MINOR ACTINIDE BEARING BLANKET MANUFACTURING PRESS

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Fuel production facilities
1. Introduction
2. Issues
3. Objectives
4. Partnership
5. Nuclear press presentation
6. First trials
7. Compaction research
8. Conclusions & perspectives
1. INTRODUCTION

- **Advanced Actinides recycling Processes**
  - Recycling for transuranics
    - *Plutonium multi-recycling*
    - *Minor actinides recovery*
  - Transmutation: heterogeneous or homogeneous mode
  - Hypothesis of a closed cycle with a Generation IV fast neutron reactor fleet implemented at mid or long term (~2040)
  - R&D in the Atalante Facility in Marcoule

- **Heterogeneous option: Recycling / Transmutation**

![Diagram of recycling and transmutation processes](astrid-reactor.png)
But why is NET SHAPE difficult?

- Springback and residual stresses, depend on:
  - Pressure level,
  - Ejection type.

- Stress gradient depends on: tools, powder and compaction cycle with:

  - Friction coefficient $\mu$ (Coulomb law (1)):
    \[
    \mu = \frac{\sigma_{\text{Applied}} - \sigma_{\text{Radial}}}{\sigma_{\text{Transmitted}}} = \frac{S_{\text{Axial}}}{S_{\text{Radial}}} = \frac{\tau_{\text{Axial}}}{\sigma_{\text{Radial}}}
    \]

  - Flow Index $\beta$ (2):
    \[
    \beta = \frac{\sigma_{\text{Radial}}}{\sigma_{\text{Applied}}}
    \]

  - Or Friction index $\mu\beta$ calculated together (Jansen law (3)):
    \[
    \mu\beta = -\frac{R}{2h} \ln\left(\frac{\sigma_{\text{Applied}}}{\sigma_{\text{Transmitted}}}\right)
    \]
3. OBJECTIVES

- Automate fuel pellet manufacturing in hot cell,
- Guarantee equipment safety,
- Minimize the waste generated,
- Nuclearize a press in a hostile environment with limited space,
- Master and optimize the manufacturing process in order to minimize damage and avoid corrective grinding,
- Guarantee the equipment behavior under irradiation,
- Minimize the powder spread,
4. PARTNERSHIP

Industrial partnership
CEA <-> CHAMPALLE

CAO-3D Design

CEA (R&D, Nuclearization)

3D conception
design
set up remote handling in hot cell

Virtual trials

Physical trials

CHAMPALLE (Manufacturer)

Supplies

Manufacturing

Trials & mounting

Radiological dimensioning

Mechanical dimensioning

Compaction modeling & simulation
5. NUCLEAR PRESS (1/5)

Main Press components:

1. Upper punch motor
2. Flange motor
3. Upper body plate
4. Upper plate displacement sensor
5. Rotary powder jar
6. Upper mobile punch plate
7. Upper mobile punch and force sensor
8. Body Columns
9. Powder Columns
10. Pellet jar
11. Mobile die plate
12. Mobile die plate displacement sensor
13. Filling shoe
14. Filling shoe motor
15. Filling shoe displacement sensor
16. Powder jar removal exit
17. Die motor
18. Lower punch with needle and force sensor
19. Lower body plate
20. Rotary base
Main press characteristics:

- 10 ton capacity,
- Uniaxial press,
- Electromechanical press (without oil),
- Floating die or single effect cycles,
- Position or force monitoring,
- Mono punch, with or without needle,
- Rotary body,
- Applied, transmitted force and displacement sensors,
- 1.3 Kg batch with rotary jar,
- Maxi production is 2 pellets/minute,
- Height = 1.2 m,
- All modules must fit through 250 mm diameter air lock
Remote handling CAD simulation for press setup in hot cell
Virtual Reality (VR) simulation for mounting, dismantling and servicing remote handling

- Confirm or modify the conception choices,
- Take into account the remote handling feedback force,
- Check the mechanism coupling between components,
- Demonstrate feasibility of technology nuclearization.
### 5. NUCLEAR PRESS (5/5)

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Location</th>
<th>Mini jar case</th>
<th>Maxi jar case</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Upper punch motor</td>
<td>57</td>
<td>95</td>
</tr>
<tr>
<td>2</td>
<td>Die motor</td>
<td>97</td>
<td>62</td>
</tr>
<tr>
<td>3</td>
<td>Filling shoe motor</td>
<td>1368</td>
<td>465</td>
</tr>
<tr>
<td>4</td>
<td>Transmitted force sensor (*)</td>
<td>28</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Die displacement sensor</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>6</td>
<td>Punch displacement sensor</td>
<td>118</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Applied force sensor (*)</td>
<td>1655</td>
<td>681</td>
</tr>
<tr>
<td>8</td>
<td>South side of the press (30 cm)</td>
<td>246</td>
<td>60</td>
</tr>
<tr>
<td>9</td>
<td>North side of the press (30 cm)</td>
<td>154</td>
<td>148</td>
</tr>
<tr>
<td>10</td>
<td>East side of the press (30 cm)</td>
<td>242</td>
<td>184</td>
</tr>
<tr>
<td>11</td>
<td>West side of the press (30 cm)</td>
<td>238</td>
<td>184</td>
</tr>
</tbody>
</table>

*Tab 1: Estimated dose rate calculations $(EDR)_{total}$ depending on the sensor positions for Mini jar (column, filling shoe, and pellet) scenario and for Maxi jar (*without sensor shielding)*
6. FIRST TRIALS

Nuclear press compaction cycle (Force piloting)

- Upper punch stress
- Lower punch press
- Upper punch position
- Die position

Applied and Transmitted Stress (MPa)

Time (s)

Position (mm)
7. COMPACTION RESEARCH

Characterization with experiments

- DEM simulation
  - 2013-2016 thesis CEA/SIMAP Grenoble

- Microscopic trials
  - Weak Acid Resin (WAR) Process

- Macroscopic trials
  - Instrumented press,
  - Instrumented radial open die,
  - Profilometer,
  - Sintering furnace.

Material properties

- Optimization compaction process
  - Instrumented press,
  - Instrumented radial open die,
  - Profilometer,
  - Sintering furnace.

FEM/DEM Coupling

- FEM simulation
  - Abaqus, Cast3M FEM calculation code

- Cam-clay Drucker prager compaction model

Behavior laws

Dymola code

Modelling

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8. CONCLUSIONS AND PERSPECTIVES

- Automatized uniaxial electromechanical press for manufacturing nuclear fuel pellets in hot cell,
- First pellet profile results are checking.

- Fuel cycle optimization process FEM simulation ABAQUS and coupling with DYMOLA (in progress)
- Granular flow with DEM Simulation (OpenFoam),
- Tool lubrication study (2015),
- Automatic radial open die (trials 2015),
- Physical trials in hot cell (October 2014),

- Glove box press integration for UO$_2$ or/and PUO$_2$ qualification,
- Hot cell press setup in ATALANTE facilities.
Thank you for your attention

Thanks to our collaborators:

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Compaction cycle

Compaction

Grinding

Mixing

Sintering

Springback
Damage
Density gradients

Shrinkage

Pellet