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Effects of the Air Flow Rate on The Oxidation of NBG-18 and 25 Nuclear Graphite Grades

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1. Introduction

For a VHTR, graphite oxidation is regarded as a critical phenomenon for degrading the integrity of graphite components under normal or abnormal conditions. The oxidation of a graphite core component can occurr by air which may permeate into the primary coolant operation and/or by impurities contained in the He coolant, or by air ingress during a severe accident [1][2].

It is well known that the oxidation properties of a graphite are highly dependent on the source of raw materials, impurities, microstructures (crystallites, pore structure), and on the processing and environmental parameters, such as the forming methods, the coolant type, moisture and impurity content, temperature, flow rate and the oxygen potential of the coolants [3].

A lot of work has been performed on the oxidation of graphite since the 1960s [4], and, for example, in the case of the temperature, a widely accepted oxidation model on
the effects of a temperature has already been developed [5]. However, in the case of the flow rate, even for its expected effects in a VHTR, for example, as to the expected changes in the bypass flow (10-20 %) during an operation [6], no systematic works have been performed .

In this respect, as a preliminary study, the effects of an air flow rate on the oxidation of NBG-18 and 25 nuclear graphite were investigated.

2. Experimental

2.1 Materials and Specimens

Specimens (cylinder: 1″ dia. x1″ length) for an oxidation experiment were prepared from NBG-18 and 25 nuclear graphite grades supplied by SGL. Table 1 shows the selected characteristics and properties of the grades. Differences in the source coke and grain size are noted.

Table 1. Characteristics of NBG-18 and -25 Nuclear Graphite Grades.

Grade	Source Coke	Forming Method	Grain Size (㎛)	Density (gcm^{-3})	Ash ppm
NBG-18	Pitch	Vib.Mold	Max. 1600	1.85	<10
NBG-25	Petro.	″	Max.60	1.82	<11

2.2 Oxidation Experiments

Oxidation experiments were performed in air by using a graphite oxidation test system which was composed of a vertical tube furnace, 3-zone furnace controller (600-1,100℃), a gas supplier, an analytical balance (capacity: 200g, resolution: 0.001g) and a flow meter (Model: KOFLOC RK-1600: 1 – 10 L/min air).

The system was manufactured by the (draft) ASTM Standard Oxidation Test Method for graphite, and by which present experiments were performed [7]. During a test, an automated data collection system was used to record the logged specimen weight and temperature data until the specimen had lost about 10% of its initial weight. Detailed experimental procedures are reported elsewhere [8].

2.3 Optical Microscopy

Differences in the pore microstructure of the specimens oxidized at different temperatures were investigated by using a polarized optical microscope (model: OLYMPUS GX 51).

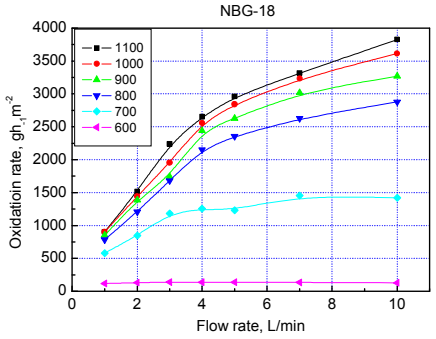
3. Results and Discussion

3.1 Effects of Flow Rate (FR) and Temperature on Oxidation Rate (OR).

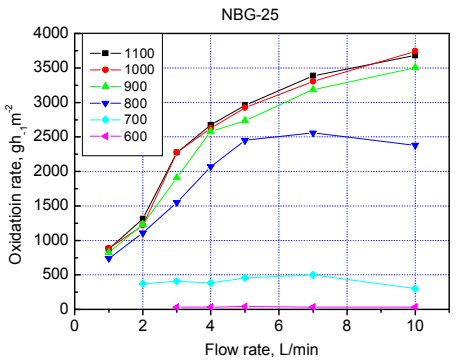
Fig. 1 shows the effects of FR and temperature on the OR of NBG-18 (a) and NBG-25 (b). It is seen that the FR effects on OR appear as temperature-dependent (600℃, 700-800℃, 900-1100℃).

No FR effects are seen for both grades at 600℃.

At 700～800℃, both grades show different FR effects on OR. At 700℃, while the OR of NBG-18 increase nearly 2 times from 550 to 1125 $gh^{-1}m^{-2}$ when FR increases from 1 to 3 L/min, NBG-25 shows a negligible flow rate effects on OR for FR of 2 ～10 L/min. For > 4 L/min, NBG-18 shows no large changes in OR. However, it is worth noting that the OR of NBG-18 is nearly three times higher than that of



(a)



(b)

Fig. 1 Relationship between the flow rate and the oxidation rate for 600～1,100℃: (a) NBG-18 (b) NBG-25.

NBG-25 for FR > 4L/min.

At 800℃, while NBG-18 shows a two step increase: step I: 1 – 4 L/min (OR: 750-2150 gh^{-1}m^{-2}), step II: 5-10 L/min (OR: 2150-2850 gh^{-1}m^{-2}), NBG-25 shows a one step increase (FR: 1-5 L/min, OR: 750-2480 gh^{-1}m^{-2}) with a little change in OR for 5 – 10 L/min FR. In Fig. 1 (a) of NBG-18, it is observed that the step I rate of increase is about three time larger than that of Step II (466.6 gh^{-1}m^{-2}/Lmin^{-1} vs. 140 gh^{-1}m^{-2}/Lmin^{-1}).

For 900-1,100℃, two grades show a quite similar FR effects on OR. Thus, the differences in grade are hardly observed. Both grades show a 2 step increase: Step I: 1-4 L/min, Step II: 4-10 L/min. The rate of increase in OR per unit flow rate (L/min) is about 533.3 gh^{-1} m^{-2}/ Lmin^{-1} for Step I and 183.3 gh^{-1}m^{-2}/Lmin^{-1} for Step II. Again, like the two step increase in OR of NBG-18 at 800℃, it is observed that the step I rate of increase is about three time larger than that of Step II.

Finally, for NBG-18, it is observed that the OR has increased by about 4.7 times when FR increases from 1 L/min to 10 L/min, and the OR at 1,100℃ increased by 30.4 times that of 600℃ at 10L/min FR.

For NBG-25, at 1,100℃, the OR appeared to increase about 4.7 times when FR increases from 1 L/min to 10 L/min, but, the OR appeared to increase 75 times that of 600℃ at 10L/min.

3.2 Comparison of Oxidized Specimen Surfaces Microstructure

Fig. 2 shows the photomicrographs of the specimen surfaces oxidized at 700℃ and 1,100℃ for 1～10 L/min FR of air. It is seen that, while the temperature effects are apparent, the flow rate effects within the same oxidation temperature are negligible for 1～7 L/min FR. In addition, the oxidation surfaces appear to reflect the oxidation reaction mechanisms. Thus, while the oxidized surfaces at 700℃ are somewhat rough (in-pore diffusion mechanism), all the as-oxidized surfaces at 1,000 ℃ show a fine and smooth microstructure (boundary layer mechanism).

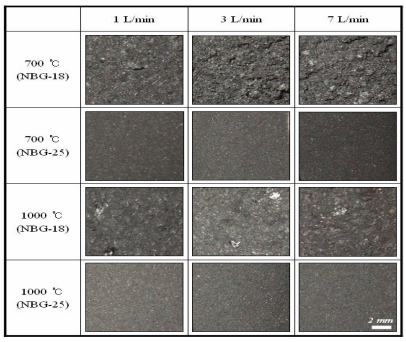


Fig. 2 Oxidized surfaces of NBG-18 and NBG-25 (Oxidation Temp.: 700 and 1,100℃, Flow rate: 1, 2, and 7 L/min).

4. Conclusion

The FR effects on OR increased with an increase in the temperature. For NBG-18, the OR has increased by about 4.7 times when FR increases from 1 to 10 L/min, and the OR at 1,100℃ increased by 30.4 times that of 600℃ at 10L/min FR. For NBG-25, at 1,100℃, the OR appeared to increase about 4.7 times when FR increases from 1 L/min to 10 L/min, but, the OR appeared to increase 75 times that of 600℃ at 10L/min. Investigation of the oxidized surfaces confirmed again the strong temperature effects on oxidation with a negligible FR effects.

Acknowledgement

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REFERENCES

[1] Neiesh C. Chokshi, Makuteswara Srinivasan, et al, Tran. of the 17th Int. Conf. on SMiRT, Prague, Czech Rep., Aug. 17-22, 2003 (paper #F05-6)(2003)
[2] H. Matsuo, JNM 138 (1986) 222-226
[3] R. E. Nightingale, Nuclear Graphite, (Academic Press, Newyork, 1962). pp. 22-50
[4] Luo Xiaowei, et al, Nuclear Engineering and Design 227 (2004) 273-280.
[5] A. Blanchard, IAEA-TECDOC-1154, App. 2.p. 207-213.
[6] ITRG. Design features and technology uncertainties for the next generation nuclear plant, INEEL/EXT-04-01816, Independent Technology Review Group, June 30, 2004.
[7] (Draft) ASTM Standard Test Method for Oxidation Rate and Threshold Oxidation Temperature for Manufactured Carbon and Graphite in Air, ASTM.
[8] Se-Hwan Chi, Gen-Chan Kim, Comparison of the Oxidation Rate and Degree of Graphitization of Selected IG and NBG Nuclear Graphite Grades, (submitted) Journal of Nuclear Materials (Dec. 2006).