ACOUSTIC EMISSION AND CRACK PROPAGATION IN MULTI-LAYERED SIC COMPOSITE TUBES

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ABSTRACT: *There is a growing interest in developing accident-tolerent fuel (ATF) cladding after the Fukushima accident. The multi-layered SiC composite, which is one of the ATF cladding concepts, has been widely studied because it has excellent high temperature strength and corrosion resistance even in case of a beyond design basis accident. However, structural reliability of the SiC-based fuel cladding is lower than that of metallic cladding materials due to its brittle nature. Since the SiC-based fuel cladding is composed of various constituents such as fiber, interphase, matrix, pores, monolithic layer, and environmental barrier coating (EBC), the fracture mechanism is complicated. Therefore, it is important to evaluate the mechanical reliability and damage behavior of SiC-based fuel cladding tubes. In this study, two types of SiC-based composite tubes were fabricated, of which the SiC phases were fabricated by the chemical vapor methods. In order to identify damage mechanisms of multi-layer composite tubes with complex structures, the mechanical strength and the crack propagation behavior were evaluated using an acoustic emission analysis method.*

KEYWORDS: *Acoustic Emission, Crack Propagation, ATF, SiC, Composite, Cladding.*

I. INTRODUCTION

Since the SiC composite has quasi-brittle properties, evaluating crack initiation and propagation behavior is important from a cladding design point of view to use the SiC composite as an accident-resistant fuel cladding. However, the strain of the multi-layered SiC composite tubes is small when the hoop strength is measured using the expanding plug method, and it is difficult to find the crack initiation point from the stress-strain curve [1]. An acoustic emission method is quite effective for analyzing crack initiation and propagation behavior of composites [2]. In this study, the determination of crack initiation point and the damage behavior of composites were studied for two multi-layered SiC composite tube using the acoustic emission method.

II. EXPERIMENTAL

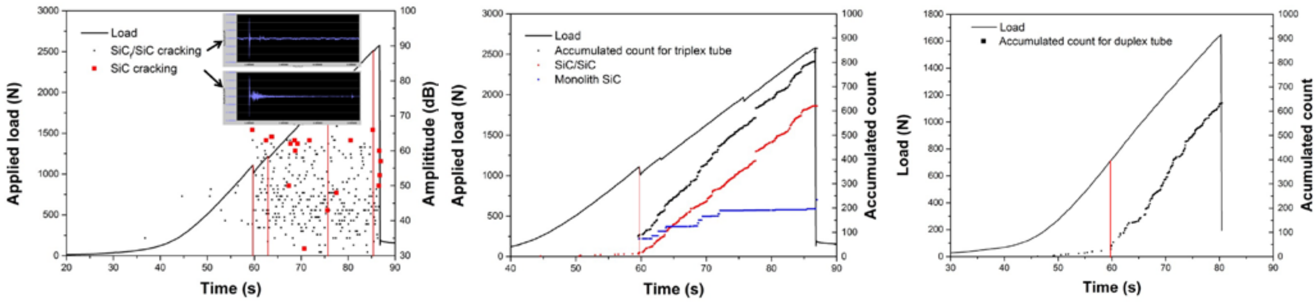
Hoop strength for duplex and triplex SiC composite tubes was evaluated using the expanding plug method [3]. A hoop test was performed for 9 specimens for each type. The duplex SiC tube consists of SiC_f/SiC inner layer and CVD SiC outer layer. The triplex SiC tube consists of CVD SiC inner layer, SiC_f/SiC intermediate layer and CVD SiC outer layer. Information on the test specimen is given in TABLE 1. To evaluate crack propagation behavior using acoustic emission method, a R-case AE sensor was attached directly to the outside of the specimen.

TABLE I. Multi-layered SiC composite tubes for hoop tests

Sample designation	Constituent layers	Dimension (mm)	Thickness ratio (%)
Duplex SiC	CVI SiC_f/SiC – CVD SiC	8.6 ID x 9.6 OD x 10.1 L	56:44
Triplex SiC	CVD SiC – CVI SiC_f/SiC – CVD SiC	8.5 ID x 10.0 OD x 9.9 L	41:42:17

II. RESULTS AND DISCUSSION

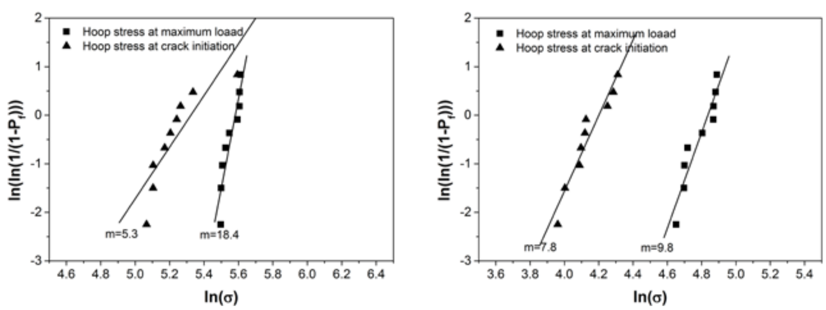
Figure 1 shows the applied load and AE signal of the as-deposited multi-layered SiC composite tubes. As shown in Fig. 1(a), the multi-layered composite tube has two types of the AE waveform. A strong burst AE waveform followed by the second weak signal with longer duration is detected when a crack is formed in monolithic SiC. On the other hand, only a short AE signal is observed for the SiC_f/SiC composite. Since the highest stress is applied the inside the tubular specimen during the expanding plug test [1,4], the crack is formed first in the SiC inner layer. After failure of the inner layer, the SiC_f/SiC composite layer expands and a load suddenly drops because the PyC layer is thinly deposited between the inner layer and the intermediate layer. The frequency of the AE signal associated with cracking in the SiC_f/SiC sharply increases, as shown in Fig. 1(b). In the case of the duplex SiC tube, load drop did not occur because there was no inner layer, as shown in Fig. 1(c). Cracks begin to form in the composite. As microcracks are formed on the matrix phase and breakage of the fibers, the signal continues to increase. The SiC outer layer cracked at the maximum load in the both specimens.



(a) (b) (c)

Fig. 1. Acoustic emission signals during hoop tests for (a), (b) triplex and (c) duplex SiC tubes.

Before the cracking occurs, some noise is generated as the specimen moves due to the expansion of inserted plug. Therefore, the crack initiation stress was determined at the moment when the SiC inner layer cracked for the triplex SiC tube and when the events rapidly increased for the duplex SiC tube. The ultimate hoop and crack initiation stresses of the duplex SiC tube with high composite ratio were much lower than those of the triplex SiC tube, as shown in Fig. 2. As-deposited duplex SiC tubes has a ultimate strength of about 280 MPa and crack initiation stress of about 120 MPa, whereas surface-machined duplex SiC tubes exhibit ultimate strength of about 130 MPa and crack initiation stress of about 70 MPa. This is believed to be due to the damage of the SiC_f/SiC composite during the grounding process. The Weibull parameter of crack initiation stress was much lower than ultimate hoop strength.



(a) (b)

Fig. 2. Weibull distribution of the multi-layered SiC composite tubes: (a) triplex and (b) duplex SiC tubes.

II. Summary

The AE method was used to evaluate crack initiation and propagation behavior of multi-layered SiC composite tubes. Based on the AE waveform, it was possible to distinguish the cracks in the monolithic SiC and SiC_f/SiC composite layers. The effects of design, thickness ratio of constituent layers, and surface roughness on the hoop strength and crack propagation behavior of the multi-layered SiC composite tubes will be discussed.

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