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Modelling of the pulverized coal plasma preparation for combustion

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The main goal of this research is to show the action of pulverized coal in the plasma chamber through computer simulation and numerical experiments carried out with the aid of developed well known thermodynamic, kinetic and multi dimensional computational fluid dynamics based on mathematical models. The data needed for the validation of the numerical procedure were obtained from a cylindrical direct flow burner equipped with a plasmatron (plasma generator) with 100kW of electric power and mounted on a full-scale boiler (Gusinoozersk TPP, Eastern Siberia). The experiments were carried out using 'Tugnuisk' bituminous coal. Two mathematical models were employed: the one ('1D Plasma-Coal') being one-dimensional, but with an emphasis on complex chemistry, the other (3D FAFNIR) being fully three-dimensional with emphasis on the geometry and overall combustion processes. 1D Plasma-Coal numerical experiments gave the predicted temperatures and velocities of gas and solids along the chamber length; while the concentrations of the gas components (CO, CO_2, H_2, CH_4, C_6H_6, N_2, H_2O) were reported for the chamber exit. The degree of coal gasification showed that 54% of coal carbon was gasified within the plasma chamber. 3D numerical results for plasma jet spreading length were in good agreement with the measured data, while the temperature profiles within the plasma chamber were over predicted. The predictions of main species concentrations reveal that oxygen was completely consumed with the exit product stream consisting of combustible gases, un-burnt volatiles and char particles.

Key words: pulverized coal combustion, plasma, mathematical modelling, combustible gases.
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Introduction

The problem of environmental pollution is inexorably linked to industrial development and prosperity. One of the more important contributors are pulverized-fuel-fired Thermo Power Plants. Coal-fired utility boilers face two primary problems: the first being the use of expensive oil for light-up; the second being the increased commercial pressures that necessitate companies to use in furnaces a wide range of coals, also perhaps beyond the quality envisaged by the manufacturer's assurances for their combustion equipment. Burning the oil for lighting-up enhances the gaseous and particulate burden of the plant. The firing coals with low quality presents two difficulties: reduced flame stability performance necessitating oil firing support and its consequential emissions; and the reduction in combustion efficiency due to higher carbon proportion in the remaining ash, leads to an increased emissions per MW of power generated. One possible solution is 'pulverised fuel thermo chemical preparation' of the coal using plasmas [1–8]. In this concept a fraction of the pulverised coal and air mixture, diverted away from the bulk of the flow, is heated by electric arc plasma within a separate plasma chamber. The electric arc plasma as a heating generator and oxidant ensures high temperature medium with more radicals wherein occurs complete volatile substances release and partial gasification of the remaining carbon. This extremely reactive fuel fraction is then able to ignite the main stream of pulverised fuel/air mixture entering into the combustion chamber of the boiler. The affect is to produce a flame that does not require an additional heat source to maintain stability, nor does it require additional fuel for light-up purposes. By eliminating the usual oil light-up fuel, the emissions of the heavy metal vanadium are eliminated, while the improved combustion results in a reduction of total emissions per MW of electricity produced. Wider application of this method is expected in the near future.

Nowadays this technology has been successfully implemented in nearly 80 Thermal Power Stations in Russia, Kazakhstan, Ukraine, Slovakia, China, Korea and Mongolia [1, 9]. The number of industrial tests of coal-plasma ignition systems; using a variety of coals (from brown coals to anthracites) and differing types of burners; proved the validity of the approach.

Nevertheless, to optimise the use of plasma technology for coal ignition, new models of physical and chemical interaction between coal particles and high temperature gas (up to 5000K) are needed. The lack of detailed experimental data increases the complexity of the investigation topic. Evaluation and assessment of the main characteristics of the combustion process such as: the temperature and velocity profiles; the concentrations of chemical species; the particles disintegration under the influence of high temperatures; the effect of chemically active species (radicals) on coal combustion kinematics; etc. are urgently needed.

Experimental exploration of plasma activation of pulverized coal ignition for a cylindrical direct flow burner

The arrangement of a direct flow burner can be seen in Figure 1. The plasma burner (muffle) is a cylinder with the plasmatron mounted on the muffle body [10].

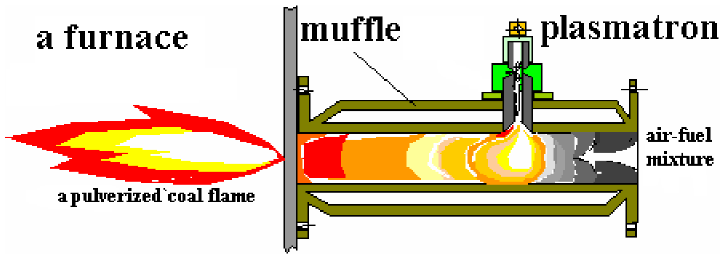

Figure 1 – Principle scheme of a plasmatron and cylindrical direct flow burner mounting

The plasmatron is a low-temperature plasma generator (Figure 1) supplied with electric power [11–14]. As a result of electric charges, an arc is formed between the electrodes, cathode and anode. Air as a plasma gas is blown between the electrodes and the high concentration of energy heats the air forming the plasma flame. The mass-averaged temperature of the plasma flame is about 3500-4000K. The shape of the typical air-plasma jet and its temperature contours are displayed in Figure 2. The measurements were taken for an unconfined plasma jet flow; the plasmatron mean temperature was about 5000K.

The mechanism for the thermo chemical preparation of pulverised coal for combustion is realised as follows. Primary air-coal mixture is fed through pulverised coal pipes to burners. If the burner is not equipped with a plasmatron the air-coal mixture is admitted into the furnace where it is ignited and combusted in the normal power station manner. If the burner is equipped with a plasmatron, the plasma flame heats the pulverised coal. The coal volatile matter is released and the coal carbon is gasified. The devolatilization and gasification products begin to react with the oxygen in the primary air-coal mixture, in turn heating more pulverised coal. However, the primary mixture is deficient in oxygen so the carbon is oxidised mainly to its monoxide. As a result we have a high-temperature (~1300K) reacting flow of particles and gaseous products of plasma thermo chemical preparation. This technology makes it possible to successively burn either high or low-grade coal having at the end a very active double-mixed fuel (burning gas and a soot) at the end of plasmatron. Blending with the secondary air, which is exist within the heater, it can be lighted and burned without the require for the supplementary fuel oil or characteristic gas customarily required to ensure stable combustion, particularly within the case of low-grade coals.

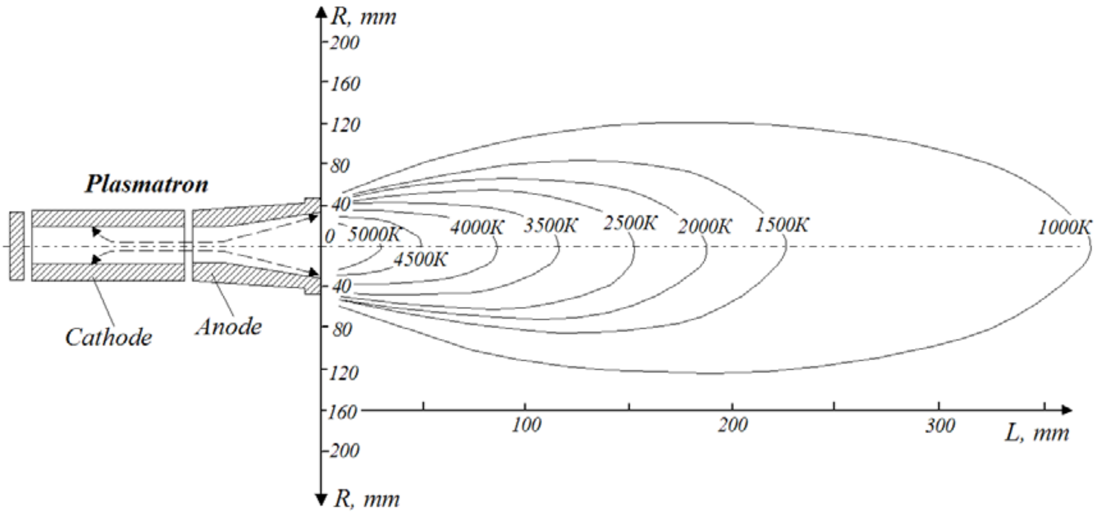

Figure 2 – Isotherms of the air-plasma flow from a plasmatron
R – distance from the plasmatron axis; L – distance from the outlet cross section of the anode.

The experiments were effected for a cylindrical direct flow burner, 0.25m in diameter and 2.35m in length, equipped with the plasma generator. The nominal electric power requirement of the plasmatron was 100kW. For this power consumption, the plasmatron efficiency and the plasma gas mass flow rate, the plasmatron generates low-temperature plasma (up to 4000K)

The detailed geometry of the muffle is shown in Figure 3. The muffle is mounted on the power boiler with a steam production of 640t/h at the Gusinoozersk Thermal Power Plant (Russia). ‘Tugnuisk’ black coal was used for the experiments. Its proximate properties are the following: moisture content=14%; ash content = 19.4%; volatile matter = 45%; lower calorific value = 5500kcal/kg. Its chemical analysis is given in Table 1.

Table 1 – Chemical characteristics of ‘Tugnuisk’ black coal (on a moisture-free weight), mass. %

C	O	H	N	S	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O+Na_2O
61.7	13.2	4.1	1.2	0.39	10.99	4.34	1.94	1.16	0.35	0.28

The coal and air mass stream rates through the suppress were 1.75t/h and 3.5t/h respectively; while the coal-air mixing inside temperature was 350K.

The obtained temperature graphs are presented in Figure 4. On the initial section of the muffle (line 1) the temperature profile has only one maximum and it is not axis-symmetric. The reason for that is impact of the plasma flame.

It is deflected from its initial direction by the effect of air-coal mixture flow direction. As seen from the figure, the temperature profile at the outlet of the muffle (line 2) has two distinctive maximums in the wall layer. The maximum temperature reaches 1300K and the extrapolated wall temperature does not exceed 800K.

The carried constitution of the gas phase at the outside of the muffle was (volume %): CO=28.5; H_2=8.0; CH_4=1.5; CO_2=2.0; N_2=59.5; others = 0.5, taking into account NO_X=50 mg/nm^3.

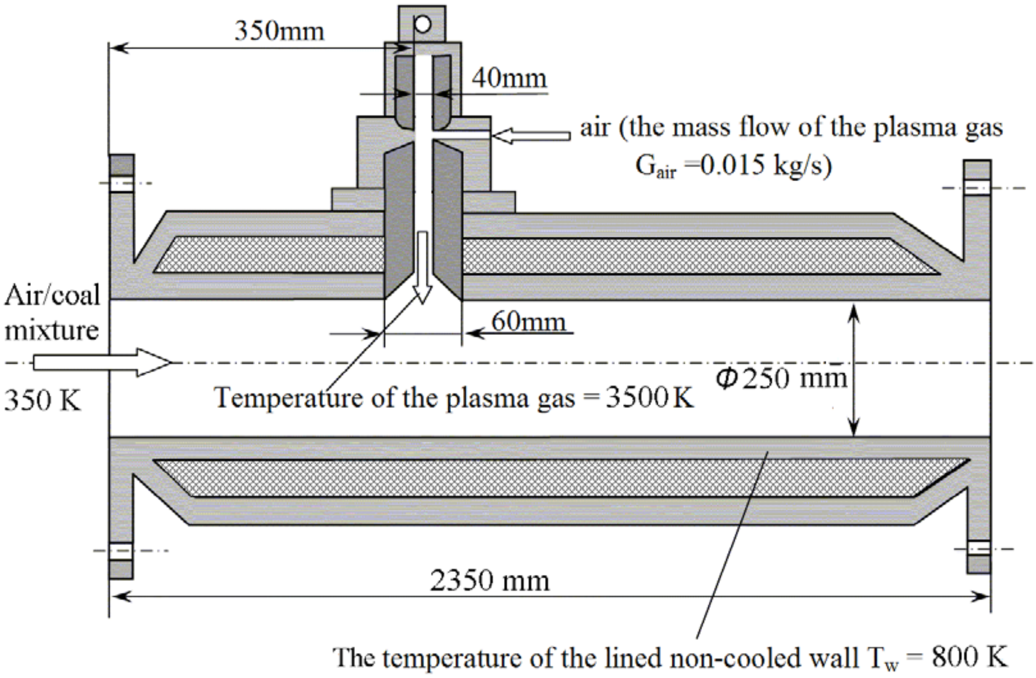

Figure 3 – Diagram of the full-scale muffle.

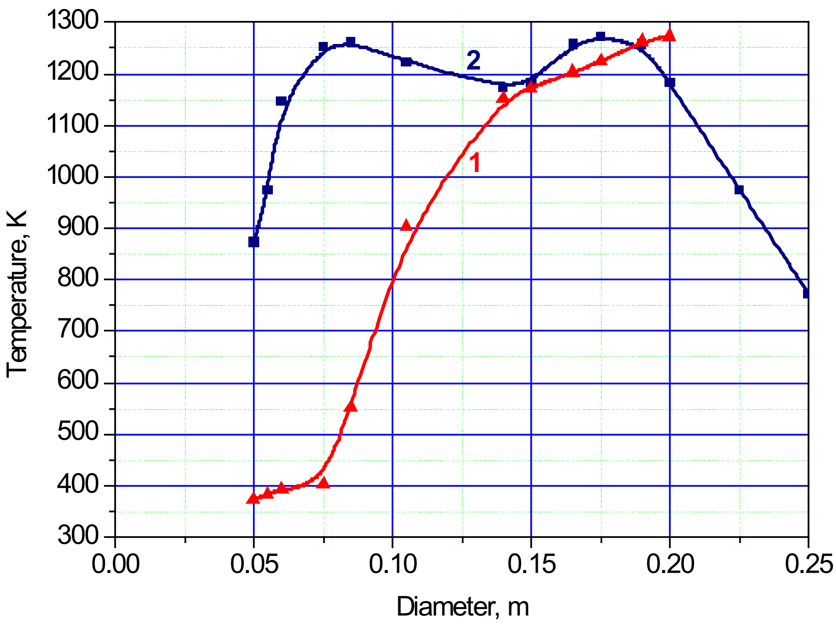

Figure 4 – Obtained temperature distribution inside the muffle.
1 –750 mm down of the plasmatron;
2 –output of the muffle.

Mathematical modelling

The numerical simulation of the coal combustion process in the plasma chamber was performed with two mathematical models: the one ('1D Plasma-Coal') being one-dimensional, but with an emphasis on complex chemistry, the other (3D FAFNIR) being fully three-dimensional with emphasis on the geometry and overall combustion processes.

One-dimensional modelling of pulverised coal plasma activation in a burner chamber

The calculations of the coal thermo chemical plasma preparation processes at the burner are carried out by the unique mathematical model of flow, heat transfer and thermo-chemical conversion of coal-dust fuel in the plasma chamber [6, 7].

The proposed model shows two-phase (coal dust particulates and gas-oxidiser), chemically reacting stream, with an inner energy source (arc discharge, plasmatron or chemical reactions). The air flow and coal dust are predicted to injected in the chamber with the same temperatures. There is particle-to-particle, gas-to-particle and gas-to- arc discharge heat and mass exchange. The exchange of heat and momentum between the flow and the chamber wall is taken into account. Some of the chemical transformations of the fuel are also considered. This is the formation of primary volatile products, the transformation of evolved volatile products in the gas phase and the gasification reaction of the coke residue.

The system of ordinary differential equations includes equations for the concentrations of components (equations of chemical kinetics) in combination with equations for the velocity and temperature of the gas and particles, respectively.

The arc was taken into account by the energy conservation equation. It is an internal heat source with an empirically specified distribution of heat release along the axis of the chamber with the plasma source. The energy conservation equation can be written as:

$$\frac{d}{dx}\left[\left(\rho_g \upsilon_g \frac{\upsilon_g^2}{2} + \sum_{l=1}^{L} \rho_{sl}\upsilon_{sl}\frac{\upsilon_{sl}^2}{2}\right)S\right] + \\ + SC_{Pg}\upsilon_g \frac{dT_g}{dx} = S\left\{\sum_{j=m+1}^{M} W_j Q_j - \right. \\ \left. -\sum_{l=1}^{L}\pi d_l^2 N_l\left[a_l\left(T_g - T_{sl}\right) + \varepsilon\sigma\left(T_w^4 - T_{sl}^4\right)\right]\right\} + \\ + \pi D\left(\Theta - 1\right) q_w \quad (1)$$

where $\rho, \upsilon, S, C_p, T, W_j, Q_j, d, N, a, \varepsilon, \sigma, D, q_w$, q_{arc} = density, [kg·m^{-3}], velocity, [m·s^{-1}], chamber's cross section, [m^2], specific heat capacity of components, [J kmol^{-1}·K^{-1}], temperature [K], the rate of the j^{th} chemical reaction, [kmol·s^{-1}·m^{-3}], reaction thermal effect, [J·kmol^{-1}], particle diameter, [m], volumetric density of the particulate matter, [m^{-3}], particles absorptivity, [W·m^{-2}·K], particles emissivity, Stephan Bolztmann constant, 5.67·10^{-8} [W·m^{-2}·K^{-4}], chamber's diameter, [m], specific heat flux into the wall, [W·m^{-2}], specific heat flux from arc, [W·m^{-3}] and indices *g, s, l, w, M* are referred to gas, solids, ordinal number of fractions, wall and number of the reaction correspondingly.

The last term of this equation is the energy influence from the arc, taking consideration of the losses to the chamber wall (q_w is a power removed from the system as convective and radiation waste via the surface πDdx). Thus, the heat contribution of the arc is can be expressed as the shift between the power of the arc and the loss of thermal energy into the chamber wall.. In the equation (1), Θ is a non-dimensional coefficient and may be written as:

$$\Theta = \frac{D(x)}{4}\cdot\frac{q_{arc}(x)}{q_w(x)} \quad (2)$$

The model is distinguished by a detailed description of the kinetics of chemical reactions. The temperature dependence of the rate constants is determined by the Arrhenius equation as:

$$k_j = A_j \cdot \exp\left(-\frac{E_j}{RT}\right)\cdot T^n \quad (3)$$

Table 2 shows the list of the chemical reactions and the corresponding kinetic parameters of the chemical reactions used in the model. Some 50 chemical reactions are included in the calculation. The starting chemical stage of coal conversion in plasma-chemical reactors is the release of volatiles. After that, char combustion, thermo chemical transformations of volatiles and char gasification, and further transformations of primary products by reactions with radicals are presented with related chemical reactions.

In Table 3 the chemical composition of the 'Tugnuisk' black coal for the computations by the model is shown. Element composition of the coal has been given in Table 1. This coal is one of the typical fuels for heat-and-power engineering used in the Gusinoozersk TPP and it is characterised as a low-grade coal [15].

Plasma thermo-chemical arrangement of coal for combustion is complicated thermal process occurring in several steps. First of all, the plasma torch heats the air-coal mixture, after ignition and then by rapid combustion and gasification of the fuel in the preliminary mixing flow.

Table 2 – Kinetic parameters of reactions included in the mathematical model

N	Reaction [a)]	*Lg A* [b)]	n	*E*	N	Reaction [a)]	*Lg A* [b)]	*N*	*E*
1	$[H_2]_s = H_2$	18.2	0	88.8	27	$H+H_2O=H_2+OH$	10.98	0	20.3
2	$[H_2O]_s = H_2O$	13.9	0	51.4	28	$H_2+O=H+OH$	7.26	1.0	8.9
3	$[CO]_s = CO$	12.3	0	44.4	29	$H_2O+M=H+OH+M$	13.3	0	105.0
4	$[CO_2]_s = CO_2$	11.3	0	32.6	30	$H_2O+O=OH+OH$	10.53	0	18.3
5	$[CH_4]_s = CH_4$	14.2	0	51.6	31	$CO+OH=CO_2+H$	4.11	1.3	-0.77
6	$[C_6H_6]_s = C_6H_6$	11.9	0	37.4	32	$CO+O_2=CO_2+O$	11.5	0	37.6
7	$C+H_2O=CO+H_2$	19.32	0	60.8	33	$CO_2+H=CO+OH$	6.15	1.3	21.6
8	$C+CO_2=CO+CO$	19.19	0	83.6	34	CO+O+M=CO2+M	12.77	0	4.1
9	$C+O_2=CO_2$	9.99	0	38.0	35	C2H2+M=C2H+H+M	11.0	0	114.0
10	$C+C+O_2=CO+CO$	9.72	0	41.8	36	$C_2H_2=C+C+H_2$	6.0	0	30.0
11	$CH_4+H=CH_3+H_2$	11.1	0	11.9	37	$C_2H_2+O_2=$ $HCO+HCO$	9.6	0	28.0
12	$CH_4+OH=$ CH_3+H_2O	0.54	3.1	2.0	38	$C_2H_2+H=C_2H+H_2$	11.3	0	19.0
13	$CH_4+M=$ CH_3+H+M	14.15	0	88.4	39	$C_2H_2+OH=CH_3+CO$	9.1	0	0.5
14	$CH_4+O=CH_3+OH$	10.2	0	9.2	40	$C_2H_2+O=CH_2+CO$	10.83	0	4.0
15	$CH_3+H_2O=$ CH_4+OH	9.84	0	24.8	41	$CH_2+H_2O=$ CH_2O+H_2	11.0	0	3.7
16	$CH_3+H_2=CH_4+H$	9.68	0	11.4	42	$CH_2+O_2=HCO+OH$	11.0	0	3.7
17	$CH_3+M=$ CH_2+H+M	13.29	0	91.6	43	$C_2H+O_2=HCO+CO$	10.0	0	7.0
18	$CH_3+O_2=CH_30+O$	10.68	0	29.0	44	$C_2H+H_2O=CH_3+CO$	9.08	0	0.5
19	$CH_3+OH=$ CH_2O+H_2	9.6	0	0	45	$C_6H_6=$ $C_2H_2+C_2H_2+C_2H_2$	12.0	0	85.0
20	$CH_3+O=CH_2O+H$	11.11	0	2.0	46	$OH+OH=H_2O+O$	9.5	0	1.1
21	$CH_3O+M=$ CH_2O+H+M	10.7	0	21.0	47	$H+OH+M=H_2O+M$	10.56	0	0.0
22	$CH_2O+M=$ $HCO+H+M$	13.52	0	81.0	48	$H+H+M=H_2+M$	9.56	0	0.0
23	$HCO+M=$ $H+CO+M$	11.16	0	19.0	49	$CH_2+OH=$ $HCO+H_2O$	10.5	0	1.5
24	$O_2+M=O+O+M$	12.7	0	115.0	50	$H+OH=H_2+O$	9.84	0	7.04
25	$H_2+M=H+H+M$	11.34	0	96.0	51	$H_2+OH=H_2O+H$	11.4	0	10.0
26	$H+O_2=O+OH$	11.27	0	16.8					

[a)] Equations 1-6 are the devolatilisation reactions.
[b)] Dimensions of A_j are $[s^{-1}]$ for the first-order reactions and $[litre{\cdot}mol^{-1}{\cdot}s^{-1}]$ for the second-order reactions.

Table 3 – Chemical composition of the coal for the computation, mass%.

Ash	C	H_2	H_2O	CO	CO_2	CH_4	C_6H_6
19.30	51.32	3.26	8.10	13.95	4.37	1.0	4.50

The calculations are performed by a step-by-step procedure whereby the chamber is subdivided into the calculation stages: First stage includes an arc zone, where air-coal mixture is heated up to the ignition temperature by the plasma jet, when the process of coal particle gasification begins. The results of the first calculation stage are the basic data for finding initial conditions for the second stage. To identify the specific initial data for the second stage, the air-coal mixture heating, the chemical heat sources (chemical reactions), the variations in coal composition as a result of volatile emissions and the partial gasification at the first stage are all taken into account. The procedure is repeated for the third stage, etc. until the whole calculation is performed.

The calculations were performed for the cylindrical chamber or muffle equipped with a plasmatron of 100kW power as illustrated in Figure 3. The temperature of the wall was supposed to be 800K. The average diameter of the coal particulates was equal to 30μm. The temperature of the air-coal particles mixture on the inlet of the chamber is 350K. The plasma muffle efficiency was taken as 90%.

The final results of the mathematical modeling are shown in Figures 5 and 6. Figure 5 displays gas and solid phase temperature and velocity variations along the plasma chamber. By the end of the chamber the gas and solid particles reach equilibrium at a temperature of 1076K. The velocities of gas and particles increase and are little different; the gas velocity more than of the solids by less than 10%. By the end of the chamber, at the outlet to the boiler, the velocities of the gas and solids are in equilibrium. Figure 6 demonstrates the changes of the rate of coal gasification along the muffle. The degree of gasification rises monotonously and by the end of the muffle it attains 54%. Integral characteristics of the process are indicated in the Table 4.

Table 4 – Integral characteristics of 'Tugnuisk' black coal plasma preparation for burning.

CO	**H_2**	**CH_4**	**CO_2**	**H_2O**	**N_2**	**O_2**	**X_C**	**V_g**	**T_g**	**t_g**
Volume %							%	m/s	K	s
27.47	6.67	0.54	6.59	0.39	57.42	0.27	53.8	53.2	889	0.039

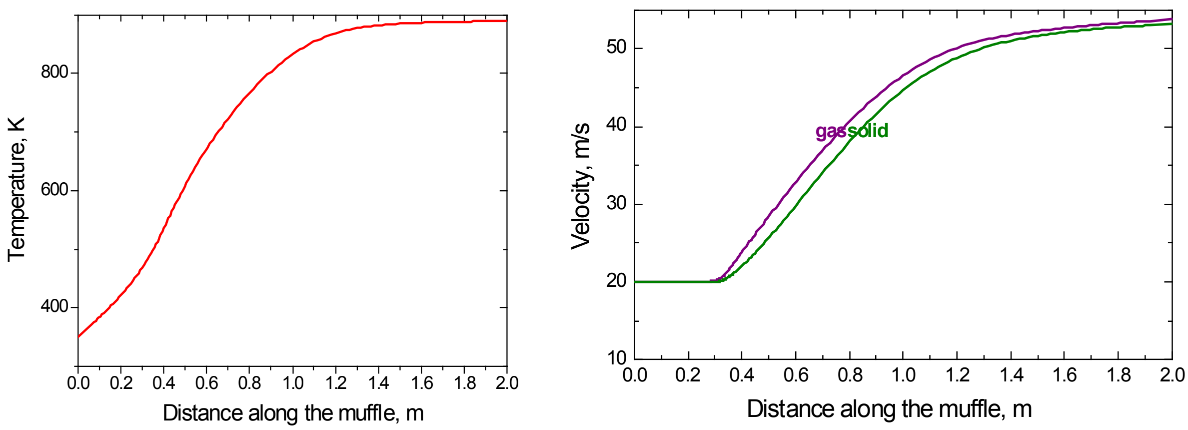

Figure 5 – Temperature and velocity of the products along the muffle

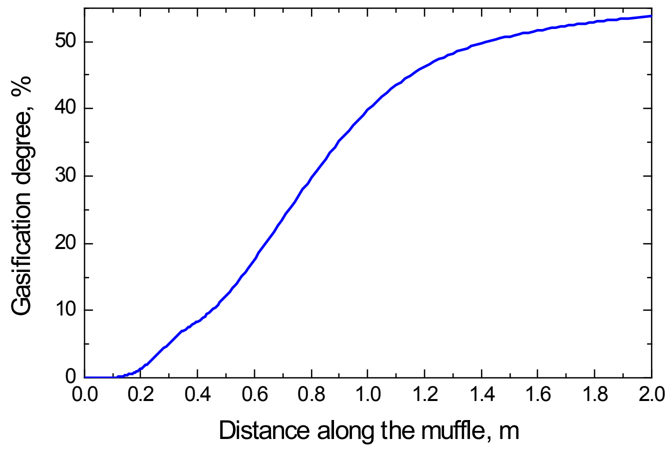

Figure 6 – Gasification degree variation along the muffle

Three-dimensional modelling of pulverised coal plasma activation in a burner chamber

For the mathematical simulation of the combustion performance a parent 3-D mathematical code (FAFNIR) was used. The code has been developed within the ICL Thermo-fluids group and has been previously described in full [16–21]. FAFNIR is a CFD code that solves the conservation equations for mass, momentum and energy. Following equations are solved for the mass ratio of volatiles, oxygen and products, as well as for the intensity of thermal radiation. Physical models are used for volatilization, volatiles incineration (fast incineration without premixing), char burnout, and turbulence (k-e).

The numerical calculations simulate the thermo chemical preparation of coal for combustion, but ignore the chemical kinetics of the plasma. The predictions are made:

- the arc discharge plasma is assumed as an internal heat source
- a low temperature plasma is taken into account (temperatures up to 4000K)
- the plasma gas is air
- the influences of electro-magnetic fields are not considered
- the density of charged particles is very low
- the dissociation of the main chemical species is not taken into account
- the combustion is presented by a fast chemistry model, without intermediate reactions and species involved in the calculation

In a preliminary calculation, the spreading rate of the plasma jet emerging from the plasmatron nozzle was simulated. The nozzle was defined with starting and ending diameter, of 40 and 60mm respectively, while the length of the nozzle was 80mm. Mean temperature of the plasma air jet was 5000K while the air mass stream via the nozzle were 36 kg/h. Predicted isotherms profiles are shown in Figure 7. Comparisons with experimental data, from Figure 2, are demonstrated in Table 5. It can be seen that predicted and measured results are in a good agreement. These initial predictions were achieved ignoring combustion.

Table 5 – Comparison of measured and predicted length of the isotherms for air plasma flow from the plasmatron nozzle.

Temperature (K)	5000	4500	4000	3500	2500	2000	1500	1000
Experiment (m)	0.030	0.050	0.086	0.116	0.153	0.188	0.227	0.375
Numerical (m)	0.030	0.086	0.109	0.123	0.167	0.202	0.255	0.370

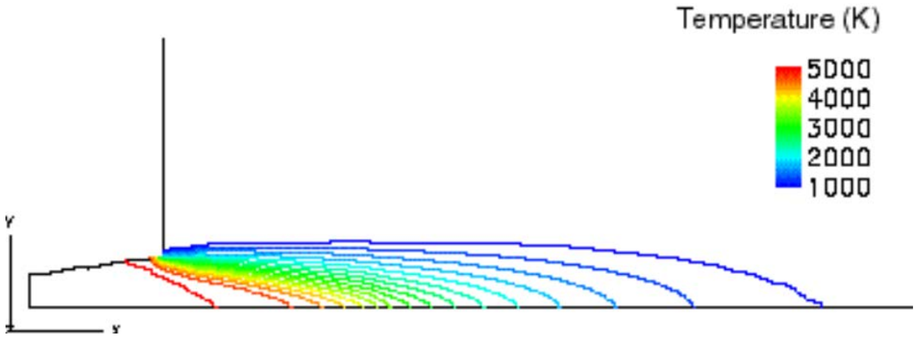

Figure 7 – Predicted isotherms of air-plasma flow from the plasmatron (temperature, K).

The coal preparation calculations, including the effects of combustion were performed for the plasma chamber of Figure 3. The specification of the Tugnuisky coal and the plasma chamber operating parameters used for numerical calculation has been given in Table 6. The operating temperature for plasma generator was modified as a result of difference between working and nominal electric power of the plasmatron. Work (net) power of the plasmatron was 60kW while nominal (gross) power was 100kW. The new value of plasma jet temperature and velocity were 2800 K and 95m/s respectively, keeping the other values as specified in Table 6.

Table 6 – Specification of Tugnuisky bituminous coal and the plasma chamber operating data.

Tugnuiski Coal		
Proximate analysis	mass %	Particle size distribution
Moisture	14.00	D= 160 μm 10 %
Volat. matter	36.27	D= 130 μm 10 %
Fixed carbon	44.33	D= 74 μm 20 %
Ash	19.40	D= 50 μm 40 %
Ultimate analysis	mass %	D= 24 μm 20 %
Carbon	61.7	Lower calorific value: 5500 kcal/kg
Hydrogen	4.10	
Nitrogen	1.20	
Sulphur	0.39	Coal feed rate: 1750 kg/h
Oxygen	13.20	

OPERATING DATA	1
Plasma chamber (muffle)	
Length (m)	2.35
Inner diameter (m)	0.25
Plasma Generator	
Electric power (kW)	100
Plasma gas	Air
Mass flow (kg/h)	54
Inlet air temperature (K)	298
Outlet air temperature (K)	3500
Inner diameter (m)	0.04
Outlet velocity (m/s)	118.2
Primary air	
Air flow (kg/h)	3500
Velocity (m/s)	20.0
Temperature (K)	350
Coal dust concentration (kg/kg)	0.50

The numerical results for combustion of pulverised Tugnuisky coal in plasma chamber are presented in Figures 8. and 9. Temperature profiles are shown as a function of radial distance at two axial locations, 0.75m (1) and 2.0m (2) from plasmatron axis. The predicted profiles along the axis showed to be perfectly axis-symmetric, on both sides perpendicular to the plasma jet. The behaviour of measured temperature profile at location 1 was affected by plasma jet flow and specific configuration of coal-air supply pipe, having two elbows very close before entering the plasma chamber. Disturbance of the main flow can be recognised at a side having a much higher temperature and probably higher concentration of coal particles, comparing with the remaining area. Second measurement at the chamber exit gives a symmetric result showing the development of flow profile and distribution. This disturbance was not included in the calculation. The assumption of equal distribution for coal particles within the inlet plane was applied.

Both predicted and measured profiles showed distinctive temperature minimum at the chamber central line. This can be explained as the effect of the plasma jet; which separates the air-coal mixture flow in two flows leaving the central part of the flow with lower fuel density. High-energy focused plasmatron, with high initial momentum, acts as a solid body penetrating via the cross flow. The coal particles trajectories are diverged showing two temperatures maximums on both sides of the centre line were combustion takes place.

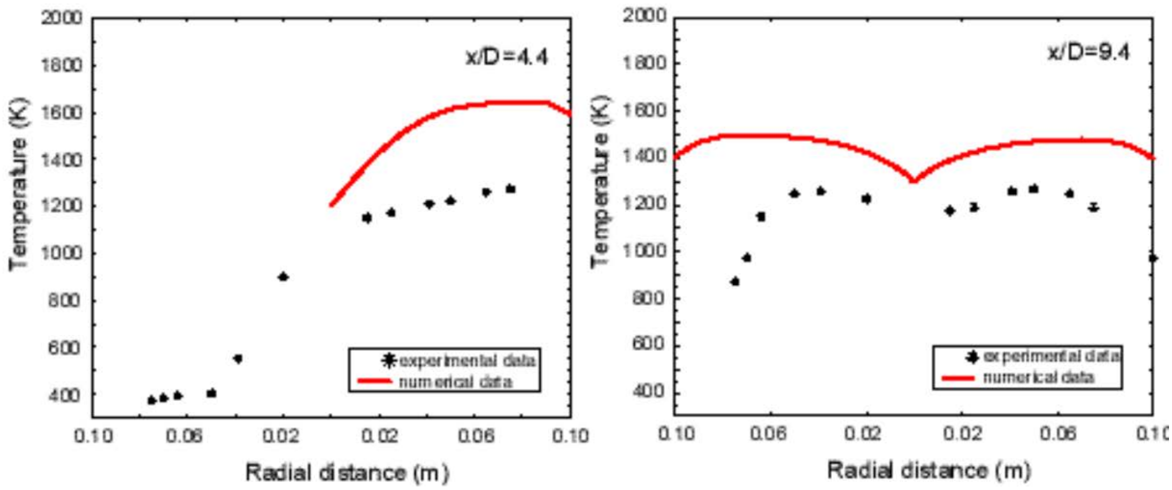

Figure 8 – Predicted radial temperature profiles.

As it shown in Figure 8, the simulation over predicts the temperature of particles combustion. This discrepancy in temperature could be attributed to the combustion model used in calculations. The simple chemical reacting system (fast chemistry model) takes into account only global nature of the combustion process with final species concentrations (CO_2, H_2O, SO_2), while the intermediate reactions and species are ignored. It can be seen from experimental measurements for gas species concentrations at the exit that only a very small fraction of the exhaust gases consists of the final combustion products as CO_2 (2.0%). A large part of the gases consists of unburnt gases such as CO, H_2 and CH_4 with amount of 28.5%, 8.0% and 1.5% respectively.

A very high concentration of CO_2 (14%) is predicted as seen in Figure 9. This resulted in high temperature predictions and lower oxygen concentration. The concentration of unburned volatiles at the exit was about 25%, while the zero oxygen concentration at the same location suggests complete consumption of the oxygen. Particles history analysis showed that about 70% of coal particles were fully burnt within the plasma chamber, this value amounts to about 55% of the carbon released from particles.

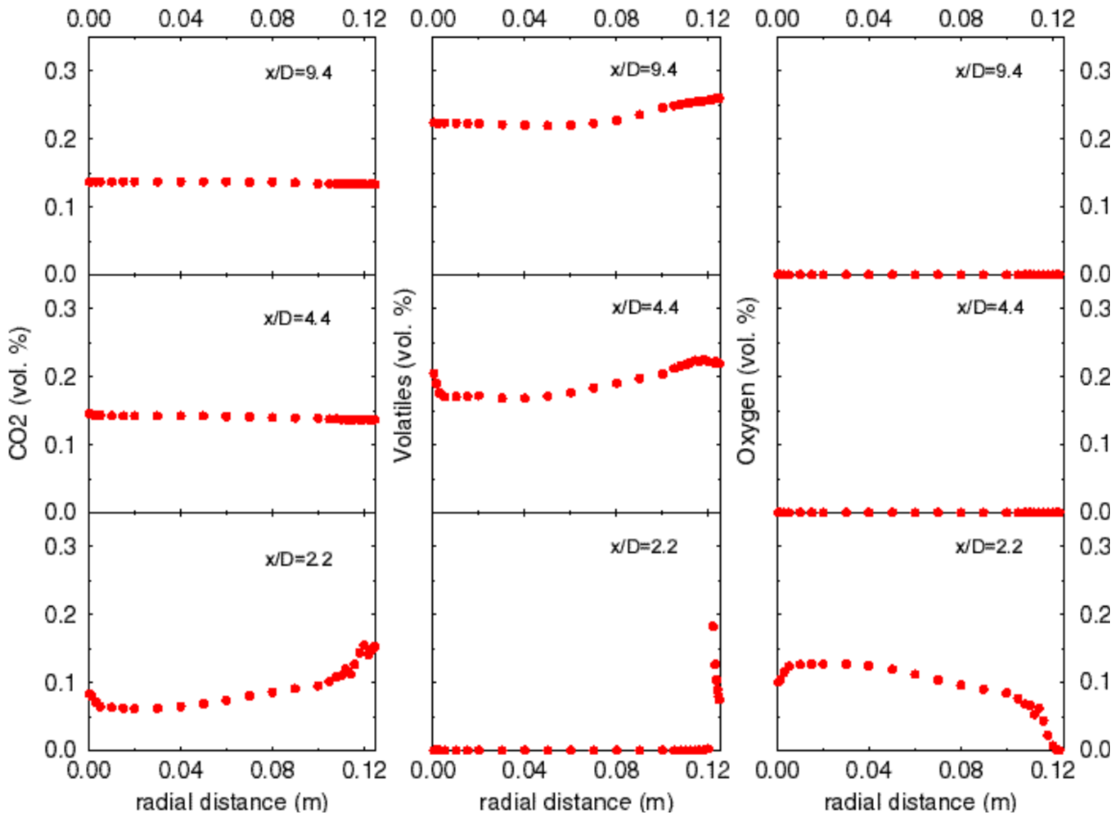

Figure 9 – Predicted radial profiles of carbon dioxide, oxygen and volatiles concentrations.

Conclusions

The results obtained confirmed the adequacy of the programs Plasma-Coal and FAFNIR for describing the processes of thermochemical preparation of coal in plasma-fuel systems. The Plasma-Coal program allows obtaining the averaged characteristics of the plasma-fuel systems with sufficient accuracy for engineering calculations, but does not provide a complete spatial picture of the process under consideration. Although the code FAFNIR has been successfully validated against experimental data for coal and gas combustion, further developments are required for better predictions of plasma thermos-chemical coal preparation for combustion. The most important step has to be taken in further development of chemical reactions kinetics mechanism. Number of most important intermediate reactions and their heat exchange rates has to be defined. Furthermore, plasma assist coal combustion is characterised with partial dissociation of molecules; which involves the atomic species and radical transformations under the influence of high gas temperatures [6]. Thus, the combination of the programs Plasma-Coal and FAFNIR will make it possible to obtain the initial data necessary for the design of industrial plasma-fuel system for thermal power plants.

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