Instrumentation of experimental fuel and future needs for PIE and hot-cell work (abstract & presentation slides)

Helge THORESEN

OECD Halden Reactor Project

Abstract

In the future there will be an increasing demand for "ordinary" fuel and materials PIE as well as other types of hot-cell engineering work related to materials testing and re-fabrication / re-instrumentation of fuel. The ever increasing requirement for going to higher fuel discharge burn-ups in commercial power plants combined with the increasing utilisation of e.g. MOX, gadolinium and additive fuels will be the driving force behind this. The stronger focus also on fuel reliability issues like cladding corrosion and CRUD and changes in operational / licensing criteria will also result in an increased need for "ordinary" PIE and re-fabrication / re-instrumentation of fuel.

In conjunction with plans for life-time extensions for existing power plants and preparations for realisation of new reactor concepts (supercritical and high-temperature reactors as well as e.g. accelerator driven systems) there will be an increasing demand also for hot-cell engineering work, especially in close relation with test reactors.

Keywords: PIE, hot-cell work

1 Tel: (+47) 69 34 42 37, helge@hrp.no
The Halden Reactor

- Research facility for the OECD Halden Reactor Project, an international cooperative effort directed at improved safety and economy for operation and design of NPPs
- Available for contract work for utilities, vendors, licensing authorities and R&D centers in the 20 member countries
- Enables irradiation of test rigs with instrumented fuel rods and material specimens

Instrumentation of fuel – key issues:

- Thermal performance & fuel conductivity degradation at increasing burn-up
- Pellet-cladding mechanical interaction and fuel swelling
- Fission gas release mechanisms and parameters
- Tolerable rod pressure - cladding lift-off
- Cladding creep properties at extended burn-up
- Fuel response to transients – load-follow operation, reconditioning at startup, LOCA, etc.
**Instrumented rig for transient testing**

- In-core Connector
- Outlet Coolant Thermocouples
- Fuel Centre - line Thermocouple
- Neutron absorber
- Pressure transducer (PF)
- Shroud (Ø 73/71mm)
- He-3 coil
- Neutron Detector (V-type)
- Differential Transformer (LVDT)
- Inlet Coolant Thermocouples
- Inlet Turbine Flowmeter
- Calibration Valve

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**UO₂ Thermal Conductivity Derived from In-pile Fuel Temperature Data**

- Determines effect of burn-up induced conductivity degradation
- Provides data on:
  - Conductivity degradation
  - Rim formation
  - Gap closure and fuel cladding bonding
  - Fission gas release feedback on fuel temperature

\[
\lambda = \frac{40400}{(464 + a^1B + (1 - 0.0032B)^*T) + 0.0132^e^{0.0018T}} \text{ W/mK}
\]

- \( a = 16 \)
- \( a = 15 (-1 \sigma) \)
- \( a = 17 (+1 \sigma) \)

**Thermal conductivity of UO₂ with 1 sigma uncertainties**
Influence of Grain Size on FGR

- According to diffusion model, in general an increased grain size will result in reduced fission gas release.
- At higher power and FGR >10%, grain size increase is less effective.
- Satisfactory prediction with FGR model.

Instrumentation and PIE of fuel – future needs:

- Higher burn-up targets will require extended database on fuel performance.
- New operation schemes will require data on fuel performance under controlled transients.
- Introduction of additive fuels, burnable poisons, MOX fuel and e.g. inert matrix fuels will require performance database.
- Next generation of power plants "soon" to be planned and built (high temperature gas reactors, liquid metal reactors, etc.)
Instrumentation of materials – key issues:

- Cracking of irradiated materials under BWR and PWR conditions
- Effect of water chemistry on crack growth and crack initiation
- Effects of fluence and alloy composition on IASCC susceptibility of stainless steels
- Investigation of pressure vessel ageing and effectiveness of annealing
Instrumentation and PIE of materials – future needs:

- Life extension of existing power plants will increase the need for material investigations
- Qualification of replacement materials
- Next generation of power plants will require test irradiation and investigation of materials