Wear Behavior of Selected Nuclear Grade Graphites at Room Temperature in Ambient Air Environment

Eung-Seon Kim, Kwang-Seok Park, Yong-Wan Kim
VHTR Technology Development Group, Korea Atomic Energy Research Institute
1045 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea
**Corresponding author: kimes@kaeri.re.kr*

1. Introduction

In a very high temperature reactor (VHTR), graphite will be used not only for as a moderator and reflector but also as a major structural component due to its excellent neutronic, thermal and mechanical properties. In the VHTR, wear of graphite components is inevitable due to a neutron irradiation-induced dimensional change, thermal gradient, relative motions of graphite components and a shock load such as an earthquake. Large wear particles accumulated at the bottom of a reactor can influence the cooling of the lower part and small wear particles accumulated on the primary circuit and heat exchanger tube can make it difficult to inspect the equipment, and also decrease the heat exchange rate [1,2]. In the present work, preliminary wear tests were performed at room temperature in ambient air environment to understand the basic wear characteristics of selected nuclear grade graphites for the VHTR.

2. Experiment

2.1 Materials

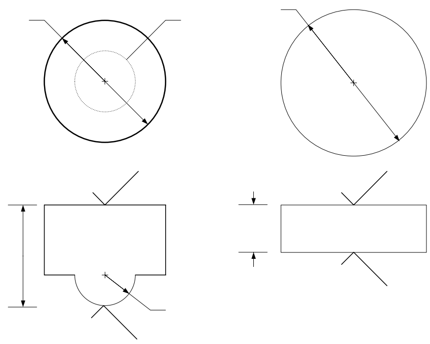
Four grades of nuclear grade graphites were used in this study: IG-110 (petroleum coke, isostatically molded) produced by the Toyo Tanso Co, Ltd, Japan and NBG-17, NBG-18 (pitch coke, vibrationally molded) and NBG-25 (petroleum coke, vibrationally molded) produced by the SGL Carbon Group, Germany. The main properties of the graphites are summarized in Table 1.

Table 1 Typical properties of the four graphites

Grade	Density (g/cm^3)	Coke particle size (μm)	Compressive strength (MPa)
IG-110	1.78	20	81.3
NBG-17	1.86	Max. 900	75.7
NBG-18	1.81	Max. 1800	72
NBG-25	1.86	Max. 60	105.4

2.2 Wear tests

The wear tests were performed using a standard SRV tester from the Optimol Company, Germany at room temperature in ambient air environment. The specimens were ball-on-disk type as shown in Fig. 1. The normal load was set as 6N. The lower specimen was stationary and the upper specimen was reciprocating motion. The stroke was 2mm with 10 Hz frequency.



(a) (b)

Fig. 1 Ball-on-disk type wear specimens; (a) upper and (b) lower specimens.

3. Results and Discussion

3.1 Wear Test Results

Fig. 2 shows the variation of friction coefficient with sliding distance for each grade. At the beginning, the friction coefficients were higher and then decreased to a stable values with the increase of sliding distance for all the grades. This trend is consistent with the typical wear behavior that at the beginning the friction coefficient is higher than that under steady state mainly due to the cutting action of the asperities on the contact surfaces.

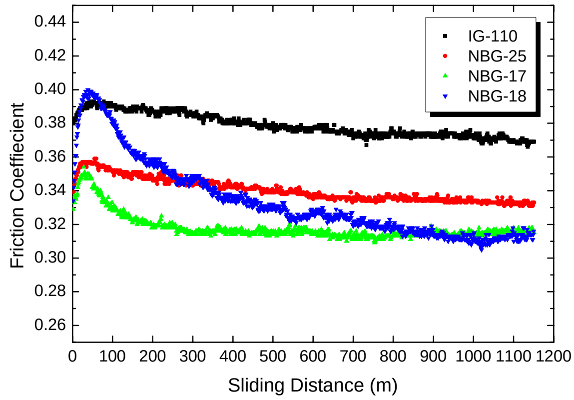
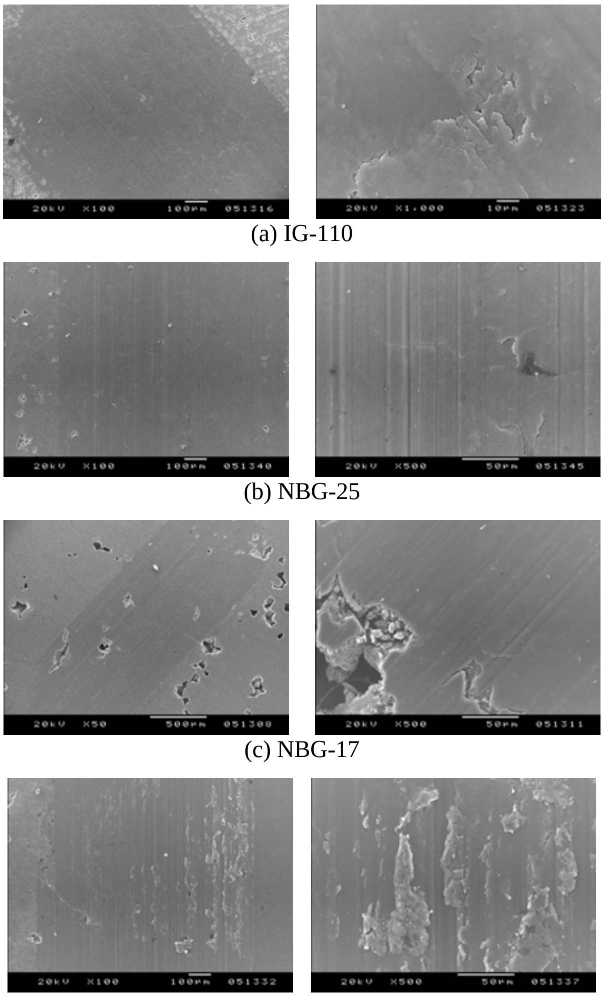


Fig. 2 Variation of friction coefficient with sliding distance

It was found that the steady friction coefficient decreased with the increase of the coke particle size. The steady friction coefficients were 0.369, 0.332, 0.316, and 0.314, respectively, corresponding to the grades of IG-110 (20 μm), NBG-25 (Max. 60 μm), NBG-17 (Max. 900 μm) and NBG-18 (Max. 1800 μm). It is known that the material properties such as the porosity, crystallinity, composition and impurity can influence graphite wear. However, the graphites used in this study are high purity nuclear grades which satisfy the ASTM D 7219-05 standard specification for isotropic and near-isotropic nuclear graphite so that the four grades have the nearly the same crystallinity, composition and impurity level and thus the porosity and size of coke particle are considered to be the main material factors affecting the wear behavior.

3.2 Worn Surfaces

The worn surfaces observed with scanning electron microscope (SEM) are shown in Fig. 3.



(a) IG-110
(b) NBG-25
(c) NBG-17
(d) NBG-18
Fig. 3 SEM photos of worn surfaces

In the fine-grained graphites, the IG-110 and NBG-25, the worn surfaces were very smooth and the pre-existing pores were fully filled with the wear debris and disappeared. The magnified photos showed that there were many pits caused by adhesion tearing and the sizes of pits were comparable to the size of coke particle. In the NBG-25, however the grooves were more clear and thicker than those observed on the surface of the IG-110 and some thin wear particles were often observed. It is reported that the particles are resulted from a jostling action between friction surfaces and adhere to the surfaces by Van der Waals force [3]. The grooves are produced by shear action of roughness asperities and debris, i.e. grinding abrasion. The friction surfaces of the NBG-17 showed that the grooves were apparent and thicker than the IG-110 and NBG-25 and the adhesion pits were hardly observed. The pre-existing pores remained but were filled with some particles produced during friction. In the NBG-18, the grooves were much thicker among the four graphite and the surface was very rough with worn particles adhered on the friction surfaces. The worn particles form the third-body layer and act as s soft, low shear stress solid lubricant to reduce the friction surfaces [4].

3. Summary

The wear behavior of selected nuclear grade graphites was preliminarily examined at room temperature in an ambient air environment and the results are summarized as follows;

1. The steady friction coefficients decreased from 0.369 for the IG-110 to 0.314 for the NBG-18 with the increase of the size of coke particle.
2. As the size of coke particle increased the wear mechanism changed from adhesive tearing to grinding abrasion.

Acknolwledgement

This study has been carried out under the Nuclear R & D Program supported by the Korean Ministry of Education, Science and Technology.

REFERENCES

[1] X. Luo, S. Yu, X. Sheng, S. He, The Influence of Roughness on Tribological Properties of Nuclear Grade Graphite, Journal of Nuclear Materials, Vol.350, p.74, 2006.
[2] X. Luo, S. Yu, X. Sheng, S. He, Temperature Effect on IG-11 Graphite Wear Performance, Nuclear Engineering and Design, Vol.235, p.2261, 2005.
[3] X. Sheng, S. Yu, X. Luo, S. He, Wear Behavior of Graphite Studies in an Air-Conditioned Environment, Nuclear Engineering and Design, Vol.223, p.109, 2003.
[4] M. GodetJ. The Third-Body Approach: A Mechanical View of Wear, Wear, Vol.10, p.437, 1984.
.