DEVELOPMENT OF A CONTINUOUS INDUCTION MELTER FOR DRY ACTIVE WASTE TREATMENT

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ABSTRACT

A continuous melter with inductively heated graphite cylinder-packed bed for dry active wastes treatment was developed for the purposes of treatment facility scale reduction and melting treatment rate increase. The melts flowed down through the packed bed and are continuously discharged from a notch. This paper reports the melting treatment rate of a 10kHz, 100kW pilot melter, refractory wall lifetime extension by lowering its porosity and having a waste feeding tube smaller than the melter inner diameter to lower the melts attachment rate to the refractory wall, diameter and composition of dust particle in the exhaust gas and its removal by ceramic filter.

Carbon Steel (CS) tubes, glass wool, and calcium silicate heat insulating materials were separately added to the melter, to measure melting treatment rates for them. To examine the effect of a low porosity on corrosion lowering, alumina refractory specimens with different porosity were soaked in a crucible with melts at a temperature of 1600□, and rotated in the melts along their longitudinal axis to accelerate corrosion. To examine the effect of the waste feeding tube on lowering melts attachment amount to the wall, simulated liquid flow experiments were done using waste guide tubes with different inner diameters and a packed bed of plastic cylinders in a vessel simulating the 100kW pilot melter, at first. Then, to certify the effect of the waste guide tube on lowering the wall corrosion, calcium silicate was melted in the 100kW pilot melter. Exhaust gas from the melter was sampled to analyze the dust particle diameter by Cascade Impacter Method, and its composition by X-ray diffraction. Then, the exhaust gas was also sampled to analyze the dust particle density before and after it passed through the ceramic filter.

Iron and heat insulating materials were melted and discharged without any problems. High frequency electric power inputs and melting treatment rates were 92kW, 140kg/h for CS melting, and 85kW, 45kg/h for heat insulating materials melting. Corrosion depth of the refractory specimen depended strongly on the kind of melts and the refractory porosity. By lowering the porosity to nearly zero, the corrosion depth was lowered to 1/20 of

that with a conventional refractory. When the gap between inner walls of waste guide tube and vessel was equivalent to one diameter of graphite cylinder, the simulated liquid attachment amount to the wall was lowered to 1/10 of that without the waste guide tube. The effect of the waste guide tube was confirmed by the refractory corrosion in the melter, too. The dust density after the ceramic filter was less thandetection limit (10mg/scm) for all major waste materials.

INTRODUCTION

A continuous induction melter system for dry active waste treatment was developed for the purposes of treatment facility scale reduction and melting treatment rate increment [1]-[3]. The melter system mainly consists of an induction melter and an off-gas treatment system (Fig.1). The induction melter includes the graphite cylinder-packed bed on which the wastes are melted by direct induction heating and heat transfer from the inductively heated graphite-packed bed. The melts flow down through the packed bed and are continuously discharged from a notch. The melter has the following characteristics: (I) a large melting treatment rate per facility scale; (II) an ability to melt wastes independent of their electric conductivity; (III) safe operation due to detachment of the melts from wastes on the packed bed; and (IV) a a small corrosivity of the melter refractory per waste treatment amount due to the short time from melting to discharge of the melts. On the other hand, exhaust gas from the melter may include flammable elements (CO and hydrocarbons), dust, and radioactive materials. The flammable elements are incinerated in the incinerator, while dust and the radioactive elements are removed by the ceramic filter.

This paper reports the melting treatment rate measurements of the two major waste materials, carbon steel (CS) and heat insulating materials, in a 100kW pilot melter, the effect of a small refractory porosity on the lowering of the corrosivity, and the effect of having a waste feeding tube smaller than the melter inner diameter on lowering the melts attachment rate to the melter refractory wall, for a longer period between the refractory wall maintenance work. This paper also reports some characteristics of the exhaust gas and the ceramic filter performance. The examined characteristics for the exhaust gas were particle diameter and composition of the dust for each major waste material to be melted and each organic waste compound to be decomposed. The ceramic filter was examined if dust density in the exhaust gas could be lowered to less than 50mg/scm [4]-[5].

EXPERIMENTAL

Melting Treatment Rate Measurements

The 100kW pilot melter system mainly consists of a 10kHz high frequency electric power generator, a melter, an incinerator, and a ceramic filter. Major specifications of the melter are listed in table 1. Iron tubes (diameter: 0.04m, height: 0.1m), and heat insulating materials of glass wool and of calcium silicate were separately added to the melter, and each kind of melt was discharged to a graphite crucible continuously. When the discharge rate reached its maximum value and remained constant, this rate was defined as the melting treatment rate of the respective melt.

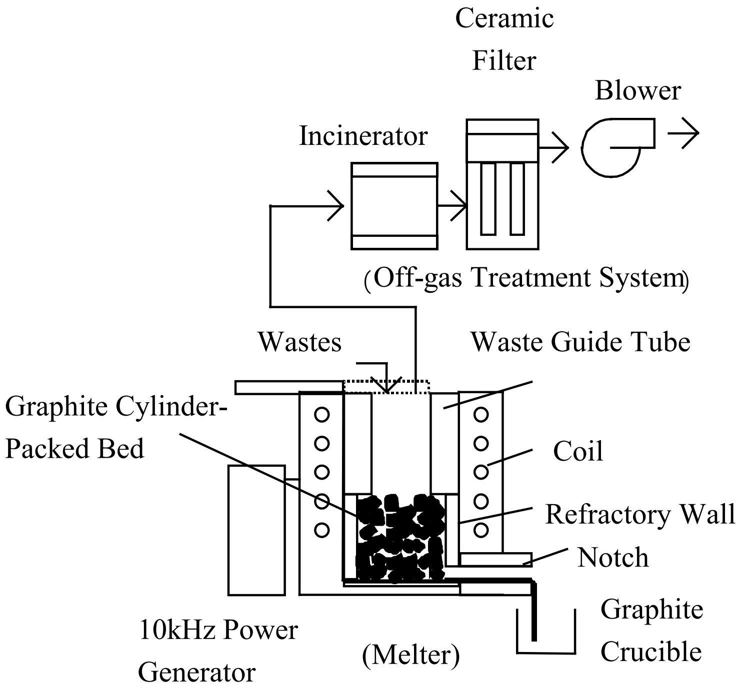

Figure 1 A Continuous Induction Melter System.

Table 1 Specifications of Melter.

Terms	Specifications
Output Power (kW)	100
Frequency (Hz)	10
Melter Inner Volume (m^3)	0.05
Graphite Cylinder Size (m)	diameter: 0.07, height: 0.07

Corrosion Tests for Refractory with Low Porosity

Alumina refractory specimens (diameter: 0.015m, height: 0.06m) with different porosities were soaked in a crucible filled with melts at a temperature of 1600. The melts were the three major waste materials: stainless steel (SS), glass wool, and calcium silicate. The refractory specimens were rotated in the crucible along their longitudinal axis to accelerate corrosion. After that, the specimens were removed and corroded depth was measured.

Measurements of Melt Attachment Amount on the Wall with a Waste Guide Tube

At first, simulated liquid flow experiments were done using different inner diameters of thin, waste guide tubes. A vessel, simulating the 100kW pilot melter, was made of a transparent acrylic acid resin to make its inside visible (Fig. 2). The vessel was packed with plastic cylinders simulating graphite ones. As the liquids simulating iron and glass wool, water and glycerol were chosen from the standpoint of their viscosity and adhesion tension to the packed bed. In the experiments, the amount of liquid attachment to the vessel wall was measured as a function of the waste guide tube inner diameter, and the diameter at which the attachment amount was lowered to 10% of that without the waste guide tube was obtained.

Then, calcium silicate heat insulating materials were melted in the 100kW pilot melter using an alumina cement feeding tube with the obtained diameter. Eight alumina refractory plates with 60% porosity were put around the graphite-packed bed in the melter, to undergo corrosion by melts attachment. The refractory porosity of 60% was chosen to increase the refractory corrosivity for easy comparison of corrosion depth between the cases with the waste guide tube and without it.

Analyses of Dust from Melter and Dust Removal Tests by Ceramic Filter

At first, gas generated in the melter was sampled to analyze the dust particle diameter, and its composition when each of the major waste materials (CS, glass wool, and calcium silicate heat insulating materials, and poly-vinyl acetate bags) were treated in the melter. The weight distribution of dust particle as a function of particle diameter (0.43µm-11µm) was measured by the Cascade Impacter Method [6]. The dust composition was examined by X-ray diffraction.

The exhaust gas was also sampled to analyze the dust particle density before and after it passed through the ceramic filter (Dia-Schumalith FT20 [8]) to see filter removal performance for each waste material. The gas was sampled at a constant flow rate, and then filtered. The dust particle density was calculated from the sampled gas volume and the weight of the dust on the filter [7]. The dust particle density values obtained before and after the ceramic filter were compared to each other.

RESULTS

Melting Treatment Rate

Figure 3 shows time dependence of the melting treatment rate. A half hour after the melting treatment started, the melting treatment rate became constant. Iron and heat insulating materials were melted and discharged without any problems.

Table 2 Specifications of ceramic filter used in the experiments.

Terms		Specifications
Material		SiC
Average Pore Diameter (μm)		10
Porosity		0.35
Gas Permeability Coefficient (cm^3□s cm^2)		0.85
Gas Flow Rate (scm)		50
Size(m)	Element	Diameter: 0.06, Height: 1.5, 12 Elements
	Housing	Diameter: 1.7, Height: 3.239

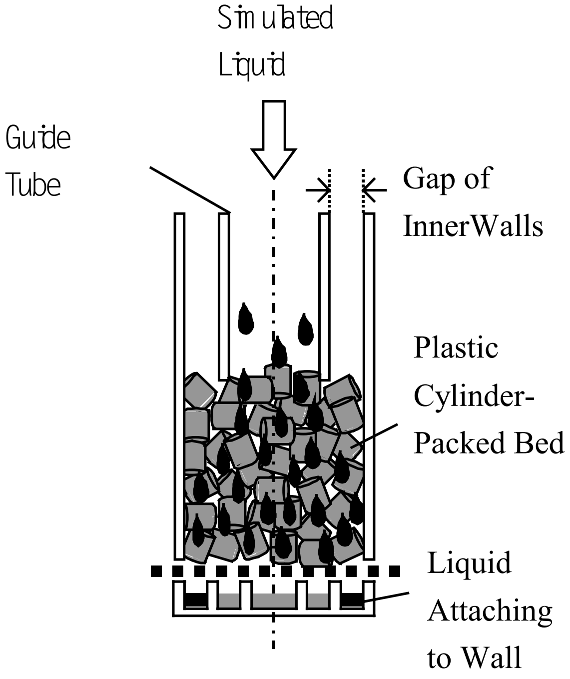

Figure 2 Apparatus for Simulated Liquid Flow Experiments.

High frequency electric power inputs and melting treatment rates were 92kW, 140kg/h for CS melting, and 85kW, 45kg/h for heat insulating materials melting.

Figure 4 shows dependence of melting treatment rate on electric power input. The melting treatment rate increased with the electric power. So, the necessary treatment rate could be obtained by choosing an appropriate electric power input.

Refractory Corrosion as a Function of Its Porosity

Figure 5 shows dependence of refractory corrosion depth on its porosity for different melts. Corrosion depth of the refractory specimen depended strongly on the kind of melts and the refractory porosity. For SS, the refractory corrosion depth was independent of its porosity, and negligible. For calcium silicate and glass wool, the corrosion depth increased with the porosity. By lowering the porosity to nearly zero, the corrosion depth was lowered to 1/20 of that with a conventional refractory (porosity: about 20%).

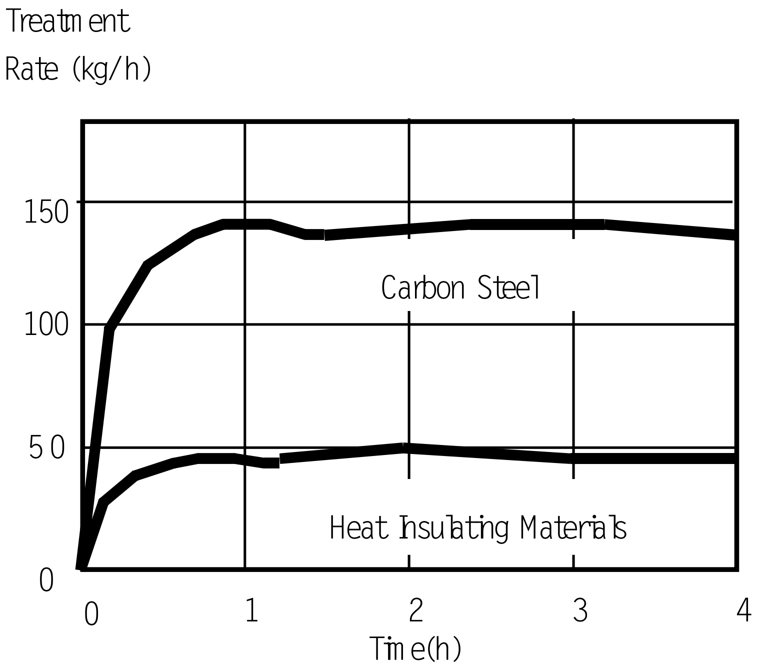

Figure 3 Time Dependence of Waste Melting Treatment Rate.

Effect of Waste Guide Tube on Lowering Melt Attachment to the Wall

Figure 6 shows dependence of simulated liquid volume attaching to inner wall of vessel, on a gap between inner walls of vessel and the waste guide tube. When the gap was equivalent to one diameter of graphite cylinder, the simulated liquid attachment amount to the wall was lowered to 1/10 of that without the waste guide tube, for each simulated liquid.

The effect of the feeding tube was confirmed by the refractory corrosion test in the melter, too. With the waste guide tube having the same inner radius as above, corrosion depth was about one tenth as much as that without the feeding tube. So, by using the refractory with a very small porosity and the waste guide tube, the refractory lifetime was expected to be 200 times as long as that without them.

Dust Particle Diameter, Its Composition, and Ceramic Filter Performance

In the case of calcium silicate heat insulating materials, the weight distribution of the dust particle was flat against its diameter, and the dust was α-$CaSiO_3$ and β-Ca_2SiO_4. In the case of glass wool, the weight distribution of the dust particle had two peaks at diameters of less than 0.43µm and about 10µm, and the dust was $9Al_2O_3$□$2B_2O_3$. In the case of carbon steel, the weight distribution of the dust particle had one peak at a diameter of less than 0.43μm, and the dust was α-Fe and FeO. In the case of poly-vinyl acetate, the weight distribution of the dust particle had one peak at a diameter of larger than 11μm, and the dust was carbon.

Table 3 lists measured results of dust densities in the exhaust gas at points before and after the ceramic filter. The dust particle density after the ceramic filter was less than the detection limit (10mg/scm) for all major waste materials. So, the ceramic filter performance satisfied the exhaust condition (50mg/scm [4]).

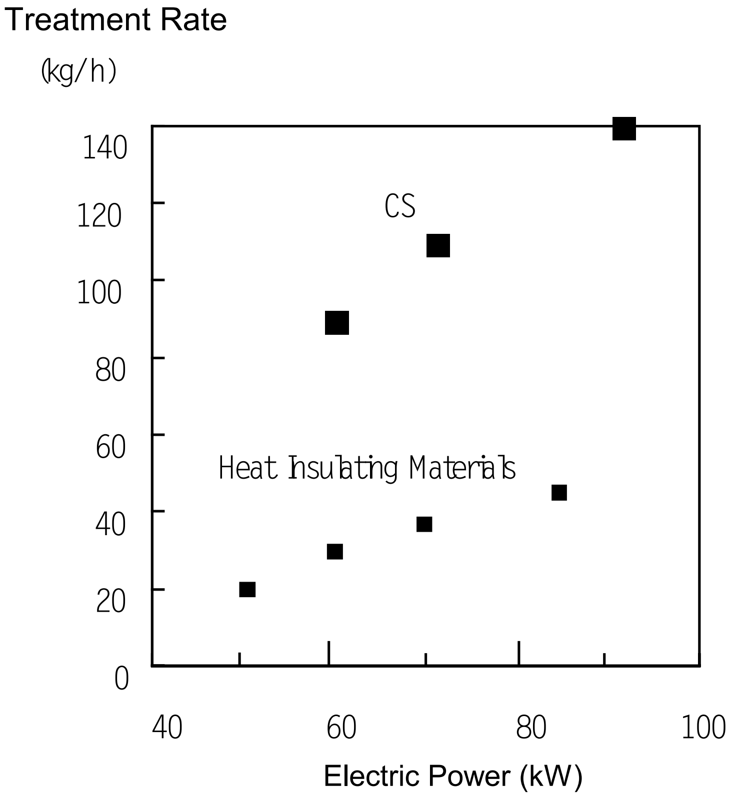

Figure 4 Dependence of Melting Treatment Rate on Electric Power Input.

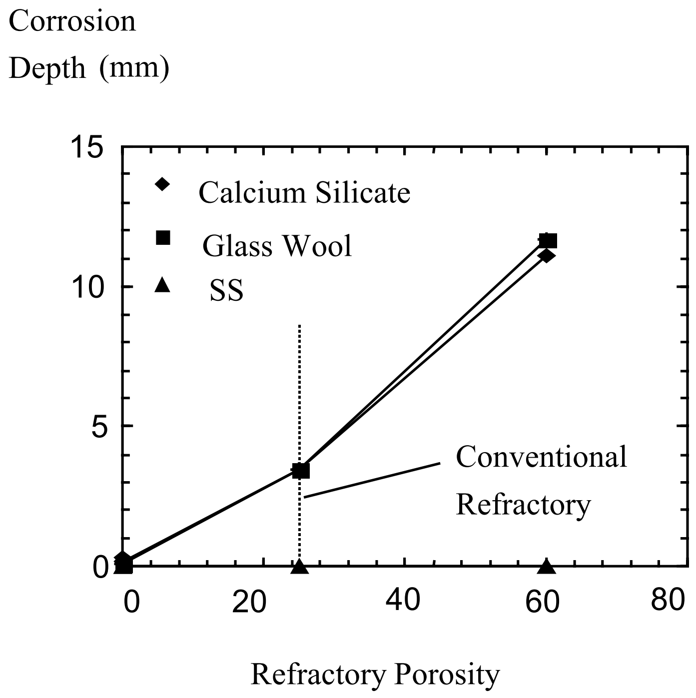

Figure 5 Dependence of Refractory Corrosion on Its Porosity for three melts.

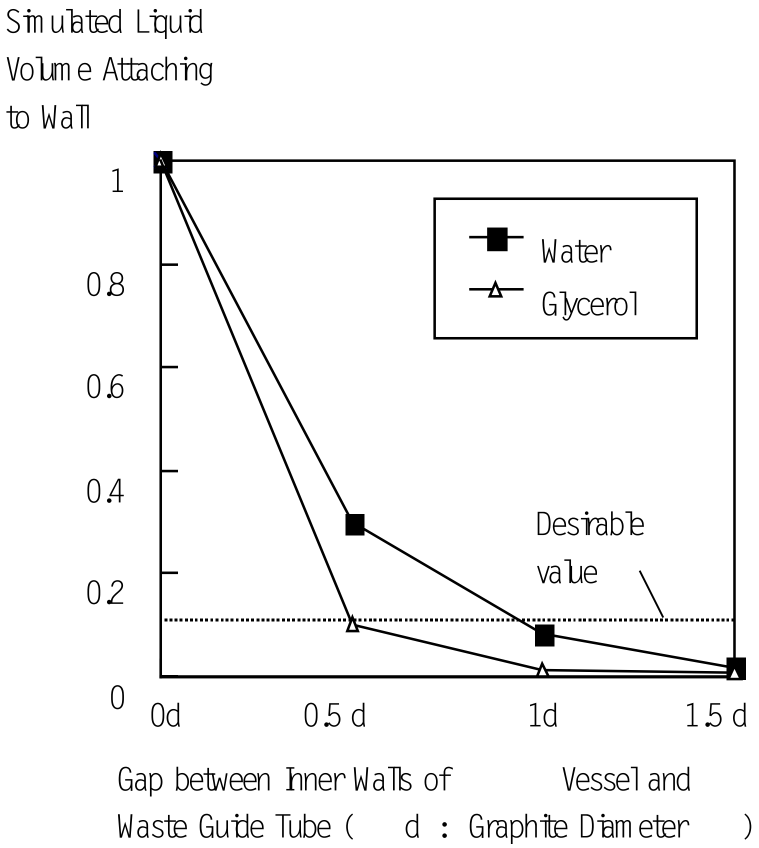

Figure 6 Dependence of Simulated Liquid Volume Attaching to Inner Wall of Vessel, on Gap Between Inner Walls of Vessel and Waste Guide Tube.

Table 3 Ceramic filter performance for dust removal.

Waste Materials		Calcium Silicate	Glass Wool	Carbon Steel	Poly-Vinyl Accetate
Density (g/Nm^3)	Before Ceramic Filter	1.6	0.09	4.4	1.96
	After Ceramic Filter	<0.01	<0.01	<0.01	<0.01

CONCLUSIONS

A continuous induction melter system for dry active waste treatment was developed, with an off-gas treatment system. The melter included the inductively heated graphite cylinder-packed bed, thorough which the melts flowed down and were continuously discharged from. The following conclusions were obtained.

1. Iron and heat insulating materials were melted and discharged without any problems. High frequency electric power inputs and melting treatment rates were 92kW, 140kg/h for CS melting, and 85kW, 45kg/h for heat

insulating materials melting.

2. Corrosion depth of the refractory specimen depended strongly on the kind of melts and the refractory porosity. By lowering the porosity to nearly zero, the corrosion depth was lowered to 1/20 of that with a normal refractory porosity (about 20%).

3. When the gap between inner walls of vessel and waste guide tube was equivalent to one diameter of graphite cylinder, the simulated liquid attachment amount to the wall was lowered to 1/10 of that without the waste guide tube. The effect of the waste guide tube was confirmed by the refractory corrosion in the melter, too. So, by using the refractory with a very small porosity and the feeding tube, the refractory lifetime would be expected to be 200 times as long as that without them.

4. Dust density in exhaust gas from the meter could be lowered to less than 10mg/scm, independently of treated waste materials.

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