Possibilities of Determining Coal Combustion and Burning at Low Temperatures Without Thermic Energy

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The present study is trying to demonstrate that the heat transfer it is not the only possibility to insure the continuity of the burning process. Analyzing the probable causes that start the fire it is necessary to take into consideration all these aspects. The present study demonstrates that the combustion temperature measurements and the thermal loading to insure the burning process are particular cases which apply only when the process is started by the transfer of thermal energy. It has been studied the possibility of combustion and burning of coal in different degrees at low temperatures in order to prove that the plasma energy can be a probable cause of ignition and burning. The obtaining data applied on coals can be extended on other inflammable materials as well as on other types of energies. The final results have proved that any kind of transferred energy could be the cause of burning processes.

Keywords: coals, combustible, SEM, plasma, burning, combustion

Plasma is a group of charged particles (positive ions, negative ions, and electrons), null particles and photons (electromagnetic radiation). The maintenance of plasma requires a constant equilibrium between the formation and the disappearance of charge carriers. Generally, plasma particles can be subject to the following interactions:

- they can interact themselves, when one particle is crossing another particle's territory;
- interactions of particles with metal / non-metal surfaces which are in contact with the plasma;
- interactions with the electric, magnetic and gravitational fields applied on the plasma by exterior reactions.

As an example, the plasma situated between the electrodes of a discharging tube is continuously interacting with the electric field between the electrodes which is produced by the maintaining generator of that plasma.

Once the plasma is stopped (electrically or otherwise), the first two processes are becoming the most important. We shall classify these processes as elementary at the interface plasma-solid. They contain interactions with the plasma reactor walls or with the electrons. So, there can take place the following processes:

- elastic processes, if as a result of the interaction, the intern energy does not change after colliding. In such a process the quantum estate of each particle remains unchanged;
- inelastic processes, if as a result of the interaction, the intern energy of one particle at least does change.

Plasma is an energy source which can be transferred and can determine combustion and burning at lower temperatures than in case of thermal transfer.

Previous burning studies have been realized in closed spaces with powerful thermal charge. In the burning process are included both the transformation of organic and inorganic mass.

Experimental part

Method and equipment

The present study, realized under 400^0 C follows the transformations of the organic mass because the inorganic mass does not suffer essential changes at low temperatures.

The purpose of this study was to realize a perfect observation of the organic mass behaviour in the oxidation process and of the probabilities to regularize the combustion and burning processes.

For carbon plasma burning it has been utilized a plasma reactor connected by induction (fig. 1). Induction connected plasmas have the advantage that their ignition is made directly with the coil. The absence of the electrodes allows the appearance of a continuous contact base between the discharge wall of the tube and the plasma volume [1-3].

After applying the electric field, the instauration of the thermal equilibrium in plasma favorites the ionization processes and the excitement of particles as well as the reverse process of their recombining.

By chemical point of view, the free radicals are the most important species in plasma because they are responsible for most of the occurring chemical reactions.

The plasma made of radicals, ions excited specie, and photons can be considered as a radiation source which can initiate different plasma processes. Most of the active species are formed in plasma volume where different reactions can occur.

The furnace type of plasma reactor is working at 2.4 MHz. The reactor has an entrance which allows the access of the gas transport and it has a connection with the vacuum pump.

The coal samples have been stamped at 10t force and then introduced on glass discs into the plasma furnace. The measurements have been made at 10, respectively, at 40 min. There have been studied two coal samples (brown coal from Berbesti and coal from Petrila).

Results and discussions

The coal samples have been analyzed according to ISO and STAS, the results can be seen in tables 1 and 2.

The samples have been under plasma action for 10, respectively for 40 min 1and they have been analyzed by spectroscopy SEM. The results are presented in tables 3, 4, 5 and 6.

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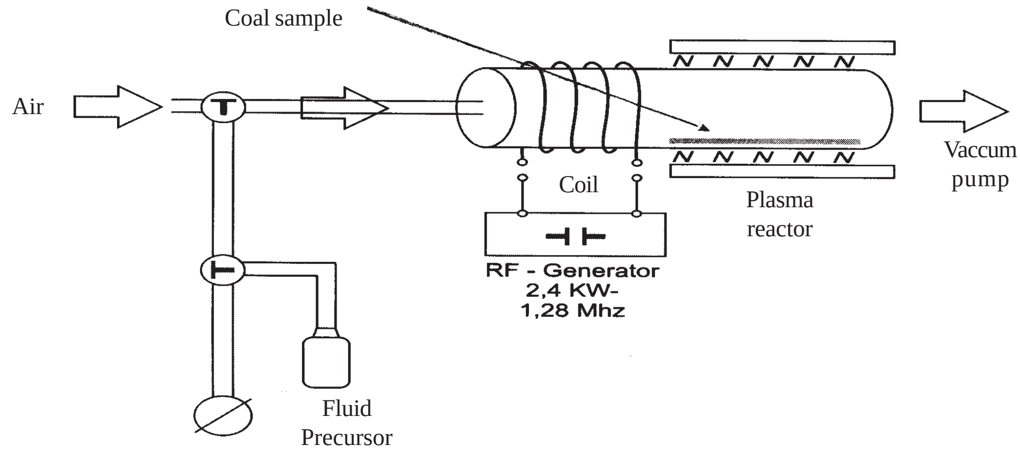


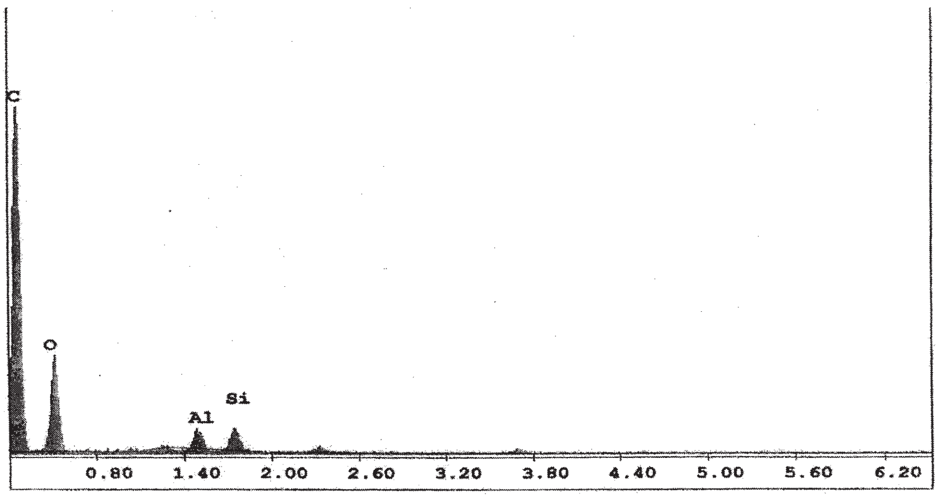
Fig. 1 The chart of the experimental installation with the plasma reactor for burning coals

Table 1
THE COAL ANALYSIS FROM BERBESTI

Specification	Symbol	Units	Values	Observations
Humidity	W^a	%	10.10	SR 8160/6-70
Ash	A^a	%	10.63	SR 8160/6-70
Carbon	C^a	%	56.22	SR 5268-90
Hydrogen	H^a	%	5.10	SR 5268-90
Sulfure	S^a	%	1.27	SR ISO 8754-96
Oxygen	O^a	%	15.38	SR 5268-90
Nitrogen	N^a	%	1.30	SR 5268-90
TOTAL		%	100.00	
Carbon Dioxide from the sample	CO_2	% mass	8.52	By treatment with hydrochloric acid

Table 2
THE STANDARD COAL ANALYSIS FROM PETRILA

Specification	Symbol	Units	Values	Observations
Humidity	W^a	%	1.44	SR 8160/6-70
Ash	A^a	%	5.65	SR 8160/6-70
Carbon	C^a	%	79.00	SR 5268-90
Hydrogen	H^a	%	4.00	SR 5268-90
Sulfure	S^a	%	1.02	SR ISO 8754-96
Oxygen	O^a	%	8.26	SR 5268-90
Nitrogen	N^a	%	0.63	SR 5268-90
TOTAL		%	100.00	
Carbon Dioxide from the sample	CO_2	% mass	13.66	By treatment with hydrochloric acid



EDAX ZAF Quantification (Standard less)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
C K	70.35	76.41	0.4106	1.0049	0.5806	1.0002
O K	27.94	22.78	0.0400	0.9909	0.1444	1.0000
Al K	0.86	0.42	0.0049	0.9285	0.6120	1.0005
Si K	0.84	0.39	0.0060	0.9566	0.7494	1.0000

Element	Net Inte.	Bkgd Inte.	Inte. Error	P / B
C K	443.20	3.25	1.07	136.37
O K	143.85	4.00	1.92	35.96
Al K	36.95	13.35	4.83	2.77
Si K	44.65	9.35	3.99	4.78

Table 3
ELEMENTAL ANALYSIS IN MASS PERCENTAGE AND ATOMIC PROCESSES OF THE SAMPLE FROM THE PETRILA COAL BURNT FOR 10 MIN IN OXYGEN PLASMA.

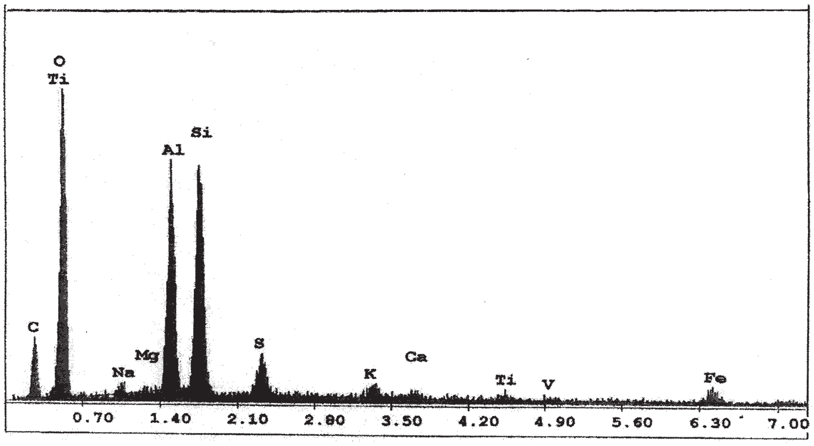


Table 4
ELEMENTAL ANALYSIS IN MASS PERCENTAGE AND ATOMIC PROCESSES OF THE SAMPLE FROM THE PETRILA COAL BURNT FOR 40 MIN IN OXYGEN PLASMA

EDAX ZAF Quantification (Standard less)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
C K	27.23	36.41	0.0565	1.0230	0.2027	1.0005
O K	48.58	49.43	0.1074	1.0087	0.2191	1.0003
Na K	0.88	0.62	0.0022	0.9476	0.2584	0.0028
Mg K	0.17	0.11	0.0006	0.9725	0.3692	1.0055
Al K	8.96	5.40	0.0437	0.9450	0.5132	1.0050
Si K	10.13	5.87	0.0526	0.9736	0.5335	1.0010
S K	1.60	0.81	0.0102	0.9677	0.6608	1.0008
K K	0.56	0.24	0.0047	0.9196	0.8972	1.0021
Ca K	0.33	0.14	0.0029	0.9412	0.9383	1.0022
Ti K	0.35	0.12	0.0030	0.8656	0.9929	1.0025
V K	0.20	0.06	0.0017	0.8506	1.0087	1.0039
Fe K	1.01	0.30	0.0091	0.8721	1.0263	1.0000

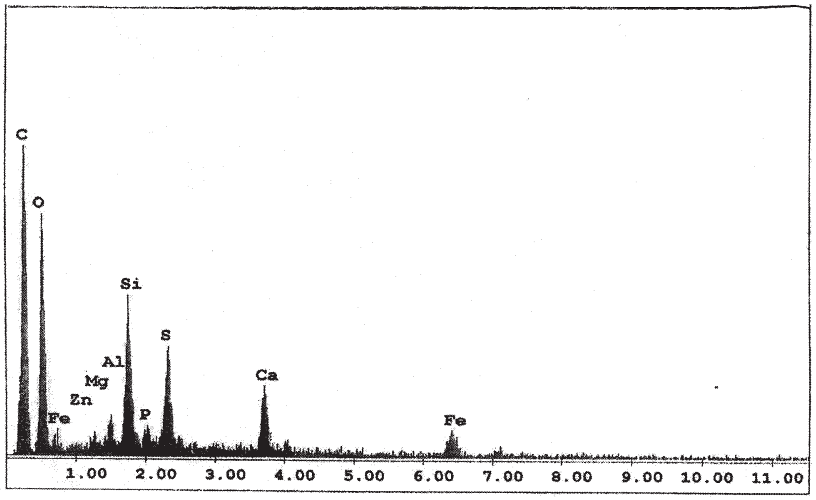


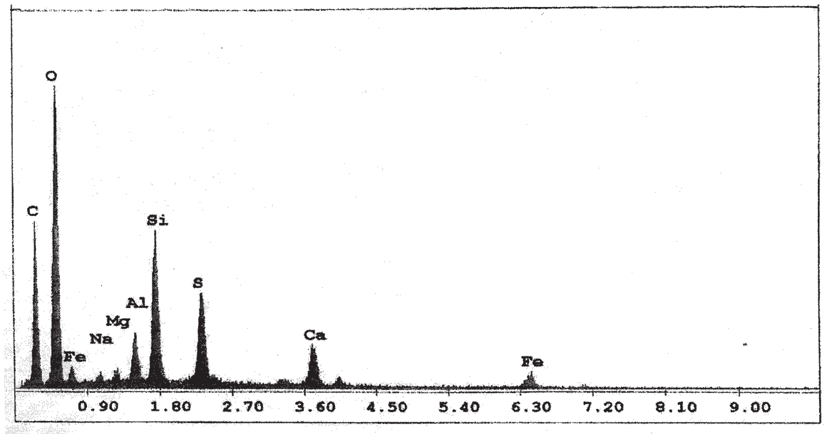
Table 5
ELEMENTAL ANALYSIS IN MASS PERCENTAGE AND ATOMIC PROCESSES OF THE SAMPLE FROM THE BERBEŞTI COAL BURNT FOR 10 MIN IN OXYGEN PLASMA

EDAX ZAF Quantification (Standard less)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
C K	59.33	68.64	0.2259	1.0106	0.3867	1.0003
O K	31.95	27.75	0.0488	0.9965	0.1534	1.0001
Zn K	0.67	0.14	0.0027	0.8541	0.4792	1.0007
Mg K	0.50	0.29	0.0019	0.9609	0.4036	1.0014
Al K	0.70	0.36	0.0036	0.9337	0.5513	1.0023
Si K	2.49	1.23	0.0166	0.9620	0.6931	1.0018
P K	0.40	0.18	0.0029	0.9311	0.7751	1.0026
S K	1.69	0.73	0.0141	0.9562	0.8723	1.0012
Ca K	1.17	0.41	0.0112	0.9281	1.0323	1.0021
Fe K	1.11	0.28	0.0101	0.8608	1.0455	1.0054

The plasma burning process is different from the classic one, because the temperature is under 400°C. It maintains the coal tailings mostly unchanged, the other reactions appear at this temperature.

Volatile outbursts and the agglutination process seem to be influential at lower temperatures when plasma burning takes place.



EDAX ZAF Quantification (Standard less)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
C K	43.76	54.07	0.1279	1.0159	0.2875	1.0004
O K	42.45	39.38	0.0821	1.0005	0.1932	1.0001
Na K	0.56	0.36	0.0016	0.9385	0.3084	1.0012
Mg K	0.45	0.27	0.0019	0.9628	0.4460	1.0022
Al K	1.64	0.90	0.0092	0.9351	0.5975	1.0034
Si K	4.76	2.52	0.0329	0.9631	0.7166	1.0021
S K	3.06	1.42	0.0251	0.9566	0.8580	1.0014
Ca K	1.85	0.68	0.0172	0.9323	0.9997	1.0017
Fe K	1.49	0.39	0.0130	0.8554	1.0255	1.0000

Table 6
ELEMENTAL ANALYSIS IN MASS PERCENTAGE AND ATOMIC PROCESSES OF THE SAMPLE FROM THE BERBEŞTI COAL BURNT FOR 40 MIN IN OXYGEN PLASMA

The variation of carbon waste related to burning time and carbonization degree is shown in the diagrams.

The intensity of carbon burning is inversely related to the carbonization degree. There are visible changes in the burning process of coal from Petrila, which can show agglutination features. The lignite from Berbesti behaves completely different by having lower rates of carbon content which are probably due to the appearance of the coking coal.

Conclusions

Plasma is an energy source, different from thermal energy, which can initiate and generate burning processes at low temperatures.

Plasma burning indicates the behaviour of the organic mass, respectively of the coal tailings, during the oxidation process.

Plasma burning indicates that in the first 10 min the burning speed is very high due to the lower degree of coal carbonization. (consequently, the volatile compounds are lower).

10 min after plasma burning we can state that the volatile compounds are finished and the burning speed is related to the coking coal burning speed, which are almost equal.

The carbon content of coal decreases during the burning process, the decrease differs because of the carbonization degree. Generally, coal has a smaller part of carbon after 10 min of burning than lignite due to shale carbonates; lignite has mostly argillaceous tailing coal.

After 40 min of burning, the water from the clay coal is still there, because it takes 500°C to evaporate, so the water does not evaporate, consequently, the coal tailings do not suffer any major transformation.

The oxygen content determined as such, not by difference, increases in the burning process; this demonstrates that it does not take part in the process because it is related to the coal tailings.

Ulterior to this research, we have to modify the classic method of burning calculus because it considers that the entire coal oxygen takes active part in the burning process.

Diagrams justify the fact that, in practice, mostly when solid fuels are burnt it is necessary an air overflow (Φ=1.2-1.3) to realize the process in optimum conditions.

It is necessary to avoid any energy transfer towards flammable organic substances which can cause ignition or explosion.

It is necessary to know all kinds of constant or energies existing in the areas of flammable material processing plants.

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