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PLASMA TREATMENT OF INCINERATION ASHES

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A b s t r a c t. Post-incineration ash, resulting from the incineration of domestic waste, has been proceeded in different experimental thermal plasma systems. Different analyses (sieving, chemical, SEM) have been used to study the characteristics of the products. Partial surface melting of reactants has been confirmed.

K e y w o r d s: thermal plasma, waste treatment, incineration ash.

INTRODUCTION

Solid residues resulting from conventional incineration of domestic, hospital, chemical or nuclear wastes as well as fine metallic powders (which are often side products in metallurgy) are considered, according to current EU regulations, as dangerous wastes, mostly due to its high leachability [1,2,3]. Thus, many techniques have been tried to neutralize them. Since the incineration has been commonly accepted as the only safe and basic technique to process various wastes the problem of further utilization, remedy, recycling and management of incineration ashes is currently of high interest [4,5].

For about a century people have been taking advantage of thermal plasma. Recently, it found use in environmental engineering, e.g. in processing of incineration ashes. In the present study the results of the preliminary tests on in-flight plasma processing of an incineration ash in different experimental systems are presented.

EXPERIMENTAL

In-flight plasma treatment of post-incineration ash was performed in three distinctly different experimental systems. The starting material was from Municipal Incineration Plant in Warsaw (Table 1.).

The solid products were collected and analyzed using different techniques: SEM, ICP-MS, sieve analysis.

Table 1. Processed materials description.

Origin	Denotation, fraction			
	ø < 0.1 mm	0.1÷0.4 mm	ø < 1 mm	ø < 3 mm
Bottom ash	A	B	C	-
Powdered slag	D	E	-	F

1. RF PLASMA

The ash (fraction B) was processed in the system shown in Fig. 1. Ar/H_2 (80/10 [dm^3min^{-1}]) mixture was used as a sheath gas. Argon was used both as the central and powder carrier gas, 30 [dm^3min^{-1}] and 10 [dm^3min^{-1}], respectively. The pressure was fixed at 500 [Torr].

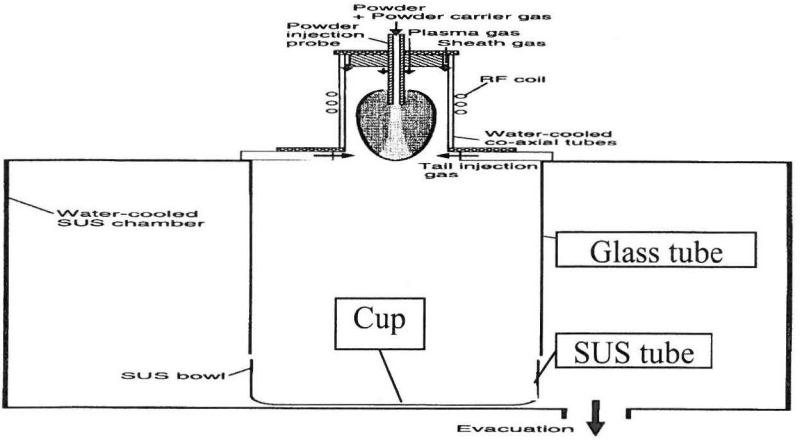

Fig. 1. RF plasma system.

2. DC PLASMA JET

Fig. 2 presents the scheme of the typical plasma reactor with a DC plasma torch. The ash (A and B fractions) was introduced through the injection port into Ar plasma (1200 dm^3h^{-1}) jet at two different power levels: low power (2,5 kW) and high power (3,6 kW).

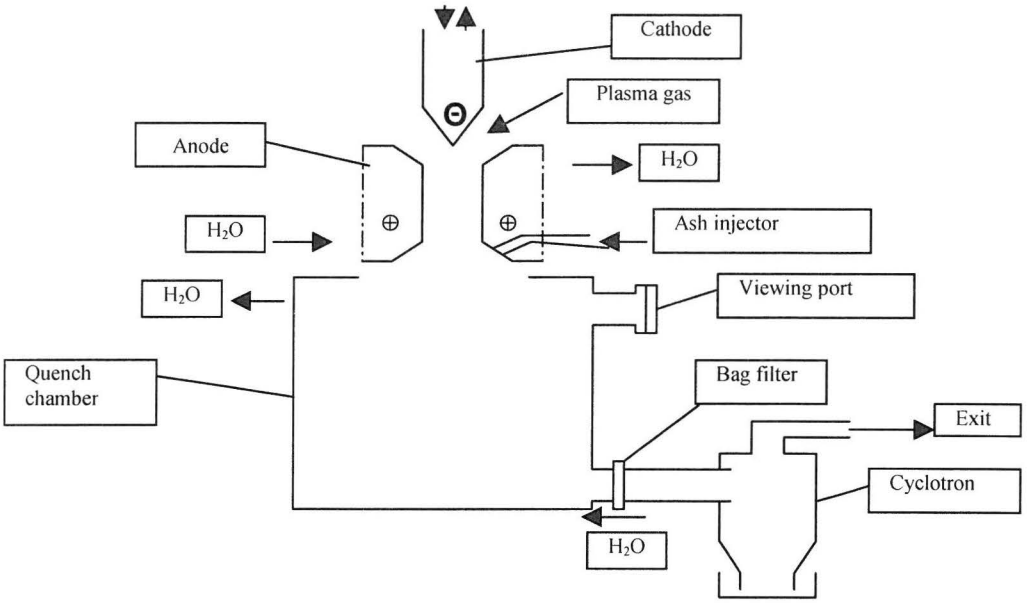

Fig. 2. DC plasma torch set-up.

3 DC ROTATING PLASMA

In this system (Fig. 3) the rotating arc discharge between cathode (tungsten tip) and copper anode was initiated and sustained in argon stream (2 [m^3h^{-1}])

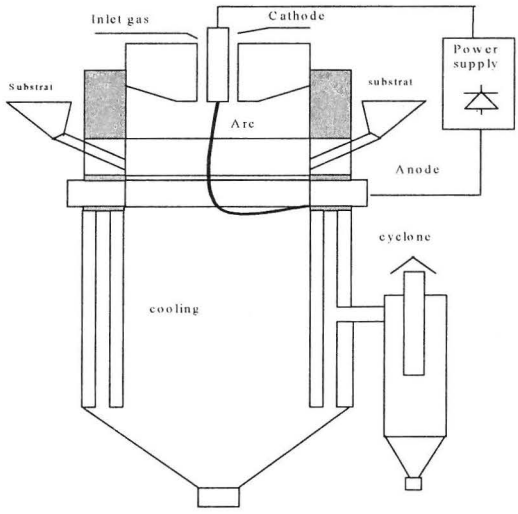

Fig. 3. DC rotating plasma system.

RESULTS AND DISCUSSION

1. Several tests were performed and the experimental parameters are shown in Table 2.

The solid products were collected from the glass tube wall, SUS tube and cup (Fig. 1), weighted and analyzed by ICP-MS technique.

Microscopic observations of powders were performed with Fig. 4 (starting material) and Fig. 5 showing the examples of product morphology. Regardless the plasma power and feeding rate there are no big differences in the structure of the product: comparing to the starting powder the resulting product from cup is surface melted and, at least, partial spheroidization is evident, as expected. Thus, even at the lowest power input and the highest ash feeding rate the plasma conditions allow for the surface melting of solids.

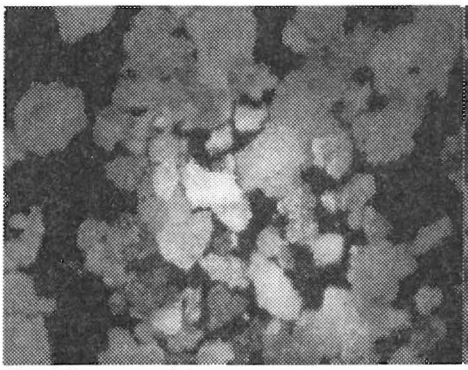

Fig. 4 Raw material.

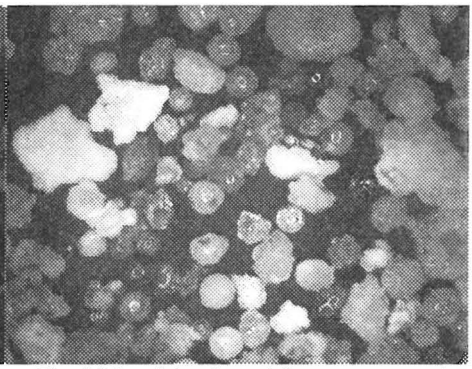

Fig. 5 Material collected from cup, run nr1.

The results of analysis show (Tab. III and IV) that the chemical nature of the processed ash changes distinctly as a result of plasma treatment. Regardless the analytical procedure the leachability of some heavy metals (e.g. As, Cu, Cr, Cd and Tl) decreased while the increase for others (Co, Ni and Pb) was observed. The results of leaching for Mo and Zn depend on the part of the system the product was collected from. Further testing will require the mass balance of elements to evaluate the overall chemical and physical transformations of ash components.

Table 2. RF plasma process parameters.

Run No. And sample	Power [kW]	Feed rate [g/min]	Mass of product collected in: [g]			Vaporization degree* [%]	Specific energy [kWh/kg]
			Cup	SUS tube	Glass tube		
1	25	4	47.71	3.93	10.18	22.8	104.2
2	25	10	51.59	3.03	10.06	20.2	41.7
3	35	2	8.54	1.17	1.46	23.5	291.7
4	35	4	47.67	5.68	7.54	21.7	145.8
5	35	10	53.37	4.49	7.42	18.2	58.3
6	45	4	47.69	6.3	7.77	22.8	187.5
7	45	10	54.49	3.49	8.26	17.7	75.0

* Quotient material collected from glass and SUS tube to entire collected material

Table 3. Content of metals, ppm (first procedure).

Run No. and sample	As	Co	Ni	Cu	Pb	Cr	Cd	Zn	Mo	Tl
Reference sample	0.12	0.072	0.24	3.53	0.5	1.99	0.57	28.2	0.67	0.1
1 Cup	0.075	0.095	0.37	0.033	5.3	7.74	0.13	18.3	0.87	< 0.0004
1 Glass Tube	0.14	0.036	0.037	0.21	2.7	< 0.09	0.11	24.8	1.6	0.001
1 SUS Tube	0.15	0.1	0.44	0.074	2.3	1.57	0.074	48.1	1.1	0.001
7 Cup	0.1	0.092	0.43	1.34	6.8	1.1	0.51	32.1	1	0.052
7 Glass Tube	0.16	0.061	0.42	0.13	0.4	0.52	0.055	16.5	0.62	< 0.001
7 SUS Tube	0.23	0.065	0.47	0.082	9.1	0.85	0.25	76.2	0.6	0.005

Table 4. Content of metals, ppm (second procedure).

Run No. and sample	As	Co	Ni	Cu	Pb	Cr	Cd	Zn	Mo	Tl
Reference sample	0.056	0.011	0.07	0.38	4	12.6	0.18	10.1	3	0.014
1 Cup	0.014	0.023	0.56	0.07	165	1	0.03	4.6	2.6	0.002
1 Glass Tube	0.056	0.02	0.19	0.014	0.8	< 0.14	0.11	< 0.7	2.4	< 0.001
1 SUS Tube	0.029	0.077	3.88	0.28	167	6.18	0.015	13.3	3	< 0.001
7 Cup	0.025	0.028	0.54	0.17	18.1	4.04	0.13	3.5	2.3	< 0.001
7 Glass Tube	0.044	0.064	2.45	0.22	6.8	3.82	0.041	9	5.3	0.001
7 SUS Tube	0.03	0.045	1.96	0.49	364	2.36	0.091	12.7	2.9	0.004

2. Coarse (B) and fine (A) ashes were fed into a DC plasma jet in the system shown in Fig. 2. The operating parameters of all runs are listed in Table V.

Table 5. DC plasma jet process parameters.

Run No	Ash	Mass [g]	Duration	Arc power [kW]	Feeding rate g/min	Specific energy kWh/kg
1.	B	3	3'18''	2	1.3	25.6
2.	B	7.5	5'44''	2.8	1.3	35.9
3.	A	11.5	4'51''	2	2.4	14.0
4.	A	20.3	7'29''	2.8	2.7	17.3

SEM observations (Figs. 6 and 7) did not reveal any distinct differences in the morphology of processed solids, even for fine fraction of ash and high power (run No. 2) Evidently, the plasma enthalpy is far too low even for a surface melting of the ash, in particular due to the relatively high feeding rate and large particle size (100 μm and less). In fact, the specific energy in all performed runs was rather low (between 17 and 36 kWh/kg), especially in comparison to RF plasma processing.

3. Operating parameters of ash treatment are shown in Table VI.

Melting degree between 40 and 93% were obtained in different runs, with the highest efficiency for fine bottom ash (material A). For this material correlation between melting degree and specific energy of the starting material was found, too. Chemical analyses are under way to better characterize the processed ash.

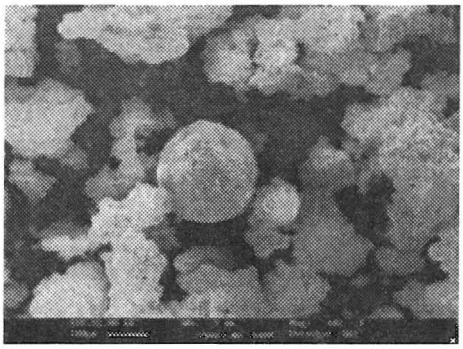

Fig. 6. SEM of the starting material.

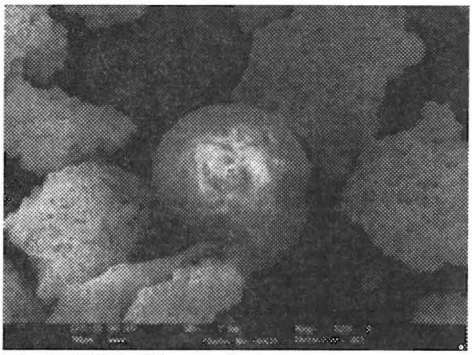

Fig. 7. SEM of the product.

Table 6. DC rotating plasma process parameters.

Material	Mass [g]	I [A]	U [V]	Duration	Power [kW]	Specific energy [kWh/kg]	Melting degree
A	51.8	110	45	2'26''	4.95	3.9	69
A	51	155	60	1'44''	9.30	5.3	84
A	54.2	198	65	3'40''	12.87	14.5	93
B	29.2	105	65	1'12''	6.83	4.7	83
B	54.6	105	65	3'55''	6.83	8.2	40
B	53	155	60	4'20''	9.30	12.7	73
D	50.2	95	55	6'20''	5.23	11.0	64
D	34.6	115	55	6'40''	6.33	20.3	65
E	54.2	105	65	2'4''	6.83	4.3	59
E	53.6	198	55	2'5''	10.89	7.1	81
E	43.4	195	75	32''	14.63	3.0	70

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OBRÓBKA PLAZMOWA POPIOŁÓW POSPALENIOWYCH

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S t r e s z c z e n i e. Popiół pospaleniowy pozostały po spaleniu odpadów domowych przerabiano w różnych systemach plazmy termicznej. Różne metody analityczne fizyczne i chemiczne były wykorzystane do charakteryzacji produktów. Potwierdzono częściowe nadtopienie powierzchni przerabianych pyłów.

S ł o w a k l u c z o w e : plazma termiczna, obróbka odpadów, popiół pospaleniowy.