FRICTION COEFFICIENTS OF NUCLEAR GRADE GRAPHITES FOR VERY HIGH TEMPERATURE GAS-COOLED REACTOR AT ROOM TEMPERATURE

Eung-Seon Kim and Yong-Wan Kim

Nuclear Hydrogen Reactor Technology Division, Korea Atomic Energy Research Institute, Daedeok-daero 1045, Dukjin-dong, Yuseon-gu, Daejeon, 305-353, Korea

Introduction

In a very high temperature gas-cooled reactor (VHTR), the friction of graphite blocks on one another or of the fuel pebbles on the graphite reflector blocks may produce graphite dust which may become a vector for fission products or could possibly impede coolant flow and thus cause local hot spots in the core [1]. However, little effort has been made to study on the wear performance of the nuclear graphite for the VHTR. In the present work, preliminary wear tests were performed at room temperature in ambient air environment to understand the basic wear characteristics of the selected nuclear grade graphites for the VHTR.

Experimental

Four grades of nuclear graphite 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 nuclear graphites

Grade	Density (g/cm^3)	Coke particle size (μm)	Compressive strength (MPa)
IG-110	1.78	20	79
NBG-17	1.86	Max. 800	75
NBG-18	1.85	Max. 1600	72
NBG-25	1.82	Max. 60	104

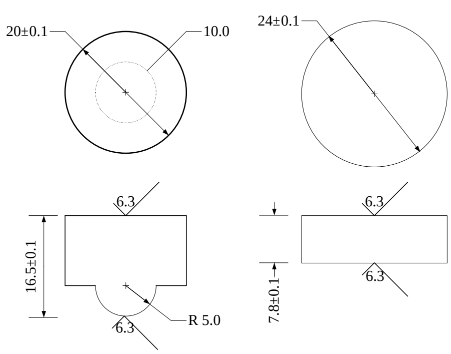


Fig. 1 Ball-on-disk type wear specimens; (a) upper and (b) lower specimens.

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.

Impurities in the graphites were analyzed by using an ICP-AES (Inductively Coupled Plasma-Atomic Emission Spectrometer, Thermo Elemental, X9, UK) and an ICP-MS (Inductively Coupled Plasma-Mass Spectrometer, Thermo Elemental, ICAP 6000, UK). To compare the crystallinity in the filler and binder phases, Raman peaks were selectively measured in backscattering geometry with a JY LabRam HR fitted with a liquid-nitrogen cooled CCD detector. The spectra were collected under ambient conditions using the 514.5 nm line of an argon-ion laser.

Results and Discussion

Fig. 2 shows the variation of a friction coefficient with sliding distances for each grade. At the beginning, the friction coefficients were higher and then decreased to stable values with the increase of sliding distances for all the grades mainly due to the cutting action of the asperities on the contact surfaces.

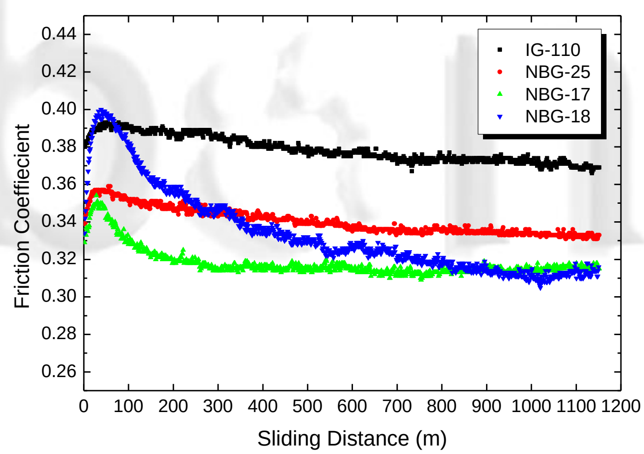
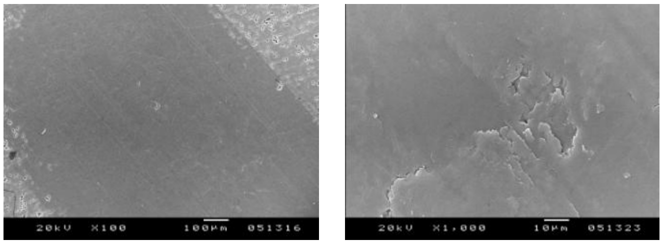
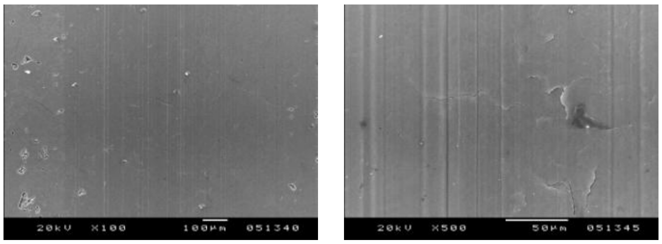


Fig. 2 Variation of friction coefficient with sliding distance

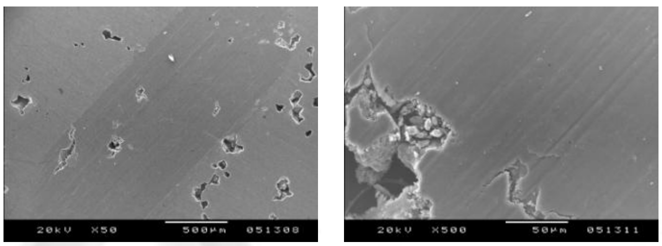
It was noticeable that the steady friction coefficient decreased with the increase of the coke particle size. The steady friction coefficients were 0.369, 0.332, 0.316, and 0.314, respectively, corresponding to the grades of IG-110, NBG-25, NBG-17 and NBG-18. It was known that the material properties such as the porosity, crystallinity, composition and impurity can influence graphite wear. However, the ICP-AES and ICP-MS results showed that the impurity level was the nearly same for the grades and thus the porosity, size of coke particle and crystallinity were considered to be the major material factors affecting the wear behavior.



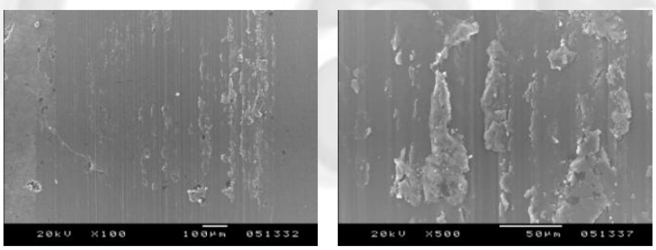
(a) IG-110



(b) NBG-25



(c) NBG-17



(d) NBG-18

Fig. 3 SEM photos of worn surfaces

The worn surfaces observed with a scanning electron microscope (SEM), are shown in Fig. 3. In the fine-grained graphites, 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 particles. In NBG-25, however, the grooves were more clear and thicker than those observed on the surface of IG-110 and some thin wear particles were often observed. It was reported that the particles resulted from a jostling action between friction surfaces and adhered 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 IG-110 and NBG-25 and the adhesion pits were hardly observed. The grooves were produced by the shear action of roughness asperities and debris, i.e. grinding abrasion. The pre-existing pores remained but were filled with some particles produced during friction. In NBG-18, the grooves were much thicker among the four graphites and the surface was very rough with worn particles adhered on the friction surfaces. The worn particles form the third-body layer and acted as a soft lubricant which reduces the friction force [4].

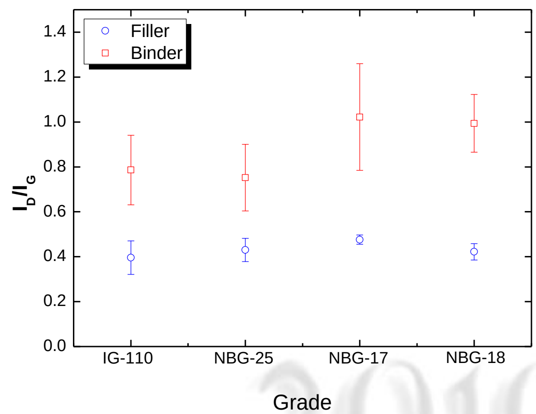


Fig. 4 Raman peak ratio, I_D/I_G in the filler and binder phases

Fig. 4 shows the Raman peak intensity ratios (I_D/I_G) of the D peak (around 1360 cm^{-1}) with respect to the G peak (near 1580 cm^{-1}) in the filler and binder phase for each grade. The I_D/I_G value which was inversely proportional to a crystalline size was much higher in the binder phase regardless of the grade. For a given contact area, relatively more binder phases may contribute to the wear in the fine-grained graphites so that the relation between the crystalline size or the degree of graphitization and the friction coefficient in graphite must be considered further.

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References

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