific firing installations.

To investigate numerically operation of direct-flow PFS the program PlasmaKinTherm is used [17]. It was developed based on computer programs Plasma-Coal and TERRA [15, 16]. The program combines the kinetics of release of volatile and carbon oxidation of coke residue with a thermodynamic approach to the calculation of plasma thermochemical conversions of the products of primary destruction of coal in the gas phase. This model considers a two-phase (coal particles and air) chemically reacted stream propagating in a channel with an internal heat source (generally a heat source of any kind, for example, torch of a plasma torch, electric arc, torch of a microwave plasma torch) or without. Uniformly mixed particles and gas flow into PFS, which is a cylindrical plug flow channel with a plasma torch. The gas is heated by the plasma heat source and heats the particles, as soon as they reach a temperature of devolatilization volatiles begin to evolve to the gas phase in accordance with the kinetic mechanism of the process [15]. The model is based on the assumption of quasi-stationarity and one-dimensionality of the process, the particles of coal are considered to be isothermal, and ash (mineral mass) is an inert component. It is also assumed that the particles do not interact with each other. Interaction of pulverized coal mixture with plasma is considered as heating of pulverized coal using flow of hot gas. Composition of coal in the model is represented by its organic and mineral matters. Organic matter of coal is given by the set of volatiles (CH_4, C_6H_6, CO, H_2, H_2O, CO_2) and carbon. The process of devolatilization is limited by the kinetics of the heating of coal particles. The evolved into the gas phase volatiles mix and react with plasma torch. Model of local thermodynamic equilibrium, which is implemented with the help of TERRA software package [16], is used to calculate the reactions in the gas phase. Such an approach allowed combining the kinetics of the release of volatile and oxidation of carbon of coke residue with the thermodynamic method of calculation of plasma thermochemical transformations of the coal destruction primary products in the gas phase.

To use the PlasmaKinTherm program in the engineering calculations of the PFS, the program was verified [17–22]. The verification of the PlasmaKinTherm program was carried out during realization of thermochemical preparation of fuel for combustion in the laboratory and with implementation on industrial boilers. For comparison of the calculated and experimental data, coals of various degrees of metamorphism (stone, brown and anthracite), humidity and ash content were used; the power of the plasma torch and the concentration of dust in the fuel mixture were varied. As a result of tests and during operation of plasma-fuel systems, results were obtained that were in good agreement with the calculated ones. Thus, the discrepancy between the calculated and experimental values of the flame temperature did not exceed 20%, the speeds at the exit from the PFS 15%, and the concentrations of PTPCB products: for CO – 10%, H_2 –12% and for CO_2 – 15%. Given the extreme complexity of plasma two-phase PTPCB processes in multicomponent heterogeneous systems, such a discrepancy between the calculation and the experiment is considered satisfactory, and the mathematical model itself adequately reflects the basic patterns of PTPCB.

Numerical Experiment

With the help of the PlasmaKinTherm program a number of calculations were carried out, the purpose of which was to study the process of plasma ignition of fuel in PFS, including investigation of the influence of the plasma torch power and concentration of coal dust in the air-fuel mixture on the temperature and composition of the PTPCB products. The criterion for stable combustion of the coal-gas mixture at the outlet from the thermochemical preparation channel is a high content of combustible gases (CO, H_2), above 15%, and heating of the gas at the outlet to the autoignition temperature (>800 °C) upon contact with air in the boiler furnace.

For numerical study of the process of plasma ignition of coal in a direct-flow cylindrical PFS (Fig. 1), a high-ash Ekibastuz coal was chosen. The consumption of coal dust was 1000 kg/h, the initial temperature of the air-fuel mixture was 27 °C, the internal diameter of the PFS was 0.2 m. Coal characteristics are given in Table 1 [6]. Ekibastuz coal with an ash content of 40%, a volatile yield of 24%, and a moisture content of 5.8% has a specific heat of combustion of 16740 kJ/kg. Average-equivalent diameter of the coal particles was 60 μm.

The effect of the power of the plasma torch on the temperature, velocity, and composition of the products of PTPCB was studied. Calculation of ignition and combustion of coal is carried out for the following values of the power of the plasma torch: 20, 40, 60, 80 and 100 kW.

It can be seen from Fig. 2 that ignition of coal particles in a PFS is ensured at the powers of a plasma torch of 40-100 kW (curves 2-5, respectively), whereas at a power of 20 kW the gas temperature practically does not increase along the length of the channel, remaining at 110 °C, clearly insufficient for fuel ignition. The effect of increasing the power of the plasma torch on the gas temperature (Fig. 2) is manifested in the displacement of the maximum of the temperatures to the plasma source located at the beginning of the PFS channel (X = 0 m).

As appears from Fig. 3 gas velocity curves are characterized by extrema at a power of the plasma torch from 40 to 100 kW (curves 2-5, respectively), whereas at the plasma torch power 20 kW gas velocity along the length of the channel practically is not increased,

Table 1
Characteristics of Ekibastuz coal, wt.%

Proximate Analysis		Ultimate Analysis			
Moisture (Total)	5.8	Hydrogen	3.05	SiO_2	23.09
Volatile Matter	24.0	Carbon	48.86	Al_2O_3	13.8
Fixed Carbon (By Difference)	30.2	Sulfur	0.73	Fe_2O_3	2.15
Ash	40.0	Nitrogen	0.8	CaO	0.34
Total	100.0	Oxygen	6.56	MgO	0.31
Higher Heating Value (Dry Mass Basis), kJ/kg	16740.0	Ash	40.0	K_2O	0.16
		Total	100.0	Na_2O	0.15
				Ash Total	40.0

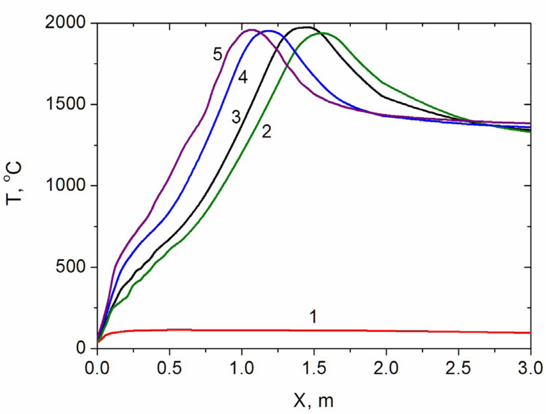

Fig. 2. Gas phase temperature dependence along the PFS length at variation of plasma torch power from 20 to 100 kW: 1 – 20 kW, 2 – 40, 3 – 60, 4 – 80, 5 – 100.

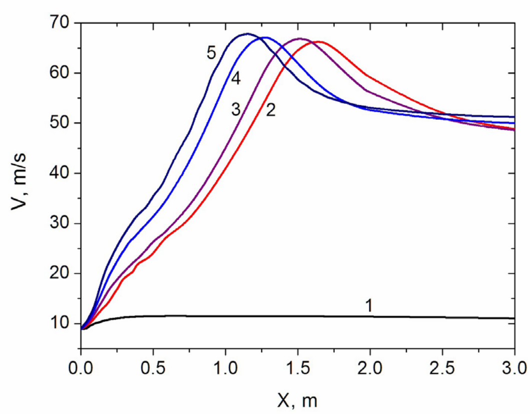

Fig. 3. Gas phase velocity dependence along the PFS length at variation of plasma torch power from 20 to 100 kW: 1 – 20 kW, 2 – 40, 3 – 60, 4 – 80, 5 – 100.

remaining 11 m/s, which is associated with low level of temperature at this power of the plasma torch (Fig. 2). Impact of increasing the power of the plasma torch on the gas velocity (Fig. 3) is in shift the velocity maximum to the plasma source, located at the beginning of the PFS channel (X = 0 m). Note that the maximal values of the gas velocity vary within a narrow range of 66.3–67.9 m/s. The behavior of velocity curves is similar to that of temperature curves for the same plasma torch power (Fig. 2).

Figure 4 shows the change in the composition of the gas phase along the PFS length at a power of the plasma torch of 60 kW. For the power of a plasma torch of 100 kW, the behavior of the concentrations of products of PTPCB is qualitatively similar. The obtained values of the concentrations of PTPCB products at the outlet of the PFS indicate the ignition of the air-fuel mixture. As the temperature in the PFS channel raises, the concentrations of combustible components increase, reaching 30.9 and 43.7% at the output from the PFS, for the powers of the plasma torch 60 and 100 kW, respectively. When the power of the plasma torch is 20 kW, the ignition of the fuel mixture is not initiated. The concentration of oxygen and nitrogen corresponds to their content in the initial air along the entire length of the PFS, and the concentrations of the formed carbon dioxide (CO_2) and water vapor (H_2O) do not exceed 0.3%.

The performed numerical investigation of the PFS parameters in relation to the power of the plasma torch made it possible to find changes in the temperatures and velocities of the gas and coal particles, as well as the concentrations of the products of PTPCB along the length of the PFS. Calculations have shown that in the power range of a plasma torch of 40-100 kW, a stable ignition of high ash coal is achieved at an air-fuel mixture rate of 1667 kg/h. This is confirmed by a high level of temperatures and concentrations of combustible components at the PFS exit. With an increase in the power of the plasma torch, the temperature and velocity maxima of the PTPCB products are shifted upstream (in the direction of the plasma torch). The maximum values of temperatures and velocities vary within a narrow range and are practically independent of the power of the plasma torch.

Steam coals are usually low-grade. They are characterized by a high humidity (up to 50%), ash (up to 80%), and low-volatile (less than 4%) [20, 21]. Ekibastuz coal ash content, which is the main power-generating fuel of Kazakhstan varies from 20 to 70% depending on the field [22]. The increase in ash content entails a corresponding decrease in the specific heat of combustion of coal. Therefore, it was investigated the effect of the ash content to the process of plasma thermochemical preparation of fuel in the PFS. In the calculations the plasma torch power is assumed to be equal to 60 kW.

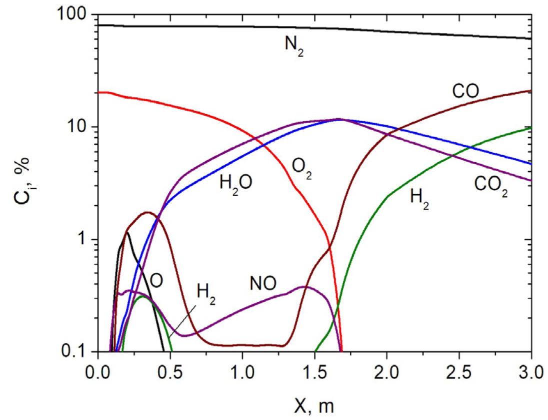

Fig. 4. Change of the gas phase composition over the PFS length at plasma torch power of 60 kW.

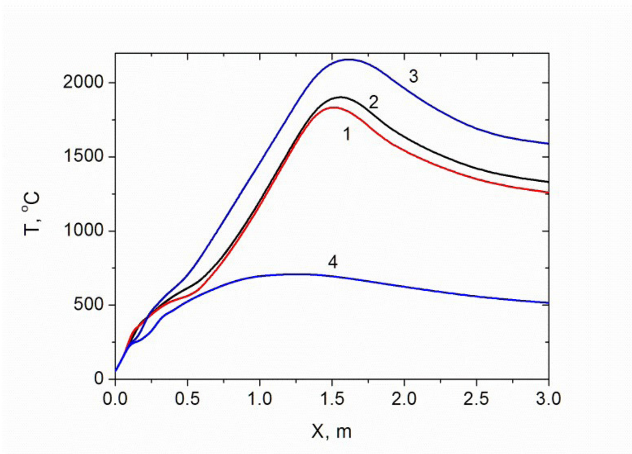

Fig. 5. Variation of temperature of the gas phase along the PFS path at coal ash content of 20 to 70%: 1 – 20%, 2 – 40, 3 – 60, 4 – 70.

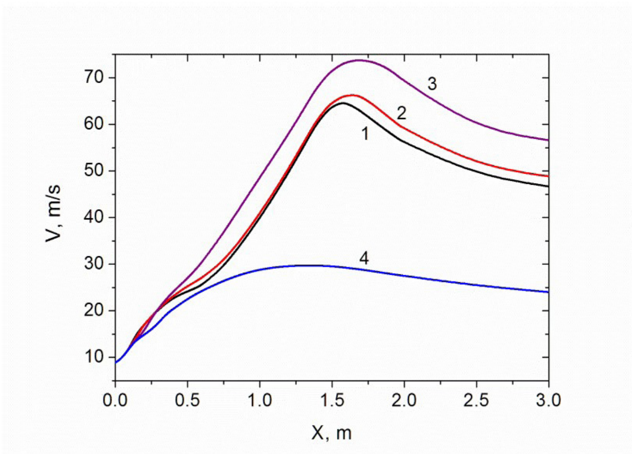

Fig. 5. Variation of velocity (b) of the gas phase along the PFS path at coal ash content of 20 to 70%: 1 – 20%, 2 – 40, 3 – 60, 4 – 70

Figures 5 and 6 display variations of temperature and velocity of the PTPCB gas phase products along the PFS. As can be seen from Fig. 5 temperature of the gas phase increases along the PFS length reaching a maximum in the central section of PFS (1.5-1.7 m). The maximum temperature is 2180, 1935 and 1845 ºC for the ash content of 60, 40 and 20%, respectively.

When the coal ash content of 70% the gas temperature reaches 710 °C that indicates a lack of the combustion process evolution. At the exit of PFS gas temperatures for the ash content of 20, 40 and 60% are relatively high (1260, 1332 and 1589 °C, respectively) for intensive self-ignition of PTPCB products (Table 2) when mixed with secondary air in the furnace of the boiler. Calculations revealed unobvious fact of exceeding the temperature of the gas phase for coal with high ash content. This is associated with a fixed concentration of pulverized coal in the fuel mixture in the calculation of all variants, and leads to an excess of oxygen at high ash content and a lack of oxygen at low ash content. With regard to the calculation of the process for ash content of 70%, the insufficient development of the process is due to low content of combustible components in the high-ash coal.

Velocity of the gas phase (Fig. 6) varies along the PFS length similar to temperature. The gas velocity increases along the PFS length, reaching a maximum at the central section of the PFS (1.5-1.7 m). The output (3.0 m) velocity of the gas amounts to significant quantities: 47, 49 and 57 m/s, for the ash content 20, 40 and 60%, respectively. Note that the exit velocity of primary air in conventional pulverized coal burner is not more than 30 m/s.

Table 2 presents the gas phase components concentrations, temperature and the carbon conversion degree at the output of the PFS. In the table are indicated: T_f is the flame temperature, C_i is concentration of gaseous components and XC is the degree of carbon conversion. X_C is determined from the carbon content of the solid gasification products calculated in accordance with the following equation:

$$X_C = (C_{in}\text{-}C_{fin})/C_{in} \cdot 100\%,$$

where C_{in} is the initial amount of carbon in the coal, and C_{fin} is the final (at current temperature of the process) amount of carbon in the solid residue. The table shows that the concentration of combustible components (H_2 and CO) is reduced with increasing ash content at almost complete lack of oxygen. The concentration of oxidants (CO_2 and H_2O) increases, indicating that sufficient development of the process of PTPCB. When the ash content 70% combustible components are not formed at significant concentrations of oxygen (13.27%) and nitrogen (79.83%) in the gas phase. The temperature of the gaseous products at the PFS outlet increases with ash content that is a consequence of heat emission due to the exothermic reactions of oxidation of carbon to CO_2. The degree of carbon conversion also increases with the coal ash content, which is associated with increasing temperature and decreasing the initial carbon concentration.

The study of the influence of the concentration of coal dust in the air-fuel mixture on the temperature and composition of products of PTPCB is necessary to identify general patterns of changes in the main parameters of the process of PTPCB and the selection of the optimal operating mode of the PFS.

The calculations were carried out for the following concentrations μ (kg/kg air): 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6 and 1.8. The moisture content of the coal was 5%. The diameter of the cylindrical channel of the PFS, the power of the plasma torch and the consumption of coal dust remained unchanged - 0.2 m, 60 kW and 1000 kg/h, respectively. Calculations were performed for three ash content of coal 20, 40 and 70%.

Table 3 presents the results of calculations of the influence of the concentration of coal dust in the fuel mixture on the main parameters of the PTPCB process (temperature and composition of the products of PTPCB at the output of the PFS). It follows from the table that the initiation of the PTPCB process for fixed values of ash content of coal is carried out at different dust concentrations in the air-fuel mixture. With increasing ash content of coal, ignition of the fuel mixture is ensured with a higher dust concentration in the fuel mixture. Thus, for coal ash content of 20%, the ignition of the air mixture is observed at a dust concentration of 0.6 kg/kg, for 40% at 0.8 kg/kg, and for coal ash content of 70% at 1.6 kg/kg, which follows from a noticeable excess of the total concentration of combustibles components

Table 2
Integral characteristics of the PTPCB products at the PFS exit

C_i, vol.%	Ash, %			
	20	40	60	70
H_2	15.31	9.82	4.29	0
CO	27.79	21.07	13.65	0
O_2	$1 \cdot 10^{-6}$	$1 \cdot 10^{-6}$	$5 \cdot 10^{-6}$	13.27
CO_2	0.62	3.31	6.55	3.78
H_2O	0.94	4.69	8.42	3.11
N_2	55.36	61.1	67.09	79.83
T_f, °C	1260	1332	1589	515
X_C, %	12.5	28.6	96.4	42.9

in the products of PTPCB more than 15% and their temperature more than 800 °C at the PFS exit. It should be noted that for all the analyzed coal ash the process of PTPCB proceeds in parallel with the combustion of fuel, as evidenced by the presence of carbon dioxide (CO_2) with a significant concentration at the output of the PFS.

Figure 7 shows the generalized dependence of the total concentration of CO and H_2 on the dust concentration for various ash content of coal. It can be seen that for the coal ash content of 20 and 40% with increasing dust concentration in the air-fuel mixture, the total concentration of syngas (CO+H_2) passes through a maximum at 1.0 and 1.3 kg/kg, respectively. With a coal ash content of 70%, the syngas concentration gradually increases with increasing dust concentration in the air mixture, reaching a maximum at a concentration of 1.8 kg/kg.

Figure 8 shows the temperature dependence of the gaseous products of PTPCB as a function of the dust concentration for the coal ash content of 20, 40 and 70%. It follows from the figure that for all the analyzed coal ash the temperature curves pass through a maximum at 0.6, 0.7 and 0.9 kg/kg, respectively. With a coal ash content of 70%, the syngas concentration gradually increases with increasing dust concentration in the air mixture, reaching a maximum at a concentration of 1.8 kg/kg.

It follows from the comparison of Figures 7 and 8 that the ignition of the air-fuel mixture (T > 800 °C) is ensured at dust concentrations of 0.6-1.0 kg/kg for coal ash content of 20%, 0.7-1.4 kg/kg for coal ash content of 40%, and 1.5-1.8 kg/kg for coal ash content of 70%.

A study of the influence of the concentration of coal dust in the air mixture on the temperature and composition of the products of plasma thermochemical preparation of fuel for combustion showed that a reliable ignition of the air mixture is ensured in the entire investigated range of ash content of coal (20-70%) at coal dust concentrations in the air-fuel mixture flow (0.5-1.8 kg/kg) used for operating pulverized coal-fired power plants.

Conclusions

1. PlasmaKinTherm program, which combines the kinetic and thermodynamic methods describing the PTPCB process in the volume of PFS, was used to perform a numerical investigation of the PFS parameters

Table 3
Effect of the concentration of coal dust in the fuel mixture on the temperature and composition of the products of PTPCB at the PFS exit

Ash, %	μ, kg/kg	T, °C	C_i, vol.%		
			CO	H_2	CO_2
20	0.4	187	–	–	0.5
	0.6	1537	14.0	5.6	5.7
	0.8	1056	16.3	8.3	5.7
	1.0	910	20.0	11.0	4.3
	1.2	779	19.4	11.8	4.9
	1.4	588	1.4	2.2	14.4
40	0.4	165	–	–	29.0
	0.6	1628	8.9	2.5	8.4
	0.8	1255	12.3	5.3	7.0
	1.0	1066	15.3	8.2	6.0
	1.2	938	18.2	10.8	4.9
	1.4	805	20.6	12.2	4.3
	1.6	709	3.0	4.2	11.7
70	0.6	626	–	–	3.5
	0.8	1749	2.7	0.5	12.4
	1.0	1450	4.9	1.3	11.0
	1.2	1335	7.2	2.5	9.6
	1.4	1217	9.5	4.1	8.4
	1.6	1081	11.2	5.8	7.8
	1.8	987	11.9	6.7	7.7

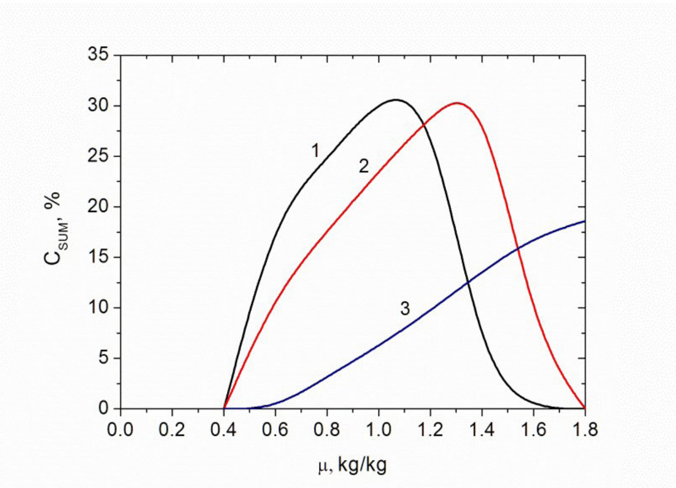

Fig. 7. Dependence of the total yield of CO and H_2 at the PFS exit on the dust concentration: 1 – Ash 20%, 2 – 40, 3 – 70.

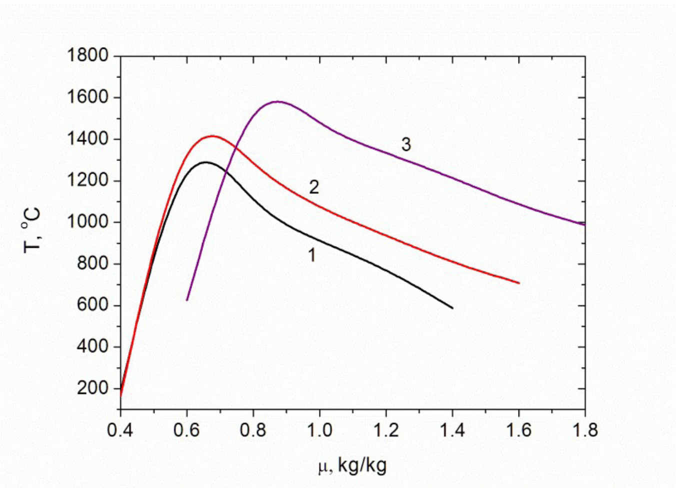

Fig. 8. Dependence of the gas temperature at the PFS exit on the dust concentration: 1 – Ash 20%, 2 – 40, 3 – 70.

depending on the plasma torch power, ash content of coal and concentration of coal dust in the air-fuel mixture. The program combines the kinetics of release of volatile and carbon oxidation of coke residue with a thermodynamic approach to the calculation of plasma thermochemical conversions of the products of primary destruction of coal in the gas phase. In the program a two-phase (coal particles and air) chemically reacted stream propagating in a channel with a plasma jet or without is considered.

2. Variations in the temperatures and velocities of the gas and coal particles, as well as the concentrations of PTPCB products along the length of the PTS, are found. Calculations have shown that in the power range of a plasma torch of 40-100 kW, a stable ignition of high ash coal is achieved at an air-fuel mixture rate of 1667 kg/h, which is confirmed by the high temperature (up to 1470 °C) and the concentrations of combustible components (up to 44%) at the PFS output.

3. With an increase in the power of the plasma torch, the temperature and velocity maxima of the PTPCB products are shifted upstream (in the direction of the plasma source). The maximum values of temperatures and velocities vary within a narrow range of values and are practically independent of the power of the plasma torch.

4. Numerical investigation of indicators of the PTPCB process in dependence on ash content of coal in the range of its values 20-70% is fulfilled. It is shown that the PFS exit concentration of combustible components (H_2 and CO) decreases with increasing ash content, the temperature of gaseous products increases and the degree of carbon conversion of coal increases to a maximum value when the ash content is 60%, decreasing sharply with further increase in the ash content.

5. A study of the influence of the concentration of coal dust in the air mixture on the temperature and composition of the products of plasma thermochemical preparation of fuel for combustion showed that a reliable ignition of the air mixture is ensured in the whole investigated range of ash content of coal (20-70%) at coal dust concentrations in the fuel mixture flow (0.5-1.8 kg/kg) used for operating pulverized coal-fired power plants. With increasing ash content of coal, ignition of the fuel mixture is ensured with a higher dust concentration in the fuel mixture. For all the analyzed coal ash the process of PTPCB proceeds in parallel with the combustion process of the fuel, which is confirmed by a significant concentration of carbon dioxide at the output of the PFS.

6. The conducted complex of numerical studies of PTPCB revealed the main regularities of heating and thermochemical transformations of pulverized coal in PFS, which makes it possible to use them in the design of the PFS for fuel oil-free start-up of boilers and stabilization of combustion of a pulverized coal flame at thermal power plants.

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Плазменное воспламенение пылеугольного факела

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АННОТАЦИЯ

Плазменная термохимическая подготовка пылеугольного топлива к сжиганию с использованием плазменно-топливных систем (ПТС) является одной из перспективных энергетических технологий. Эта технология позволяет повысить эффективность топливоиспользования и улучшить экологические показатели тепловых электростанций, а также исключить использование мазута, традиционного топлива для растопки котлов и стабилизации горения пылеугольного факела. В данной работе представлены результаты численных расчетов воспламенения пылеугольного факела в ПТС. ПТС предназначена для безмазутной растопки котлов и стабилизации горения пылеугольного факела и представляет собой оснащенную плазматроном пылеугольную горелку. С помощью программы PlasmaKinTherm, объединяющей кинетические и термодинамические методы расчета процессов движения, нагрева, термохимических превращений и воспламенения пылеугольной смеси в объеме ПТС, ранее было выявлено влияние мощности плазмотрона и зольности угля на эффективность воспламенения аэросмеси. Также одним из основных режимных параметров ПТС, обеспечивающих воспламенение топлива, является концентрация угольной пыли в аэросмеси, которая может варьироваться в широких пределах. Поэтому были исследованы условия воспламенения аэросмеси в ПТС в зависимости от концентрации угля в аэросмеси в интервале от 0.4 до 1.8 кг угля на 1 кг воздуха. Расчеты выполнены применительно к цилиндрической ПТС диаметром 0.2 м и длиной 2 м при фиксированных величинах расхода угля (1000 кг/ч) и мощности плазмотрона (60 кВт) для трех значений зольности угля (20, 40 и 70%). Выявлены основные закономерности процесса плазменной термохимической подготовки топлива к сжиганию.

Ключевые слова: уголь, аэросмесь, плазма, воспламенение, численный эксперимент.

Шаңкөмірлі жалынның плазмалық тұтануы

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АҢДАТПА

Плазма-отынды жүйесі (ПОЖ) көмегімен іске асырылатын шаңкөмірлі отындарды өртеуге арналған плазмалық термохимиялық даярлау энергетикалық технологиялардың бірі болып табылады. Бұл технология отынның тиімділігін арттыруға және жылу электр станцияларының экологиялық көрсеткіштерін жақсартуға, сондай-ақ мазутсыз қазандықтары тұтандыру үшін дәстүрлі отынды пайдалануды және көмір отынының жануын тұрақтандыруды қамтамасыз етуге мүмкіндік береді. ПОЖ-дағы шаңкөмірлі жалын тұтануының сандық есептеулерінің нәтижелері келтірілген. ПОЖ қазандықтарды мазутсыз тұтандыру мен шаңкөмірлі жалынның өртенуін тұрақтандыруға арналған және плазмотронмен жабдықталған қыздырғышы болып табылады. PlasmaKinTherm бағдарламасы көмегімен бұрын ПОЖ көлемінде жылу, термохимиялық трансформация және өртенген көмір қоспасының өрттеу процестерін есептеу үшін кинетикалық және термодинамикалық әдістерді біріктіретін, плазмалық плазмотрон қуаттылығы мен аэроқоспасының тұтану тиімділігіне көмірдің әсері анықталды. Соңымен қатар, отынның жануын қамтамасыз ететін ПОС-ның негізгі режимдерінің бірі, ол ауа қоспасындағы көмір шаңдарының концентрациясы болып табылады, ол кеңінен өзгеруі мүмкін. Сондықтан, көмірдің концентрациясы 1 кг-дан 0,4-тен 1,8 кг-ға дейін көмірдің қоспасындағы қоспаға байланысты ПОЖ-дегі қоспаның тұтану жағдайлары зерттелді. Есептеулер диаметрі 0.2 м және ұзындығы 2 м цилиндр тәрізді ПОЖ, көмірдің белгіленген шығыны (1000 кг/сағ) және плазмотронның қуаттылығы (60 кВт) және көмірдің үш күлділігі (20, 40 және 70%) үшін орындалған. Отындарды өртеу үшін плазмалық термохимиялық даярлау үрдістің негізгі заңдылықтары анықталған.

Түйінді сөздер: көмір, отын қоспасы, плазма, тұтану, сандық эксперимент.