Demonstration of Plasma Torch melting for the Treatment of Paraffin-Solidified Radioactive Waste Forms Using Surrogates

Sangdoo Park*, Jeongsu Jung
KHNP-CRI, 70, Yuseong-daero 1312beon-gil, Yuseong-gu, Daejeon, Republic of Korea
**Corresponding author: s.d.park@khnp.co.kr*

***Keywords :** Plasma Torch melter, Paraffin-Solidified

1. Introduction

In the past, paraffin-based solidification was utilized to dispose of concentrated liquid radioactive waste dried solids generated from nuclear power plants. However, the resulting waste forms failed to satisfy homogeneity and leaching characteristics required for final disposal, remaining stored within power plants to date. While methods such as overpacking using High-Integrity Containers(HICs) are necessary to dispose of these waste forms, the initial paraffin solidification process paradoxically increased the overall volume by approximately 20% to 50% compared to the original raw waste, leading to higher disposal costs as well as the loss of valuable disposal space. Accordingly, to evaluate the feasibility of volume reduction for paraffin waste forms using Plasma Torch Melting Technology, a demonstration test was conducted using surrogate sample.

2.Experimental Methods

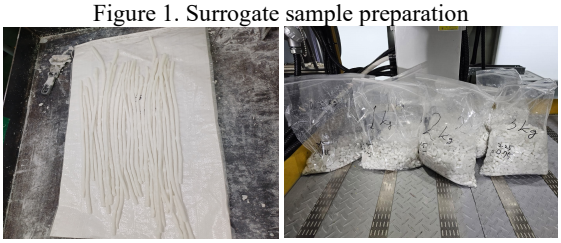
2.1 Preparation of Surrogate Sample

Chemical analysis of the concentrated liquid waste dried solids confirmed that boron(195,333 ppm) and sodium(76,000 ppm) [1] were the primary components. The mixing ratio of paraffin varied depending on the operating procedures of each nuclear power plant, it was found to be within 20% to 50% of the weight of the dried solids. Accordingly, a simulated dried waste was prepared by mixing boric oxide and borax, and the final surrogate sample was fabricated by melting and blending paraffin corresponding to 50% of the weight of the simulated dried waste. A total of 13 kg of samples was prepared. The mixing ratio of individual components are listed in Table 1, while the fabrication process of the surrogate sample is shown in Figure 1.

Table 1. Mixing ratio of substances

B_2O_3	$Na_2B_4O_7 \cdot 10H_2O$	Paraffin
4.05	2.62	3.33

Figure 1. Surrogate sample preparation



2.2 Plasma Torch Melting System

This plasma torch melting system used in this study has a maximum power capacity of 100 kW. The system is equipped with a versatile plasma torch capable of operating in both non-transferred and transferred modes, with nitrogen employed as the working gas. The furnace is designed to maintain an internal operating temperature of approximately 1,100℃ and kept under negative pressure to prevent the leakage of hazardous substances during the melting process. To ensure structural durability at high temperatures, the furnace is cooled using a water-jacket system. For the discharge of molten slag, a dam-type overflow system is utilized, allowing for stable and controlled removal of the melt.

2.3 Feeding Samples

The samples were fed into the melting furnace at one-hour intervals. The specific mass for each feeding stage is detailed in Table 2.

Table 2. Feeding mass of samples per cycle

Cycle	Time (h)	Feeding Mass (kg)	Cumulative Mass (kg)
1st	0	0.5	0.5
2nd	1	0.5	1
3rd	2	1	2
4th	3	1	3
5th	4	1	4
6th	5	2	6
7th	6	2	8
8th	7	2	10
9th	8	3	13

3. Results and Discussion

3.1 Volume Reduction and Material Balance

The results of the volume reduction are summarized in Table 3. To ensure a precise material balance, the final molten product was categorized into discharged slag and residual holdup within the melting chamber.

Table 3. Material balance and volume reduction

Parameter	Input	Disch.	Holdup	Total (Final State)
Mass (kg)	13.00	4.15	3.38	7.53
Volume (L)	9.90	1.18	0.96	2.14
Density (kg/L)	1.31	3.52	3.52	3.52
VRR (%)	-	-	-	78.4
VRF	-	-	-	4.63

3.2 Thermogravimetric Analysis Results

According to the TGA Results for the samples before and after treatment, the untreated sample exhibited a rapid mass loss between approximately 100℃ and 400℃, with a final weight loss of 32.62%(Fig. 2). In contrast, while the treated samples collected from the melting furnace(Fig. 3) and slag container(Fig. 4) showed a relatively noticeable mass loss in the range of 100℃ to 200℃, their final weight loss remained at around 2%.

Figure 2. TGA result of the untreated sample

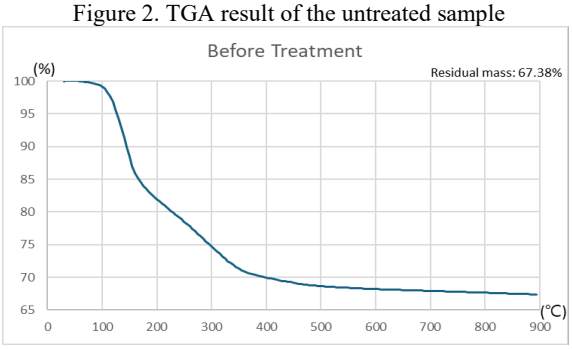


Figure 3. TGA result of the treated sample(furnace)

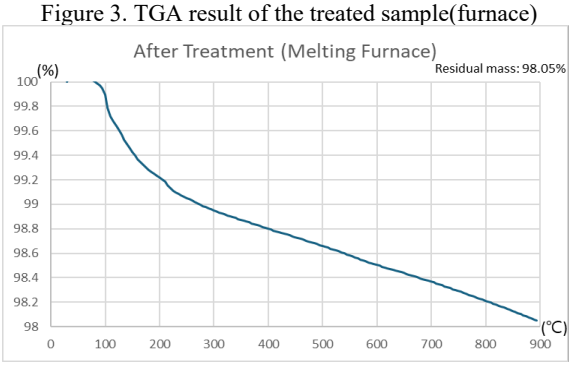
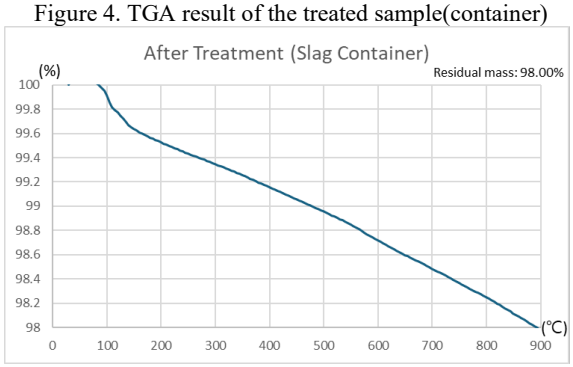


Figure 4. TGA result of the treated sample(container)



4. Conclusions

The Treatment of simulated paraffin-solidified waste using the 100 kW PTM system achieved a significant volume reduction rate of approximately 78.4%. Furthermore, TGA results for the treated sample revealed no distinct mass loss regions, apart from a minor weight decrease between 100℃ and 200℃ attributed to moisture evaporation. Given that the final mass loss was limited to around 2%, it can be inferred that most of the paraffin within the sample was effectively decomposed and removed. Consequently, plasma torch melting technology demonstrates strong potential as a viable method for the volume reduction of paraffin-solidified waste.

REFERENCES

[1] Development of glass formulation for the vitrification of boric acid concentrates, KHNP, p. 12, 2009