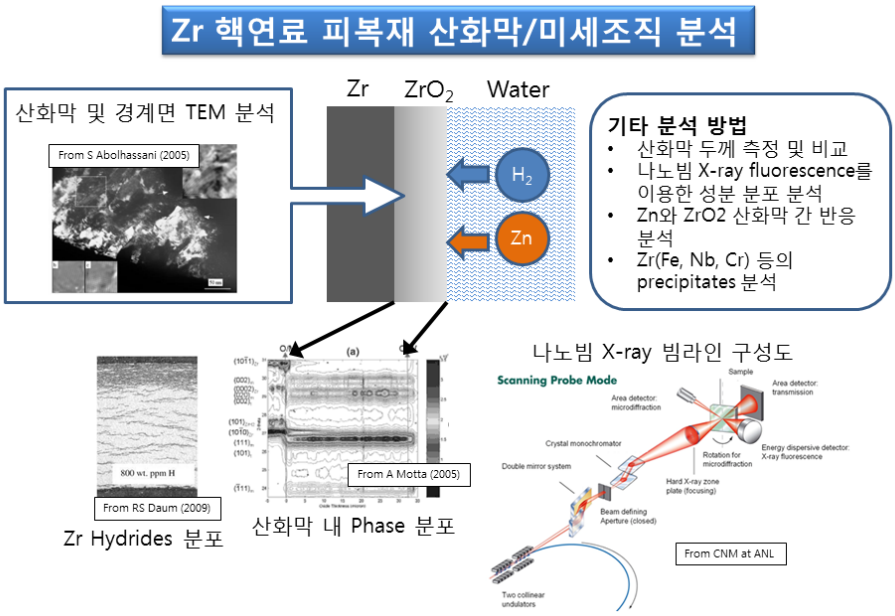
Development of technologies for oxide characterization and material integrity enhancement of zirconium fuel claddings in nuclear power plants

지르코늄 핵연료 피복관의 산화막특성 분석 기술 및 건전성 향상 기술 개발

2013.12.1. ~ 2016.11.30.

The objective of this R&D project is to provide guidance on the modification of the current primary water chemistry guidelines which can improve the material integrity of zirconium fuel claddings in pressurized water reactors (PWRs). Some PWRs have adopted modified water chemistry operating conditions, such as high hydrogen concentration (as high as 50 cc/kg) and zinc (Zn) injection (typically ~10 ppb), to mitigate stress corrosion cracking (SCC) issues of Ni-base structural materials of PWRs or to reduce the amount of corrosion product activation. Some plants already have been operating at as high as 40 cc/kg hydrogen, which is higher than the typical value of 30 cc/kg, and they are even planning to increase higher to, e.g., 50 cc/kg of hydrogen. The higher hydrogen condition appears to be beneficial from the SCC perspective of Ni-base structural materials, but relatively little has been known on the effect of such a high hydrogen condition on the fuel cladding integrity. It is also necessary to investigate the effect of Zn injection on the fuel cladding integrity.



Research on Regulation Technology Development for Cracking Resistance and Life Prediction of Ni-base Welds Considering Thermal Aging and Residual Stress

장기열적시효와 잔류응력을 고려한 니켈계 합금 용접부의 균열저항성변화 및 수명예측에 관한 안전규제기술개발 연구

2014.12.1. ~ 2017.07.31.

Main purpose of this work is to experimentally measure the variations of microstructure and cracking resistance of Ni-base weld 182 considering the long-term thermal aging and residual stresses. It is also intended to estimate the variation of 182 welds' life due to the thermal aging and residual stresses by using a prediction equation for the crack initiation time.

This work is mainly composed of three research topics: microstructural and mechanical properties analysis of 182 welds, primary water stress corrosion cracking resistance evaluation, and residual stress analysis.

○ Analysis of microstructural and mechanical properties:

- Production of 182 weld deposits aged during 15 year- and 30 year-equivalent time
- Analysis of microstructure, micro-hardness, and tensile properties for as-welded and aged weld specimens
- Production of cold-rolled specimens
- Analysis of microstructural and mechanical properties for cold-rolled specimens

○ Evaluation of primary water stress corrosion cracking resistance:

- Manufacturing of crack initiation test facility
- Measurement of crack initiation time for as-welded and aged 182 weld specimens in simulated primary water conditions
- Measurement of crack initiation time for cold-rolled 182 weld specimens
- Life prediction of 182 welds considering thermal aging and residual stresses by using a prediction equation for the crack initiation time

○ Weld residual stress analysis:

- Numerical analysis of residual stress in a pressurizer or bottom-mounted instrumentation nozzle

- Determining the cold rolling conditions of 182 weld specimens
- Development of weld residual stress analysis method considering a hardening behavior.

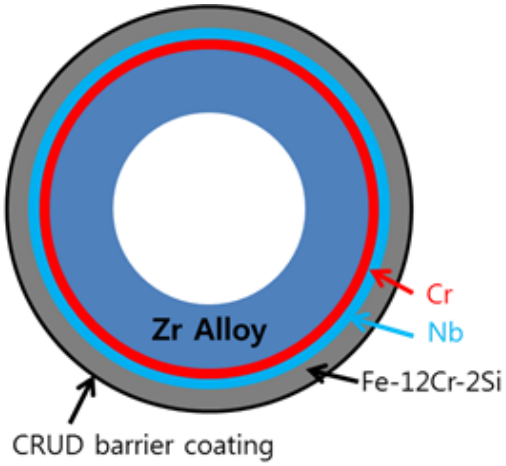
Development of technologies for Manufacturing Multi Metalic Layerd Composite LWR Fuel Cladding to Enhance Accident Tolerance and CRUD Deposition Resistance

사고 저항성 및 크러드 흡착 저항성 향상을 위한 다중 금속층 복합구조 경수로 핵연료 피복관 제조 응용기술 개발

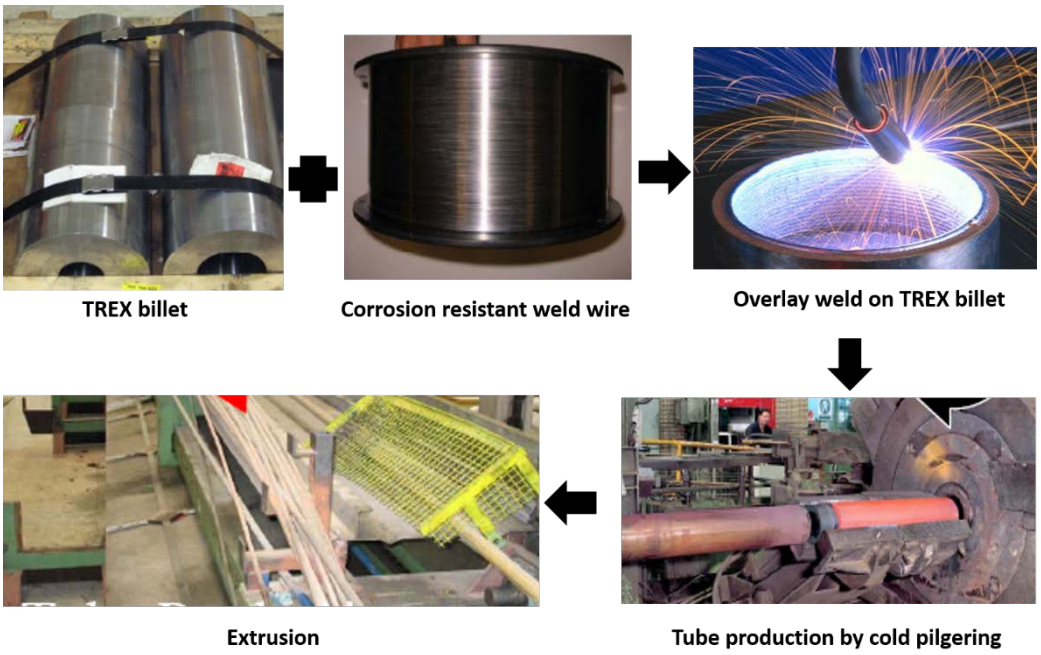
2016.6.1. ~ 2019.5.31.

The objective of this R&D project is to develop a multi-metallic layered composite (MMLC) fuel cladding, a completely new concept for an accident tolerant fuel and preventing CRUD(Chalk River Unidentified Deposits) on the fuel cladding surface. The iteration on the MMLC, as well as the CRUD-resistant coating technology development, will make the MMLC resistant to both normal LWR degradation modes and to accidents, adding precious time to react in the case of a severe accident. The gains to be realized include:

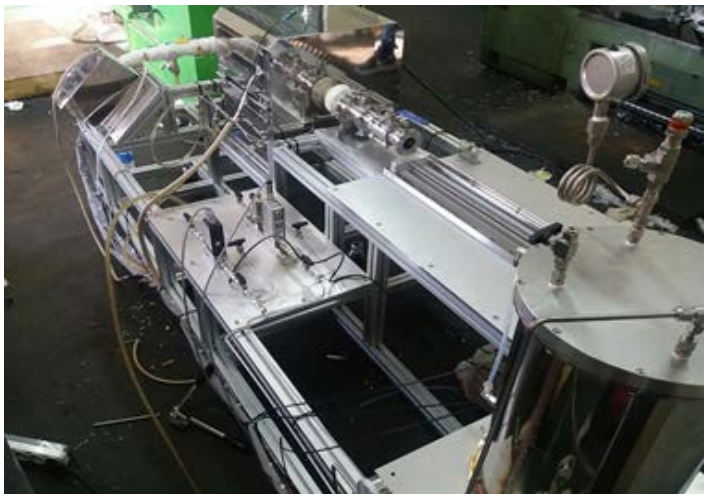
- Decreased hydrogen production in an accident, due to 50% less Zr in the reactor
- Removal of the CRUD-induced localized corrosion mode of failure
- Decrease in primary circuit activation and worker dose due to CRUD elimination
- Elimination of CRUD, removing the chance of a CRUD-induced power shift



다중 금속층 복합구조 경수로 핵연료 피복관 단면도 [from Prof. M. Short]



용접 및 필거링 공정을 통해 제작된 MMLC 피복관 공정 예시



고온산화실험 장치

Development of Basic Technologies for FeCrAl alloy LWR Fuel Cladding Materials to Enhance Accident Tolerance

---

사고저항성 향상을 위한 FeCrAl 기반 경수로 핵연료 피복재 기초기술 개발

2017.7.14. ~ 2019.12.31.

○ Development of basic technologies for FeCrAl alloy LWR fuel cladding materials to enhance accident tolerance

- Optimization of composition of FeCrAl alloy satisfying characteristics of LWR fuel cladding
- Confirm the improvement of FeCrAl compared to zirconium alloy

○ Optimization of FeCrAl alloy composition using computational thermodynamics

- Determination of optimum composition ratio of Cr and Al, which are major alloying elements
- Optimization of small quantities alloy elements: Mo, Ti, Y, Nb, Zr, etc.

○ Specimen preparation of FeCrAl alloy

- Optimization of FeCrAl alloy model specimen manufacturing process
- Observation of microstructure by Rolling / Annealing Process
- Specimen preparation of FeCrAl alloy with optimized composition

○ Confirm the improvement level of FeCrAl compared to zirconium alloy

- Tensile property measurement at room temperature and high temperature
- Long-term corrosion test under normal LWR operating condition
- Evaluation of irradiation resistance using proton or ion beam
- Evaluation of high temperature oxidation resistance