Effect of the Heat Treatment on the Graphite Matrix of Fuel Element for HTGR

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1. Introduction

Generation-IV reactors have been developed for the safety, high burn-up, long-term irradiation cycle and /or additionally for the hydrogen production. For High Temperature Gas-cooled Reactors (HTGR), one of the Gen-IV reactors, have been using the fuel element which is manufactured by mixing and combining Tristructural-isotropic (TRISO)-coated uranium-containing particles with graphite powder. The fuel elements are considered with two types of concepts for HTGR, which are the block type reactor and the pebble bed reactor [1]. In this paper, the cylinder-formed fuel element for the block type reactor is focused on, which consists of the large part of graphite matrix [2].

One of the most important properties of the graphite matrix is the mechanical strength for the high reliability because the graphite matrix should be enabled to protect the TRISO particles from the irradiation environment and the impact from the outside.

In this study, the three kinds of candidate graphites and Phenol as a binder were chosen and mixed with each other, formed and heated for the compressive strength test. The objective of this research is to optimize the kinds and composition of the mixed graphite and the forming process by evaluating the compressive strength before/after heat treatment (carbonization of binder).

2. Experimental Procedure

This experiment is the basic research using different preparation process such as pulverization and wet milling from the commercial fuel element forming process. Fig. 1 shows the schematic diagram for fuel element fabrication process.

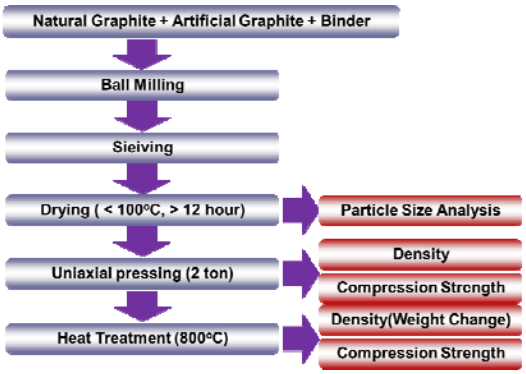

Fig. 1. Manufacturing flow diagram of pellet-type graphite sample

Three kinds of graphite (G, R and S) among the several candidate graphites are chosen for this study. (G, R : Natural graphite, S : Artificial graphite)

And two kinds of graphite matrix (G : S or R : S = 4 : 1 based on wt%) are mixed with 10 and 20 wt% Phenol and solvent, and milled by the planetary ball mill for 2 hours, respectively (Table. I). Then, the graphite mixture was dried for over 12 hours. The particle size of mixed graphite was measured by CILAS 1064 particle size analyzer.

Table I: Compositions of the various mixing conditions

Graphite	G + S	R + S
Phenol (wt%)	10 & 20	
Wet Milling	2hrs	

The dried graphite mixture is pressed into the pellet-type (green pellet) by applying compressive pressures of 2 ton/cm^2. Prepared green pellets were heat-treated at 800^{o}C for 2h in N_2 atmosphere (1liter/min). The compressive strength of the samples was measured by INSTRON SFL. In addition, the bulk density of the samples before and after heat treatment was also measured.

3. Results

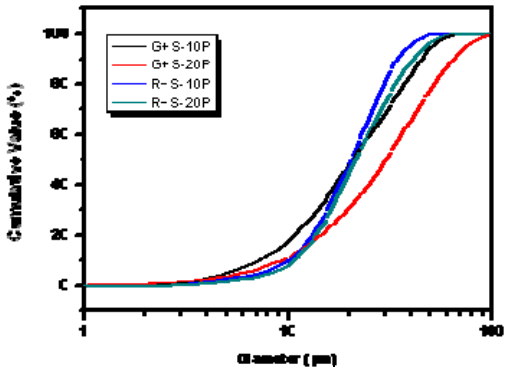

Fig. 2. Particle Size Analyze of mixed graphite samples (P : Phenol)

Fig. 2 shows the results of the particle size analyze tests on the milled graphite powder samples. It shows that the contents of binder Phenol and the kinds of graphite affect the particle size. In case of the binder content, as the contents of Phenol is decreased the

graphite particle size becomes finer. R+S with Phenol is slightly finer than G+S with Phenol.

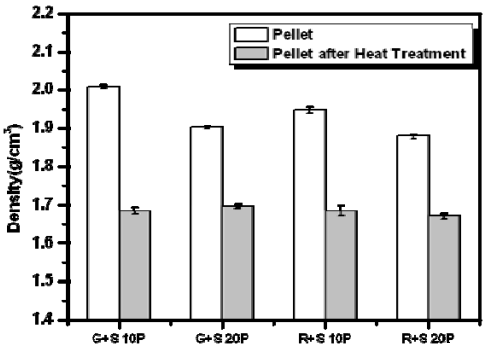

Fig. 3. Density of the pellets (Green pellets and the heat treated pellets)

Fig. 3 shows the density of the green graphite pellets and the heat treated samples. As shown in Fig. 3, the density of green pellet is 1.88 ~ 2.0 g/cm^3 and the heat-treated pellets show the density of 1.67 ~ 1.70 g/cm^3 in both cases of 10 and 20 wt% Phenol addition. It was observed the dimension change and weight loss occurred due to the vaporization of binder.

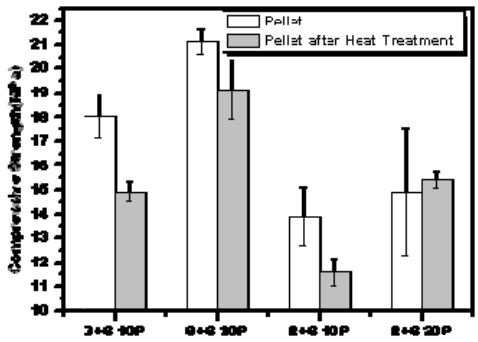

Fig. 4. The result of compressive strength test

Fig. 4 shows results of the compressive strength tests on the green pellets and the heat treated pellets. The compressive strength of G+S+P graphite pellets is relatively higher than that of R+S+P pellets in the both conditions, before and after heat treatment.

4. Conclusion

In this study, the effect of heat treatment on graphite matrix was studied in terms of the density and the compressive strength.

The size (diameter & length) of pellet is increased by heat treatment. Due to additional weight reduction and swelling (length & diameter) of samples the density of graphite pellet is decreased from about 2.0 to about 1.7g/cm^3.

From the mechanical test results, the compressive strength of graphite pellets was related to the various conditions such as the contents of binder, the kinds of graphite and the heat treatment. Both the green pellet and the heat treated pellet, the compressive strength of G+S+P pellets is relatively higher than that of R+S+P pellets.

To optimize fuel element matrix, the effect of Phenol and other binders, graphite composition and the heat treatment on the mechanical properties will be deeply investigated for further study.

REFERENCES

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