He Leak Tight SiC/SiC Fuel Pin with Zircaloy End-cap for HWBR Irradiation Test at Halden

Akira Kohyama, Hirotatsu Kishimoto and Joon-Soo Park

OASIS (Organization of Advanced Sustainability Initiative for Energy System/Material), Muroran Institute of Technology, Japan

Introduction

SiC/SiC cladding R& D is an important part of accident tolerant fuel (ATF) activities on-going and under planning worldwide. Among many domestic activities in Japan, OASIS, Muroran Institute of Technology is currently running many R & D projects funded by METI and MEXT. Where, reactor irradiation test is an important subject and HBWR irradiation at Halden is on-going with start-up of reactor irradiation anticipated by March 2015. The current results of SiC/SiC cladding segments with Zircaloy tubes jointed both ends present excellent He leak tightness satisfying HBWR reactor irradiation specification for Zircaloy fuel cladding. Currently two projects, SCARLET project and INSPIRE project are planning to start HBWR irradiation test of SiC/SiC claddings by DEMO-NITE process, during Japanese Fiscal Year (JFY) 2014 and 2015, the former un-fueled 2nd generation claddings under PWR condition and the latter fueled 1st generation claddings under BWR condition , respectively. The design details of these experiments and the current status are briefly introduced.

Background

Fibers

- The invention of PCS-Type SiC fibers by Professor Yajima was followed by many R & D efforts and the first Nicalon^{R} fibers was supplied on 1979.
- The R & Ds over 3 decade established highly crystallize and near stoichiometry SiC fibers.
- The production capability of those fibers is reaching to 10 ton/year level and quality and stability improvements have been greatly accomplished.
- Especially, high temperature stability of those fibers make many innovative fabrication concepts of SiC/SiC, such as Nano Infiltration and Transient Eutectic (NITE) process.

NITE Process Development

- The original NITE process is based on aqua-slurry to make preforms which are subjected to be sintered under high temperature pressurization environment.
- Under the R & D of the original NITE process, many products including 10mm diameter tubes were fabricated and provided excellent performances.
- However, the productivity and stability of quality were poor showing the difficulty for becoming industrial products.
- DEMO-NITE process utilizing polymer based slurry to make dry intermediate products as materials for making preforms solved major technological issues of the original NITE process.

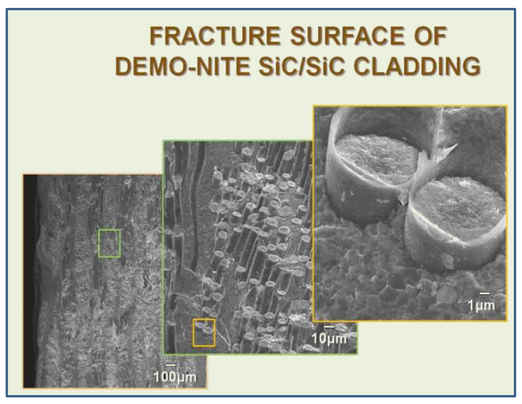
He Leak Tight SiC/SiC Claddings by DEMO-NITE Process

Major R & D Targets of SCARLET Project

- Replaceable SiC/SiC cladding from Zircaloy cladding, which satisfies ASTM Standard for LWR application to produce 10mm^{id}, 1 mm^{t}, and 200mm^{l} claddings with sufficient gas tightness.
- Neutron irradiation tests with un-fuelled test segments at Halden Reactor under PWR water condition.

The Products

- SiC/SiC claddings with sufficient dimensional accuracy and He gas leak tightness fabricated.
- The fracture surface inspected indicate sufficient microstructure with high density and fiber pull-outs.



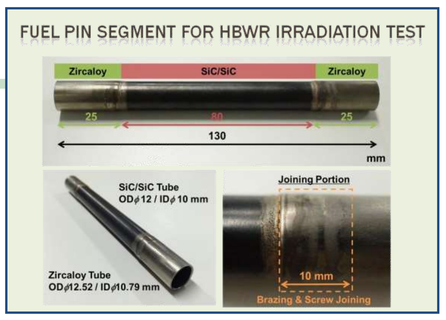
SiC/SiC fuel pin segments with Zircaloy End-caps

SiC/SiC Claddings with Zircaloy Claddings Jointed

- Mechanical and metallurgical joining were applied for making the SiC/SiC with Zircaloy tube jointed segments.
- The excess blazing materials on the surface were polished out before applying final EB welding.

Test segments delivered to IFE Halden

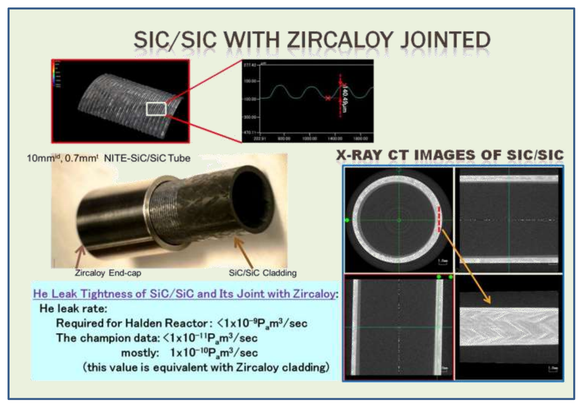
- 16 fuel pin segments for HBWR irradiation test has been delivered September 2014.
- Those segments are under final procedure for inserting collapsible bellows followed by end-cap welding by Electron beam at IFE.

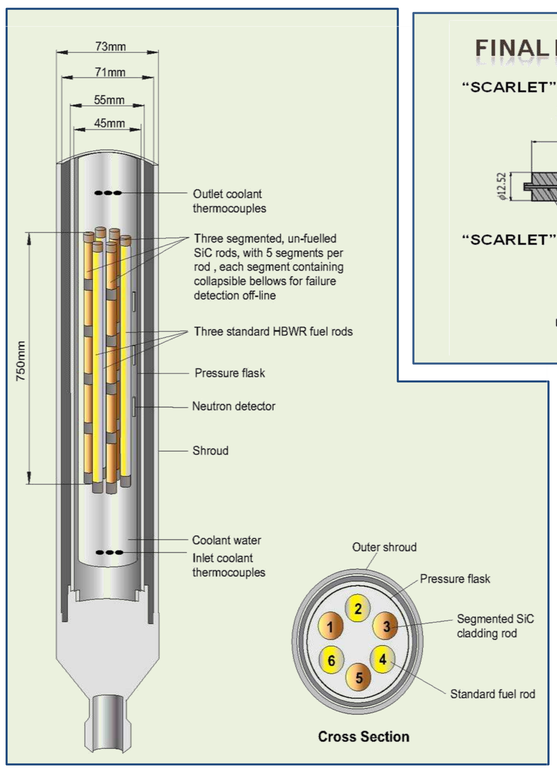


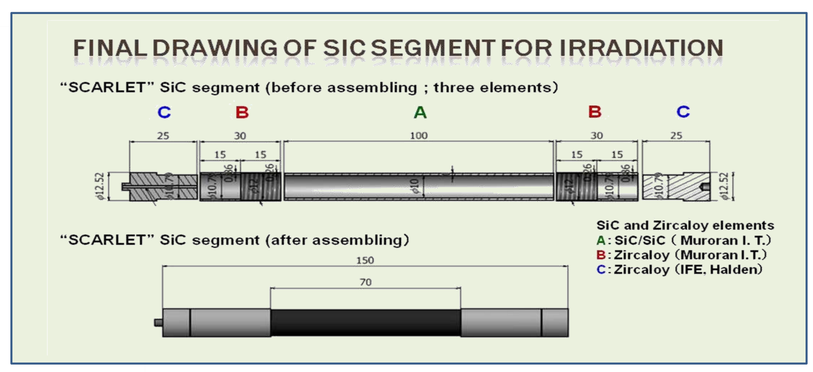
Concept of SiC/SiC fuel pin segments with Zircaloy End-caps

SiC/SiC Claddings with Zircaloy Claddings Jointed

- For enabling the final EB welding of Zircaloy end-caps followed to the insertion of fuel pellets into the segments (the next target for INSPIRE), Zircaloy tube joint is applied.
- The final goal for ATF is to use SiC/SiC end-caps to eliminate Zircaloy or any metallic elements.
- The clear definition about severe accident may change potential fuel pin design.







- The Zircaloy joints with SiC/SiC are applying mechanically by ultra-fine threading about 100μm pitch and metallurgical way high temperature blazing.
- Laser welding and EB welding are under development with/without blazing materials. These methods will be applied to INSPIRE irradiation

Summary

- ✓ **He leak tight SiC/SiC cladding segments with Zircaloy end-caps were successfully fabricated for neutron irradiation test in HBWR at Harden, now under the final process of EB welding for Zircaloy end caps and claddings.**
- ✓ **This accomplishment is based on the development of DEMO-NITE process for making ATF oriented SiC/SiC cladding and the development of joining method for SiC/SiC and Zircaloy.**