Plasma-thermal remelting of ash and slag waste from waste incineration plants

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Abstract. This work is devoted to the study of the process of processing ash residues from a waste incineration plant (WIP) using a computational and experimental approach. The purpose of this work is to prevent environmental pollution by melting WIP ash and slag and obtaining a useful product with neutral properties. To achieve this goal, a combined method of heating ash and slag was proposed.

1 ntroduction

Thermal neutralization of municipal solid waste (MSW) is the most effective way to solve the problem of cleaning populated areas from household waste. Despite some shortcomings, the current situation requires an immediate solution to this problem, and waste incineration plants (WIPs) provide the opportunity to do this quickly, despite technical and technological limitations. It should be noted that the main problems of the MSZ are related to the purification of highly toxic gases and the disposal of ash and slag materials. There are fly ash and bottom ash. Fly ash is carried away from the combustion chamber with exhaust gases and is retained by cyclones and bag filters. It contains a high content of volatile and heavy metals and toxic substances absorbed on its particles. The bottom ash, which forms on the firebox grate and is discharged from the furnace grates, also contains heavy metals, but less than in fly ash.

The chemical composition of ash and slag waste contains basic elements, such as: CaO 12.3 – 32.6%; MgO – 2.2 – 3.8%; SiO_2 – 11.8 – 48%; Al_2O_3 – 3.6 – 11.1%; Fe_2O_3 – 7.2 – 11.3%; Na_2O – 0.5 – 6.4%; K_2O - 1.2 – 3.9%; SO_3 – 1.2 – 10.1%; TiO_2 – 0.2 – 4.7%; Cl - 1.8 – 7%; C – 2.3%; H_2O – 4.7%. Analyzes were carried out for Moscow MSZ No. 2, Incheon, South Korea and Cherepovets.

The defining compounds of ash residues are oxides of silicon, calcium, and aluminum, which determine the melting point and properties of the slag after the melt. In addition, they contain alkali metals, rare earth elements, heavy metals and trace elements.

One of the real ways to solve the problem of processing hazardous ash and slag waste from incineration plants is its melting in a plasma-thermal electric furnace, which leads to a significant reduction in the volume of ash and converts it into a chemically inert slag. The fusibility characteristics of ash and slag have been established [1]: the liquid-melting state of slag is 1130°C and ash is 1110°C.

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1.1 Technological feature for melt ash WIP

Despite the variety of methods for processing toxic ash residues from MSZ, the most effective industrial equipment is ore-smelting furnaces with direct or 3-phase alternating current.

For The purpose of melting the MSZ ash residue, without chemical reactions, is the need to homogenize several oxides, significantly reduce the volume of ash and convert it into vitrified inert slag.

Any such furnace is the main element of the technological chain, which includes equipment for removing and receiving smelting products (slags and gases) from the furnace and their subsequent processing. The peripheral part of the furnace includes a power source, a cooling and exhaust gas purification system, molds for receiving molten slag and a number of other elements.

In both designs, the melt of the ash and slag charge initially begins with an arc discharge between the electrodes along conductive channels (graphite tracks) with the formation of electric arc plasma, from which the surrounding charge melts. Then the discharge stops and the melting process continues with resistive heating of the ash and slag until the melt is drained. Thus, heating and melting of dispersed ash and slag particles is carried out by a combined method - arc plasma and resistive due to the flow of electric current. Therefore, electric melting furnaces are called plasma-thermal.

In order to improve the conditions of slag-smelting production and the flowability of ash into the volume of the electric furnace, the ash residues of the MSZ are subject to granulation (granule diameter 2-2.5 mm).

Since ash melting occurs mainly by Joule heating of the charge, special requirements for current (kiloamperes) and voltage (hundreds of volts) are imposed on the power supply of the ore smelting furnace. To obtain vitrified inert slag, about 2% wt. is added to the ash composition. limestone in the form of $CaCO_3$ or fluff $Ca(OH)_2$.

2 Experimental melting of WIP ash

2.1 Experimental setup

Experimental studies were carried out on the basis of the Novokuznetsk Metallurgical Plant together with SDB of electrothermal equipment.

Positi In figure 1 shows a diagram of the ore smelting plant. It consists of: an electric furnace, a thyristor power supply, a gas cleaning system, and a container for draining fused slag. The furnace is a metal water-cooled casing, lined from the inside with high-temperature brick. A bottom electrode – anode – is installed on the bottom of the furnace. Loading the furnace with ash and slag is carried out by one-time supply of material into the furnace volume. The arc is ignited between the graphite electrode - the cathode and the melt pool by touching the electrodes and then spreading them apart.

The melt temperature is measured by an optical pyrometer OPPIR-017. Power supply parameters: U_{xx} = 90 V, I_{nom} = 5.0 kA. Flue gases are removed by a smoke exhauster through a cleaning system (cyclone, bag filter) into the exhaust pipe. The melting times of the ash and slag residue are indicated below.

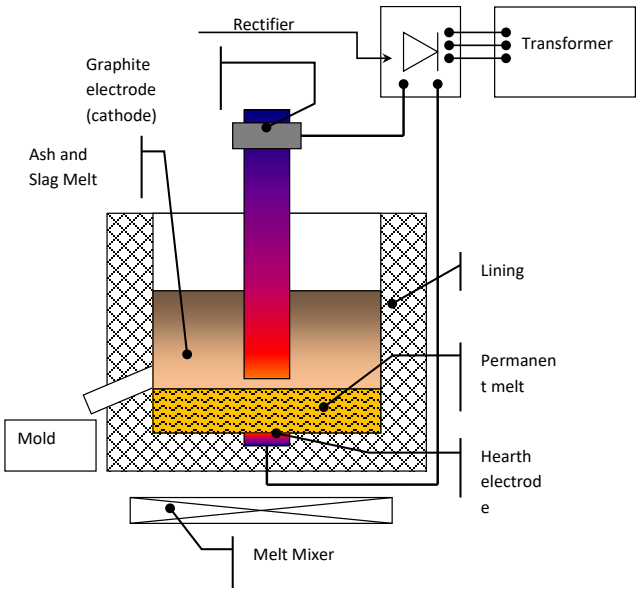

Fig. 1. Diagram of the ash remelting installation.

2.2 Experimental ash smelting

The ore smelting electric furnace was preheated for 20 minutes. arc discharge on coke. During the warm-up period, discharge parameters: U = 60 V, I = 4.0 kA. After heating, ash was gradually poured (in portions of 29 kg) into the electric furnace. Initially the load was 95kg. It was carried out within 7 minutes. The current did not decrease, because the main process took place on coke (carbon). After 27 min. During the remelting process, the arc current remained at the same level.

The ash was located on the walls of the electric furnace. Mechanically it moved to the center of the melt. Added 225 kg of ash. The total loading weight was 320 kg. During the loading process, the current decreased to I = 3.5 kA. After loading the entire mass of ash, the current dropped to I = 2.5 kA, the voltage remained at the same level (U = 60 V). After 23 min. a melt swamp appeared, the burning of the arc discharge stopped. 50 kg of limestone ($CaCO_3$) was added to the melted ash. Melting of the ash and slag continued by resistive heating due to the flow of current. By heat transfer from the resulting melt and mixing of the molten mass, homogenization of the entire melt occurs.

As the melt appeared, the current gradually increased. By the time the ash completely melted, I = 4.5 kA, U = 60 V. The ash melt time was 2 hours 55 minutes. The time for draining the molten ash was 13 minutes. The drainage was carried out into a container with water twater = 20^0C. The full cycle of the experiment (heating, remelting, draining) was 3 hours 30 minutes. Temperature of the ash melt at the drain tmelt=1350^0C.

The specific electricity consumption was 1.08 kWh/kg.

Fig. 2. Vitrified slag.

3 Conclusion

As a result of targeted scientific and technical research, a plasma-thermal technology for melting toxic ash and slag waste from waste incineration plants was proposed and justified. The equipment is based on an ore smelting electric furnace of direct or 3-phase alternating current with the capacity of the corresponding incinerator for municipal waste. The experimental studies carried out showed the high efficiency of melting the ash residue of the MSZ for the ecology of the environment.

This work was carried out under state contract with IT SB RAS (№ 121031800229-1)

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