

Corrosion and Mechanical Properties of SiC-Based ATF Fuel Cladding

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1. Introduction

SiC fiber reinforced SiC matrix composite (SiC/SiC) cladding is a promising candidate concept for accident-tolerant fuel (ATF) cladding because it has an exceptional properties under accident conditions such as oxidation resistance and high temperature mechanical properties. Therefore, it has little technical issues in terms of the performance during an accident scenario. On the other hand, it has attracted attention on performance under normal operation such as hydrothermal corrosion and irradiation properties.

In this study, SiC/SiC cladding manufactured by chemical vapor infiltration was examined to verify the performance during normal and accident conditions.

2. Methods and Results

2.1 Hot steam corrosion

Test specimens with 10 mm length, 10 mm OD, and 0.75 mm in thickness were prepared by checmical vapor processes [1]. They was exposed to hot steam of 200 cm/s at 1600°C for 5 hours. As shown in Fig. 1, tubular shape maintained after corrosion test but a crack was observed in outer CVD SiC and intermediate SiC/SiC.

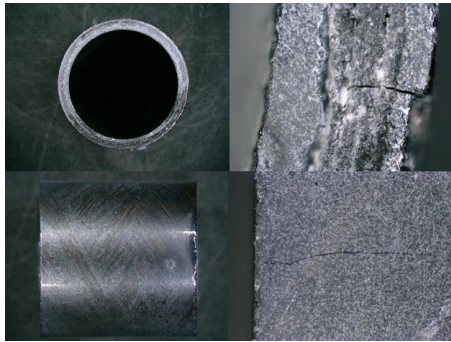
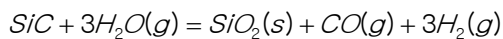


Fig. 1. SiC/SiC tube after testing in hot steam at 1600°C for 5 hours.

SiC reacts with H₂O according to following reactions depending on temperature and vapor pressure: Active oxidation [2]:



Passive oxidation



The weight was slightly increased by 1.01% as listed in Table I. It indicate that a condensed phase SiO₂ formed on the surface by the passive oxidation. The passivation may provide long-term structural integrity during hot steam corrosion at 1600°C.

Table I: Weight Change after Hot Steam Corrosion

	Before test	After test
Weight(g)	0.6669	0.6737
OD(mm)	10.07	10.07
L(mm)	10.10	10.11

In order to evaluate the mechanical degradation, an expanded plug wedge test was carried out. The hoop strength was calculated by following equation [3].

$$\sigma_{\theta} = \frac{r_i^2 P}{r_o^2 - r_i^2} \left(1 + \frac{r_o^2}{r_i^2}\right)$$

Fig. 2 shows the mechanical strength after the hot steam corrosion test. Although a surface crack was generated during the hot steam test, only 29% of hoop strength was reduced. It means that composite layer still has structural integrity after exposure to hot steam.

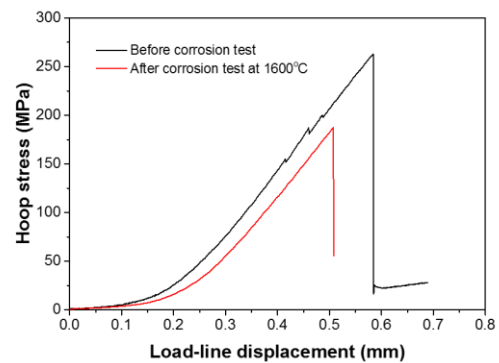


Fig. 2. Mechanical strength of SiC/SiC tube after testing in hot steam at 1600°C for 5 hours.

2.2 Environmental Barrier Coating

Fig. 3 shows the TiCrN- or CrAlN-coated SiC tubes with various compositions.

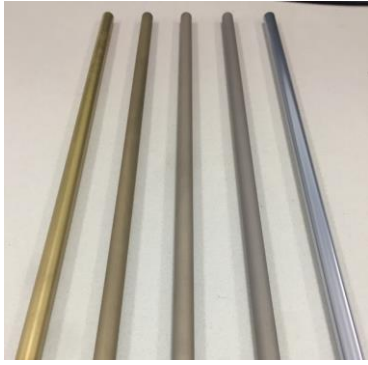


Fig. 3. Environmental barrier coatings deposited on SiC.

For the thermal cycle test, SiC was deposited on graphite rods using a chemical vapor deposition method, followed by a deposition of TiCrN and CrAlN on SiC which is the outer layer of a multi-layered SiC composite tube. Test specimens were exposed to 400°C for 10 minutes. They were taken out in the furnace, and then repeated 10 times. All specimens shows no damage after thermal cycle tests at all. Fig. 4 shows the TiCrN-coated SiC specimen.

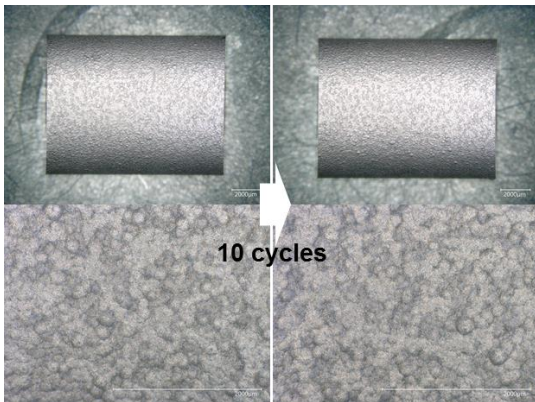


Fig. 4. Microstructure of TiCrN coated SiC after thermal cycle tests.

Hydrothermal corrosion tests were carried out for 90 days in 310°C, 10 MPa water in static autoclave for the selection of coating materials. The corrosion rate of TiCrN was very slow and its weight gain was only about 0.03 mg/cm², caused by the formation of titanium oxides. On the other hand, CrAlN experienced a little weight loss which was measured to be about 0.02 mg/cm².

3. Conclusions

SiC/SiC cladding is one of the three leading ATF cladding concepts, coated-Zr alloy, FeCrAl alloy, and SiC/SiC. It has exceptional severe accident performance among the ATF claddings but the hydrothermal corrosion is the biggest technical problem. Environmental barrier coatings were adopted on

SiC/SiC ATF cladding in this study which will likely improve compatibility of SiC/SiC cladding with coolant water.

Acknowledgement

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