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A study in the applicability of plasma treatment technology for perlite heat insulation material

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1. Introduction

Plasma treatment technology is a process that uses an electrically excited gas to melt or treat organic and inorganic materials. This technology can also be used to reduce the volume of radioactive waste generated from nuclear power plants. This demonstration test was conducted to evaluate the suitability of plasma treatment for perlite as simulated radioactive waste using a 100 kW Plasma treatment facility.

2. Experimental

2.1 Preparing simulant

For the demonstration test, simulant was prepared by mixing perlite with additive CaO as shown in Table 1 and Fig. 1.

Table 1. Mixed simulant composition and proportion

Items	Perlite			Additive
Composition	SiO_2	Al_2O_3	Na_2O	CaO
Proportion(%)	38.7	5.4	5.9	50.0

(a) preparing materials (b) Making simulants
Fig. 1. Mixing Samples

2.2 Mass and quantity of the simulant

In order to verify the continuous melting feasibility of the simulant, a total of 261kg was prepared. Perlite was formulated in two size ranges, 3~6 mm and 4~8 mm, with 44 and 43 units, respectively. The hourly input weight was planned as shown in table 2 and was divided accordingly into weights to be fed during the demonstration test as shown in Fig. 2.

Table 2. Mass and Quantity of the simulant

No.	1	2	3	…	85	86	87	Sum.
Mass(kg)	3	3	3	…	3	3	3	261
Quantity	1	1	1	…	1	1	1	87

(a) Perlite(target waste) (b) Divided simulants

3. Results and discussion

3.1 Operation Parameters

The key parameters for operating the plasma treatment facility include the distance between the torch and the molten material [mm], current [A], voltage [V], and power output [kW]. The parameter ranges according to the operating mode are presented in Table 3.1. During non-transferred mode operation, the average voltage, current, and power output were 573 V, 147 A and 82 kW, respectively. In transferred mode operation, the average voltage, current, and power output were 590 V, 155 A and 82 kW, respectively.

Table 3.1. Parameter ranges according to the operation Modes

mode / Parameter range	Non-trasferred mode	Transferred Mode
Torch distance [mm]	90~110	80~130
Current [A]	140~155	150~160
Voltage [V]	468~679	529~652
Power [kW]	76~89	84~100

3.2 Melting furnace temperature

The transition from non-transferred to transferred mode operation took 52 minutes after torch ignition. At the moment of transition, the temperature of the melting furnace was

480℃, and it was observed to rise to a maximum of 1,255℃ as shown in Fig. 3.1.

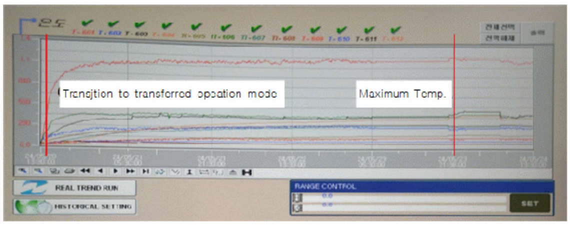

Fig. 3.1 Furnace Temperature

3.3 Cooling water temperarture

During the test, the ambient temperature ranged from 11℃ to 25℃. As shown in Fig. 3.2, during non-transferred mode operation after ignition, the torch cooling water outlet temperature increased from 18℃ to 37℃. After activating the cooling fan, the temperature was maintained at an average of 29℃ during transferred mode operation.

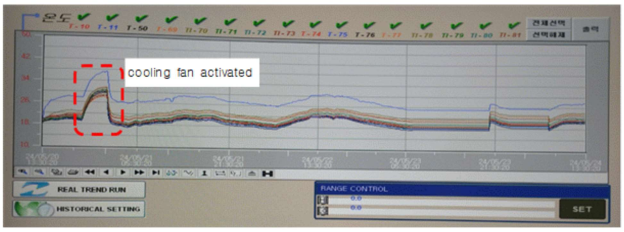

Fig. 3.2 Cooling water temperature

3.4 Discharge of molten material

The molten material was not discharged immediately upon feeding but instead formed a dam at the furnace outlet. As the continuous feeding of the simulant increased the molten pool and accelerated the flow, the dam eventually collapsed, allowing the molten material to be discharged. The Discharge intervals were irregular, and the discharge shape is illustrated in Fig. 3.3(a). Additionally, clinker formation was observed at the outlet, as shown in Fig. 3.3(b). A comparative measurement of the input and discharged simulant weights indicated that 261 kg was fed, while 232.9 was discharged, leaving 28.1 kg of remaining material, as presented in Table 3.2.

(a) Discharge shape (b) Clinker

Fig 3.3 Discharge and clinker

Table 3.2 Test Result

	Input	Output
Mass[kg]	261.00	232.90
Volume[L]	1,283.40	79.60
Density[kg/cm²]	0.20	2.93
Specific volume[L/kg]	4.92	0.34
Specific volume change amount[L]	4.58	
Volume reduction ratio[%]	93.8	
Volume reduction factor	16.12	

4. Conclusion

Using a 100 kW plasma treatment facility, a continuous operation was conducted for 96 hours, during which 261.0 kg of simulant was melted, resulting in the discharge of 232.9 kg. The clinker removal device functioned effectively, preventing any blockage issues at the discharge outlet throughout the operation. The volume reduction ratio(VRR) was determined to be 93.8%, and the volume reduction factor(CRF) was calculated as 16.12. These results demonstrate the efficient melting performance of the plasma treatment facility and its significant volume reduction capability.

REFERENCES

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