Post-Irradiation Examination Capabilities of M1 Hotcell in IMEF

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1. Introduction IMEF

2. M1 hotcell equipment
   • Gamma scanning system
   • Dimensional measurement system
   • X-ray CT system
   • Fission gas analysis system
   • Vacuum heating system

3. Summary
Introduction

- **Irradiated Materials Examination Facility (IMEF)**
  - Conducting PIE on irradiated materials used in the HANARO research reactor and power plant reactors
    - Irradiation behavior evaluation of developing fuels and structural materials for next-generation reactors
    - Integrity and life estimation of the structural parts in an operating reactor
    - Back and fuel cycle demonstration tests

Figure. IMEF and HANRO building

Figure. Operating area of IMEF
Introduction

IMEF outline

- Construction: 1988 yr ~ 1993 yr
- 3 stories and a basement (4,000 m²)
- 71m in a total hot cell length
- 8 hot cells with 31 working units

![IMEF 1st floor layout](image)

Table. Main function and equipment of hotcell

<table>
<thead>
<tr>
<th>Hotcell</th>
<th>Main Function</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>Non-destructive test</td>
<td>Gamma scanning system, X-ray CT, Dimension measurement system, Fission gas analysis system, Vacuum heating system</td>
</tr>
<tr>
<td>M2</td>
<td>Dismantling &amp; Cutting</td>
<td>CNC milling M/C, Capsule cutting M/C</td>
</tr>
<tr>
<td>M3</td>
<td>Specimen preparation</td>
<td>Micro cutting M/C, Mounting press, Polishing M/C</td>
</tr>
<tr>
<td>M4</td>
<td>Specimen storage</td>
<td>Storage rack</td>
</tr>
<tr>
<td>M5 line</td>
<td>Mechanical tests</td>
<td>Impact tester, 2-D optical coordinate tester, UTM</td>
</tr>
<tr>
<td>M7</td>
<td>Microscopy</td>
<td>OM, Hardness tester, Density equipment, SEM</td>
</tr>
<tr>
<td>Hot Lab.</td>
<td>Material Morphology</td>
<td>Shielded EPMA, TEM with EDX, Micro X-ray CT</td>
</tr>
</tbody>
</table>
Introduction

Cask receiving
Opening cask
Moving into M1 hotcell
Dismantling capsule

Specimen preparation

Non-destructive tests

Impact test
Dimensional Measurement
Mechanical tests

EPMA
TEM

Density, Hardness, OM ...

Fuel
Material
M1 hotcell equipment

Gamma scanning

- Installed in operating area: MCA, PC, Bench controller
- on the outside the hotcell wall (service area): HPGe detector
- Automatically measuring radionuclide using the bench system
- Using tungsten collimator to minimize the detector deadtime

Figure. Schematic diagram of gamma scanning installed in M1 hotcell
M1 hotcell equipment

Gamma scanning

Figure. Example of gamma scanning for R&D research fuel
Dimensional measurement

- Measuring diameters of fuel rods using the LVDT
- Automatically measuring the diameter using the bench system
- Confirming a change of diameters and swelling

Figure. LVDT installed in M1 hotcell

Figure. Example of diameter measurement

Figure. Bench controller
Dimensional measurement

- Developed for measuring thickness and oxide thickness of plate fuel
- Measuring the plate thickness and the oxide thickness using a LVDT and ECT respectively after performing the calibration by standard specimen
- Maximum measureable size: ~ 700 mm(L), ~ 100 mm(W)
- Minimum measureable gap: ~ 1 mm
## X-ray CT system

<table>
<thead>
<tr>
<th>X-ray Tube</th>
<th>Voltage</th>
<th>20 - 450 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>0 - 15 mA</td>
<td></td>
</tr>
<tr>
<td>Focus size</td>
<td>0.4/1.0 mm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Line Detector Array (LDA)</th>
<th>Length</th>
<th>500mm (effective), non-curved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch</td>
<td>254 μm pitch, 1984 elements in 32 modules</td>
<td></td>
</tr>
<tr>
<td>Scintillator</td>
<td>CdWO4</td>
<td></td>
</tr>
<tr>
<td>Collimator</td>
<td>1 mm, tungsten</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample bench</th>
<th>Turn table diameter</th>
<th>400 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. height and width(sampl)</td>
<td>Height : 400mm</td>
<td>Width : 120mm</td>
</tr>
<tr>
<td>Focus-detector distance</td>
<td>800 ~ 1500 mm</td>
<td></td>
</tr>
</tbody>
</table>

| Software                    | CT software with GOST module |   |

Figure. 450kV X-ray system layout

Figure. 450kV X-ray system installed in hotcell
M1 hotcell equipment

- **X-ray CT system**
  - Observing internal fuel shapes and cracks without destruction
  - Measuring the dimensions using the 3D software and CT technology
  - Reducing specimen waste during the cutting by providing precise fuel shapes and position

Figure. (a) Research reactor fuel, (b) DR scan image, (c) CT scan image
(d) CT scan image(section view) and (e) CT scan image(section view)

Figure. Example of dimensional measurement using X-ray program
### M1 hotcell equipment

#### Fission gas analysis

- Measuring an internal void and a released fission gas
- Puncturing a fuel rod using the laser system
- Analyzing ratio of a released fission gas using the QMS after performing a calibration
- Laser: Fiber laser, 250 W
- QMS: 1 ~ 200 amu

![Figure. Laser puncturing system installed in hotcell](image1)

![Figure. Glove box and vacuum system](image2)

![Figure. Example of fission gas analysis results](image3)
M1 hotcell equipment

■ Heating system

- Developed to confirm various reactions according to the temperature
- Renovated as a vacuum heating furnace to prevent oxidation of a specimen
- Using the rotary and diffusion pump (~$10^{-6}$ Torr)

Figure. Vacuum heating system installed in M1 hotcell
M1 hotcell equipment

- Heating system

Figure. Example of heating test for R&D research fuel

- Fuel compact
- Coated particle fuel

Removing graphite by heating
Summary

1. Test equipment and jigs for NDT have been developed and operated in M1 hotcell. And various PIEs were successfully performed and provided a high-quality PIE data.

2. Burst test and hydriding for the surveillance test of the pressure tube will be performed in M1 hotcell.

3. Through this, IMEF has been devoted to supplying high-quality PIE data to R&D projects on nuclear fuel and materials.
Thank you