RECANT R&D OF C/C COMPOSITE CONTROL ROD FOR HTGRs

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INTRODUCTION

Japan Atomic Energy research Institute's(JAERI) graphite moderated gas-cooled reactor, the high temperature Engineering Test Reactor(HTTR) has been under construction since 1990. The HTTR has a core consisting of an array of stacked graphite fuel blocks and replaceable reflector blocks, which is exposed at very high temperature, especially up to 1600°C in the fuel region. The reactor is designed to be controlled by the control rods as shown in Fig. 1. B_4C pellets are enclosed in the iron based metallic(Alloy 800) capsule of the control rod and linked together. According to the scenario of abnormal reactor operations(for example, scram conditions), control rod will be inserted into the core to stop the reactor operation, and if the rods will be exposed above 900°C at the time, life time of the control rods is extremely shortened mainly due to degradation of creep strength of control rod material. Therefor, to up-grade the performance of the reactor, it is very important to develop new type of control rod for high temperature services.

This paper described the new type of control rod made of Carbon/Carbon composite(C/C) for the HTGR's high temperature service up to 2000°C, which means that this type of control rods can be used almost independently of reactor operation conditions, and shows the mechanical properties of those control rod elements before and after irradiation in the attempt of determine the preferable C/C materials and manufacturing process for the control rod fabrications.

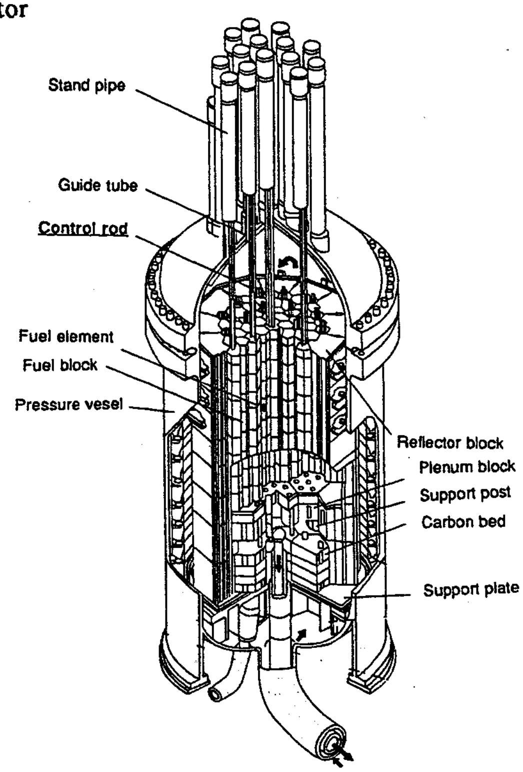


Fig. 1 The structual view of the HTTR

EXPERIMENTAL

Typical PAN and pitch carbon fiber(Toyo rayon Co. LTD.) are prepared to textile pre-forms of 2-dimensional enforced control rod elements. The pre-forms of the elements are carbonized at 1000°C after impregnation with pitch, then graphitized at 3000°C and purified by haloganation process.
The elements fabricated by this process are consisted of B_4C pellet holder, lace track and pin, as shown in Fig. 2, respectively. The pellet holder and the lace track are pre-formed by the combination of cross knitting and

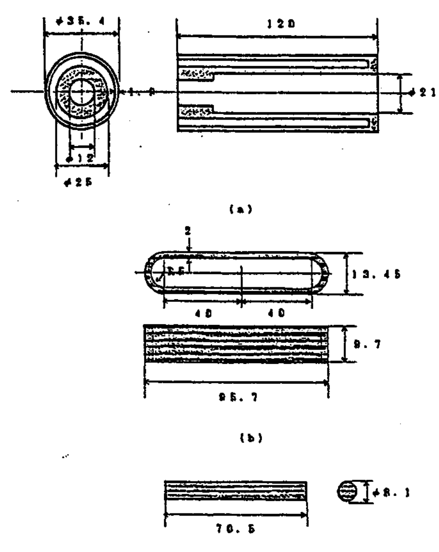


Fig. 2 Control rod elements for HTTR (a)Holder,(b)Lace track and (c)Pin.

filament winding techniques of carbon fibers, and the pin are fabricated by fiber laminating technique. The control rod is assembled with the pellet holders connected by the lace tracks with the pins.

Those elements are tested by instron typed testing machine in air at room temperature. Compressive strength tests of the pellet holder are carried out by radial or axial loading,. Tensile strength of the lace track and three point bending strength of the pin are measured by pulling or bending testing techniques. Bending force on the pin is loaded across or parallel to the fiber layer.

RESULTS AND DISCUSSION

Figure 3 shows load-displacement curves of pellet holder made of PAN and pitch fiber. It is noticeable that after peak loading, stable fracture with large scaled deformation of both fibers are observed. Stable fracture of the holder loaded to radial direction are also observed, and there are no remarkable difference in the deformation and fracture behaviors of the holders made of PAN and pitch fiber. The facts mean that 2-dimensional enforced pellet holder behaves quasi-plastic deformation much enough to guarantee retaining function of the capsulated B_4C pellet in the holder at its fracture such as metallic control rod under compressive loading, and it is indicated that 2-dimensional enforced micro structure of the holder with carbon fiber intercepts crack propagation, which yield unstable fracture of brittle materials such as graphite, and enable flexible deformation under compressive loading.

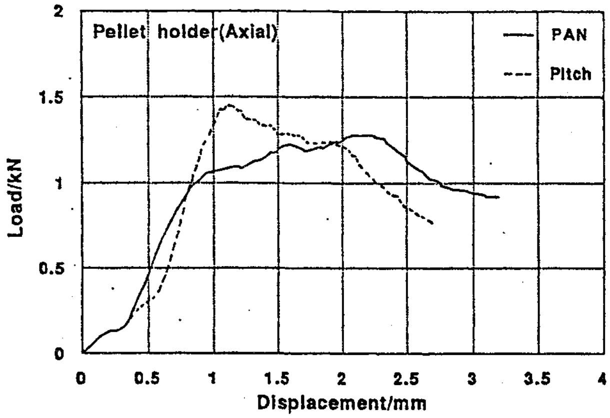
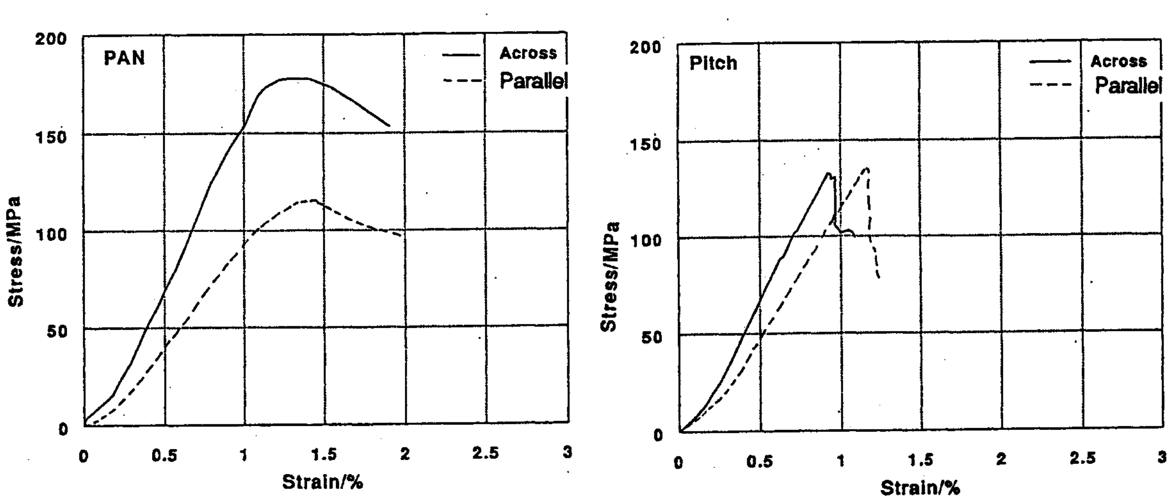


Fig. 3 Load-displacement curves of PAN and pitch pellet holder(loaded to axial direction)

Bending stress-strain curves of the pin elements of PAN and pitch carbon fibers are shown in Figs. 4(a) and (b). Stable fracture and unisotropic fracture strength of PAN carbon fiber are observed, whereas unstable fracture is yielded in the element of pitch carbon fiber.



(a) (b)

Fig. 4 Bending stress-strain curves of PAN(a) and pitch(b) specimens loaded across and parallel to fiber layer.