# PERFORMANCE OF C/C COMPOSITE COMPONENTS FABRICATED FOR THE CONTROL ROD USE IN HTGR

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## Introduction

For the past few years R & D have been carried out at Japan Atomic Energy Research Institute(JAERI) on C/C composite control rod which is to be used for the HTTR, High Temperature Engineering Test Reactor. HTTR is a helium-cooled graphite-moderated high temperature reactor, which has been in operation since November 1998[1]. The purpose of the development of C/C composite control rod for the HTTR is to increase the thermal resistance of the control rod so that the reactivity control is to be less-restricted in the process of shut-down. Moreover, the use of the material with the higher thermal resistance would make it possible to raise the normal operation temperature of the future reactors. In the meanwhile, at JAERI the feasibility has also been studied on the high temperature gas-cooled reactor-gas turbine power generating system. In the study a conceptual design of 600MWt reactor and basic design of turbo components have been carried out[2].

As for R & D on the C/C composite control rod, first, some C/C composites have been characterized as a material, including the effect of irradiation effect[3]. Then, some concepts of C/C composite control rod, together with the fabrication method for the rod components, have been investigated[4,5]. In the present paper, the possibility of use of C/C composite for the control rod is assessed on the basis of the results of strength tests on components such as tubes and bolts made of two kinds of materials.

## Experimental

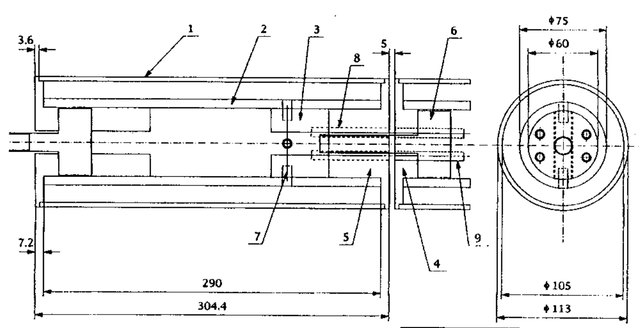
Two kinds of C/C composites were used in the present experiment; AC250(Across Ltd.) and CX-270(Toyo Tanso Co.). First, two materials were characterized through measurements of mechanical and physical properties, the results of which are shown in Table 1. It was considered that both materials had enough strength as candidates for the control rod use. A concept for the control rod shown in Fig. 1 was employed here. As components for the rod, outer tubes(113mmOD x 105mmID x 300mmL), inner tubes(75mmOD x 60mmID x 300mmL), M16 and M8 bolts were fabricated using the materials above. For the tubes 2-dimensional precursor sheet was rooled up to a planned thickness, after which it was impregnated and sintered at about 2000 C. Bolts were machined from a layered precursor sheets which had been impregnated and sintered beforehand.

Tubes and bolts were optically inspected to see if they were fabricated with enough precisions. The tubes were cut into ring-type specimens with thickness of 10 to 50 mm. These specimens were subject to ring compressive test or buckling test at a cross-head speed of 1 mm/min. For bolts tensile, bending, compressive and shear strength tests were carried out using a servohydraulic testing machine at a stroke speed of 1.25 mm/min.

Table 1 Characterization of 2D reinforced C/C composites

| Materials / Characterization | AC250-2D | CX270 |
|---|---|---|
| Density(g/cm3) | 1.7 | 1.59 |
| Tensile strength(MPa) | 131.9 (//) | 227 (//) |
| Compressive strength(MPa) | 194.8 (⊥) | 88(//) 226 (⊥) |
| 3 point bending strength(MPa) | 171.3 (⊥) | 169 (⊥) |
| Shear strength(MPa) | 17.6 (⊥) | -------- |
| Young's modulus(GPa) | 50.7 | 102 |
| Thermal conductivity(W/mK) | 68.6(//) 10.47(⊥) | 35(//) 5(⊥) |
| Thermal expansion(10-6/K) | 0.6(//) 8.2(⊥) | <1(//) 8(⊥) |
| Electrical resistivity($\mu\Omega$ m) | 17(//) | 17.1(//) |

Loading or measuring direction; (//)Parallel to fiber, (⊥);Transverse to fiber




| No. | Component | Material | Quantity |
|---|---|---|---|
| 1 | Outer tube | C/C | 1 |
| 2 | Inner tube | C/C | 1 |
| 3 | Lid supporting plug | C/C | 1 |
| 4 | Upper lid | C/C | 1 |
| 5 | Lower lid | C/C | 1 |
| 6 | M16 Bolt | C/C | 1 |
| 7 | M8 Bolt | C/C | 8 |
| 8 | M8 Bolt | C/C | 4 |
| 9 | M8 Bolt | C/C | 4 |

Fig. 1 A concept of C/C composite control rod

## Results and Discussion

The optical inspection indicated that the dimensions of the tubes and bo;ts could be deemed to be precise enough to assemble a control rod from them.

Results of the ring compressive tests on tube specimens are shown in Fig. 2. Here, one can see that the tube specimens showed the gradual decrease in stress after the maximum stress is reached. It was observed that at Stage 1 in Fig. 2 several inner layers of the ring specimen were fractured and some layers were delaminated. At Stage 2 a large amount of delamination occurred and the crack propagated up to about a half of thickness of the specimen wall. At Stage 3, though the crack lenght was as large as that at the maximum stress, the large deformation of specimen was observed. Buckling tests indicated that specimens fractured very abruptly at the maximum stress with no subsequent gradual decrease in stress.

Results of the tensile or compressive test of M8 bolts are shown in Fig.3 for both materials. It is seen that the AC-250 showed the larger strength and the more brittle nature, comparing with CX-270. There was a good correlation found between the number of pitch and the tensile or compressive fracture strength, which means that the load was sustained uniformly with all the screw threadsconcerned.

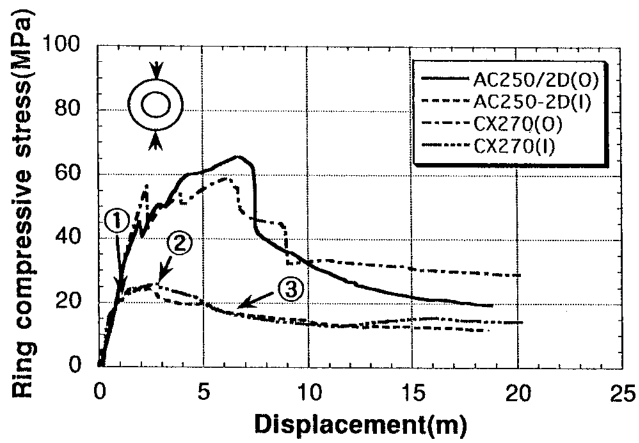



Fig. 2 Ring compressive stress vs. displacement curves for the tube specimens of AC250 and CX-270.

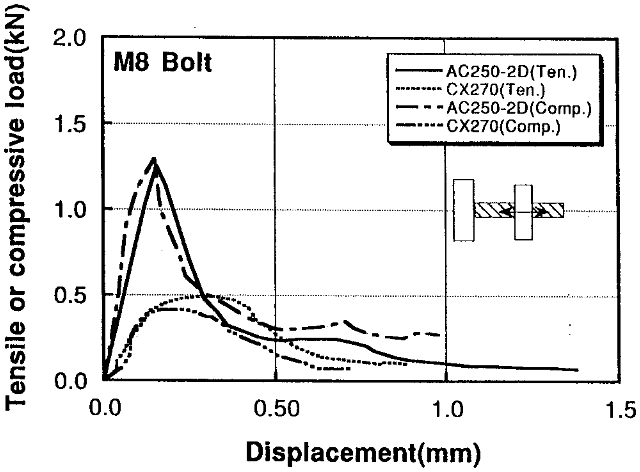



Fig. 3 Tensile or compressive load vs. displacement curves for M8 bolts made of AC250 and CX-270.

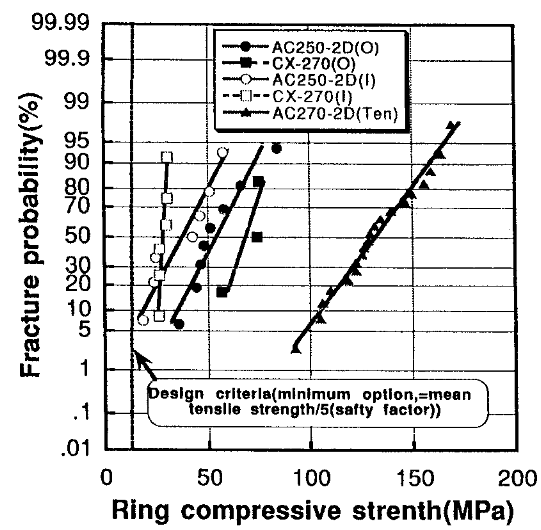



Fig. 4 Distribution of ring compressive strength of tube specimens of AC250 and CX-270..

Fig. 4 shows the ring compressive strength of the tube specimens plotted on the normal probability papaer. Here, the dotted vertical line is a design strength determined temporarily by setting the safety factor as 5. All the tubes exceeded the design strength, although it seems that some improvement in strength is preferable..

## Conclusion

Tubes and bolts for control rod use in the HTTR were fabricated using 2-dimensional C/C composite materials, AC250-2D and CX-270, to examine if the fabrication of the components was possible and they could sustain enough mechanical integrity. (1) It was found that the fabrication of C/C composite components was possible. (2) The strength of the tubes was high enough to design a control rod, although the further improvement of the fabrication method seemed to be preferable. (3) Bolts showed good performance in the tensile, compressive and bending tests.

## References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