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Separation Characteristics of Heavy Metal Compounds by Hot Gas Cleaning System

Keywords: Gasifying-Melting Furnace, Hot Gas Cleaning, Small-Scale Industrial Waste Incineration, Heavy Metal Compounds

Introduction

Industrial waste is thermally treated to reduce its volume. Then majority of heavy metal components in the waste migrates to flue gas side. Since most of them are potential catalyst for dioxin generation so that it is desirable to remove them at higher temperature than its re-synthesizing temperature region.

Hot gas cleaning is a method to collect solid particles at elevated temperature but of course it does not separate gaseous materials. This suggests that heavy metal can be separated selectively from flue gas containing many heavy metal compounds by operating at different temperatures.

Objectives and Approach

The purpose of this research is the basic study for the development of separation technology of heavy metal compounds from hot flue gas. **Figure 1** depicts the separation concept of heavy metal compounds. While the hot flue gas containing heavy metals from a melting furnace of industrial waste passes through the high temperature dust collector which can be varied the operating temperature. The heavy metals can be separated due to different boiling point of each heavy metal. On the basis of this concept, the concentration of heavy metals in the flue gas were sampled and measured at inlet, outlet of the ceramic filter housing in the actual industrial waste processing system. Speciation of heavy metals in collected ashes was clarified by separating heavy metals according to compounds using their elution characteristics. Moreover, equilibrium analysis was performed to determine the effect of temperature, flue gases conditions on heavy metals speciation, and it was compared with experimental data. From these results, we discussed about separation performance of heavy metal compounds by hot gas cleaning.

Experimental

Figure 2 shows the schematic diagram of industrial waste processing system for this study. A typical composition of car shredder dusts is shown in **Table 1**. In table 1, a non combustible ingredient contains heavy metals such as Si, Ca, Fe, Cu, Na, Al, Cd, Pb, Zn, Cr, As and Ti. Car shredder dusts were fed at a rate of 75kg/hr into a pyrolysis incinerator. Hot flue gas was treated at high temperature dust collector with a ceramic filter. The physical property of the ceramic honeycomb filter (CERALLEC, NGK Insulators, Ltd.) which is installed in high temperature dust collector is shown in **Table 2**.

In order to consider the influence of the sampling temperature on the state of heavy metal in the fly ash, the sampling methods as shown in Figure 3 were adopted and to identify the kind of metals in fly ash at the dust collector inlet and outlet, fly ash and captured dust are analyzed. About 1g of ash was dissolved with 100 ml distilled water and boiled for 5 minutes. After filtration (Millipore, pore size 0.2μm), it divided into water soluble and non-water soluble materials then analyzed by ICP (HITACHI, P-4010S).

Thermodynamics Equilibrium Analysis of Heavy Metal Compounds

Assuming that the reaction between the heavy metal and HCl, SO_2 in high temperature dust collector were pseudo-first-order reaction, the temperature dependability of the heavy metal compound to combustion exhaust gas composition was analyzed by thermodynamics equilibrium analysis software (FACTSage 5.0).

Results and Discussion

Hot flue gas emitted from the gasifying-melting furnace during car shredder dust incineration entered hot gas cleaner. **Table 3** shows total and fractional separation efficiency of heavy metal compounds with ceramic filter, together with equilibrium analyzing results. It is shown in Table 3, total dust collection efficiency is high (96%) and there is a good agreement between experimental data and with equilibrium analyzing ones except Cd, As, Hg. Moreover, Cu called catalyst of dioxin generation is removable with the high temperature gas cleaning system.

Table 4 and **Table 5** show existence state of Pb and Cu compounds at various sampling temperature. As seen in Table 4, the agreement between experimental data and with equilibrium analyzing ones are good and a decrease in the sampling temperature shifts the existence of Pb-chloride particles. On the other hand, a increase in the sampling temperature shifts the existence of Pb-sulfate particles. From the results of Table 5, Cu compounds mainly exist not as water-soluble compounds but water-insoluble compounds (CuO) at inlet sampling point.

Figures 4~6 show the influence of temperature, HCl gas concentration and SO_2 gas concentration on existence state of Pb, Cu compounds. As seen in figure 6, the concentration of SO_2 gas increases, the mass fraction of Pb-sulfate rapidly increases. It is indicate that SO_2 gas concentration is greater effect on gas to particle conversion of Pb than HCl gas concentration.

Conclusions

To investigate compositions of heavy metals Cu, Pb in the hot flue gas and fly ash, gas and fly ash from the hot gas cleaning system have been sampled and analyzed. The results have been compared with equilibrium analyzing result.

Cu compounds in the hot flue gas were existed as solid and collected by the hot gas cleaning. Therefore, it is found that the Cu called catalyst of dioxin generation is removable with the high temperature gas cleaning system.

Pb compounds were easily affected by the flue gases composition, especially by SO_2 gas and then showed phase changing from gas phase compounds to solid phase compounds at the high temperature.

Acknowledgement

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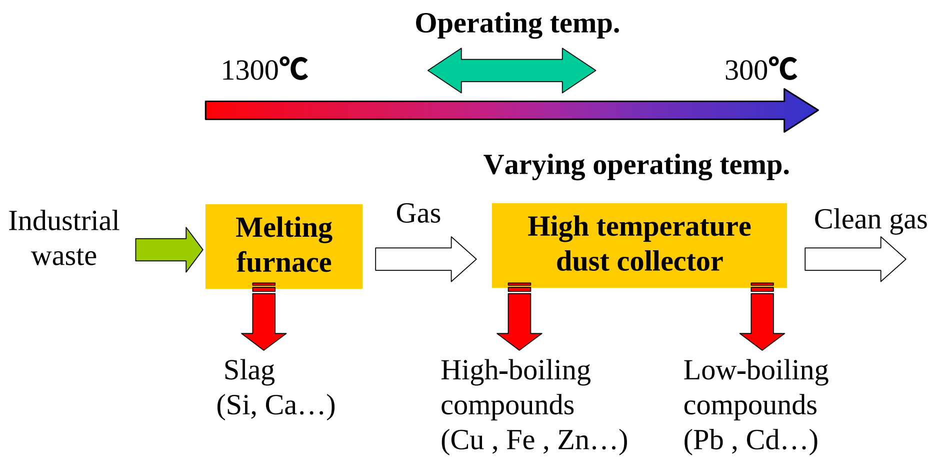

Fig.1 Separation of heavy metal compounds.

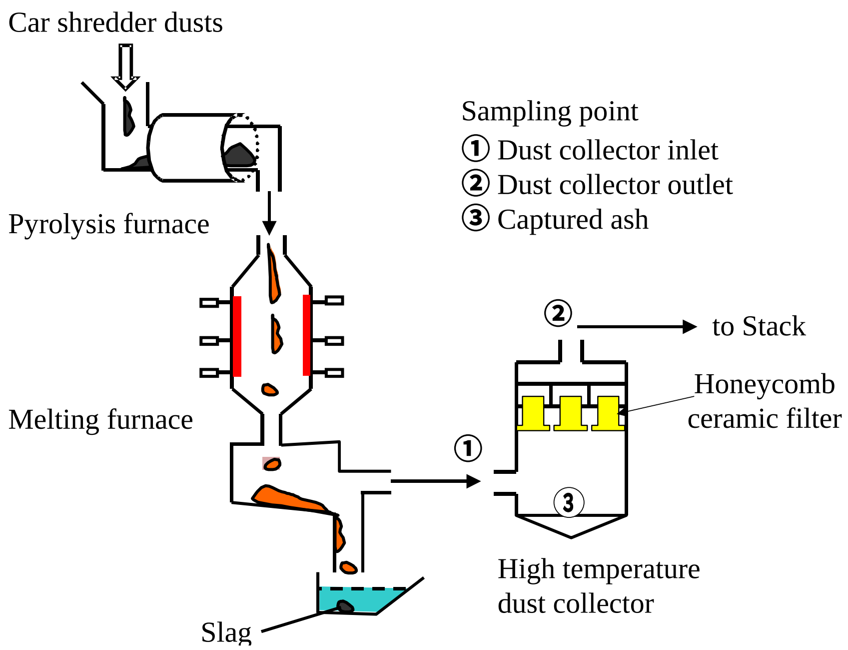

Fig.2 Industrial waste processing system.

Table 1 Properties of car shredder dust

Items		Mass fraction [wt %]
Elemental	Carbon	48.0
	Hydrogen	7.0
	Oxygen	21.6
	Nitrogen	1.2
	Sulfur	0.04
	Chlorine	2.5
Proximate	Moisture	7.2
	Combustible	80.3
	Non combustible	12.0
Lower combustion heat [kcal/kg]		5000

Table 2 Physical properties of ceramic filter

Material	Cordierite
Dimensions	150 mm×150 mm×300 Lmm
Total filtration area	46 m^2
Mean pore size	15 μm
Porosity	40 %
Working temperature	～900 ℃
Filtration velocity	1 m/min
Pressure drop	50～200 mmAq.

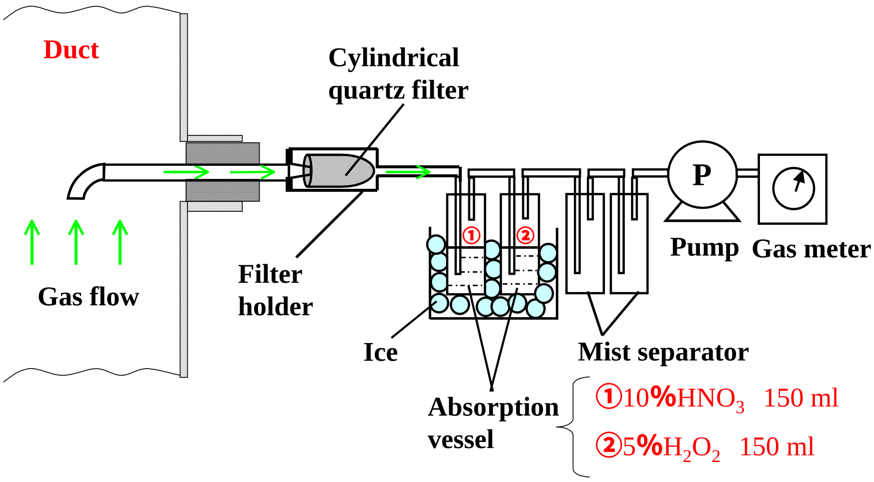

Fig.3 Fly ash sampling system from flue gases (JIS Z 8808, Type II).

Table 3 Fractional collection efficiency of ceramic filter

	①Inlet [mg/Nm^3]	②Outlet [mg/Nm^3]	③Captured dust [mg/kg]	④Collection efficiency of ceramic filter [%]	
Total dust	600	24		96.0	**FACT result**
Cd	0.12	0.083	20	30.8	90.6
Pb	40.5	8.15	520	79.9	61.3
Zn	150	42.5	550000	71.7	94.9
Cu	52	2.45	69000	95.3	99.5
Fe	4.1	0.08	65000	98.1	100
Cr	0.145	0.04	230	75.5	56.9
As	0.045	<0.001	8	>97.8	0
Ti	0.024	0.0034	11	86.2	100
Hg	0.028	0.0098	<0.01	64.4	0

Table 4 Existence state of Pb compounds

Sampling point (Sampling temp.)		Non water soluble compound	Water soluble compound	Gas
① Dust collector inlet (280℃)	Exp.	80.7%	15.2%	4.1%
	FACT	64% $PbSO_4$(s)	30.4% $PbCl_2$(s)	5.6% $PbCl_4$(g)
② Dust collector outlet (120℃)	Exp.	11.7%	81.5%	6.8%
	FACT	-	95% $PbCl_2$(s)	5% $PbCl_4$(g)
③ Captured dust by ceramic filter (539℃)	Exp.	99.8%	0.2%	-
	FACT	100% $PbSO_4$(s)	-	-

Table 5 Existence state of Cu compounds

Sampling point (Sampling temp.)		Non water soluble compound	Water soluble compound	Gas
① Dust collector inlet (280℃)	Exp.	93.2%	2.6%	4.2%
	FACT	100% CuO(s)	-	-
② Dust collector outlet (120℃)	Exp.	30%	59%	11%
	FACT	69.7% CuO(s)	-	30.3% $(CuCl)_3$(g)
③ Captured dust by ceramic filter (539℃)	Exp.	99.5%	0.5%	-
	FACT	100% CuO(s)	-	-

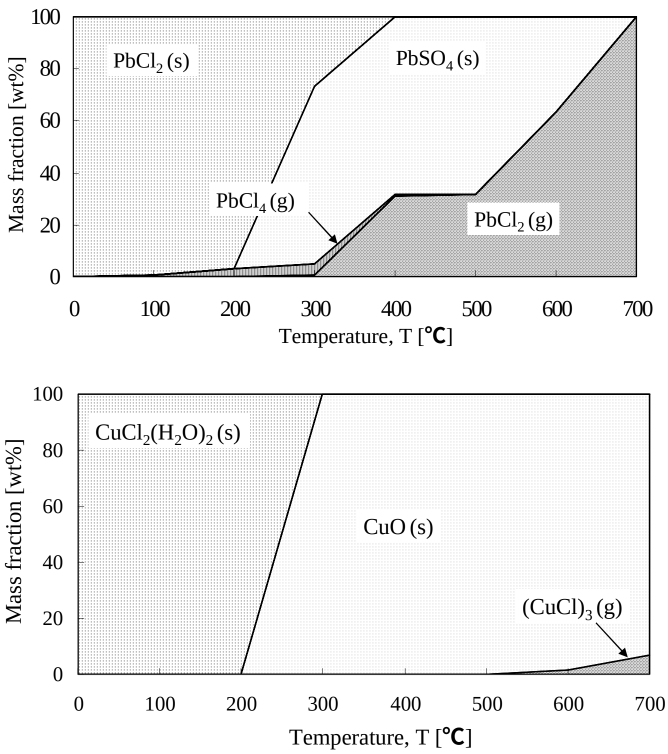

Fig.4 Influence of temperature on existence state of Pb, Cu compounds.

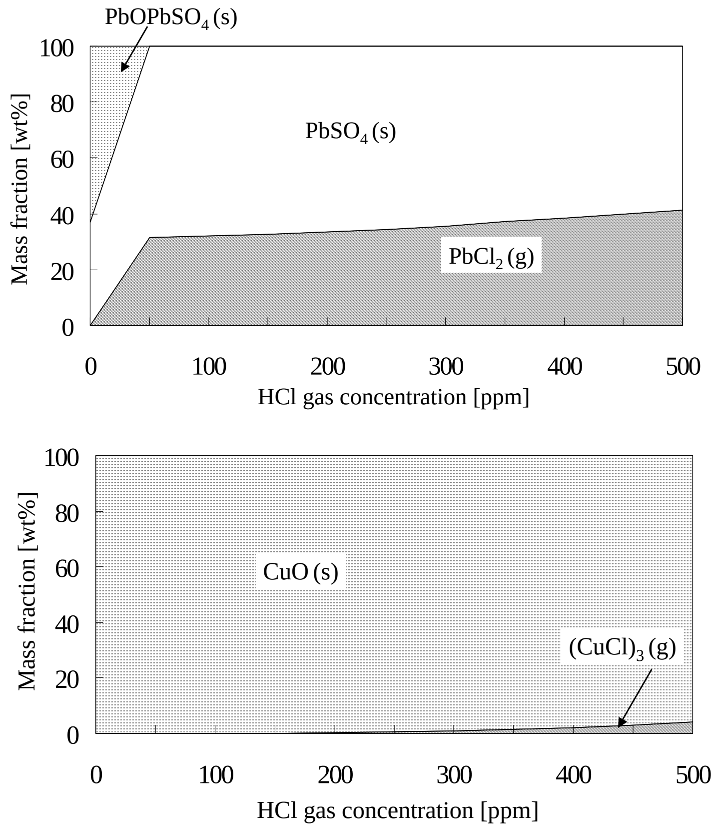

Fig.5 Influence of HCl gas conc. on existence state of Pb, Cu compounds.

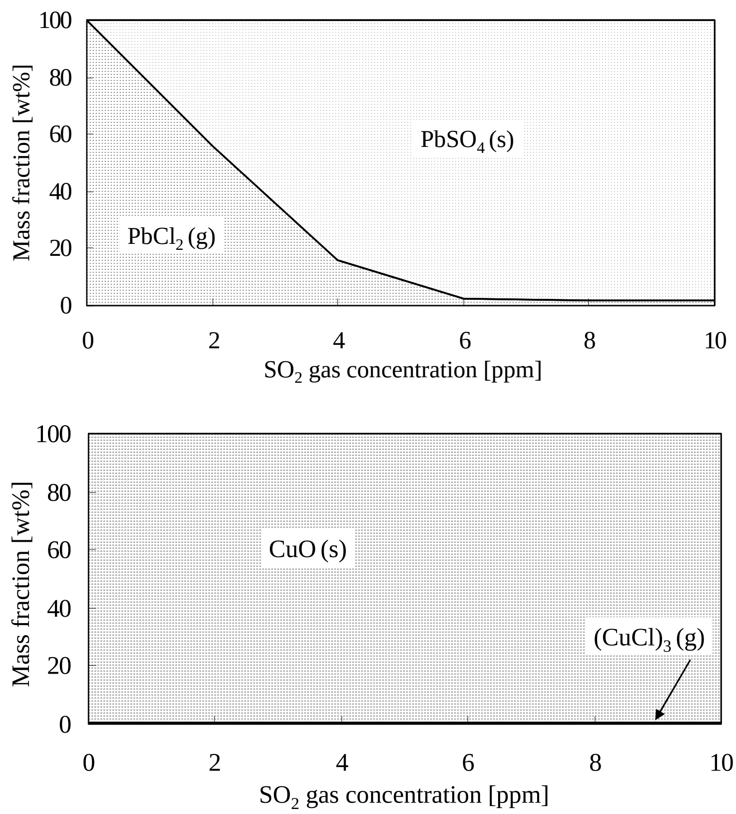

Fig.6 Influence of SO_2 gas conc. on existence state of Pb, Cu compounds.