In-reactor SiC/SiC Segment Irradiation under Dynamic Reactor Water Condition at Halden
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Abstract
As an important activity for ensuring light water reactor safety, R & D s of accident tolerant fuel (ATF) are on-going at OASIS. Currently INSPIRE project is planning to start HBWR irradiation during FY 2015. This project concerns fuel-clad interaction with the level of 10 GWd/t burning under BWR water condition. The design details of this experiment and the current status are presented. This presentation emphasizing the recent accomplishment of Helium leak tight SiC/SiC fuel claddings over 200mm long. Although there have been many challenges with different process technologies worldwide fabricating all SiC/SiC cladding, so far the results are not satisfactory especially on Helium leak tightness, except NITE process. Major direction except DEMO-NITE process is to use metal liner, such as US and France. The current results on DEMO-NITE process present excellent He leak tightness satisfying HBWR reactor irradiation specification for Zircaloy fuel claddings.

Background
- Fibers
  - The invention of PCS-Type SiC fibers by Professor Yajima was followed by many R & D efforts and the first Nicalon® fibers was supplied on 1979.
  - The R & Ds over 3 decades 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.
  - Owing to the high temperature stability of those fibers, the outstanding and innovative fabrication concepts of SiC/SiC: Nano Infiltration and Transient Eutectic (NITE) process was invented as an international patent.

Helium Leak Tight SiC/SiC Claddings by DEMO-NITE Process
- Major R & D Targets of INSPIRE Project
  - Replaceable SiC/SiC cladding from Zircaloy cladding, which satisfies ASTM Standard for LWR application to produce 10mm², 1mm³, and 200mm³ claddings with sufficient gas tightness.
  - Neutron irradiation tests with fuelled test segments at Halden Reactor under BWR water condition.
- The Products
  - SiC/SiC claddings with sufficient dimensional accuracy and Helium 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
  - 6 fuel pin segments for HBWR irradiation test will be delivered February 2015.
  - Those segments are under final procedure for inserting fuels followed by end-cap welding by Electron beam at IFE.

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.

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 to SiC/SiC segment, followed to the insertion of fuel pellets into the segments at IFE, Halden, SiC/SiC segment with Zircaloy tubes jointed both ends is designed.
  - The joining of Zircaloy tubes to both ends of SiC/SiC segment is to be done by OASIS. Thus EB welding of Zircaloy end caps at Halden becomes with Zircaloy tubes.
  - The final goal for ATF R & D is to use SiC/SiC end-caps to eliminate Zircaloy or any metallic elements.
  - The clear definition about severe accident to be made very soon may change potential fuel pin design with increased accidental tolerance.

Summary
- He leak tight SiC/SiC cladding segments with Zircaloy end-caps are under preparation for neutron irradiation test in HBWR at Halden.
- EB welding of Zircaloy end caps and Zircaloy claddings will be conducted at HBWR.
- 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.