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Non-linear dynamical behavior of a fuel pins bundle.

T. Catterou, V. Blanc, G. Ricciardi, Bruno Cochelin, Stéphane Bourgeois

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NONLINEAR DYNAMICAL BEHAVIOR OF A FUEL PINS BUNDLE

Thomas CATTEROU

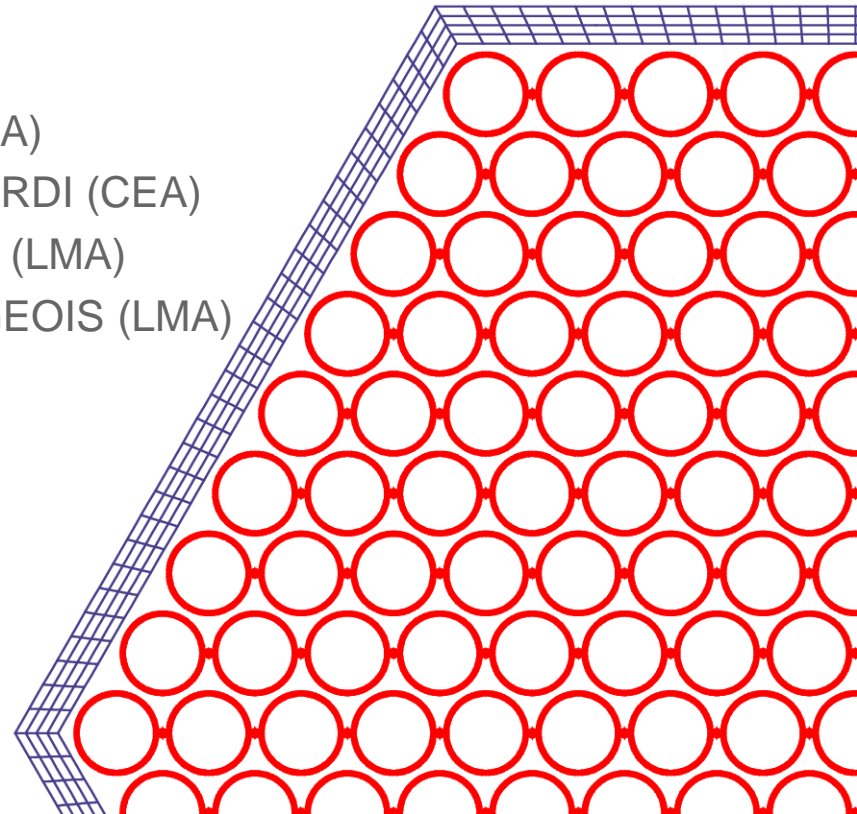
Guided by :

Victor BLANC (CEA)

Guillaume RICCIARDI (CEA)

Bruno COCHELIN (LMA)

Stéphane BOURGEOIS (LMA)



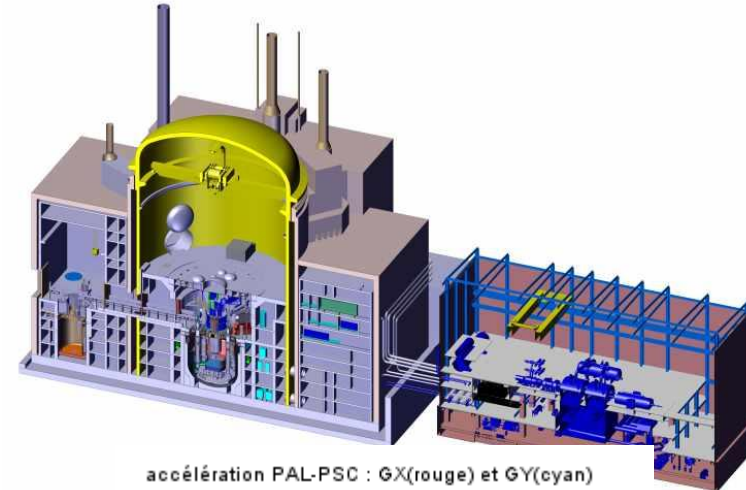
- ❑ An introduction to the Sodium Fast Reactor ASTRID
- ❑ State of the art
- ❑ Linear dynamic analysis of a fuel pins bundle
- ❑ Motivation and methodology of the study
- ❑ Non-linear behaviour, pins bundle with clearances
- ❑ Future applications

ASTRID

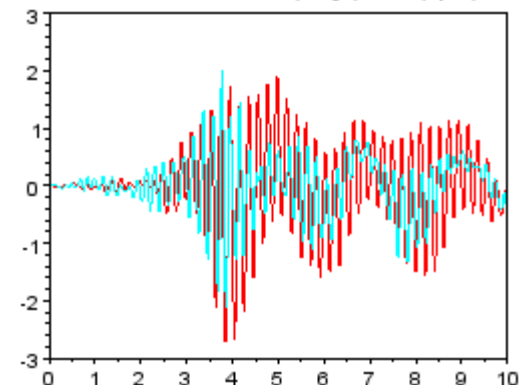
*Advanced Sodium Technological Reactor
for Industrial Demonstration*



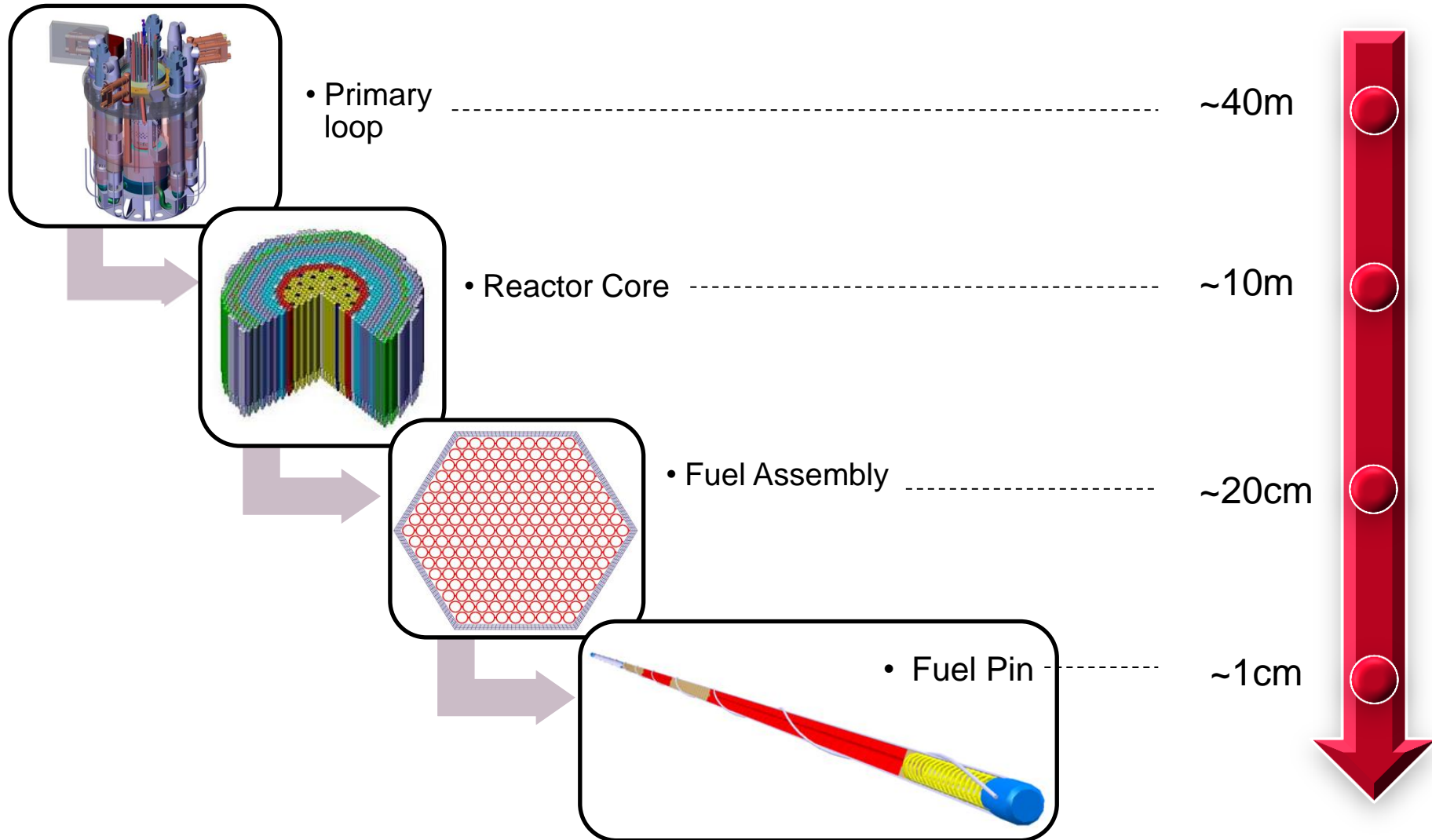
- Technological demonstration reactor
- Gen IV system
 - Safety
 - Level at least equivalent to GEN III
 - Integrating FUKUSHIMA accident feedback
 - Durability
 - Close cycle of fuel
 - Pu multi recycling to preserve natural resources
 - Operability

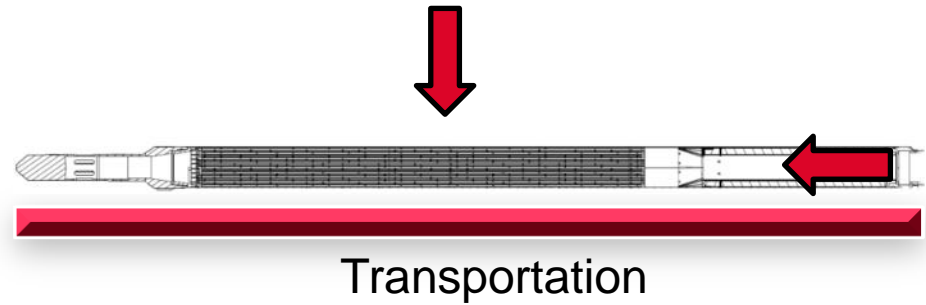
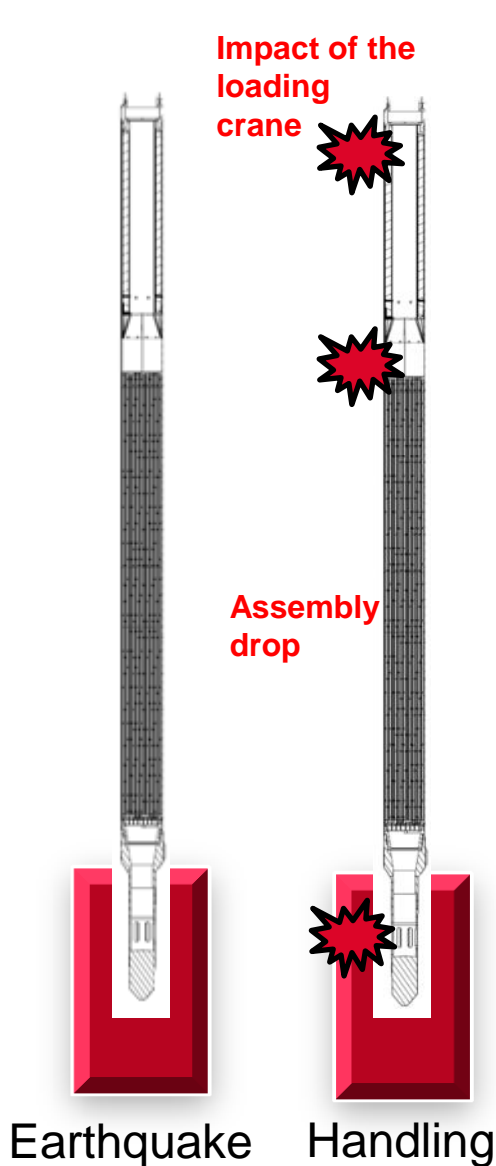


accélération PAL-PSC : GX(rouge) et GY(cyan)



Various scales of study

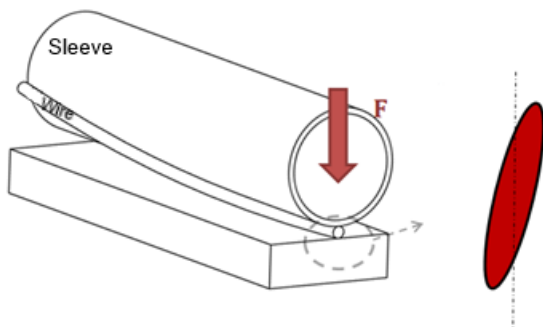
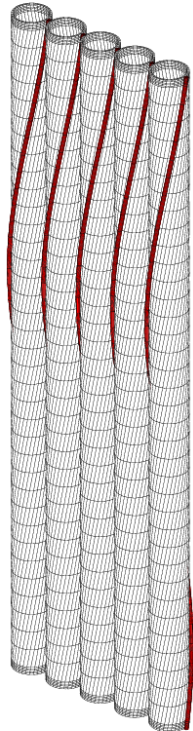




Goals :

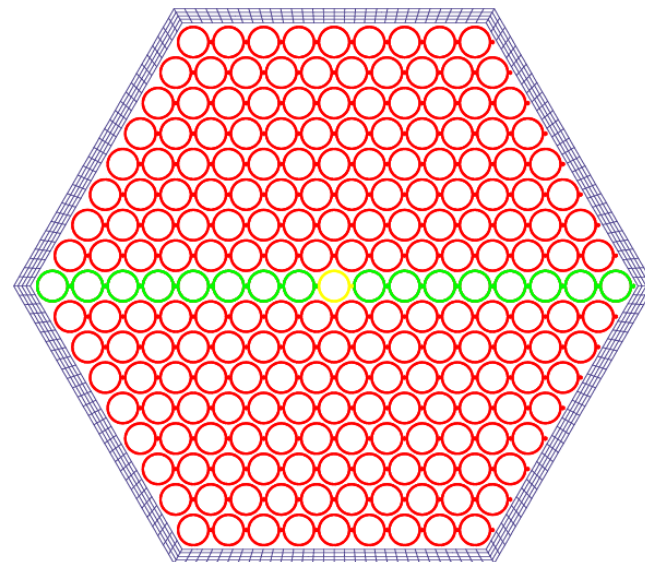
- To describe the dynamical behaviour of the fuel pins bundles with internal clearances
- To assess stresses in the pins induced by dynamic loads





Difficulties :

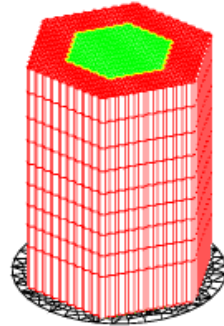
- To create a numerical models with a large amount of potentiel contact (~30000)
- Identify local stress in a tube from a beam calculation (sizing studies).
- Quick and accurate calculations...



Progress in the field in the CEA

Moussalam[1], Broc [2].

Seismic studies on Fast breeder reactor core



Vizcaino (2014)



Review and study of the longest lines on one winding pitch

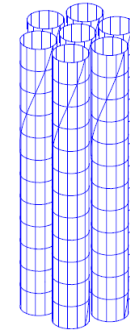
Maximum stress calculation but:

- Without clearance
- No impact effect
- Incomplete modelling of the fuel bundle.

[1] SMiRT21 (2011), "Industrial model for the dynamic behavior of [...] LMFBR core"
[2] SMiRT20 (2009), "Fluid Structure Interaction models for the dynamic behaviour of tube bundles [...]"

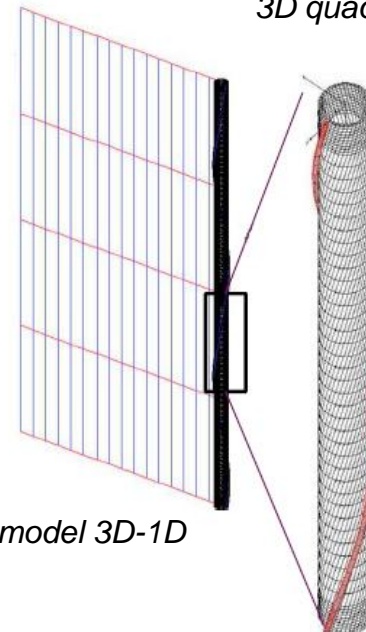
DOMAJEUR2 / Bamboo Leturq (2015)

Thermomechanic of the pins bundle

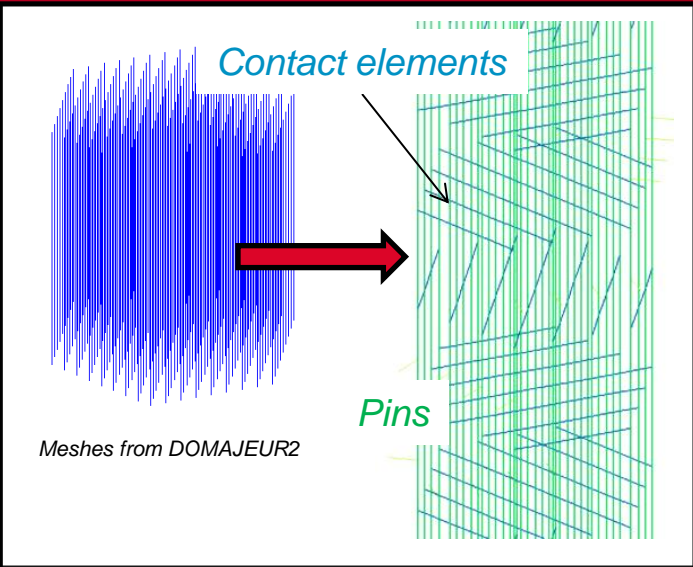


Catterou (2015)

3D quadratic finite elements

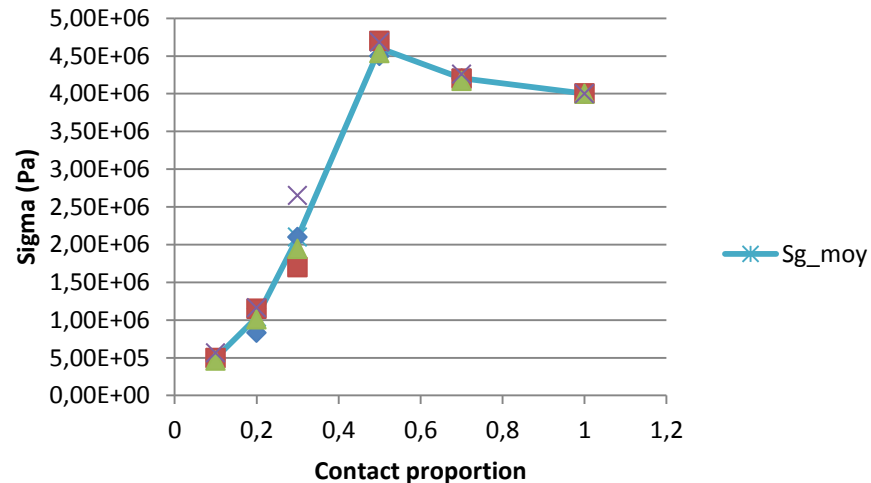


Mixed model 3D-1D



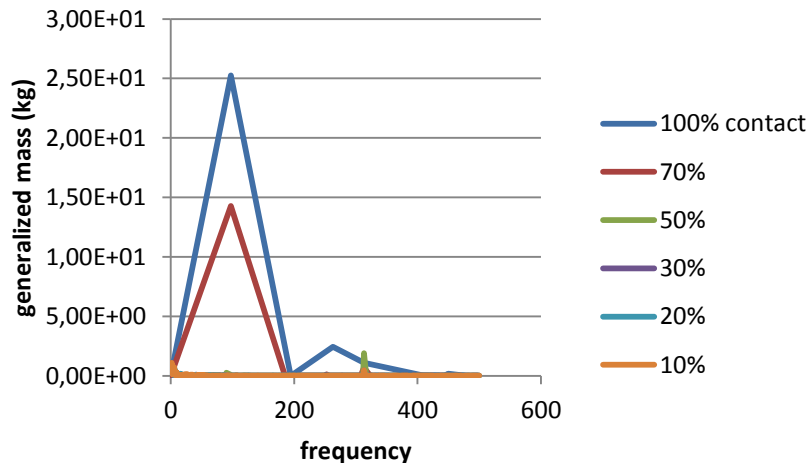
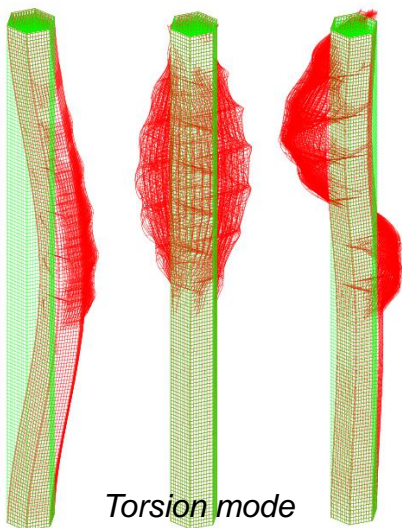
■ Dynamic analysis
 Input : imposed acceleration on the first mode

Maximum stress



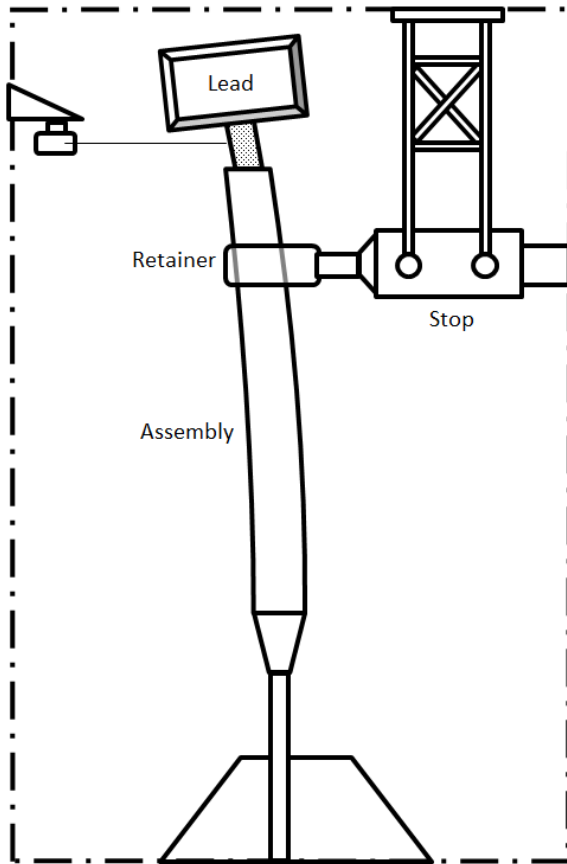
■ Modal analysis

Mode 1 Mode 2 Mode 3

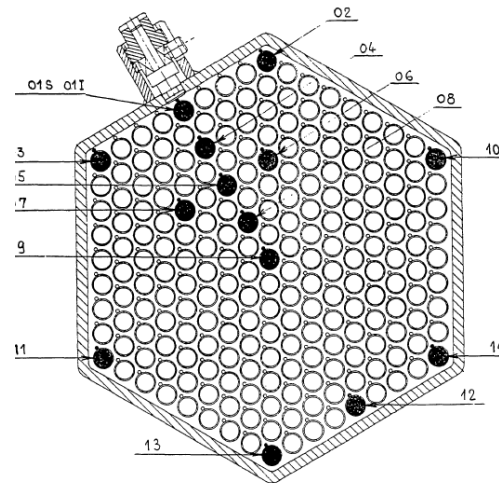


Observations:
 Results are very dependant of the presence and the characterization of the contact elements.

■ Experimental equipment : BELIER (CEA)

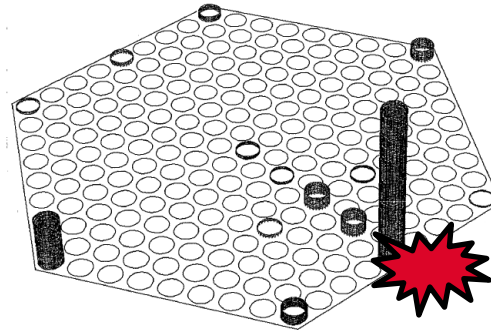
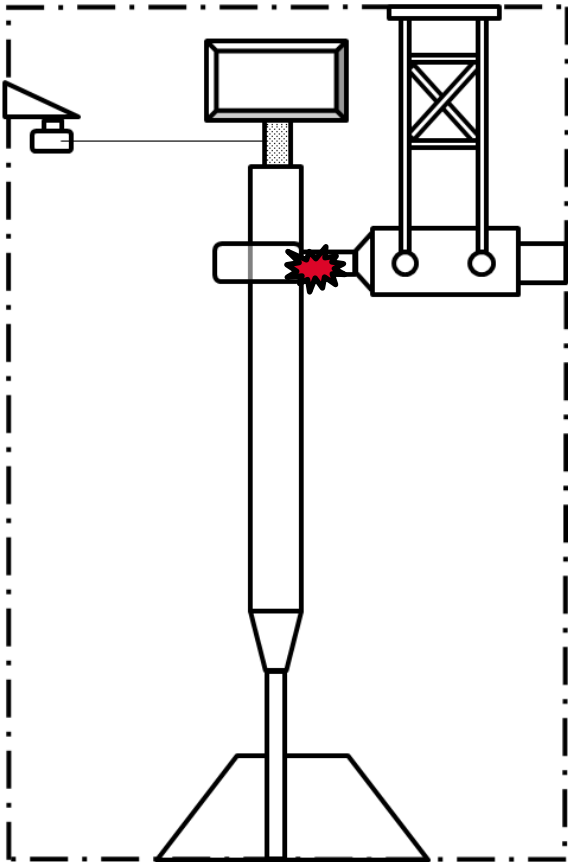


- Tests in CEA Cadarache between 1989 and 1995
- In air and in water
- Homogeneous clearance or without clearance
- Some instrumented pins on the height of the impact.

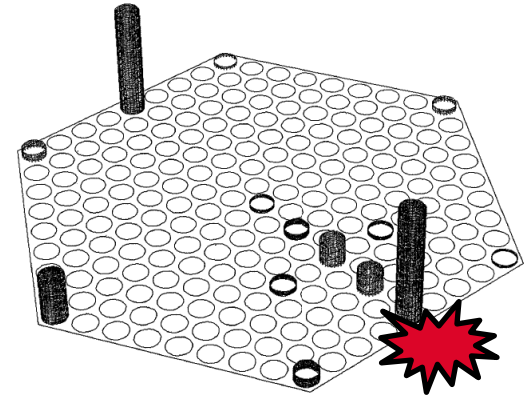


● *Instrumented pin*

■ Experimental equipment : BELIER (CEA)



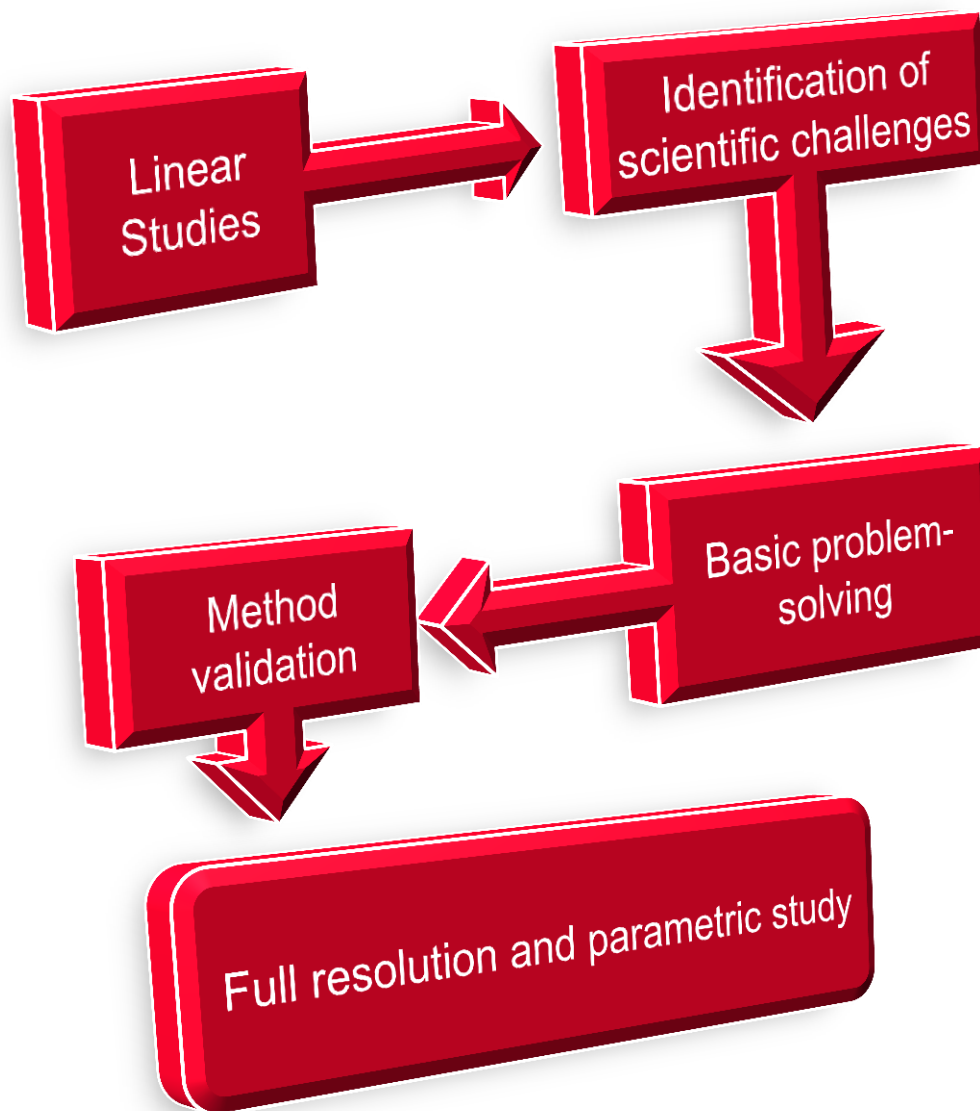
Pins bundle without clearances



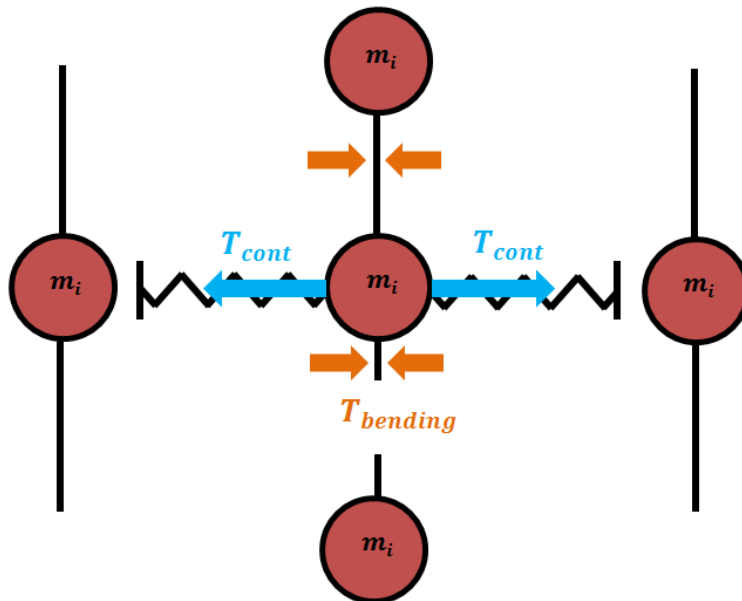
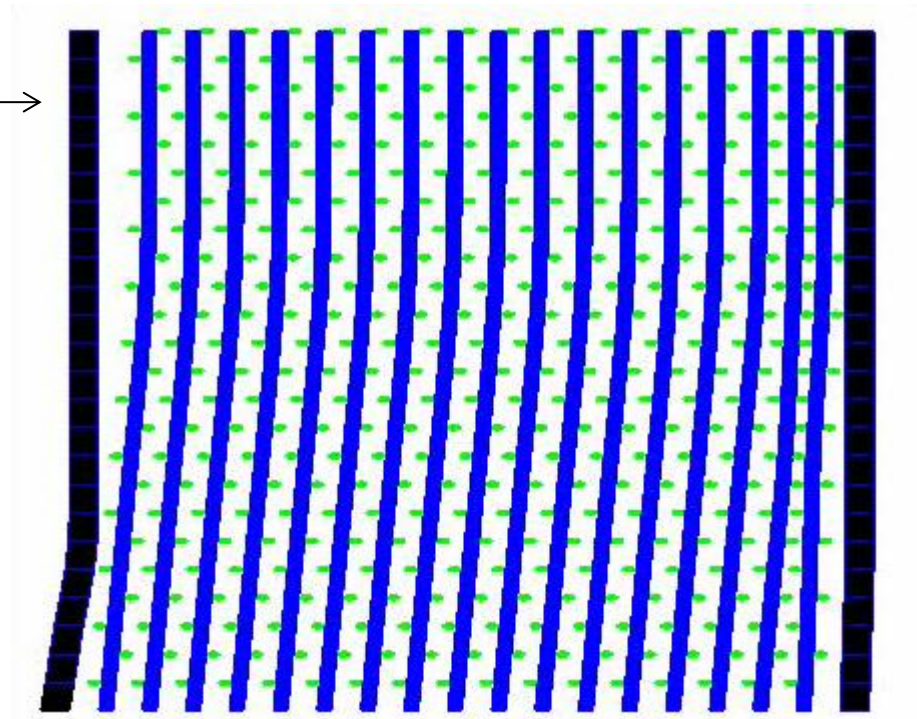
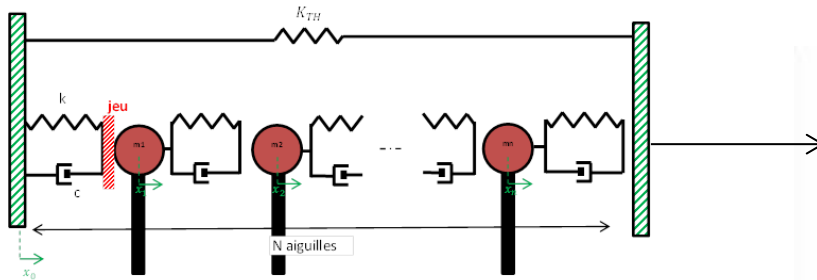
Pins bundle with homogeneous clearances

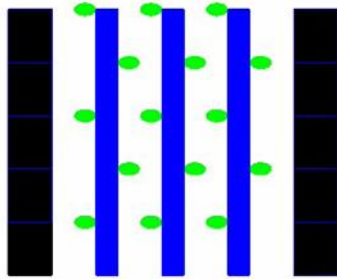
- Which is the most critical situation ?
- Are there particular clearance distributions which could be more harmful?

→ Necessity to model clearances in the bundle.



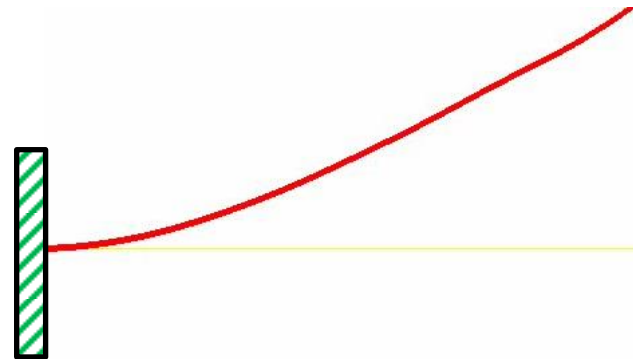
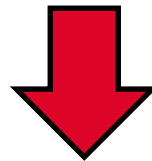
- Use of a mass-spring system
Aborted, bad simulation of the bending.





- Use of a mass-spring system
Aborted, bad simulation of the bending.

- Resolution of an elementary problem analytically and with the finite element software CAST3M



- Integration scheme approval
- Study on the influence of the contact moment search algorithm
- Determination of the stability barrier of the numerical solution

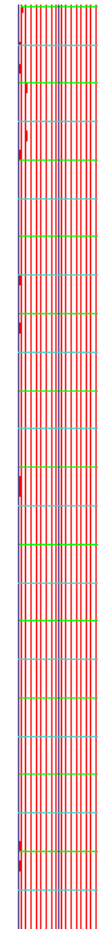
Experimental calculation of the behavior of a pin in a transport configuration

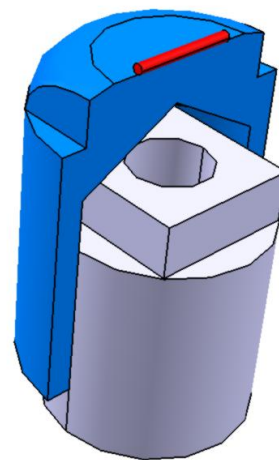
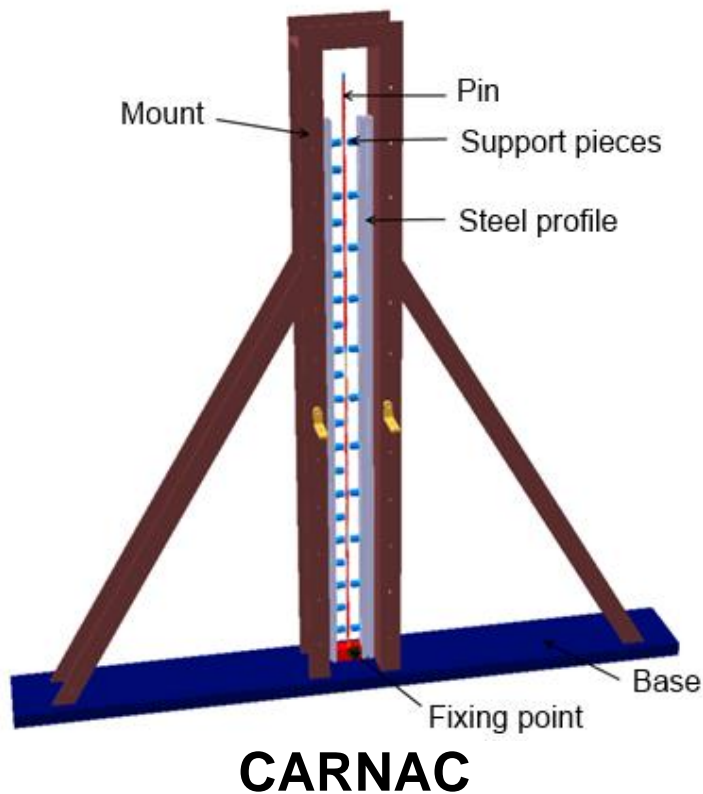


To come

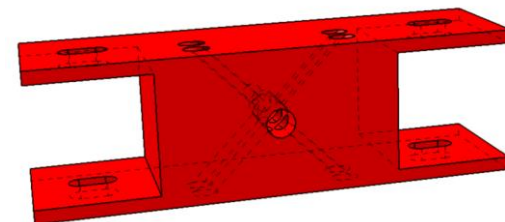
- Calculation on a 2D then a 3D pin's beam.
- Statistical analysis of the influence of the repartition of clearances in the beam.
- Experimental validation

Experimental calculation of the dynamic of a line of pins

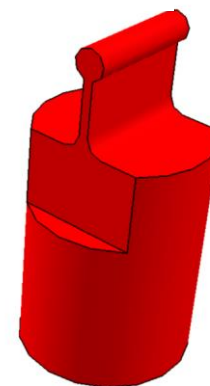




Support pieces



Fixing point



Goals:

- To identify the influence of clearances on the dynamical behavior of one pin.
- To validate numerical model

- Small and numerous clearances in the pins beam influence strongly the dynamical behavior of the structure.
- Difficulty to estimate if a study without clearance is conservative or not.
- Some points must be examined carefully to ensure a right answer:
 - The integration scheme
 - The force law and the contact model
 - The estimation of the contact moment and period

- Integration scheme validation.
- Contact detection algorithm validation.
- 3D pins bundle model achievement.
- Statistical study of the impact of clearance and its repartition.

Thank you for
your attention !

