Non-linear dynamical behavior of a fuel pins bundle.

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NONLINEAR DYNAMICAL BEHAVIOR OF A FUEL PINS BUNDLE

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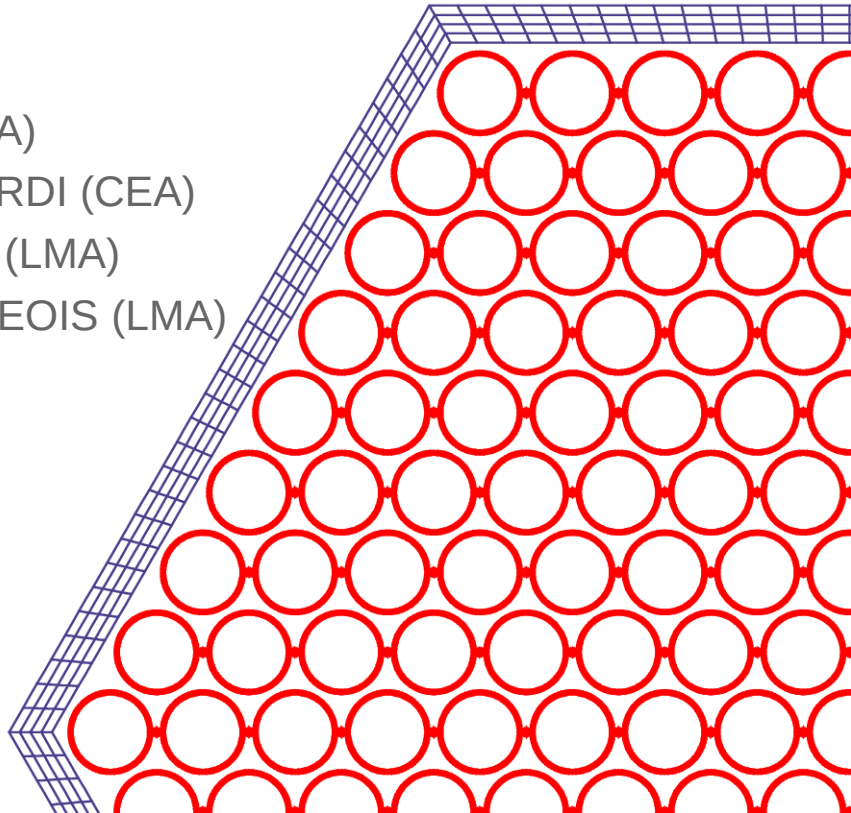


OUTLINE

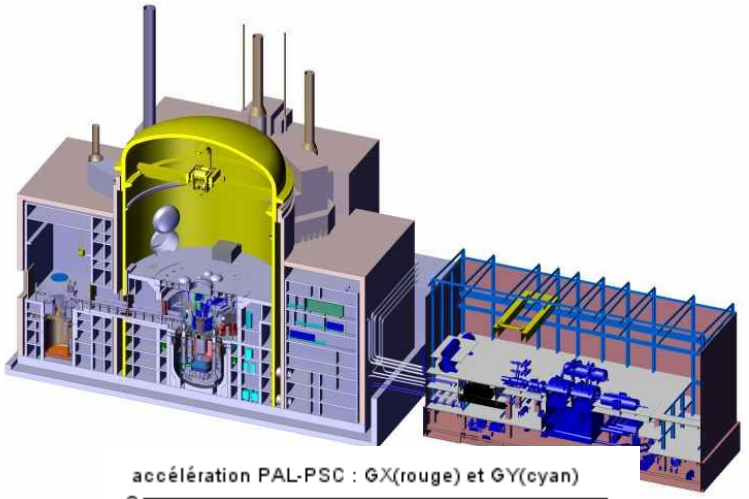
- An introduction to the Sodium Fast Reactor ASTRID
- State of the art
- Linear dynamic analysis of a fuel pins bundle
- Motivation and methodology of the study
- Non-linear behaviour, pins bundle with clearances
- Future applications

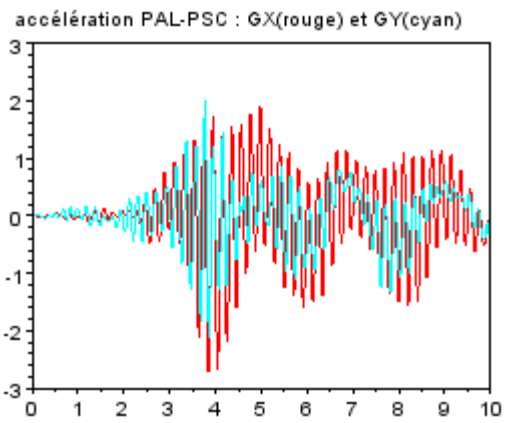
A INTRODUCTION TO THE FAST SODIUM REACTOR ASTRID

ASTRID

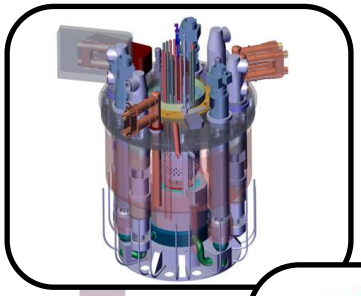
Advanced Sodium Technological Reactor for Industrial Demonstration

- 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

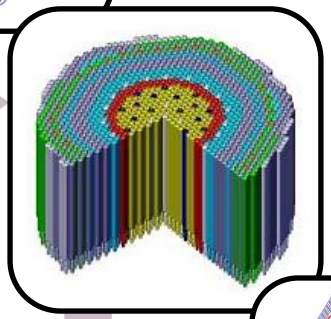




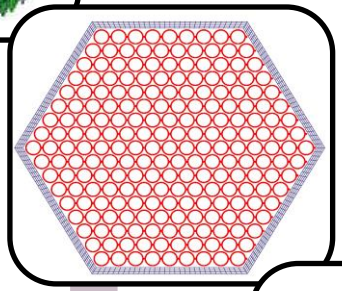
Various scales of study



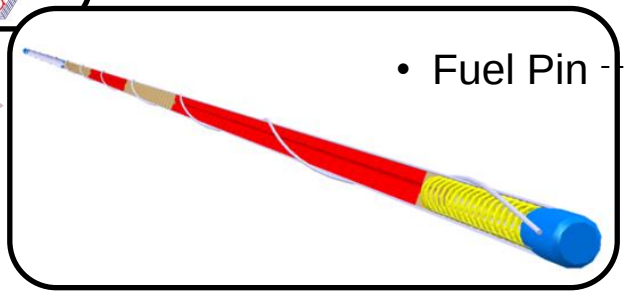
- Primary loop ---------- ~40m



- Reactor Core ---------- ~10m

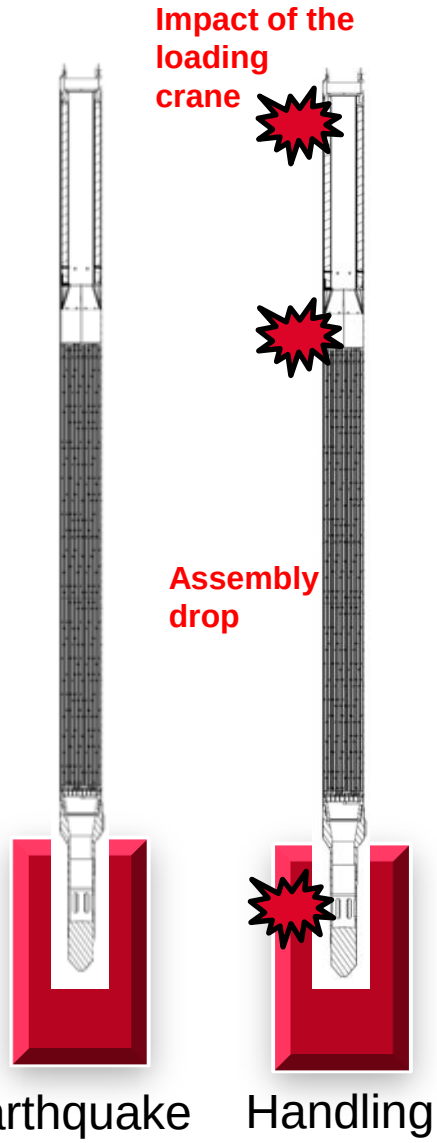


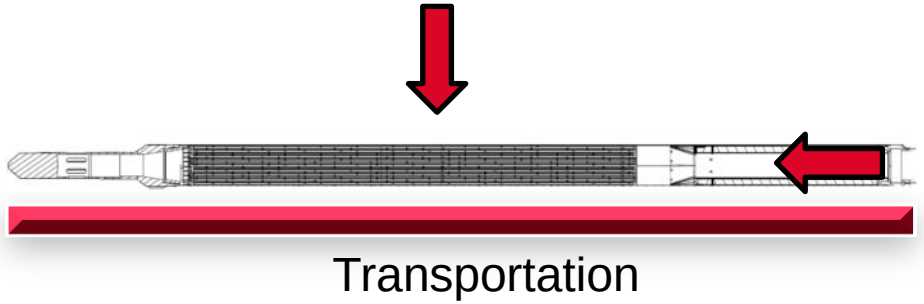
- Fuel Assembly ---------- ~20cm



- Fuel Pin ---------- ~1cm

AIM OF THE STUDY

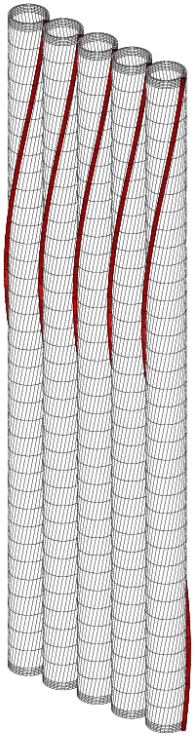


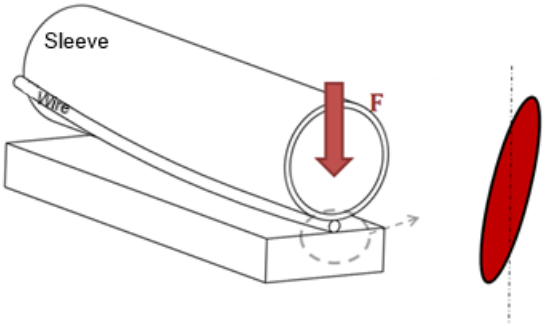


Goals :

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

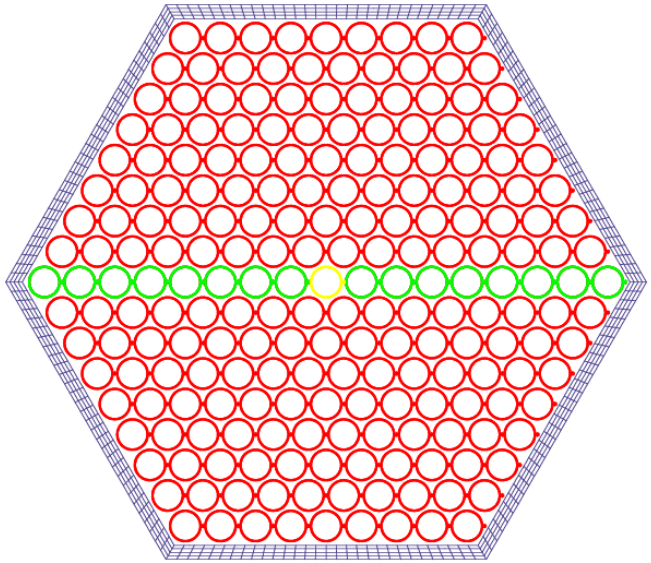
AIM OF THE STUDY





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…

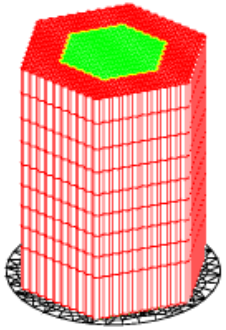


STATE OF THE ART

- Progress in the field in the CEA

  - Moussalam[1], Broc [2].

    Seismic studies on Fast breeder reactor core

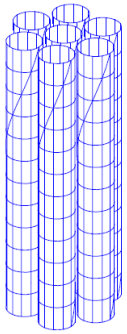


  - Vizcaino (2014)

Review and study of the longest lines on one winding pitch

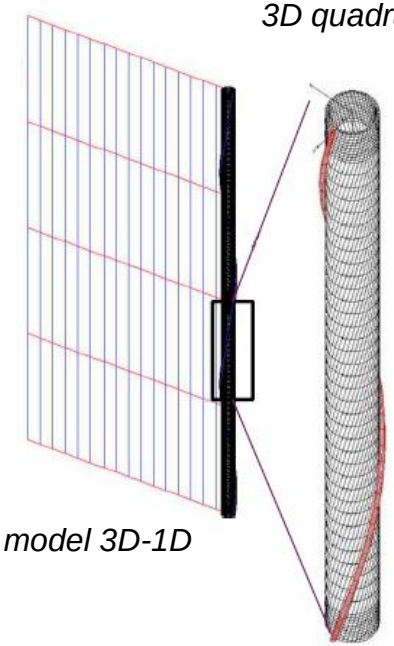
  - DOMAJEUR2 / Bamboo Leturq (2015)

    Thermomechanic of the pins bundle



  - Catterou (2015)

3D quadratic finite elements

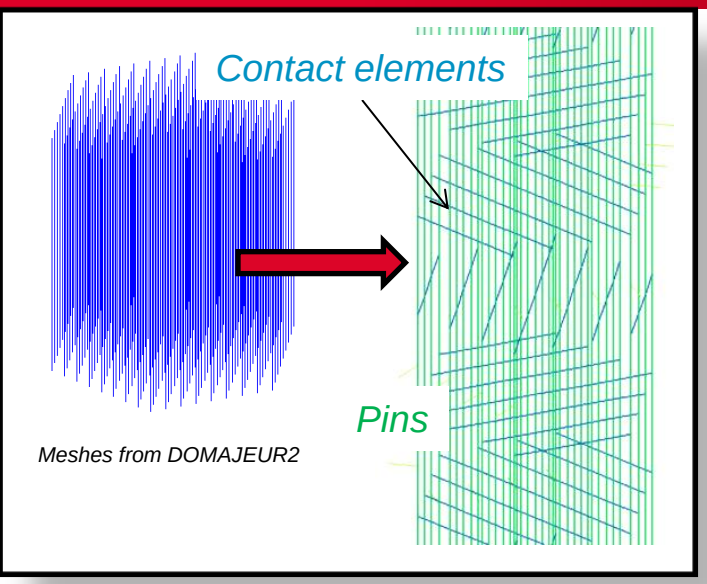


Mixed model 3D-1D

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 […]

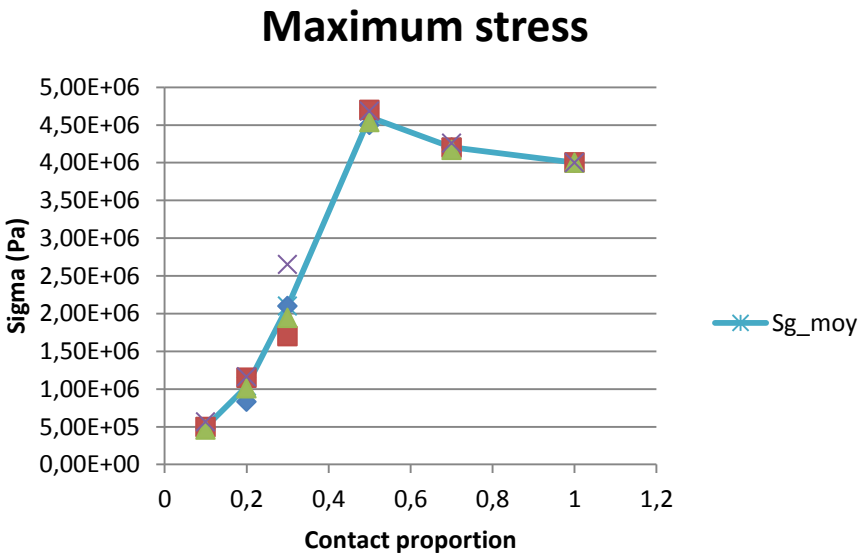
LINEAR DYNAMIC ANALYSIS OF A PIN BUNDLE



Meshes from DOMAJEUR2

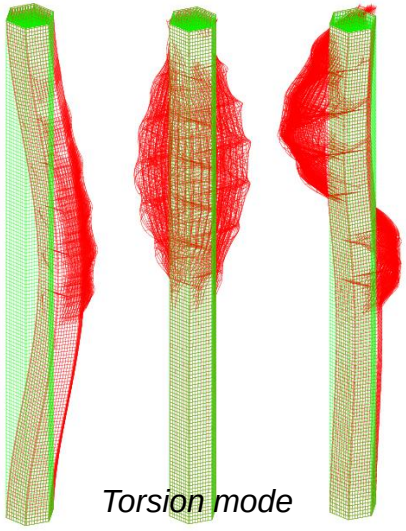
Dynamic analysis

Input : imposed acceleration ont the first mode

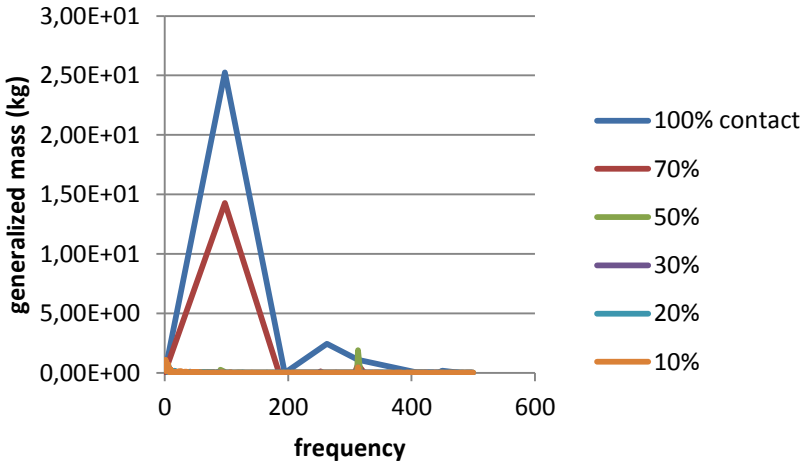


Modal analysis

Mode 1 Mode 2 Mode 3



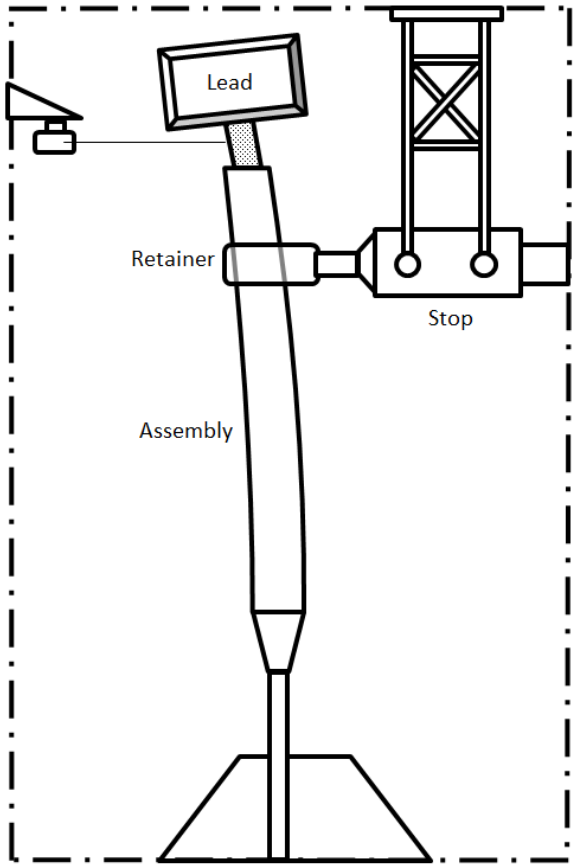
Torsion mode



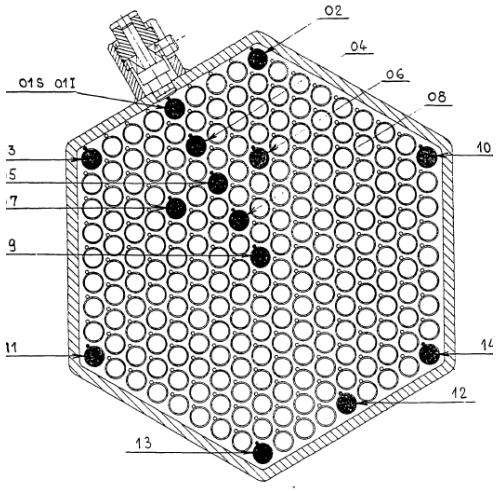
Observations:
Results are very dependant of the presence and the caracterization of the contact elements.

STATE OF THE ART

- Experimental equipment : BELIER (CEA)



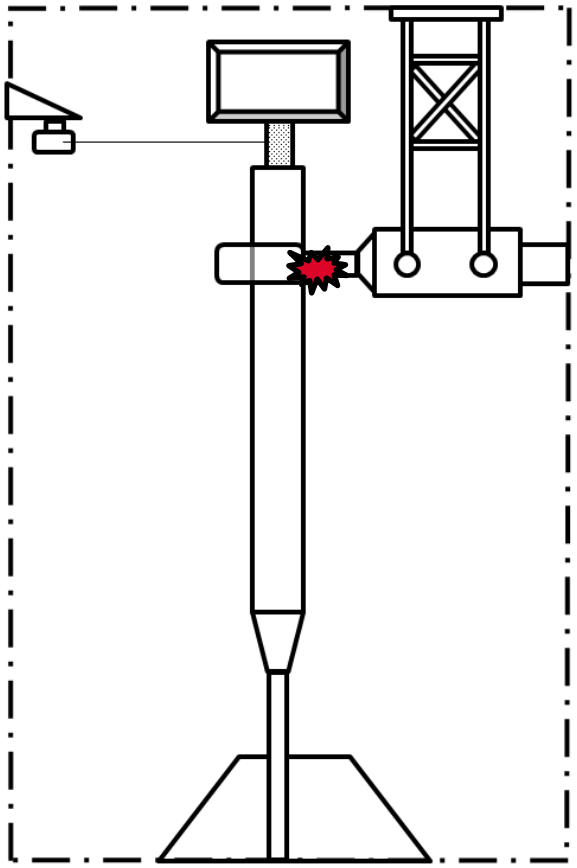
- Tests in CEA Cadarache between 1989 and 1995
- In air and in water
- Homogeneous clearance or without clearance
- Some instrumented pins on the heigh of the impact.

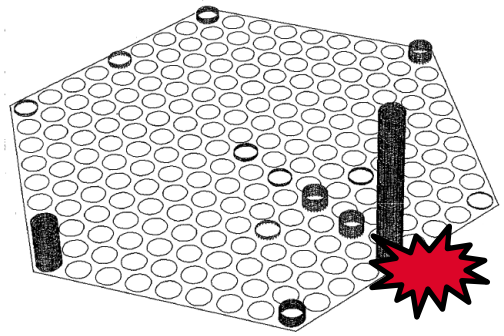


● *Instrumented pin*

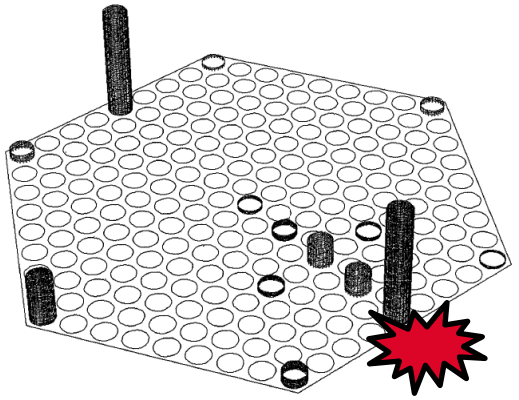
STATE OF THE ART

- Experimental equipement : BELIER (CEA)





Pins bundle without clearances

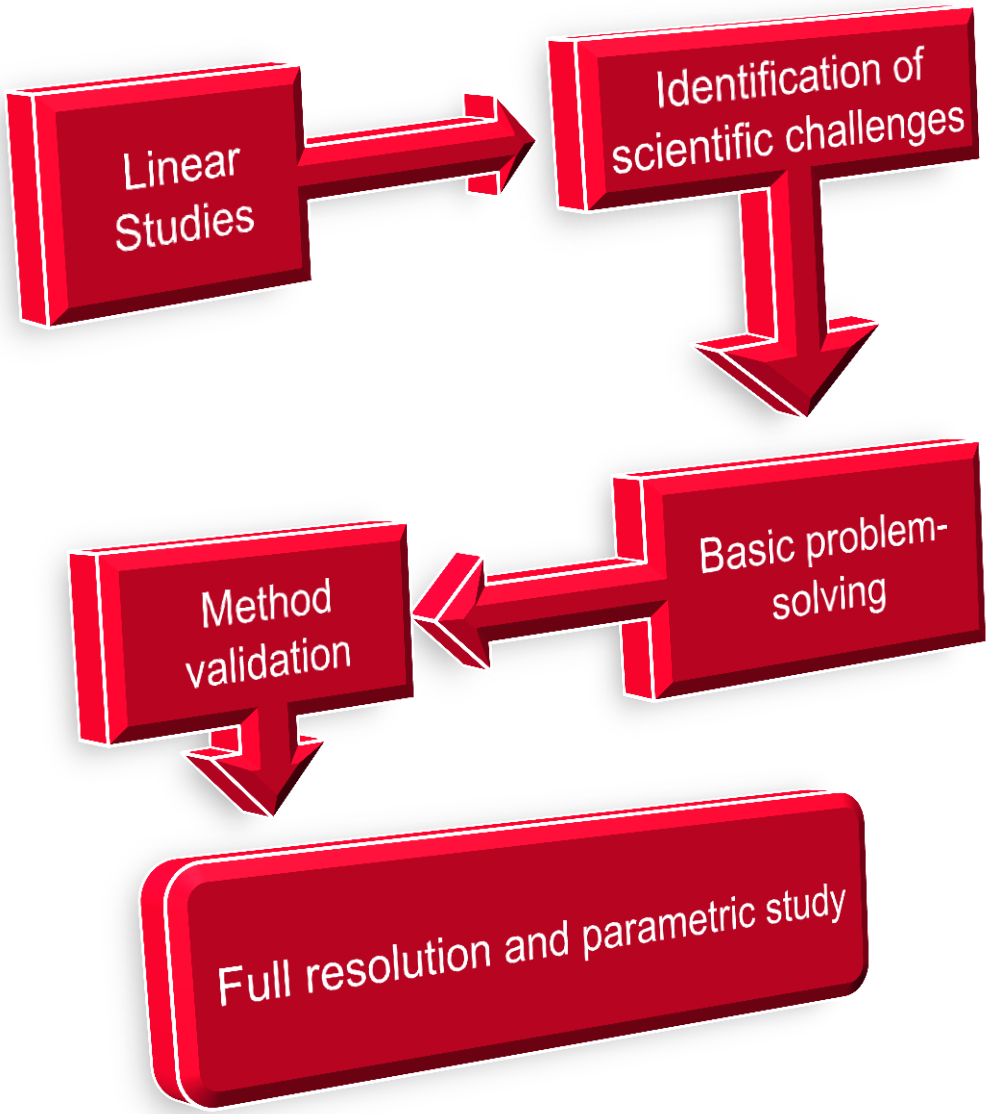


Pins bundle with homogeneous clearances

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

→ Necessity to model clearances in the bundle.

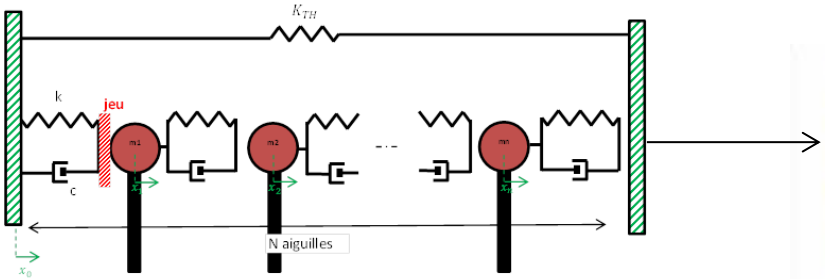
METHODOLOGY AND STATE-OF-THE-ART

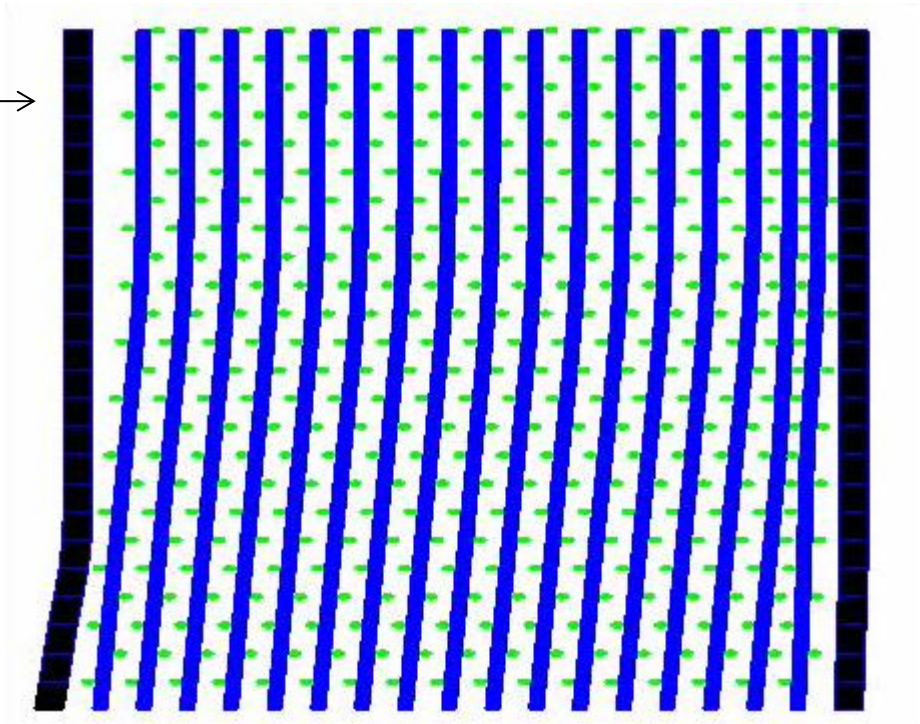


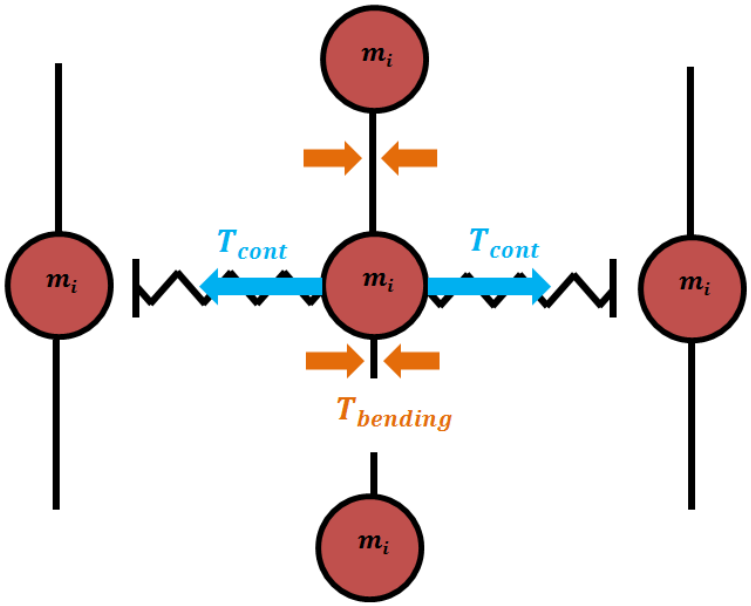
NON-LINEAR STUDIES

- Use of a mass-spring system

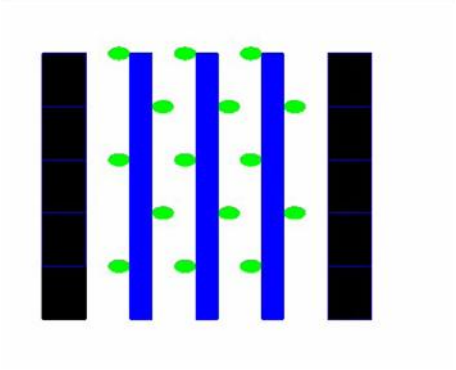
Aborted, bad simulation of the bending.







NON-LINEAR STUDIES



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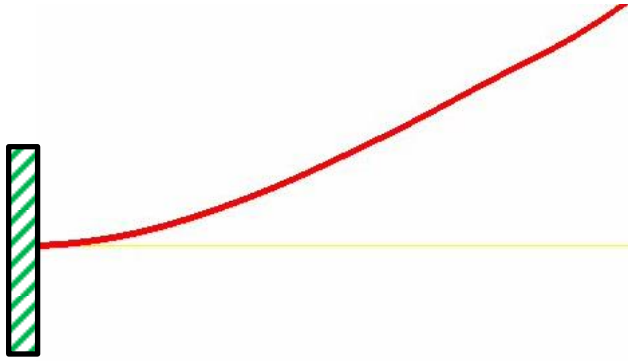
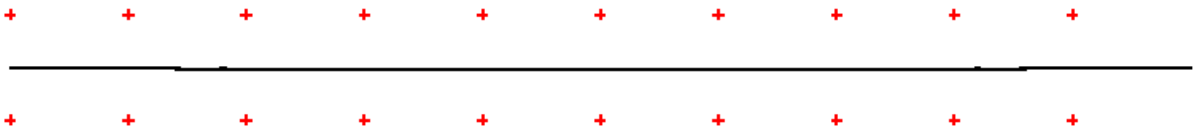


- Resolution of an elementary problem analytically and with the finite element software CAST3M

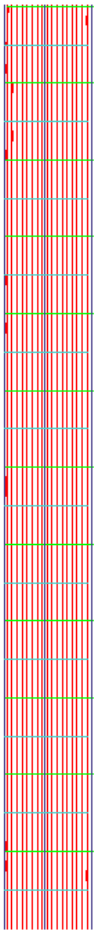
- Integration scheme approval
- Study on the influence of the contact moment search algorithm
- Determination of the stability barrier of the numerical solution

NON-LINEAR STUDIES (WORK IN PROGRESS)

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

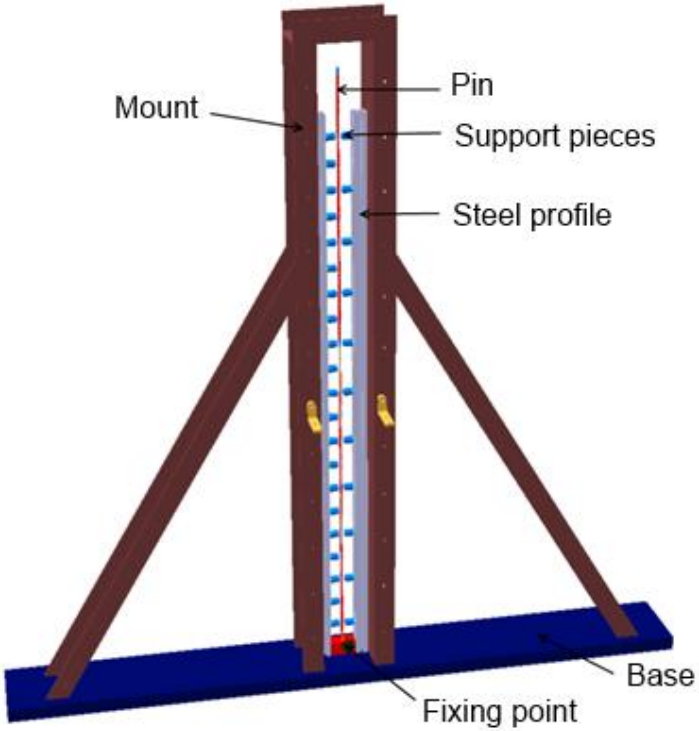


Experimental calculation of the dynamic of a line of pins

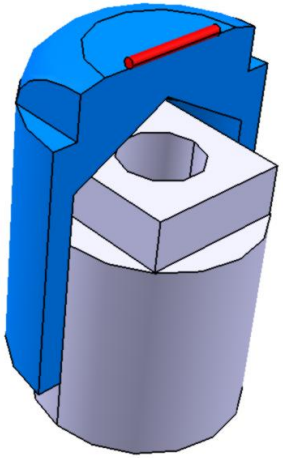


To come

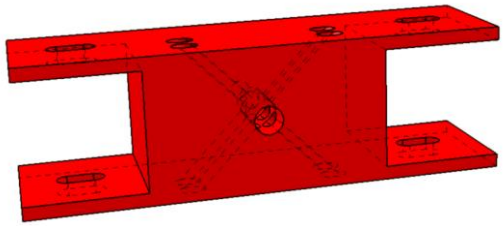
- Calculation on a 2D then a 3D pin's beam.
- Statistical analysis of the influence of the repartition of clearances in the beam.
- Experimental validation

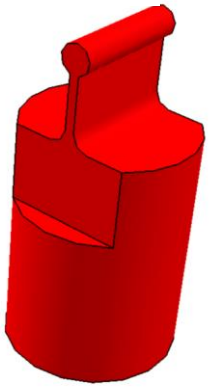


CARNAC



Support pieces





Fixing point

Goals:

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

CONCLUSIONS

- 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

FUTURE WORK

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

Thank you for
your attention !