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Plasma Vitrification of Waste Incinerator Ashes

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ABSTRACT

The results of vitrification of partially toxic ashes mixed with the power plant fly ash are presented and discussed. . The vitrification process was done with the use of plasma torch reactor. The vitrified product properties including hardness and leaching tests results for different ash to filler ratio are presented. The final product (vitrified material)obtained after the plasma treatment is environmentally acceptable. It can return to the environment as an aggregate in the construction industry.

INTRODUCTION

The incineration of some wastes (e.g. industrial, medical, military) results in the formation of relatively highly toxic residues. The toxic leftovers (ash, slag, filter deposits, sedimentation residues) could be easily disposed in landfills assuming that they were first immobilised and converted into a non leaching product. When the leftovers are heated to a sufficient temperature, their elements, including minerals and toxic heavy metals, melt and glassify. Various molten-glass processes are commercially available for the destruction and/or immobilisation of toxic residues.[1,4] Even partial solidification (vitrification) of those residues requires the temperature above 1700 K which is not available in most incinerators but easily reachable in thermal plasma reactors.[2] Temperatures of the order of 10000 K are typical for arc in plasma furnaces and all inorganic residues can be solidified. The system of plasma vitrification of ash produces a chemically stable and mechanically resistant product. After vitrification the mineral product looks like a glassy, basalt structured lava (even of higher than basalt mechanical strength), and its main components are silicon, aluminium and calcium oxides in the form of chemically inactive compounds, resistant to flushing.

In Poland there is a number of small medical waste incinerators (each serving a few hospitals) dispersed around the country. The output of toxic residues of particular incinerators can be not sufficient for continuous feeding of plasma furnace requiring about 500 kg ashes per hour. However there is a lot of fly ashes coming from the coal fired power plants. Because of similar morphology of fly ashes they can be used as an admixture to the medical ashes.

The aim of our work was to melt and vitrify the ashes coming from medical waste incinerators with power plant fly ashes acting as a filler. The vitrification process was done with the use of plasma torch reactor. The vitrified product properties including hardness and leaching tests results for different ash and filler ratio are presented.

EXPERIMENTAL

The DC plasma furnace as the heating system was designed in the Technical University of Lodz and applied to treat the ash samples with high degree of flexibility. The furnace was water-cooled and the transferred arc-plasma system had a maximum output power of 150 kW. The position of the torch inside the reactor could be modified, altering the length of the transferred arc. A gravity feeding system was developed for the process. The temperatures of different points of the reactor were measured, the signals from the measuring devices as well as the arc current, arc voltage and amount of material being fed were stored by a data acquisition system and a portable computer. The gases generated in the process passed through a condenser, a wet cleaning system and then stacked. At the beginning a single, water-cooled, plasma torch was operating in a non transferred mode producing laminar argon plasma-jet flow. After reaching the sufficient electrical conductivity between the feed and the graphite crucible, the laminar torch was automatically switched on to transferred arc mode. Before each operation the furnace was purged with argon to avoid oxidation and it was preheated within two hours. The plasma power was adjusted to ensure efficient melting and sufficient melt liquidity of the material feed. Throughout the test, I-U characteristics, torch and reactor cooling losses, feed rate and furnace temperature, were recorded.

The temperature of the furnace charge was measured with an infrared camera with very narrow spectral range 0.8-1.1 mm and very small target area 0.16 mm^2 allowed the accuracy ±0.5% with computer data logging.

Some samples of vitrified material in the form of lumps were tested with the Vicker's method. to measure their hardness.

The heavy metals leaching tests are made using demineralised water with conductivity below $0.1 \cdot 10^{-9}$ S/cm. Extraction was done for 24 hours in shaker at room temperature. Concentrations of ions in the extracts are measured by anodic stripping voltamperometric technique (the graphite electrode with mercury membrane is applied).

Determination of oxides concentration in ashes was done using the method of X-ray fluorescence spectrometry.

RESULTS

The typical bottom ash from one of the Polish hospital incinerators was taken as representative sample of medical toxic residues. The ash was obtained from the incinerator after being collected for a few days. Since the ash was kept in an open air it contained about 10% humidity. As the filler we have used a fly ash produced by typical coal fired power plant of Lodz district (EC-2). The morphology of the both ashes is presented in Table 1.

During each run typically 5 kg of mineral feed (homogenised ash) was melted and continuously overflowed. Casting in the water-cooled container gave the lumps of the final vitrified product. The solid material obtained after cooling was then analysed. Both the feed and the product weights were recorded for mass balance purposes.

The vitrification tests were carried out in the plasma reactor described previously.[3] The main compound of the both streams (bottom and fly ashes) was silica oxide. This influenced the

melting point of the mixture being between 1550 – 1600^{0}C. The plasma furnace after preheating during 6 hours was ready to run the test lasting half an hour.
The testing were done for three different ratios of bottom to fly ash (0.25, 0.50, 0.75). In all the cases the cooled slag was homogenous and vitreous in nature. The final product looks like a having basalt structure. The vitrified material mass was only 85% of mass of the material fed into to furnace for the mixture ratio 0.75 and 95% for the mixture ratio 0.25.

Table 1. Chemical analysis of the hospital incinerator bottom ash and the power plant fly ash

Oxide	**Content**	
	Bottom ash [weight %]	*Fly ash* [weight %]
SiO_2	47.35	50.02
Al_2O_3	3.05	23.20
Fe_2O_3	7.35	9.25
Mn_3O_4	*	0.15
TiO_2	*	0.96
CaO	16.25	4.08
Na_2O	*	0.96
MgO	2.45	2.48
K_2O	*	3.40
P_2O_5	0.30	0.32
SO_3	0.48	0.52
Organic compounds	*	4.25

*) contents not measured

The example of plasma vitrified product for 50/50% mixture of bottom ash coming from medical waste incineration and fly ash coming from the power plant is shown in Fig.1.

Table 2. Analysis of heavy metals concentration in aqueous extract obtained from leaching test for bottom ash (medical incinerator), fly ash (power plant) and vitrified slag for mixture of bottom and fly ashes 50/50%.

Metal ion	**Concentration in aqueous extract [mg/dm^3]**		
	Bottom ash	*Fly ash*	*Vitrified slag*
Pb^{2+}	0.80	0.50	<0.005 *
Cu^{2+}	0.63	0.55	0.010
Ni^{2+}	0.84	0.28	<0.005 *
Zn^{2+}	0.52	0.66	<0.005 *
Cr^{3+}	0.05	2.26	<0.005 *
Mn^{2+}	0.42	0.78	<0.005 *

* Below detectable limit

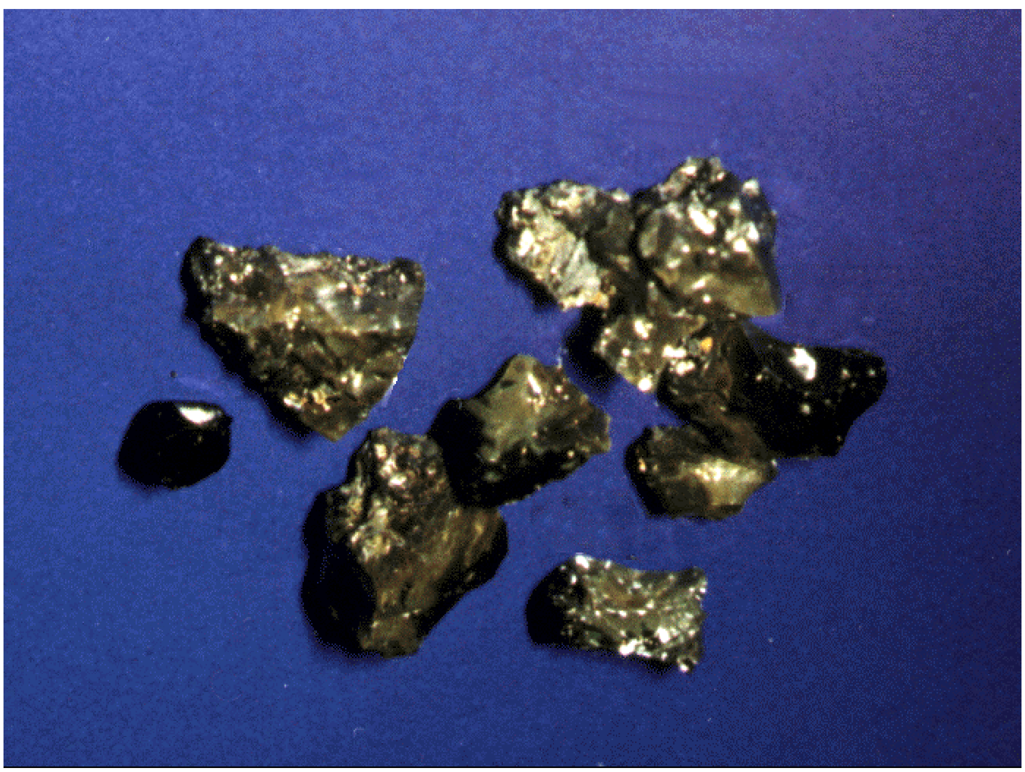

Fig.1 The plasma vitrified product for 50/50% mixture of bottom ash coming from medical waste incineration and fly ash coming from the power plant

CONCLUSIONS

It has been proved that the designed plasma furnace is efficient in vitrification of ashes coming from medical incinerators (partially toxic) mixed with power plant fly ash (mostly inert). In all the cases the cooled slag was homogenous and vitreous in nature and it was having basalt -like structure resistant to leaching (Table 2). The Vicker's hardness of the product samples depended on the mixture composition and varied between 480 and 520. The higher value corresponds to the lower ratio of the medical bottom ash to the power plant fly ash. It is caused by the higher content of Al_2O_3 in the fly ash (Table 1). The final product obtained after the plasma treatment (vitrified material) is environmentally acceptable. It can return to the environment as an aggregate in the construction industry.

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