Handling Technology of Low Decontaminated TRU Fuel for the Simplified Pelletizing Method Fuel Fabrication System

T. Namekawa, Y. Yamada, A. Kitamura, T. Hosogane, and K. Kawaguchi

Japan Atomic Energy Agency (JAEA)
Specification of the Fuel on FaCT Project

- **Specification of fuel**
  - Elements: 255pins/assembly
  - Pu content: 18 wt% (inner core), 21 wt% (outer core)
  - Pellet diameter: φ 8.74mm
  - Density: more than 95 %TD
  - O/M ratio: less than 1.97
  - MA content: ~5.0 wt%
  - FP content: 0.2 wt%

- Plant scale: 200t-HM/200days
- Operation days: 250 days/year (including casual maintenance)
Six Technical Issues of Fuel Fabrication Technology
Development

Issues for rationalizing present process and issues for measures against MA and FP bearing are intertwined.
R&D Issues Specific on Low decontaminated TRU Fuel Fabrication

Feature | Affect | Required technology | R&D issue
--- | --- | --- | ---
MA,FP bearing | Pellet manufacture | Manufacturing condition | Sintering character control
 | Fuel wellness | Fuel design | Physical property database
 |  |  | Irradiation behaviour
High heat generation | Fuel manufacture | Measure against degradation | Non-organic additives
 |  | Prevention of oxidation | Die lubrication Pressing
 |  | Measure against heat | Evaluation of change
 |  |  | Storage
 |  |  | Cooling system
High radiation | Operation | In-cell equipment | Remote fabrication
 |  | Decontamination | Feedstock containing
 |  | Measure against degradation | Decontamination system
 |  |  | Waste management
 |  |  | Irradiation resistance parts
 |  | Equipment | Measuring technology
 |  | Nuclear material detection | Measuring equipment
Influence of Multi-element to Sintering & Irradiation behaviour

Specified MA and FP bearing fuel is expected to be feasible.
**Fundamental Requirement for In-cell Equipment**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Development Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compatibility to specification</strong></td>
<td></td>
</tr>
<tr>
<td>Processing accuracy</td>
<td>Stability and homogeneity of process condition</td>
</tr>
<tr>
<td>Measurement accuracy</td>
<td>Measurement method</td>
</tr>
<tr>
<td><strong>Automation</strong></td>
<td></td>
</tr>
<tr>
<td>Intra-equipment material flow</td>
<td>Automatic transfer</td>
</tr>
<tr>
<td>Inter-equipment material flow</td>
<td>Automatic control</td>
</tr>
<tr>
<td>Process control</td>
<td>Automatic control</td>
</tr>
<tr>
<td></td>
<td>Anomaly detection</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance system</strong></td>
<td></td>
</tr>
<tr>
<td>Equipment structure</td>
<td>Modularizing</td>
</tr>
<tr>
<td>Remote handling</td>
<td>Easy handling</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The technology can be developed
- based on proven automation technology at present glove-box equipment
- considering balance of hurdle on each requirement;
  
  Compatibility to specification / Automation & Maintenance
  Automation / Maintenance
Optimum Concept for In-cell Equipment Maintenance

**Process cell**
- Removal and/or re-alignment of pellet
- Removal of old module
- Mounting of new module

**Handling device**
- Robot arm for pellet handling
- Manipulator system for remote maintenance

**Decontamination cell**
- Rough decontamination of module
- Takedown of module
- Fine decontamination of module

**Handling device**
- Master slave manipulator, Robot arm

**Maintenance glove box**
- Repair by parts replacement
Fundamental Structure of Module

Present

Motor

Remote operation bolt

module

Positioning pin

Rough guide

Bolt

Hook

Hanger
## Modularized Pressing Machine

<table>
<thead>
<tr>
<th>Pressing machine</th>
<th>Equipment composed</th>
<th>Composite module</th>
<th>Module</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Powder feeder</td>
<td>Powder feeder</td>
<td>Air knocker</td>
</tr>
<tr>
<td></td>
<td>Press head</td>
<td>Press head</td>
<td>Press</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Press head</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 other modules</td>
</tr>
<tr>
<td></td>
<td>Pellet pushing rod</td>
<td>Pellet pushing rod</td>
<td>Stop sensor</td>
</tr>
<tr>
<td></td>
<td>Pellet conveyer</td>
<td>Pellet conveyer</td>
<td>Pellet sensor</td>
</tr>
<tr>
<td></td>
<td>Inspection equipment</td>
<td>Inspection equipment</td>
<td>Pellet chuck</td>
</tr>
<tr>
<td></td>
<td>Pellet alignment equipment</td>
<td>Pellet alignment equipment</td>
<td>Pellet traverser</td>
</tr>
<tr>
<td></td>
<td>Pellet transfer</td>
<td>Pellet transfer</td>
<td>Pellet transfer device</td>
</tr>
<tr>
<td></td>
<td>Empty tray transfer</td>
<td>Empty tray transfer</td>
<td>Side roller</td>
</tr>
<tr>
<td></td>
<td>Pellet tray transfer</td>
<td>Pellet tray transfer</td>
<td>Side roller</td>
</tr>
<tr>
<td></td>
<td>Dust collector</td>
<td>Dust collector</td>
<td>Collector head</td>
</tr>
</tbody>
</table>

| No. of modules   | 10                | 27              |
Modularizing for more precise equipment

- In-line analyzer for physical properties of MOX powder
  - moisture
  - grain size distribution
  - flowability

- Pellet inspection equipment
Handing Device & Man-Machine-Interface

Robot manipulation

MMI to reduce work load on an operator

Visual picture
Measure against MA Decay Heat

- Maximum heat rate is substantially 20W/kgHM at 5wt% of MA bearing MOX (depend on recycle scenario)

- Undesirable effects to fuel production quality;
  - degradation of organic additives
  - re-oxidation of source powder and pellet
  - oxidation of cladding
  - mechanical interaction between pin bundle and wrapper tube, etc.

- Measures to reduce undesirable effects of heat generation of the MA-MOX;
  - deconcentrate the source fuel (easy, but enhance equipment volume)
  - improve function of heat release (if possible)
  - prevent oxidation by surrounding inert gas (high cost)
  - forced cooling operation (reasonable), etc.
Advanced fuel fabrication process proves heat resistance due to MA decay

- **UO₂ Powder**
- **MH conversion**
- **MOX or PuO₂ Powder**

**Recycled MOX** → **Weighing** → **Ball Milling** → **Binder Mixing** → **Granulation** → **Lubricant Mix.** → **Pressing** → **De-waxing** → **Sintering** → **De-gassing** → **Grinding** → **Inspection** → **Pellet**

**Present MOX Pellet Fabrication Process**

- No organic additives at granulation
- Less organic lubricant at pressing

**PuEAS’ MOX Powder**

**Binder-less Granulation** → **Pressing** → **Sintering** → **Inspection** → **Pellet**

**Simplified Pelletizing Method**

*Pu Enrichment Adjustment in Solution*
Feasibility estimation of forced cooling by air blow on assembling process

- At assembling, the heat generation of max. 2.6 kW/assembly (130kgHM) might cause undesirable effects such as oxidation of cladding materials.
- Pin bundle without wrapper tube can be cooled down by air blow at right angle to pin bundle that is proven by full scale mock-up tests.
- So is pin bundle loaded into wrapper tube by air blow which is introduced belong its sodium coolant flow channel.
- Air blow shutdown test is going on.
Feasibility estimation of forced cooling by air blow on pellet storage

To prevent O/M drift, a pellet should be kept below 60°C.
Air blow cooling system on the design condition is feasible.
Feasibility estimation of forced cooling by air blow on new assembly storage

Design specification: 848 pits/storage

Below 300° C
Estimation of Impact on Air ventilation
Concluding Remarks

• R&D are going on toward a C&R in 2010 to decide the adoption.

• The interim summarizing by JAEA shows that in-cell remote maintenance system and MA decay heat removal system are generally expected to be feasible on a 200tH/y-scale plant.