Transactions of the Korean Nuclear Society Spring Meeting
Kyoungju, Korea, October 24-25, 2013

Fabrication and Measurements of Hoop Strength of a Multi-Layered SiC Composite Tube

Daejong Kim*, Jongmin Lee, Weon-Ju Kim, and Ji Yeon Park
Nuclear Materials Division, KAERI, 989-111Daedeok-daero, Yuseong-gu, Daejeon 305-353
**Corresponding author: dkim@kaeri.re.kr*

1. Introduction

Silicon carbide has a low neutron absorption cross section, a high melting point, and low chemical interaction, making it possible to use as fuel cladding in light water reactors. A multi-layered SiC composite tube as the LWR fuel cladding is composed of the monolith SiC inner layer, SiC/SiC composite intermediate layer, and monolith SiC outer layer [1].

In this study, the influence of the winding patterns of the SiC fiber on the fiber volume fraction and hoop strength were investigated.

2. Experimental

2.1 Fabrication of the SiC composite tube

Monolith SiC was deposited onto high purity graphite rod by a CVD method. The CVI (chemical vapor infiltration)-processed SiC_f/SiC composite with a pyrolytic carbon (PyC) interphase was employed as an intermediate layer of the fuel cladding tube. Nuclear grade Tyranno SA3 SiC fibers with 800, 1600 and 3200 filaments/yarn and Hi-Nicalon Type S were wound by a filament winding method to fabricate of thin SiC_f/SiC composite layer. Fig. 1 shows the filament winding apparatus. The PyC interphase was chemically vapor-deposited on the SiC fiber performs. Then SiC matrix was infiltrated by the CVI process using MTS gas. Finally, monolith SiC as an EBC layer was deposited by the CVD method.

Fig. 1. Filament winding on SiC coated graphite rod.

2.2 Hoop strength measurements

Graphite substrate was removed by oxidation to fabricate a multi-layered SiC composite tube. A polyurethane plug with 8.4 mm in diameter and 22 mm in length was inserted in the tube. Then, four LVDTs were attached on the outside of the composite tube as shown in Fig. 2. A compressive load was applied to the plug.

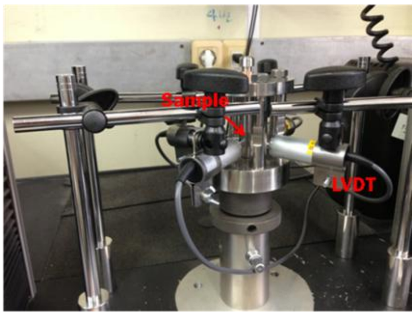


Fig. 2. Hoop test apparatus for a multi-layered SiC composite tube

3. Results and Discussion

3.1 Winding patterns and fiber volume fraction

Fig. 3 shows the winding patterns of Tyranno SA3 fiber with 800 filaments/yarn. Four samples were wound with 55^o of the winding angle. Winding patterns of SiC fiber were changed depending on the travel distance of the roller.

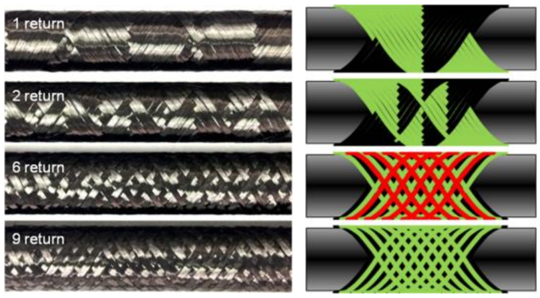
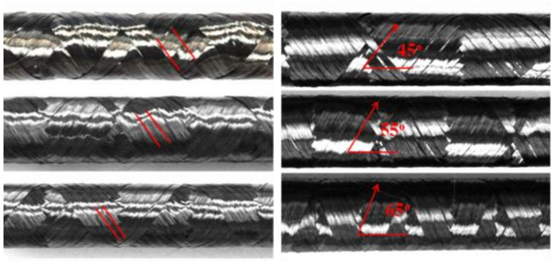


Fig. 3. Filament winding patterns of Tyranno SA3 SiC fiber with 800 filaments/yarn.

The winding angle was controlled in the range of 45 to 64^o by changing travel rate of the roller as shown in Fig 4. Also, the filament counts were adjusted from 800 to 3200 with doubling of the fiber yarn at 55^o of winding angle.



(a) (b)

Fig. 4. (a) Filament counts of 3200, 1600, 800 filaments/yarn and (b) winding angles of 45, 55, 65^o of Tyrano SA3 SiC fiber.

Fig. 5 shows the fiber volume fraction in the SiC_f/SiC composite layer. Tyranno SA3 – 800 filaments with a bamboo-like fiber pattern (1 return as shown in Fig. 3) has the highest fiber volume fraction.

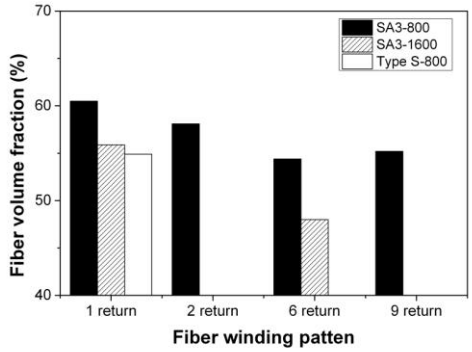
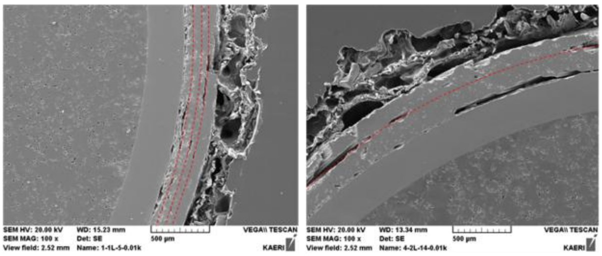


Fig. 5. Fiber volume fraction in the SiC composite layer.

3.3 Chemical vapor infiltration behaviors

Fig. 6 shows the CVI-processed SiC composite with 800 and 1600 filaments of SiC fiber. The SiC composite with 800 filaments consisted of 2 layers (4 stacks). On the other hand, the SiC composite with 1600 filaments is composed of 1 layer (2 stacks) as shown in Fig. 6. The large pores in the composite layer exist between fiber stacks. Pore size is much larger for the SiC with 1600 filaments than 800 filaments.



(a) (b)

Fig. 6. Infiltration behaviors of the SiC_f/SiC composites with (a) 800 and (b) 1600 filaments/yarn.

3.4 Hoop strength of the composite tube

Fig. 8 shows the hoop strength of the multi-layered SiC composite tubes. Hoop strength was highest for the composite tube of Tyranno SA3 with 800 filaments because of high fiber volume fraction and homogeneous distribution of small pores. The strength increased as the winding angle increased to the perpendicular.

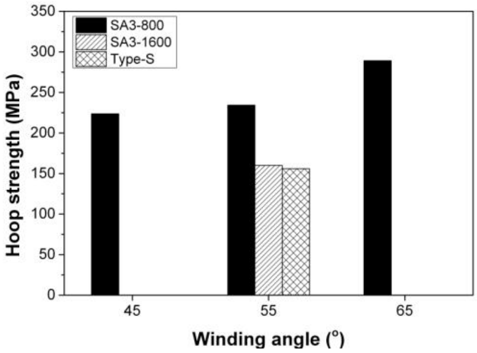


Fig. 7. Hoop strength of the SiC composite tube.

3. Summary

The multi-layered SiC composite tubes were fabricated by chemical vapor deposition/infiltration methods for LWR fuel cladding. The influence of the winding patterns of the SiC fiber on the fiber volume fraction and hoop strength were investigated. Tyranno SA3 – 800 filaments with a bamboo-like fiber pattern has the highest fiber volume fraction. Hoop strength was also the highest for the composite tube of Tyranno SA3 with 800 filaments because of high fiber volume fraction and homogeneous distribution of small pores. The strength increased as the winding angle increased.

Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2012M2A8A5009818).

REFERENCES

[1] L. Hallsadius, S. Johnson, and E. Lahoda, Cladding for high performance fuel, Progress in Nuclear Energy, Vol. 57, p. 71, 2012.