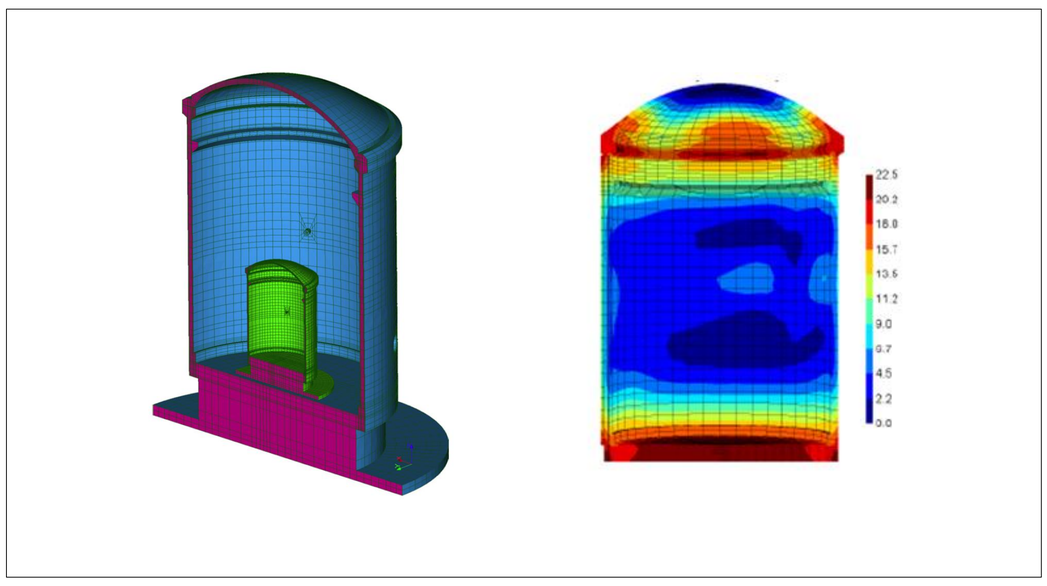
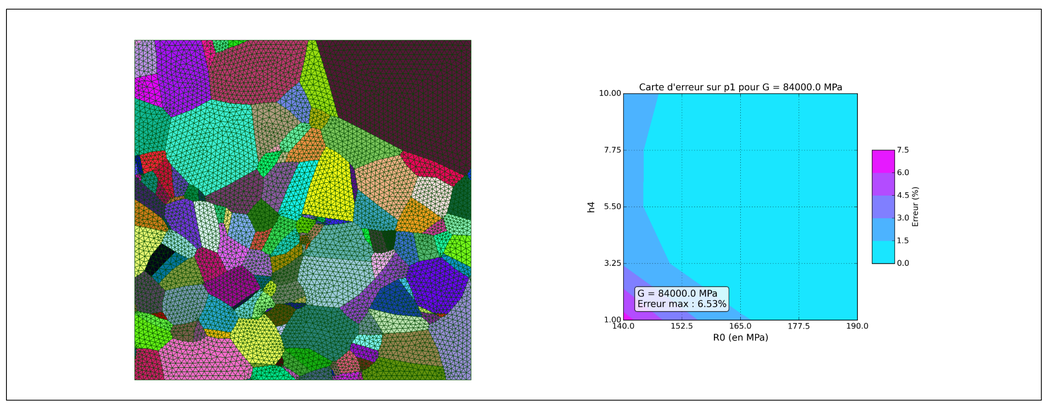
R&D in code_aster
Reduced Order Models

CONTEXT

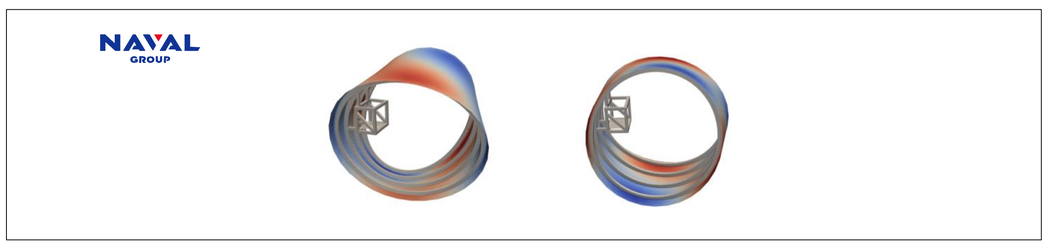
Numerical models are getting bigger and bigger, they also require parametric and probabilistic analyses. For example, to adjust the parameters of a complex behavior law or to acquire sensor data.



VERCORS project: identify creeping laws for concrete (EDF/R&D)



Identification of polycristalline laws bar reduced order models (EDF/R&D)



Reduced order model for FSI applications (Naval Group / EDF)

USING IN CODE_ASTER

`DEFI_BASE_REDUITE, DEFI_DOMAINE_REDUIT, REST_REDUIT_COMPLET, STAT_NON_LINE and THER_NON_LINE`

PhD THESIS

T. Dinh Trong – Modèles hyper-réduits pour la simulation simplifiée du soudage en substitut de calcul hors d'atteinte – ENSMP – 2018

L. Khoun – Réduction de modèles pour les problèmes vibro-acoustiques transitoires dans code_aster. Applications à la détection sous-marine et au pré-dimensionnement des structures immergées aux ondes de choc faibles – Sorbonne Univ. – *In progress …*

A. Benaceur – Méthodes de reduction de modèle pour la thermo-mécanique en robinetterie– Univ. Paris-Est – 2018

SCIENTIFIC CHALLENGES

Given a parameter space $\mathcal{P}$ with parameters $\mu \in \mathcal{P}$ and high-fidelity problem in algebraic form:

$$\mathbb{A}_{\mathcal{N}}(\boldsymbol{\mu})\boldsymbol{u}_{\mathcal{N}}(\boldsymbol{\mu}) = \boldsymbol{f}_{\mathcal{N}}(\boldsymbol{\mu}) \text{ with } \mathbb{A}_{\mathcal{N}}(\boldsymbol{\mu}) \in \mathbb{R}^{\mathcal{N}\times\mathcal{N}}$$

Construct a reduced model in algebraic form:

$$\mathbb{A}_{N}(\boldsymbol{\mu})\boldsymbol{u}_{N}(\boldsymbol{\mu}) = \boldsymbol{f}_{N}(\boldsymbol{\mu}) \text{ with } \mathbb{A}_{N}(\boldsymbol{\mu}) \in \mathbb{R}^{N\times N}$$

Reduction is for $N \ll \mathcal{N}$

From an high fidelity model (DOM):

$$\boldsymbol{u}_{\mathcal{N}}(\boldsymbol{\mu}) = \sum_{k=0}^{\mathcal{N}} \boldsymbol{\varphi}^k a^k$$

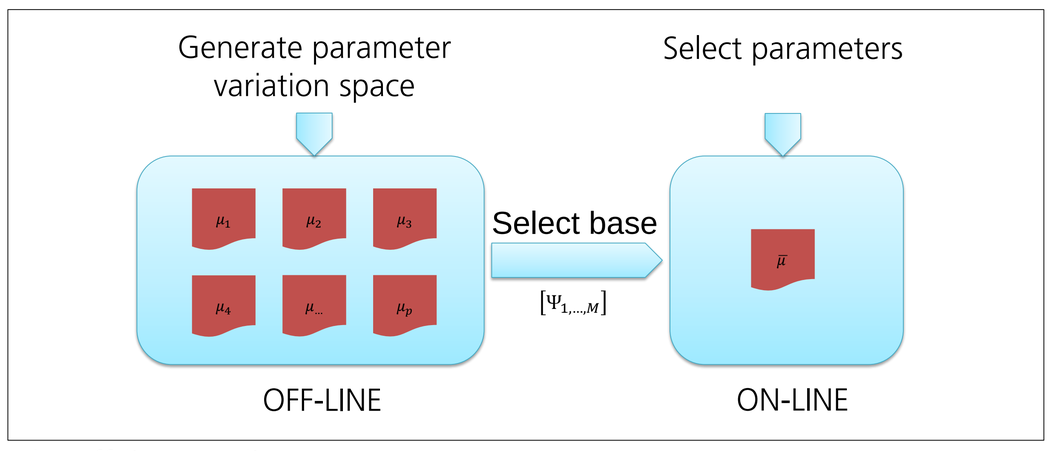
Sum of polynomial functions:
- Base functions $\boldsymbol{\varphi}^k$ are poor
- $\mathcal{N}$ is large

Construct a reduced order model (ROM):

$$\boldsymbol{u}_{N}(\boldsymbol{\mu}) = \sum_{k=0}^{N} \boldsymbol{\Psi}^k b^k$$

Sum of empiric functions:
- Base functions $\boldsymbol{\Psi}^k$ are rich
- N is small

The efficiency of model reduction depends on :
- The nature of the equations (elliptic, parabolic, hyperbolic for instance)
- The non-linearity of operator
- The numbers of parameters and their nature



The off-line / on-line strategy

SOME PUBLICATIONS

A. Benaceur, V. Ehrlacher, A. Ern, and S. Meunier – *A Progressive Reduced Basis/Empirical Interpolation Method for Nonlinear Parabolic Problems* – SIAM J. Sci. Comput., 40, pp. 2930-2955, 2018.

M. Abbas, Q.-A. Ta and D. Ryckelynck – *Implémentation de la méthode d'Hyper-Réduction de modèle dans code_aster et analyses paramétriques* – Colloque National en Calcul des Structures, 2013.

T. Dinh Trong, D. Ryckelynck, S. Hendili and M. Abbas – *Modèle hyper-réduit directionnel pour la prévision simplifiée des contraintes résiduelles de soudage* – Colloque National en Calcul des Structures, 2017.

C. Leblond, J.-F. Sigrist – *A reduced basis approach for the parametric low frequency response of submerged viscoelastic structures* – Finite Elements in Analysis and Design, 119, pp. 15-29, 2016.

Contacts:
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