AcouFren

Software integration of industrial squeal simulation procedures

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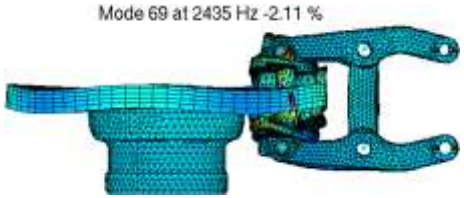
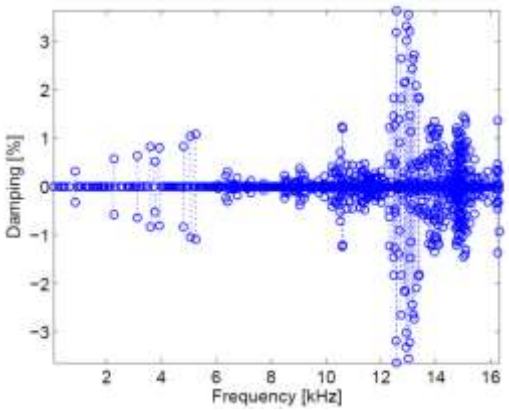
SDTools

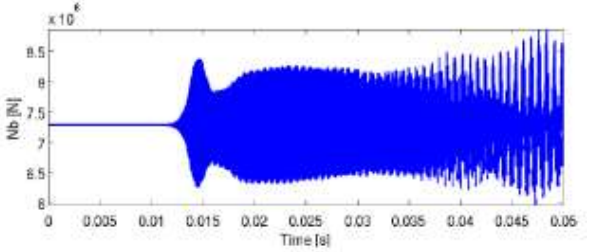
Introduction

- Industrial state of the art
  - Full industrial mesh
  - Updated components
  - Updated subassemblies
  - Instability analysis



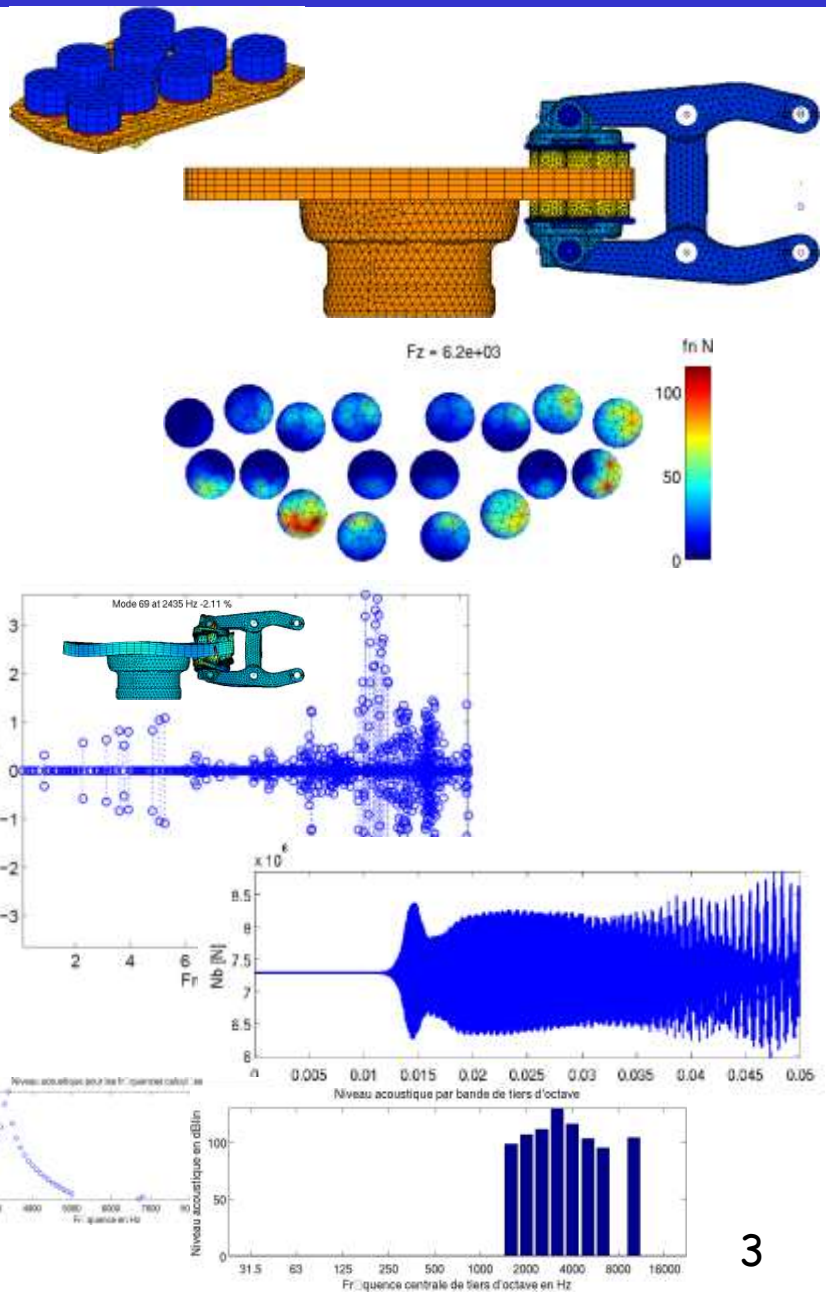


- Non-linear analyses are necessary
  - Most procedures cannot process industrial models
  - Transient analysis is the most direct and is chosen here
- Figures
  - 1 million DOF system over 0.5s using a time step of 1 μs
  - Simulation time > 30 days
  - Data volume (displacement and velocity) 7.3 TB
- Need for optimization at all levels !



Simulation tool capabilities

- Simplified pad generator (PadGen)
- Full/Reduced TGV or AGC assembly generation
  - Disc remeshing, pad integration, kinematic positioning
- Full/Reduced Static computations
  - Integration of a large array unsymmetric solver (pardiso)
- Full/Reduced Stability computations
- Transient simulations with model reduction, and modal damping capability for disc
- Driver for ENPC Acoustic simulations
- Post treatments
  - Macro. Contact data
  - Contact fields (Fn, Ft, g, w_{slide})
  - Local indicators (DOF sensors)
  - Energies/ component contributions
  - Squared normal velocities/ component contributions
- Report integration

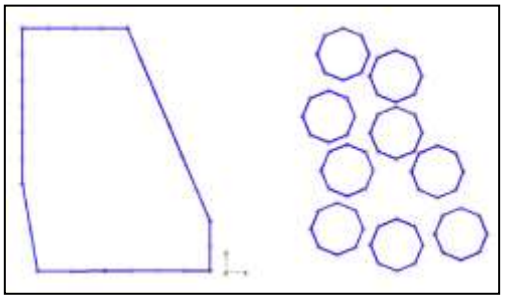


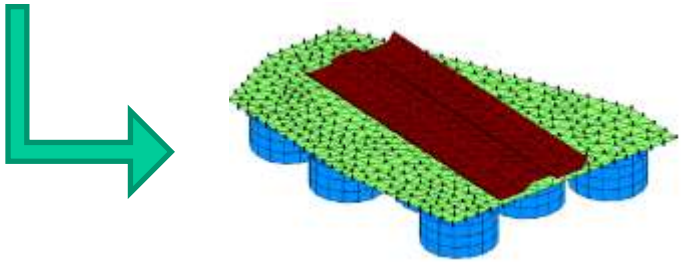
Outline

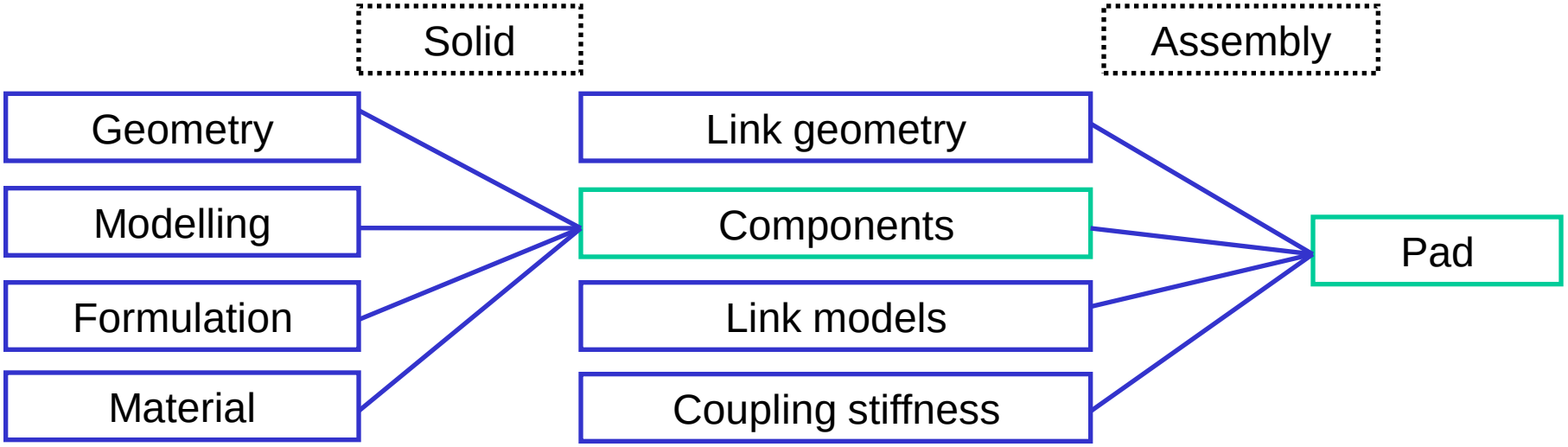
- Technical aspects
  - Industrial mesh generation
  - Model reduction
  - Performance
- Procedures integration
  - Post-treatment and Reporting
  - GUI environment

Simplified pad generation

- Design prototyping context
  - Low detail level
  - Trends needed to qualify solutions
  - Accuracy/Performance trade-off
- Automatic generation
  - Provide 2D topologies
  - Material and coupling parameters
  - Generic formulations

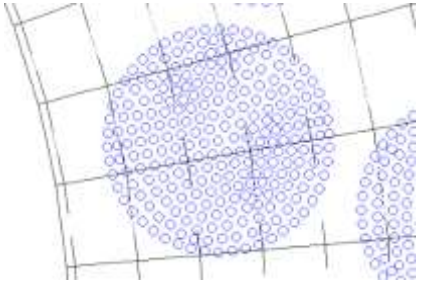


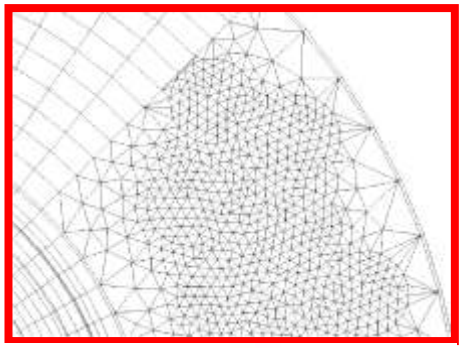


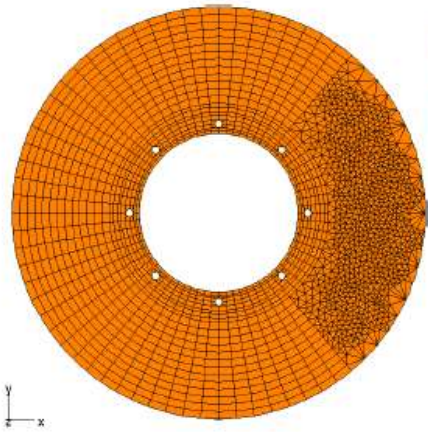


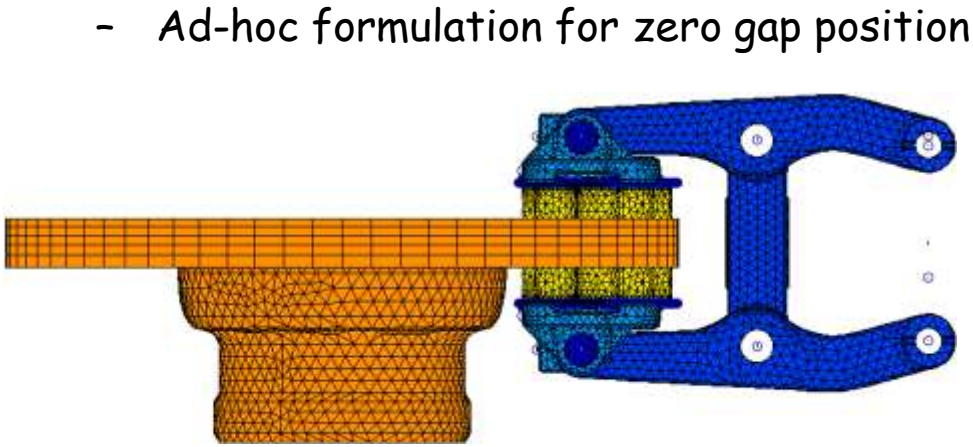
Disc remeshing and kinematic positioning

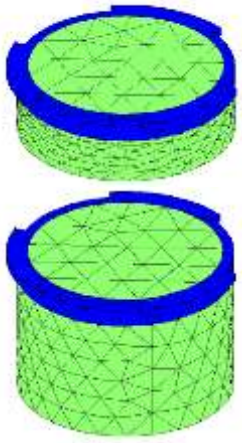
- Using a conforming mesh is needed
  - Avoids locking due to overconstraints
  - Simplifies treatment of Lagrangian contact
- Procedure
  - Disc section extraction
  - Integration of lining mesh trace on skin topology
  - Local volume remeshing
  - Disc free modes expansion (component modal damping)
- Parametrization of lining wear
  - Lining thickness mesh adaptation
  - Ad-hoc formulation for zero gap positioning





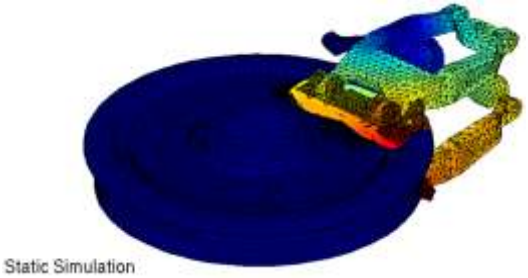


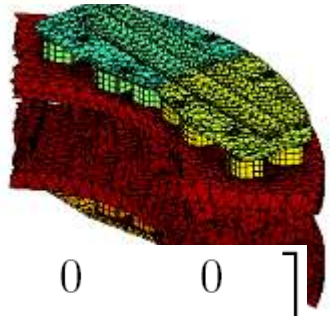




Model reduction procedure

- Use of the CMT, developed by SDTools since 2008
  - Domain decomposition
    - A reduced part behaves linearly
    - A non reduced part bears the non-linear DOF
  - Use of the full assembled modes as Rayleigh-Ritz basis
    - Exact nominal modes
    - Interface reduction possible



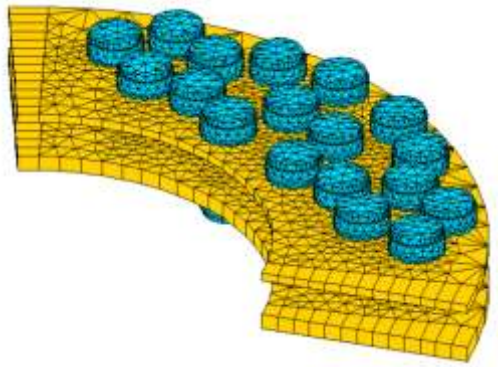


- Level 1: database generation
  - Precomputation for pad switching
  - Model sizes reduced to full pads
  - Statics model based on 72 configurations
  - Dynamic model 1000 modes of 3 pad config.

$$[K_{all}] = \begin{bmatrix} K_{tim} & K_{pg}^T & 0 & 0 \\ K_{pg} & K_{pad} & 0 & 0 \\ 0 & 0 & K_{dc} & K_{doc}^T \\ 0 & 0 & K_{doc} & K_{do} \end{bmatrix}$$

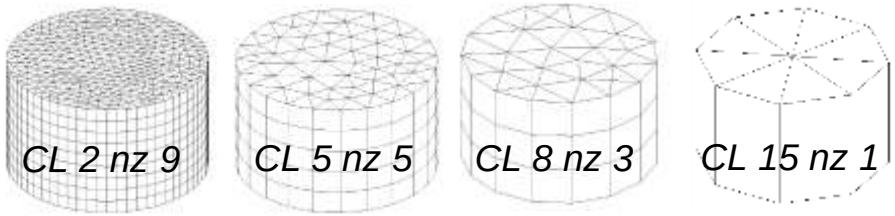
Invariant

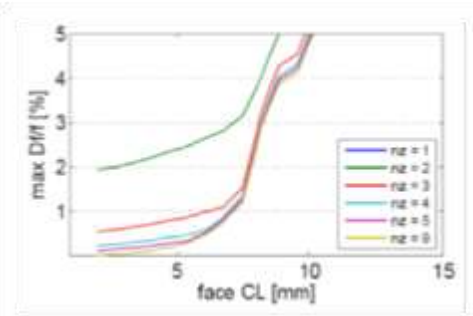
- Level 2: transient simulation
  - Reduction to lining elements and disc in contact
  - Compact sizes (30,000 to 120,000 DOF)

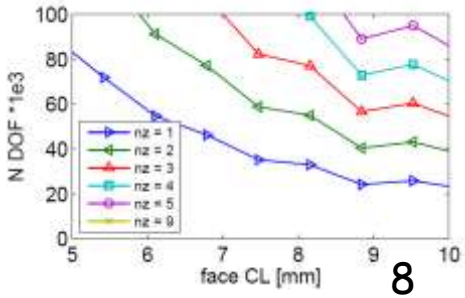


Performance

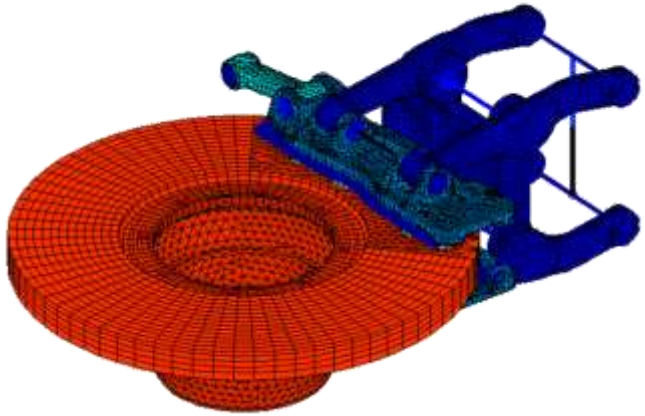
- New solver implementation in SDT
  - Static resolution using Largange contact and sliding friction
  - Inversion of a 10^6 DOF non symmetric matrix not possible with MATLAB
  - Use of PARDISO library from INTEL : performed in a few minutes
- Compilation of critical sparse operations
  - Use of MKL libraries for matrix vector products (transient)
  - Gain of 33% performance
- Mesh size vs computation times trade-off
  - Linings kept in transient simulation
  - Estimation based on the number of contact points and reduced DOF
  - Target base 1h / 0,01ms simulated : 3,000 Cpoints, 30,000 DOF
  - Constraint regarding mesh convergence (PadGen) : 3,500 Cpoints, 50,000 DOF







Out-of-core aspects



- Data volumes are very large
  - Level 1 reduced model : 7 GB
  - Level 2 reduced model : 10 GB
  - 1,000 full complex modes : 16 GB
  - 0,5s transient simulation : 60 GB
- Overwhelms most systems RAM capacity
- Solutions
  - Use of HDF5 for partial data loading
    - Meta-data kept, actual data on disk
  - Block-wise handling of intensive operations
  - Transient simulation subsampling and block-wise saving
  - Integration of curve models to restitute signals on-the-fly at display

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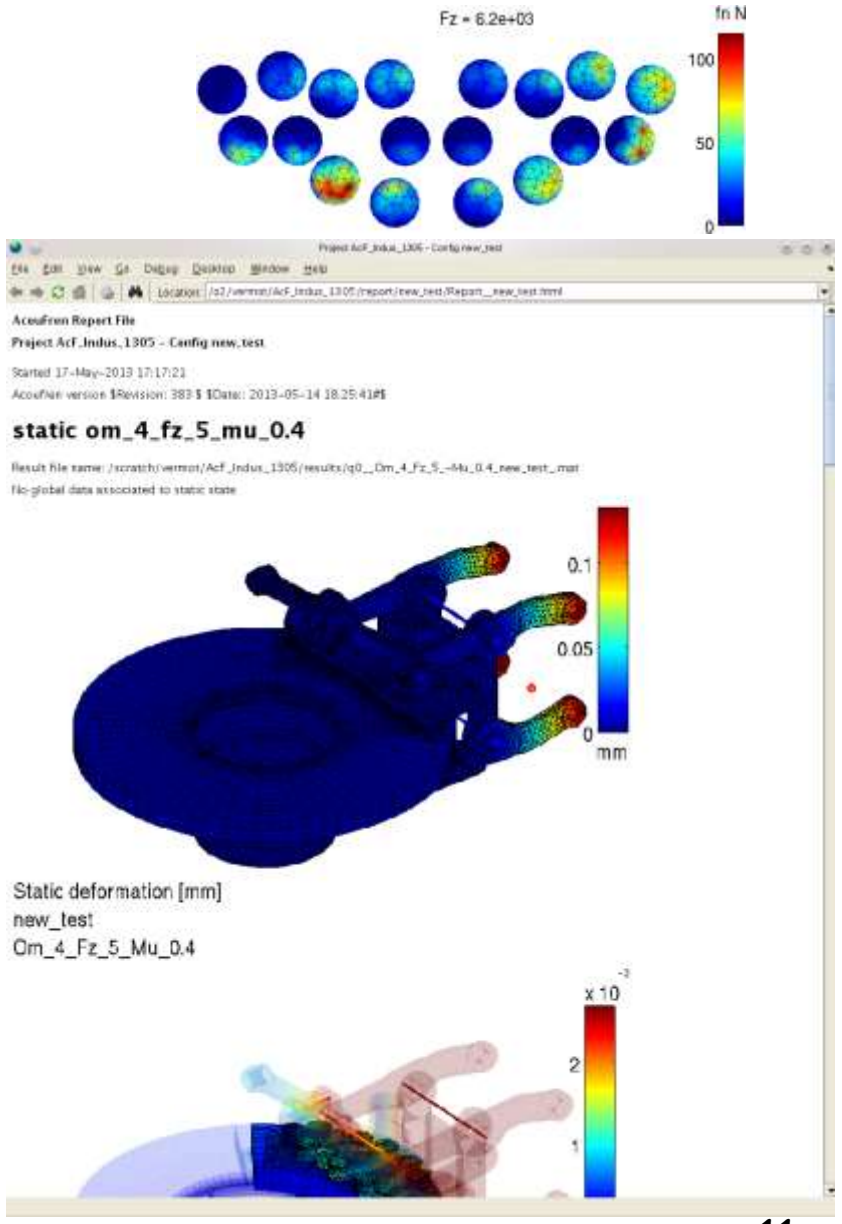
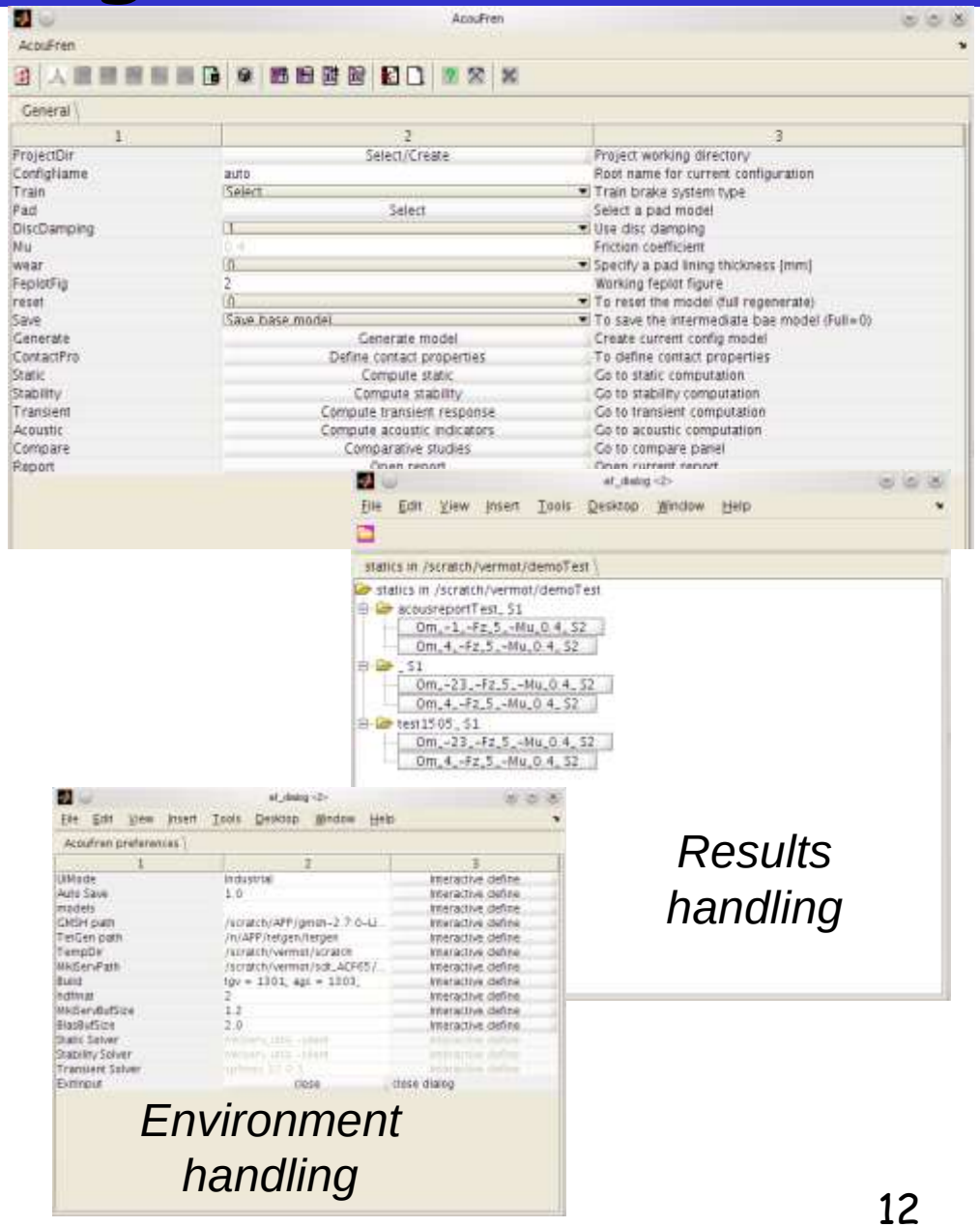
Post-treatments and auto-reporting

- Post treatments
  - Macro. Contact data
  - Contact fields (Fn, Ft, g, wslide)
  - Local indicators (DOF sensors)
  - Energies/ component contributions
  - Squared normal velocities/ component contributions
  - Calls to the acoustic solver
- Automatic reporting strategies
  - Critical tool for an efficient analysis
  - Predefined views and curve presentation
  - Automatic naming
  - Integration in an HTML report compatible with Word



GUI integration

- SDT implementation of JAVA based interface
- Data architecture implementation per project
- A tab per module
- UI layout
  - Load/Save projects, models, results
  - Tab dependent toolbar
  - Equivalent script generation
  - Post treatment visualization
- Dynamic results hierarchy
  - Each saved results parametered
  - Presentation as a levelled tree
  - No physical sub-directory handling



Conclusion, Perspectives

- A very advanced tool
- Provides a relevant working basis
  - Refined model studies
  - Parametrization necessary
- Deployable for industrial applications
- Perspectives
  - Optimization of transient simulations
    - Formulation benchmarks
    - Use of parallelization for non-linearities
  - Integration refinement for industrial application cases
  - External brake models import