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Experience in Combustion of Various Dewatered Sludges at a Commercial-Scale Fluidized Bed Incinerator

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ABSTRACT

A commercial-scale Fluidized Bed Incinerator(FBI) to treat dewatered sludges has been developed by Jindo Corporation, Korea, as one of the governmental R&D project during 1990 to 1997. The FBI plant was constructed at Kunsan city and fully in operation after finishing the successful test-burn period since June 1998. The company now has a capability of the design, construction and operation of commercial FBI plants. This paper introduces the experiences of design and operation of Kunsan FBI plant, which has the capacity of 60 ton/day and incinerates various sludges from waste water treatment facilities and liquid waste such as waste oil or waste solvent.

INTRODUCTION

In 1997, domestic generation of sludge was about 7,000,000 ton/day in Korea and has increased since then. Most domestic sludge has been is treated by landfill or ocean dumping. However, direct landfill of sludge will be forbidden by law in 2001, and ocean dumping is trending to be reduced. Therefore, appropriate treatment means of sludge is needed. The technologies of sludge incineration, drying, recycling and melting has been developed by various domestic companies. In Jindo Corp., the technology of fluidized bed incineration to treat sludge has been developed since 1990, and design, construction and the operation of the plant has been completed in 1998. In this paper, outlines and operation characteristics for the commercial scale fluidized bed incinerator to treat 60 ton sludge/day are introduced.

COMMERCIAL FLUIDIZED BED COMBUSTOR(FBI)

The FBI system with a capacity of 60 tonnes of sludge per day is consisted of storage, supply, incineration, waste heat recovery, flue gas treatment, ash treatment, ventilation, water supply and drain facilities.

Waste storage & supply facility

A storage facility of waste consists of sludge pit and waste oil & waste solvent tank, and a supply facility consists of piston pump and mono pump. Supplying system

of waste oil and waste solvent consists of three different types according to spray degree determined by viscosity so that liquid waste is easily supplied regardless of property changes. There are a direct spray from storage tank to fluidized bed, a spray to fluidized bed after feeding to service tank and heat tracing by steam, and a spray to fluidized bed after feeding to piston pump hopper and mixing with sludge.

Incinerator & waste heat recovery facility

The incinerator has a Tuyere type air distributor using water cooled dispersion disc and a bottom ignition burner. Fly ash collected at the entrance of waste heat boiler is recycled to fluidized bed. Auto-ignition system is composed of burner and precombustor, and indirect heating method using a bottom preheating burner with precombustor is utilized. The specification of this facility is following; in order to recover waste heat from flue gas, waste heat boiler and air preheater are installed. Steam production of the waste heat boiler is 2.5 ton/hr (0.5) and with a steam pressure of 7 kg/cm2G. The air preheater is designed with two stages so as to increase the efficiency of waste heat recovery. Main combustion air preheated from an air preheater intoduces to wind box. The air preheater is connected to secondary air duct so that secondary air could be used as preheating air.

Flue gas treatment facility

The flue gas treatment facility consists of a attemperator for gas temperature control, a lime reactor(dry scrubber) and a bag filter for dust collection. The attemperator is used to control combustion air cooled in waste heat recovery facility up to 180C which is the operation temperature of dry gas reactor and filter. The attemperator is composed of two fluid nozzles and PID controller for microtemperature control. The lime reactor of duct type, that is, a dry scrubber for emission control of SOx and HCl is installed. The system for feeding hydrated lime consists of a lime silo, lime feed blower, a lime feeder and so on. The lime feeder has a flow rate controller which controls feed amount according to the incinerated amount of waste and its sulfur content.

Combustion air supply facility

Combustion air supply facility is composed of a primary and secondary air blowers. Design pressure of the primary air blower is 2500mmAq in consideration of pressure drop of orifice, air preheater, tuyere and fluidized bed height. Design flow rate is determined to feed sufficient combustion air without the secondary air blower. The primary air blower is also used for the burner at the ignition of combustion air and at the beginning of burner ignition. The secondary air controls multistep combustion, and exhaust pressure is 370 mmAq in consideration of pressure drop of orifice and duct.

Ash treatment facility

The ash treatment facility classifies the bag filter ash of fine dust and the ash produced from waste heat boiler, air preheater and attemperator, and then all the ashes are transported, stored and treated. The ash collected in former step of bag filter uss as raw material of brick, the bag filter ash is transported to landfill site.

OPERATIONAL CONDITIONS

Characteristics of waste & auxiliary fuel

Table 1. shows the alalytical results of waste and auxiliary fuel. 11 kinds of sludge, sludge A sludge K are used as described in Table 1, and properties and composition of

waste oil and waste solvent are analysed using proper analytical methods. The moisture content varies from 56 to 92% and the ash content ranges from 1.5 to 8.1% in weight.

Operation condition

Table 2. shows a summary of operational conditions during test operation of the commercial FBI plant. Liquid feeding ranges 5-10 ton/day and solid sludge feeds around 10 ton/day. The other test operational conditions are given in the Table.

RESULTS OF TEST OPERATION IN COMMERCIAL FBI

Characteristics of bed pressure drop

When the wastewater sludge, in which moisture content is high and ash content is low, is incinerated, the usability of fly ash as bed materials of fluidized bed without additional of fresh sand is investigated. In case of incinerating the mixture of various sludges with waste solvent except for B, F and J, in which moisture content is low and ash content is high, variations of bed pressure drop with operation time for the commercial FBI operation with recycle of fly ash (a) and for the commercial FBI and pilot plants without recycle of fly ash (b) are shown in Fig. 2. Figures (a) and (b) in Fig. 2 show that bed pressure drop decreases with increasing operation time regardless of recycle of fly ash. Therefore it is found that the amount of the recycled ash is not sufficient to maintain the proper bed hieght without adding fresh sand as bed materials for both cases. However, by comparison of bed pressure drop with time, in case of recycle of fly ash, the time to decrease up to a certain pressure drop is required 4 times less than that for no recycle of fly ash.

Combustion behavior of sludge clusters

Combustion procedure of sludge cake in a fluidized bed incinerator has been obserbed. Combustion steps of sludge is investigated by sampling materials in the bed from the drain during incineration. Fig. 3 shows sludge samples in 60 TPD FBI during incineration of the mixture of sludge and waste solvent (or waste oil). As sludge clusters enter into fluidized bed incinerator, it is heated and moisture is evaporated. Then, agglomeration of particles is proceeded by surface forces. In case of above 750C of cluster surface temperature, the cluster is not only divided by devolatilization and combustion of volatile matter, but changed to fine ashes according to attrition by bed materials as shown in Fig. 3.

Incineration characteristics in 60 TPD FBI

Operation data such as vertical temperature distribution at the incinerator and concentrations of SO2, HCl and trace heavy metals in flue gas emitted from stack could be obtained during commercial operation. Measuring results at twice a month for 24 month of operating time has been recorded. Fig. 4 shows vertical temperature distributions in the incinerator for various kinds of sludge. Fig. 5 shows SO2 and HCl concentrations emitted from stack. Fig. 6 shows concentrations of trace heavy metals such as Cr, Hg, Cu, Pb and Cd at stack. As shown in Fig. 4, in case of sludge I, of which heating value is high and moisture content is low, it can be incinerated without mixing waste oil and waste solvent. As a result, the incinerator can be operated at about 860C in stable by the combustion of combustible matter in sludge. Since most of other sludges besides of sludge I have high moisture content and low heat capacity. It is very difficult to operate continuously without co-incineration with auxiliary fuel such

as waste oil or waste solvent. As a result, the temperature at the free board of the incinerator maintains about 950℃. From Fig. 5, SOx emission is lower than 175ppm during operation period, and HCl emission is about 40 ppm at the beginning but the concentration becomes lower than 5 ppm after 15 months. As shown in Fig. 6, the emission of heavy metals(Cr, Hg, Cu, Pb, Cd) at stack is lower than regulatory level. Although Pb content in sludge is a little bit high, it can be controlled by incineration process and flue gas treatment system. The results of leaching test of such heavy metals in ashes were very low not detected.

CONCLUSION

A pilot plant of FBI for sludge treatment has been developed by the company since 1990 and the commercial scale plant with a capacity of 60 ton/day has been completed to construct in1998. The plant has been in commercial operation since then, and it has been upgraded in design and installation by a continuous trial operation. Also the trial operation data was feedback to the design factor so as to minimize troubles and the plant has been in successful operation.

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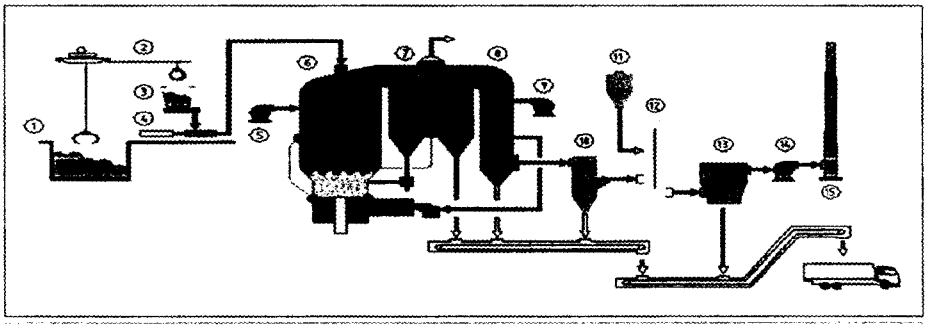
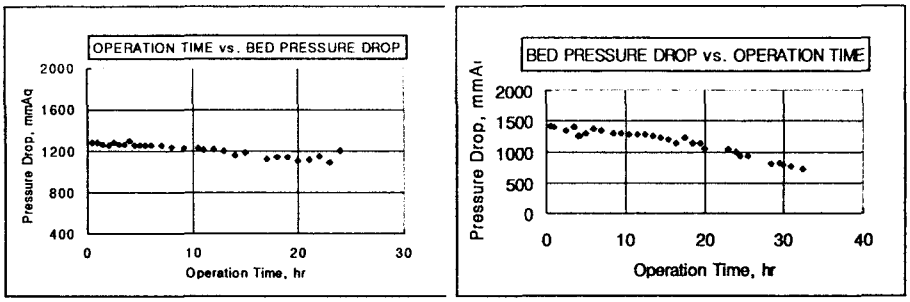


①Sludge Pit ②Crane ③Sludge Service Hopper ④Piston Pump
⑤Secondary Air Fan ⑥Fluidized Bed Incinerator ⑦Waste Heat Boiler
⑧Air Preheater ⑨Primary Air Blower ⑩Attemperator ⑪Lime Silo
⑫Lime Reactor ⑬Bag Filter ⑭ID Fan ⑮Stack

Fig. 1 Flow diagram of 60ton/day fuidized bed combustor System.



a) with fly ash recycle in 60TPD FBC b) without fly ash recycle in 60TPD FBC

Fig. 2 Variation of bed pressure drop with regard to the operation time

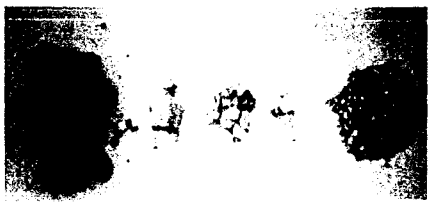


Fig. 3 Picture of sludge cluster combustion history in 60TPD FBC

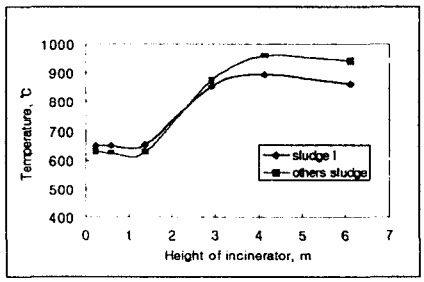


Fig. 4 Axial temperature profiles with the variation of air to fuel ratio

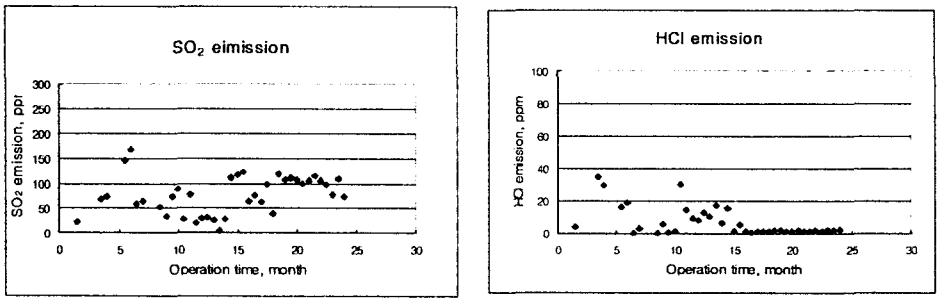


Fig. 5 Variation of SO_2 and HCl emission with regard to the operation time

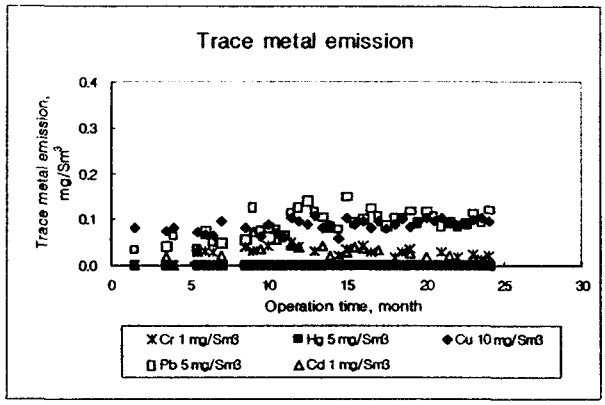


Fig. 6 Variation of trace heavy metal emission with regard to the operation time

Table 1. Results of characteristics of waste & aux. Fuel

WASTE	HHV (db)	Proximate Analysis (wet, wt.%)				Ultimate Analysis (db, wt.%)					
	cal/g	Mo.	V.M	F.C	Ash	C	H	O	N	S	ASH
SLUDGE A	4627	86.84	10.04	1.61	1.51	44.30	4.88	31.36	7.50	0.49	11.47
SLUDGE B	3260	79.72	12.82	1.76	5.70	30.50	3.98	33.66	3.05	0.70	28.11
SLUDGE C	3974	91.75	5.64	0.44	2.16	35.40	4.38	35.09	3.70	0.58	20.85
SLUDGE D	5501	85.29	10.65	0.80	3.26	47.00	5.51	23.58	1.10	0.65	22.16
SLUDGE E	3989	82.01	11.78	1.91	4.30	36.40	4.24	28.21	6.58	0.65	23.90
SLUDGE F	2496	76.18	15.11	0.57	8.14	23.50	4.47	9.01	3.08	1.15	58.77
SLUDGE G	4165	91.64	6.27	0.36	1.72	35.60	4.31	32.36	6.50	0.66	20.57
SLUDGE H	2981	84.05	9.78	1.16	5.00	28.40	3.50	31.98	4.45	0.32	31.35
SLUDGE I	4445	72.00	22.85	0.71	4.44	40.60	5.39	33.88	3.90	0.37	15.86
SLUDGE J	2814	66.67	18.61	1.47	13.24	-	-	-	-	-	-
SLUDGE K	4678	56.8	-	-	-	-	-	-	-	-	-

WASTE (or AUX. FUEL)	HHV(db) cal/g	Moisture (%)	Ultimate Analysis (db, wt.%)						
			C	H	O	N	S	Cl	Ash
Waste oil			85.30	14.00	0.46	0.00	0.24	0.00	0.00
Waste solvent			78.00	12.00	3.00	0.00	0.00	5.00	2.00
No. 2 oil	10200		85.00	14.10	0.30	0.10	0.50	0.00	0.00

Table 2. Operation parameters and conditions in commercial scale 60ton/day FBC Plant

Parameters	Operation Condition
Incineration rate (F)	
Waste treatment sludge cake	50 ton/day (±10)
Waste oil / Waste solvent (or Refinery oil for aux. fuel)	5 ~ 10 ton/day
Superficial gas velocity(U)	0.9 ~ 1.4 m/sec
Air to fuel ratio(m)	1.4 (± 0.2)
Bed temperature(Tb)	600 ~ 750 ℃
FBC outlet temperature(Tout)	850 ~ 950 ℃
1st combustion air rate(Q_1/Q_T)	0.6 ~ 0.9