Post-irradiation Microstructure and Dimensional Change of A3-3 Graphite Matrix Compacts for HTGR Fuel

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1. Introduction

A3-3 graphite is the most commonly used for matrix graphite compact encapsulating tristructural-isotropic (TRISO) fuel particles in High Temperature Gas-cooled Reactor (HTGR) which is one of Generation IV reactors. When compared to other nuclear graphites, A3-3 graphite has great fission product sorptivity so as to be used as TRISO fuel compact. A3-3 graphite matrix is composed of 64% natural graphite, 16% synthetic graphite, and 20% phenolic resin.

The first irradiation test of TRISO fuel and A3-3 graphite matrix was performed in HANARO during the period of August 2013~March 2014 [1-3]. The objective for the irradiation test was to provide our understanding of fuel fabrication procedures and irradiation performance. The irradiation device consisted of two rods. While the one contained nine TRISO fuel compacts, the other included five TRISO fuel compacts and eight graphite specimens. The eight graphite specimens consisted of four A3-3 graphite matrix and IG-110 graphite compacts. Fig. 1 shows the schematic of fuel rods and their compositions. Fuel and graphite compacts in the two rods are shown in Fig. 2.

In this study, we are interest in the irradiation of A3-3 graphie matrix compacts. Microstructure and dimension of A3-3 graphite matrix were investigated and compared to non-irradiated compacts. Experiments were perfomed in Irradiated Materials Examination Facilities (IMEF) at Korea Atomic Energy Research Institute (KAERI).

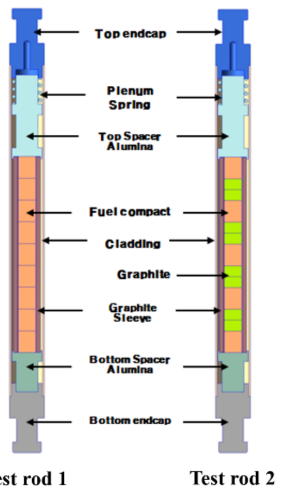

Fig. 1. Schematic of two test rods.

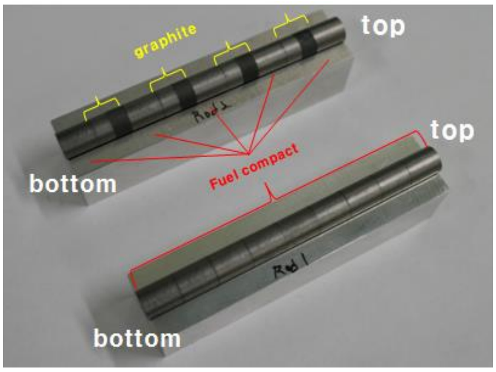

Fig. 2. Fuel and graphite compacts in the two test rods

2. Experiments

Fuel and graphite compacts in the Fig. 2 were taken out from the two rods after the irradiation test. The top, middle, and bottom diameters, and height of A3-3 graphite matrix compacts were measured three times each by a micrometer. The weight of compacts also measured three times by a balance. The density of compacts was calculated using the average dimension and weight. The A3-3 graphite matrix compacts were cut into several pieces to investigate the microstructure of different direction as indicated in Fig. 3. The pieces were mounted in carbonized resin and polished by diamond paste successively up to 1μm. The microstructure of irradiated compacts was investigated by Electron Probe Micro-Analysis (EPMA).

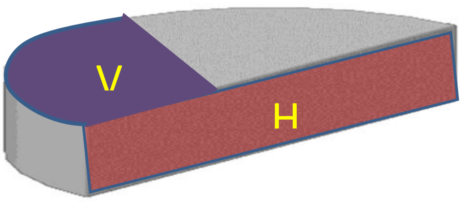

Fig. 3. Schematic indicating (H) parallel and (V) perpendicular cross sections to the axial direction

3. Results and discussion

Table 1 and Table 2 shows post-irradiated and pre-irradiated dimension, weight, and density of A3-3 graphite compacts. It was found that while the diameter of A3-3 graphite compact increased by ~0.07%, the height of compacts was decreased by ~0.77% after irradiation. It is suggested that decreased height is due to the anisotropic microstructure of A3-3. The graphite grains are aligned to radial direction as will be discussed later. Therefore, the void and pores are also lacated between the aligned longitudinal grains. The amount of void and pores is probably decreased by the irradiation and high temperature for 8 months decreasing the height of compacts. The reason of increased diameter is under discussion. The weight and density of A3-3 graphite matrix compacts were increased by ~0.32% and ~9.45%, respectively. The weight increase is probably due to the defect formation in the A3-3 graphite structure during the irradiation. The increased weight and decreased volume increased the density value.

While Fig. 4 shows the SEM images of pre-irradiated A3-3 graphite compacts, Fig. 5 shows the EPMA images of post-irradiated compacts. The V and H-sections are indicated (see also Fig. 2). Although the contrast of Fig. 4 and 5 is different, the aligned grains of graphite along the pressing direction is clearly seen in both V sections. On the other hand, randomly aligned grains and 20~50um sized pores are found in the H sections of both pre- and post-irradiated graphite compacts. It was found that the unique features of V and H sections are still obverved in post-irradiated compacts. The only difference between pre- and post-irradiated compacts is more clearly seen graphite grains after irradiation due to the number of defects between grains formed by irradiation. .

Table1. Dimension, weight, and density of irradiated A3-3 graphite compacts.

ID	Top (mm)	Middle (mm)	Bottom (mm)	Height (mm)
M1-9	7.994	7.985	7.972	5.030
M1-8	7.996	7.985	7.968	5.031
M1-7	7.997	7.995	7.973	5.047
M1-6	7.989	7.986	7.979	5.020

ID	Weight (g)	Density (g/cm^3)
M1-9	0.45137	1.7926
M1-8	0.45097	1.7910
M1-7	0.44975	1.7780
M1-6	0.44873	1.7854

Table2. Average top, middle, and bottom diameters, and height of A3-3 graphite compacts before irradiation.

ID	Top (mm)	Middle (mm)	Bottom (mm)	Height (mm)
M1-9	7.985	7.983	7.962	5.064
M1-8	7.987	7.980	7.965	5.061
M1-7	7.990	7.985	7.973	5.072
M1-6	7.986	7.984	7.963	5.046

ID	Weight (g)	Density (g/cm^3)
M1-9	0.4499	1.636
M1-8	0.4499	1.637
M1-7	0.4484	1.625
M1-6	0.4473	1.632

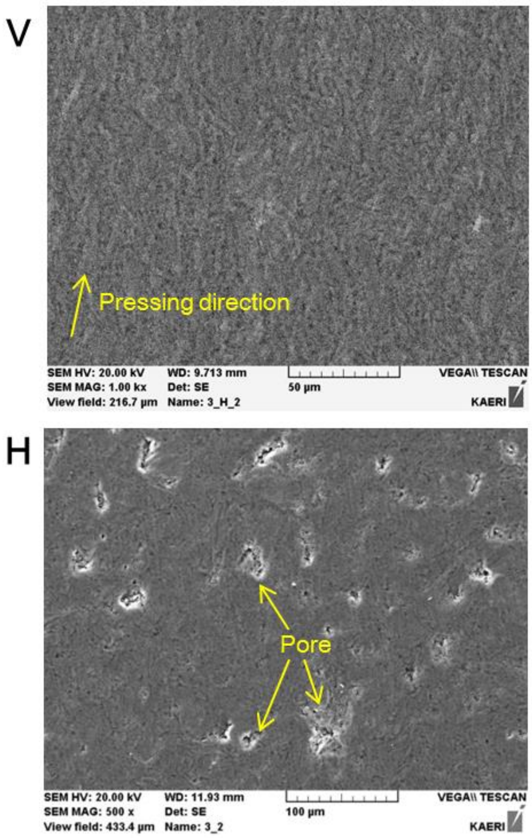

Fig. 4. EPMA images of H and V sections of pre-irradiated A3-3 graphite matrix

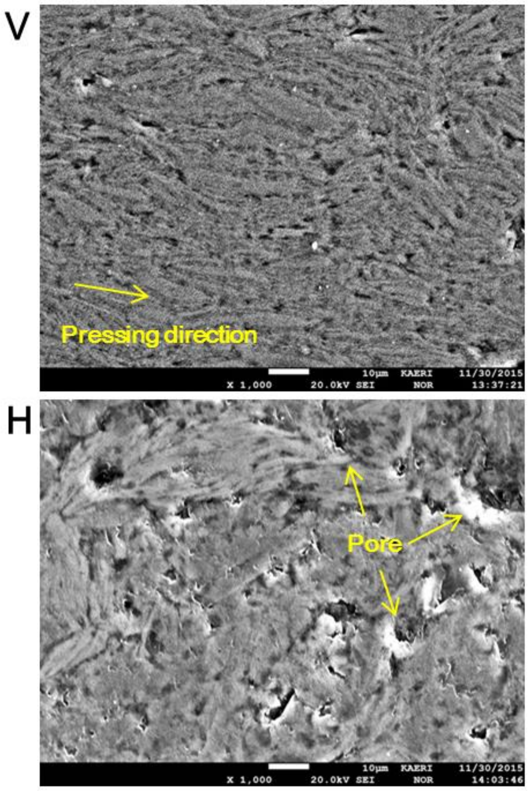

Fig. 5. EPMA images of H and V sections of post-irradiated A3-3 graphite matrix

4. Conclusions

Dimensional change and microstructure of A3-3 graphite matrix compacts were investigated after the irradiation test in HANARO. While the diameter was increased, the height of A3-3 graphite compacts was decreased. Density calculation results in 9.45% increased value after irradiation due to the weight increase and volume decrease. In microstructure investigation, grain alignment and pores are observed in V and H sections, respectively in both pre- and post-irradiated compacts.

REFERENCES

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