DE LA RECHERCHE À L'INDUSTRIE

www.cea.fr

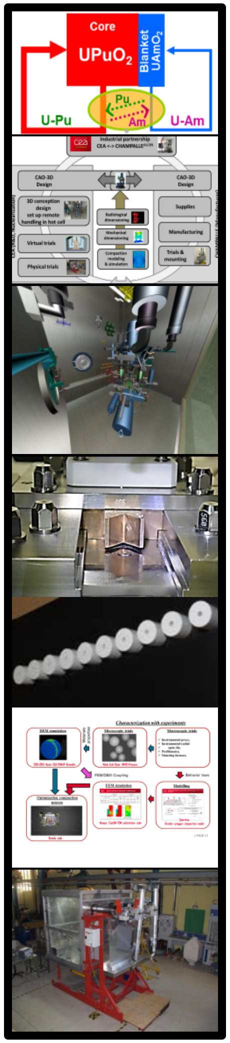
51st Annual Meeting – HOTLAB-2014

MINOR ACTINIDE BEARING BLANKET MANUFACTURING PRESS

HOTLAB 2014| Jean-Philippe BAYLE - DEN/DTEC/SDTC/Ltap
Jean-philippe.bayle@cea.fr

Tuesday, September 23
Fuel production facilities

CONTENTS



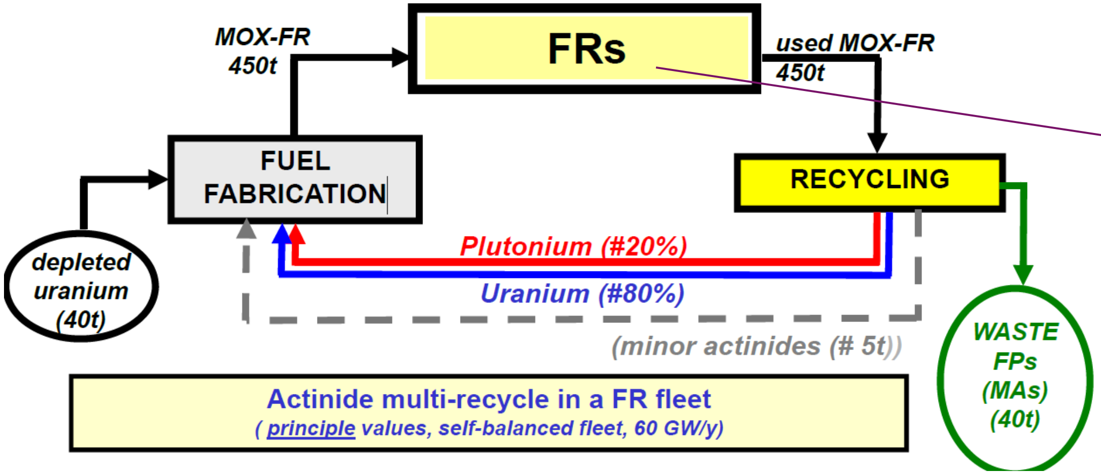
1. INTRODUCTION

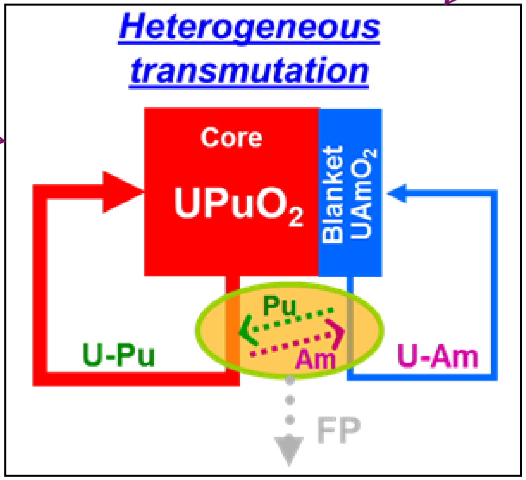
❑ Advanced Actinides recycling Processes

- ➢ 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

ASTRID Reactor: A transmutation tool

❑ Heterogeneous option: Recycling / Transmutation





2. ISSUES

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 μ (Coulomb law (1)):

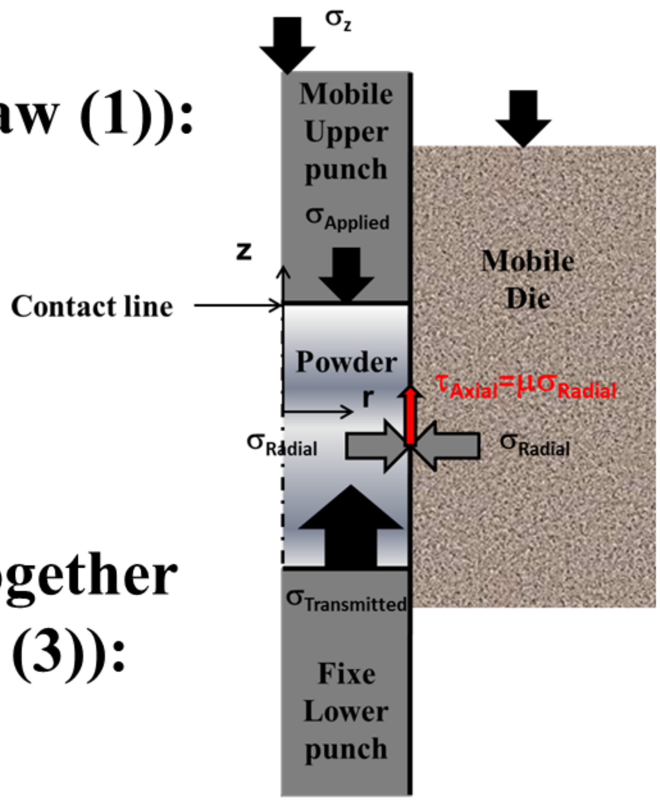
(1) $$\mu = \frac{\sigma_{Applied} - \sigma_{Radial}}{\sigma_{Transmitted}} \frac{S_{Axial}}{S_{Radial}} = \frac{\tau_{Axial}}{\sigma_{Radial}}$$

  - ✓ Flow Index β (2):

(2) $$\beta = \frac{\sigma_{Radial}}{\sigma_{Applied}}$$

  - ✓ Or Friction index μβ calculated together (Jansen law (3)):

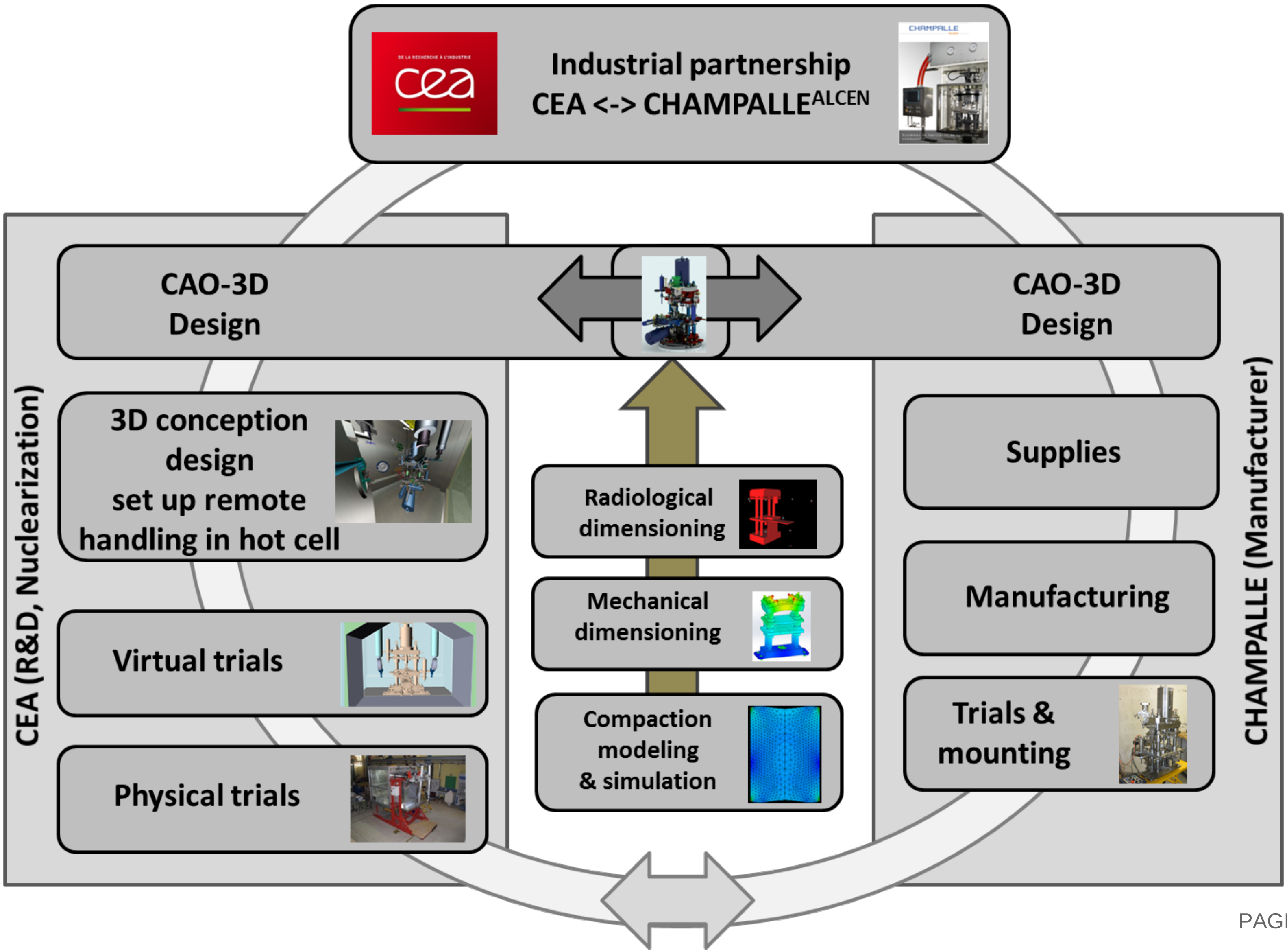
(3) $$\mu\beta = -\frac{R}{2h}\ln\left(\frac{\sigma_{Applied}}{\sigma_{Transmitted}}\right)$$



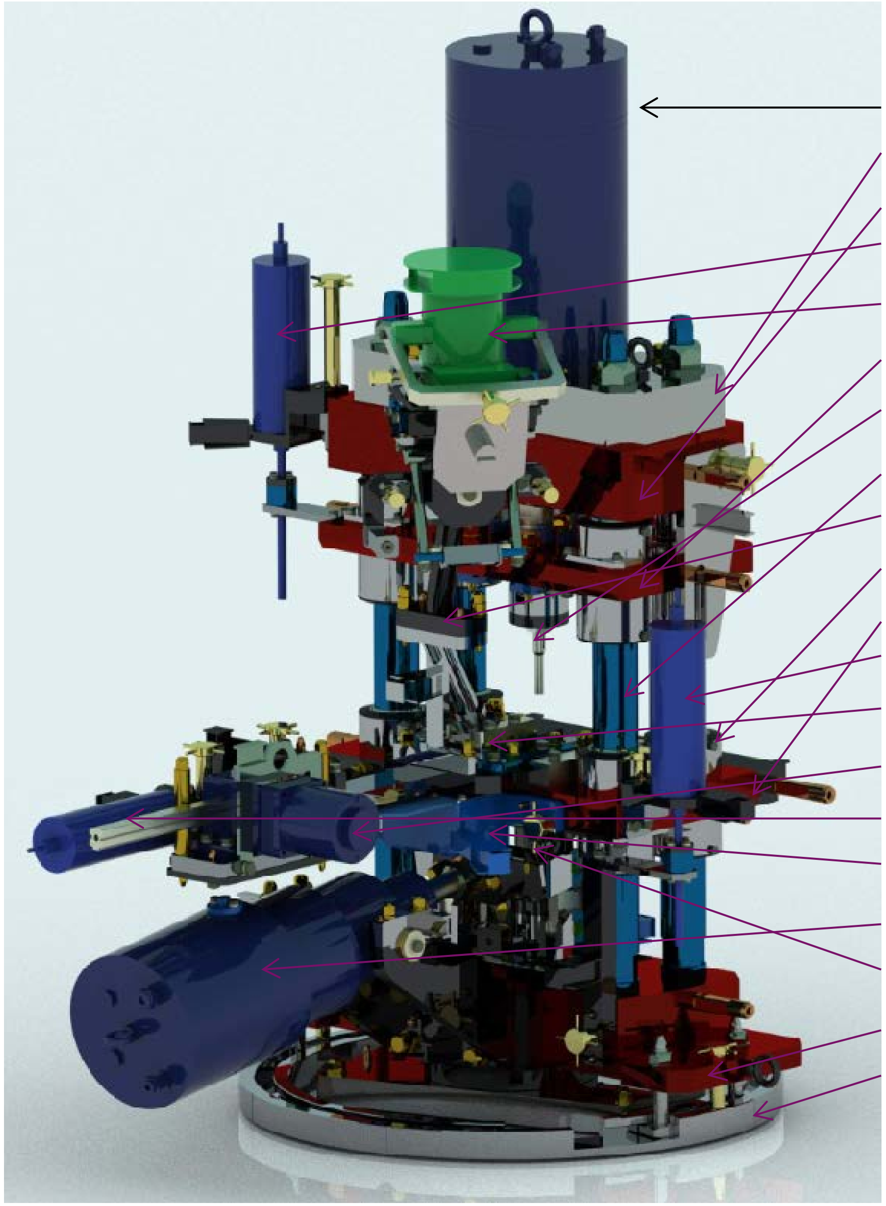
3. OBJECTIVES

- 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

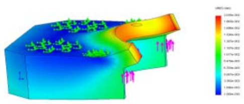


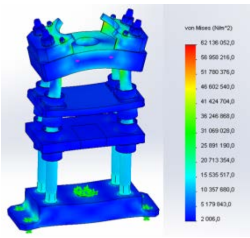
5. NUCLEAR PRESS (1/5)

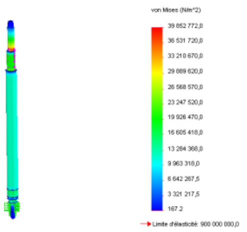


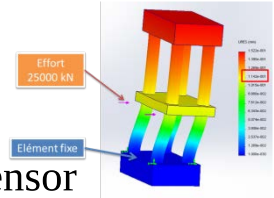
Main Press components:

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







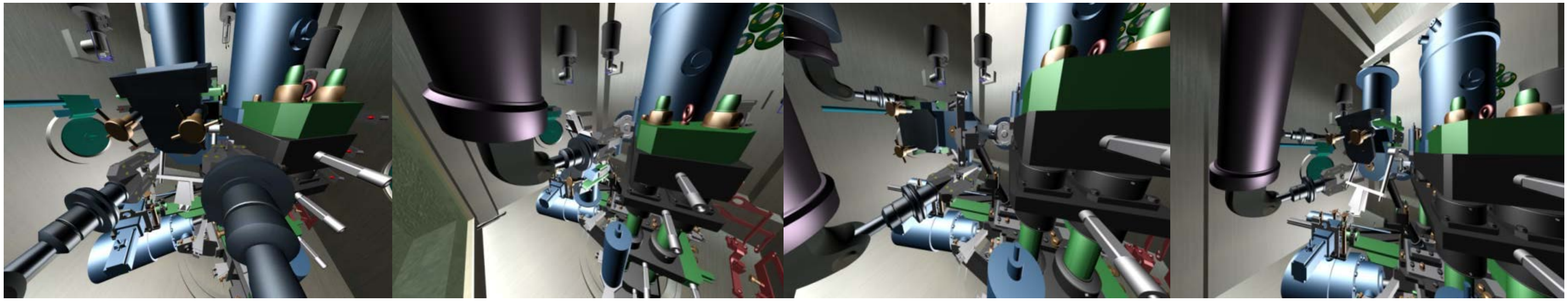


5. NUCLEAR PRESS (2/5)

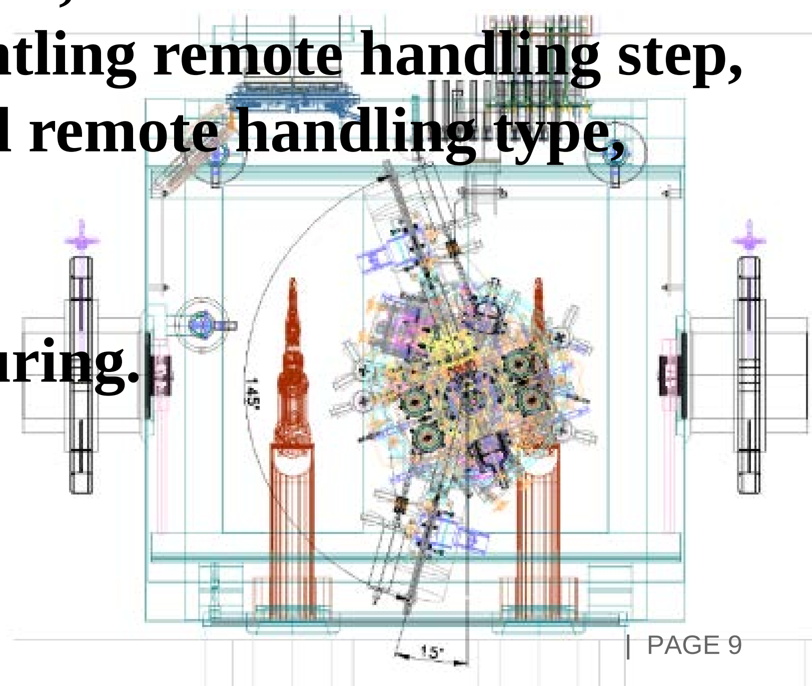
Main press characteristics:

- 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

5. NUCLEAR PRESS (3/5)



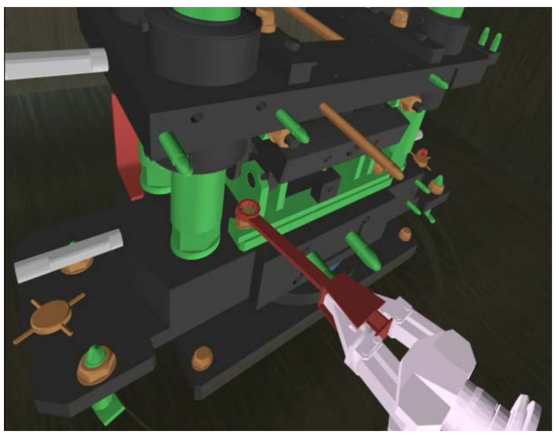
- ❑Validate the modular decomposition,
- ❑Validate the mounting and dismantling remote handling step,
- ❑Dimension the hot cell volume and remote handling type,
- ❑Validate accessibility,
- ❑Validate the servicing operations,
- ❑Launch the supply and manufacturing.



[Remote handling CAD simulation for press setup in hot cell]()

5. NUCLEAR PRESS (4/5)

- ❑ **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.**



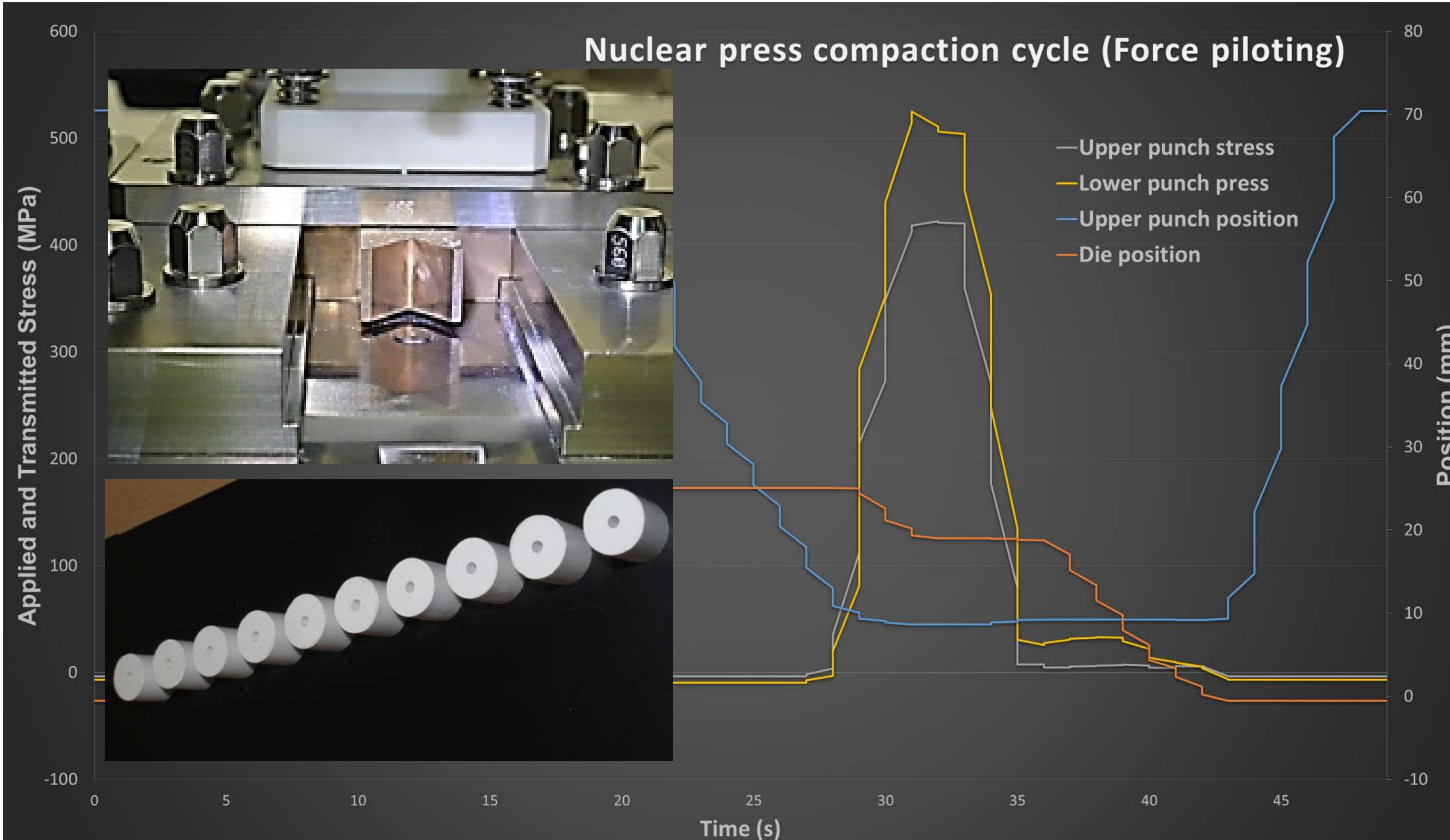
Virtual Reality (VR) simulation
for mounting, dismantling and servicing remote handling

5. NUCLEAR PRESS (5/5)

Sensor	Location	Dose rate EDR_{total} (µGy/h)	
		Mini jar case	Maxi jar case
1	Upper punch motor	57	95
2	Die motor	97	62
3	Filling shoe motor	*1368*	*465*
4	Transmitted force sensor (*)	28	5
5	Die displacment sensor	16	13
6	Punch displacment sensor	118	3
7	Applied force sensor (*)	*1655*	*681*
8	South side of the press (30 cm)	246	60
9	North side of the press (30 cm)	154	148
10	East side of the press (30 cm)	242	184
11	West side of the press (30 cm)	238	184

*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)*

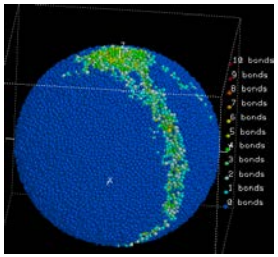
6. FIRST TRIALS



7. COMPACTION RESEARCH

Characterization with experiments

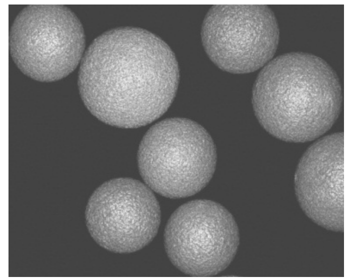
DEM simulation



2013-2016 thesis CEA/SIMAP Grenoble

Material properties

Microscopic trials



Weak Acid Resin (WAR) Process

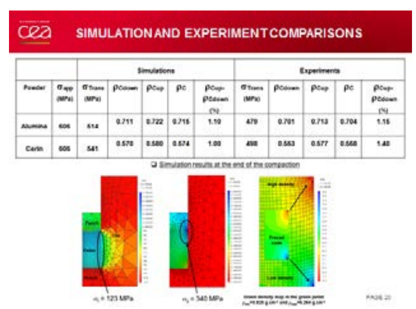
Macroscopic trials

- ✓ Instrumented press,
- ✓ Instrumented radial
- ✓ open die,
- ✓ Profilometer,
- ✓ Sintering furnace.

FEM/DEM Coupling

Behavior laws

FEM simulation

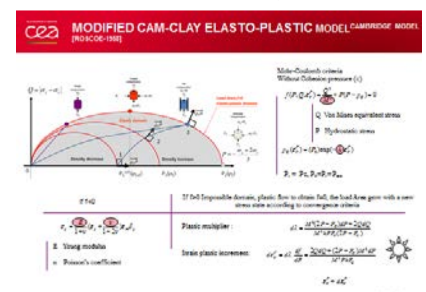

SIMULATION AND EXPERIMENT COMPARISONS

		Simulations					Experiments				
Powder	σ_{app} (MPa)	σ_{Trans} (MPa)	ρ_{Cdown}	ρ_{Cup}	ρ_C	$\rho_{Cup}-\rho_{Cdown}$ (%)	σ_{Trans} (MPa)	ρ_{Cdown}	ρ_{Cup}	ρ_C	$\rho_{Cup}-\rho_{Cdown}$ (%)
Alumina	606	514	0.711	0.722	0.716	1.10	479	0.701	0.713	0.704	1.15
Cerin	605	541	0.570	0.580	0.574	1.00	498	0.563	0.577	0.568	1.40

Simulation results at the end of the compaction

Abaqus, Cast3M FEM caclculation code

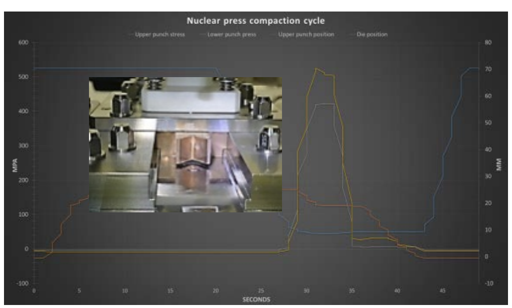
Modelling



Cam-clay

Drucker pragger compaction model

Optimization compaction process

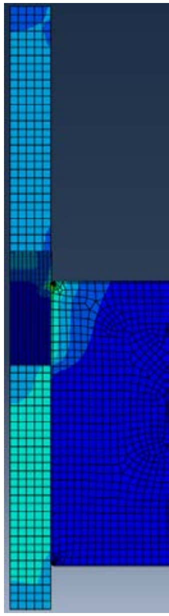


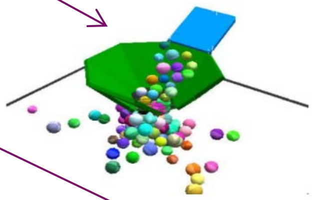
Dymola code

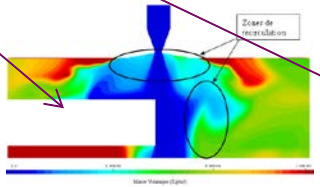
8. CONCLUSIONS AND PERSPECTIVES

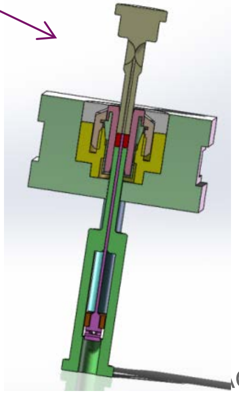
- **Automatized uniaxial electromechanical press for manufacturing nuclear fuel pellets in hot cell,**
- First pellet profile results are checking.

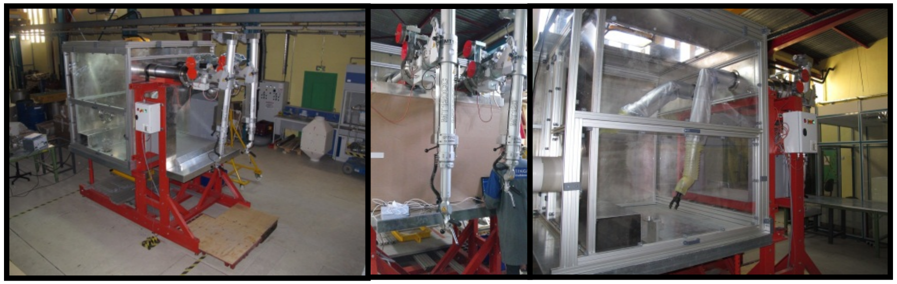
- Fuel cycle optimization process FEM simulation ABAQUS and coupling with DYMOLA (in progress)
- Granular flow with DEM Simulation (OpenFoam),
- Tool lubrication study (2015),
- Automatic radial open die (trials 2015),
- Physical trials in hot cell (October 2014),











- 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:

CEA/DEN/DTEC/SDTC: C. FERRY, V. ROYET

LTAP: E. TRONCHE, C. BRENNEIS, P. MOYER, F. GOBIN.

CHAMPALLE: F. RENARD, V. REYNAUD, P. BAPTISTE, P. GOSSET, D. LAGET, J. CRESTAN, J-P. CHAMPALLE.

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 μ (Coulomb law (1)):

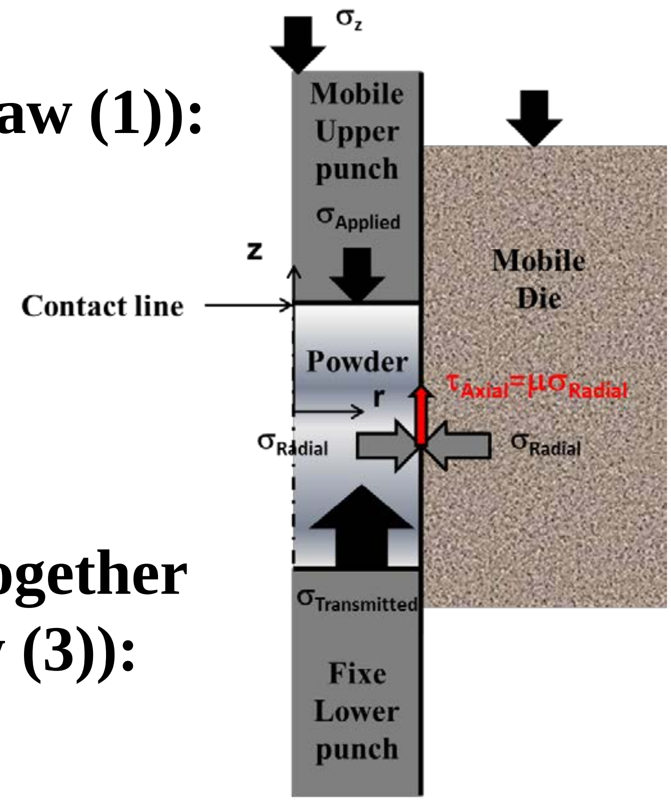
(1) $$\mu = \frac{\sigma_{Applied} - \sigma_{Radial}}{\sigma_{Transmitted}} \frac{S_{Axial}}{S_{Radial}} = \frac{\tau_{Axial}}{\sigma_{Radial}}$$

  - ✓ Flow Index β (2):

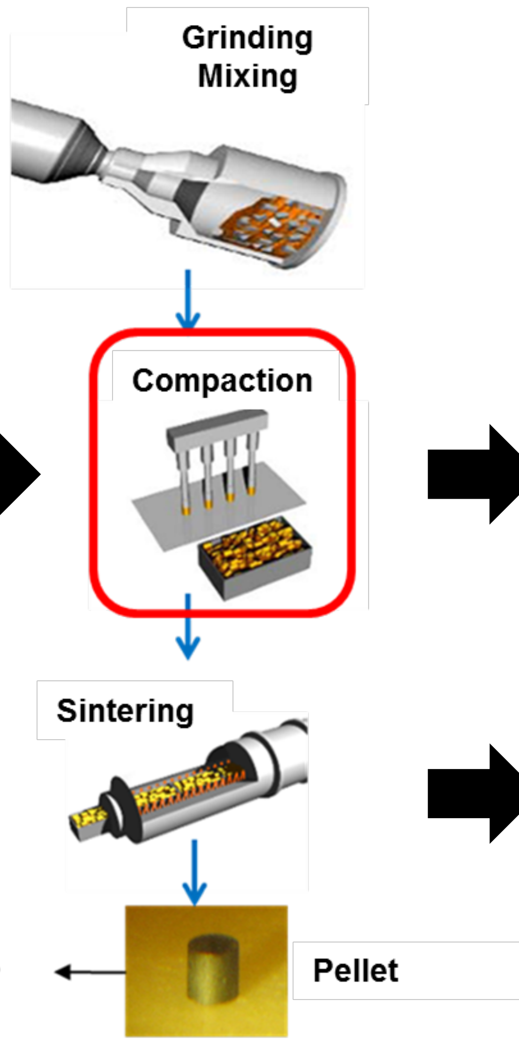
(2) $$\beta = \frac{\sigma_{Radial}}{\sigma_{Applied}}$$

  - ✓ Or Friction index μβ calculated together (Jansen law (3)):

(3) $$\mu\beta = -\frac{R}{2h}\ln\left(\frac{\sigma_{Applied}}{\sigma_{Transmitted}}\right)$$



Compaction cycle



Springback
Damage
Density gradients

Shrinkage