Integrity Surveillance Test for HTGR Graphite Core Components by Small Specimens

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1. Introduction

For a graphite moderate high-temperature gas-cooled reactor (HTGR), a reliable monitoring of the mechanical property changes of graphite core components owing to a possible oxidation or neutron-irradiation is a critical issue for safe operation of a reactor. For safety, an increase in the failure probability of the components owing to the degradation of mechanical properties should be analysed and reflected during the operating condition renewal process. In monitoring the degradation of the mechanical properties of graphite core components, however, since the reactor environment has limits in the number, shape, and volume of the pre-installed specimens for integrity evaluation, small specimen test techniques are required. In the present study, specimen size effects on the flexural strength and fracture toughness were discussed based on the data obtained in KAERI for nuclear application.

2. Materials and Specimen

Specimens in various sizes and shapes were prepared for a flexural strength test and fracture toughness test from the advanced nuclear graphite grades for an HTGR. The grades selected are NBG-17, -18, - 25, IG-110, -430, and PCEA. The grain size, forming methods, and number of specimens of the grades selected for this study are shown in **Table 1**.

Table 1 Nuclear graphite grades examined in this study.

		IG-110	IG-430	PCEA		NBG-17		NBG-18		NBG-25	
Grain Size (㎛)		10	10	360		Max. 800		Max: 1,600		20	
Forming Method		Iso-static	Iso-static	Ext.		Vibr.		Vibr		Iso-static	
Nu. Of Spe.	Fl	70		70				70			
	Fr	13	10	a	c	a	c	a	c	a	c
				10	8	10	10	4	7	10	10

The specimen sizes and shapes examined in this study are as follows: three rectangular beams in sizes of 3.2T x 6.3 x 50.5, 6.5T x 12.0 x 52.0, and 18.0T x 16.0 x 64.0 (mm) were tested for flexural strength measurements (Fl: Total: 210 specimens, Cross-head speed: 0.5 mm/min), and a single-edged notched beam (SENB) specimen (50.0 xW:10.0 xT:4.0 mm, Fr: Total: 92 specimens) was tested for fracture toughness measurements. All tests were performed at room temperature based on the respective ASTM test standard, i.e., ASTM C 651-91 (Flexural strength) and ASTM D 7779-11 (Fracture toughness).

3. Results and Discussion

3.1 Flexural Strength Test

The results of a flexural strength test (**Figure 1**) on three different specimen sizes show that the maximum differences from the specimen size are 8 – 37 %, and the specimen size effects on the flexural strength are grade dependent. While NBG-18(a) shows rather significant specimen size effects (37% difference between the 3T and 18T), the differences in IG-110 and PCEA were insignificant (7.6-15%) [1].

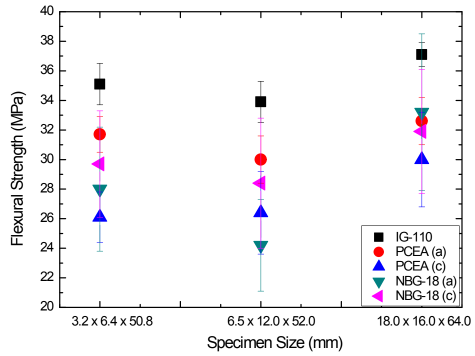

Fig. 1 Flexural strength- specimen size relationship.

Regarding the validity of the obtained results for the grades examined in this study, the data obtained were compared with those databases reported by Martin Metcalfe, et al [1], where the flexural strength were plotted with respect to the (specimen minimum dimension/grain size) ratio. Comparison with the database showed that, while IG-110-3.2T specimens showed some upward deviation from the trend curve, the IG-110-6.5T and 18.0T data were located out of database scale. Except IG-110, all the data from three specimen sizes on PCEA and NBG-18 showed a good correlation with the database. They prepared the database on the flexural strength – (specimen minimum dimension/grain size) ratio from 50 references on flexure strength test.

3.2 Fracture toughness test

The results of a fracture toughness test, Fig. 2, show that all K_{IC} obtained appear to be more or less smaller than those obtained from larger size specimens regardless of the grade. The IG-110 and NBG-18 showed the smallest and largest K_{IC} values, respectively.

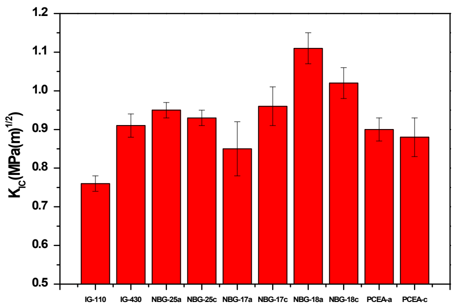

Fig. 2. Results of fracture toughness test (SENB specimen : L:50.0 x W:10.0 x T:4.0 mm).

Compared to K_{IC}, the G-Δa curves obtained in this study were quite comparable to the values obtained from large specimens [**2**]. No clear correlations between K_{IC} and G-Δa (G max) were observed, and the grades formed by iso-static molding (IG-110, IG-430, NBG-25) showed a smaller G-Δa (G max) curve than the extruded or vibration molding grades.

3. Conclusions

The present study on the specimen size effects on flexural strength and fracture toughness measurements of nuclear graphite grades for HTGR shows that the small graphite specimens examined in this study may be applied to an integrity surveillance test of HTGR graphite core components.

Acknowledgement

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