Z-set to Abaqus

Efficient tools for advanced material modeling, damage analysis and crack propagation simulations

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Company overview

The development team is formed by PhD **mechanical** engineers specialized in **numerical modeling** and **simulation**.

Our mission is to provide industry with **solutions** and innovative technologies for advanced multi-disciplinary analysis, with a special emphasis on **materials** related issues.

We deliver our expertise in development of numerical methods in structural computations for advanced **non-linear problems**.

Our developments help mechanical engineers in simulation of **material behavior** and optimization of the final product design (**durability prediction and fatigue analysis**).

Material modeling workflow

Classical FEA and design optimization workflow

Model setup

Finite Element simulation

Lifetime post-processing
Visualization and results treatment

Results analysis and optimization

Nonlinear material modeling (Z-mat, Zsopt)

- constitutive model implementation
- material parameters calibration

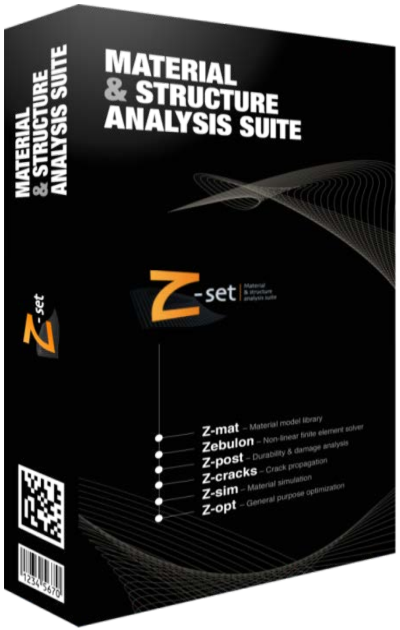
Customized FE algorithms (Z-mat, Z-cracks)

- global consistent tangent operator
- acceleration methods
- remeshing
- crack propagation

Powerful lifetime assessment models (Z-post)

Z-set material modeling and FE solutions

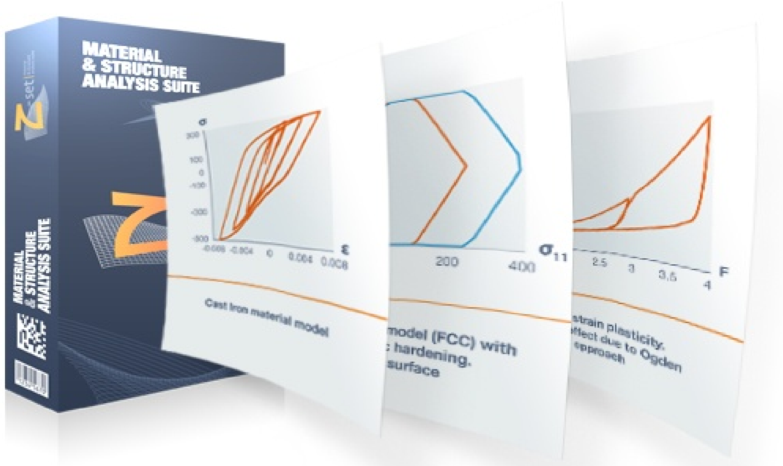
Z-set suite



Z-set is a comprehensive suite of integrated analysis programs for general purpose structural analysis with a special emphasis on **advanced material representation**

- Advanced material modeling library for major FE codes
- Material parameters identification GUI
- Generic optimization
- Damage and durability analysis post-processing
- Specific data visualization
- Crack initiation and propagation
- Add-on for large commercial codes

Z-mat - advanced material library



Many material models

- Elasticity, hyperelasticity
- Plasticity, viscoplasticity
- Cyclic plasticity
- Damage
- Creep, relaxation
- Anisotropy (elastic, plastic, damage)
- Crystal plasticity
- Visco-elasticity
- Nonlinear behavior of multi-phase materials (composite, polycrystals)
- Aging
- Porous plasticity
- Shape memory effect
- Polymer finite strain models

Models for industrial applications

- Aeronautics
- Car manufacturers
- Automotive equipment suppliers
- Energy
- Metals manufacturers
- Polymer, Rubber, Glass industry

Z-mat – modular design

Elasticity

Kinematic hardening

Thermal strain

Behavior

Isotropic hardening

Plastic Flow

Kinematic hardening

Potential

Criterion

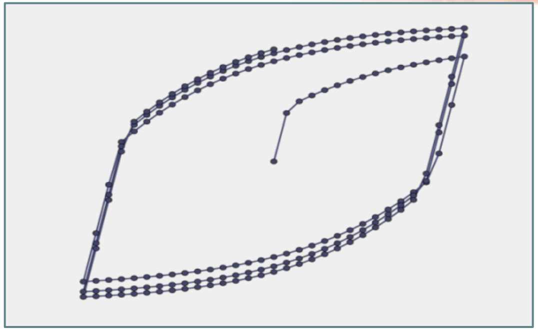
Strain partition : $\underset{\sim}{\epsilon} = \underset{\sim}{\epsilon}^{el} + \left(\underset{\sim}{\epsilon}^{th}\right) + \sum \underset{\sim}{\epsilon}^{i}$

Extention to finite strains : $\underset{\sim}{\mathbf{F}} = \underset{\sim}{\mathbf{F}}^{el}\underset{\sim}{\mathbf{F}}^{p}$

- refined modeling of a wide range of strain rates associated with different deformation mechanisms
- each potential can have its own flow law (plastic or viscoplastic) and hardening objects
- interaction between potentials

Typical assembly for viscoplasticity

- Behavior
  - Elasticity
  - Thermal strain
  - Potential
    - Criterion
    - Flow
    - Isotropic hardening
    - Kinematic hardening
    - Kinematic hardening
  - Potential
    - . . .

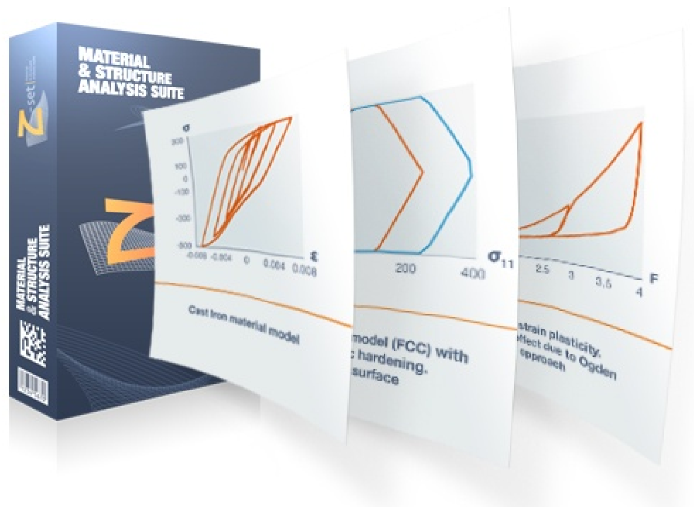


Z-mat input file

```
***behavior gen_evp
 **elasticity isotropic
   young 200000.
   poisson 0.3
 **potential gen_evp ep
  *criterion mises
  *flow plasticity
  *isotropic nonlinear
   R0 100.000
   Q  100.000
   b   10.000
  *kinematic nonlinear
   C  30000.0
   D  150.000
***return
```

- C++ code
- Object factory mechanism

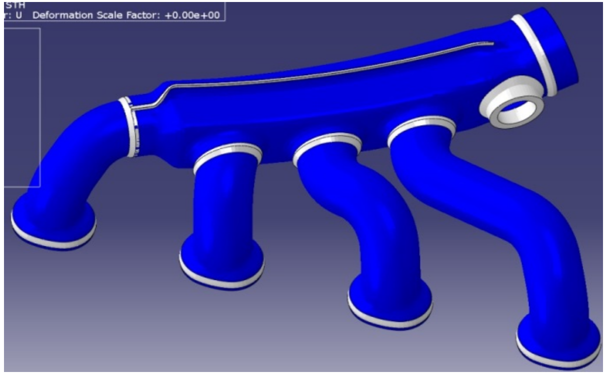
Z-mat - advanced material library



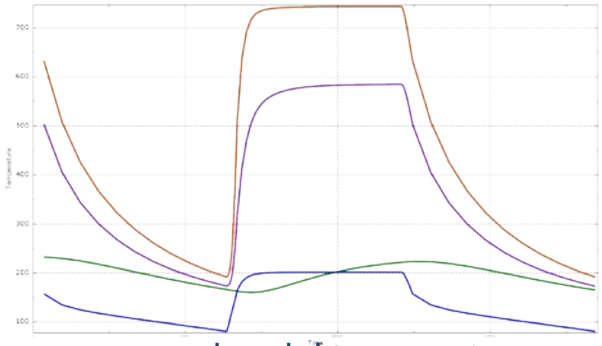
Z-mat is a material modeling and development platform

- Easy plug-in to Abaqus
- Designed to be used with other User Subroutines
- Compatible with Abaqus Implicit and Explicit solvers
- Supports most types of Abaqus elements: volumic, shells, membranes etc.
- Safe multithreading for local integration
- Robust integration algorithms (implicit, explicit and mixed)
- Consitent Tangent Operator
- Comes with **Z-sim** and **Z-opt** software for fast material prototyping and parameters fitting

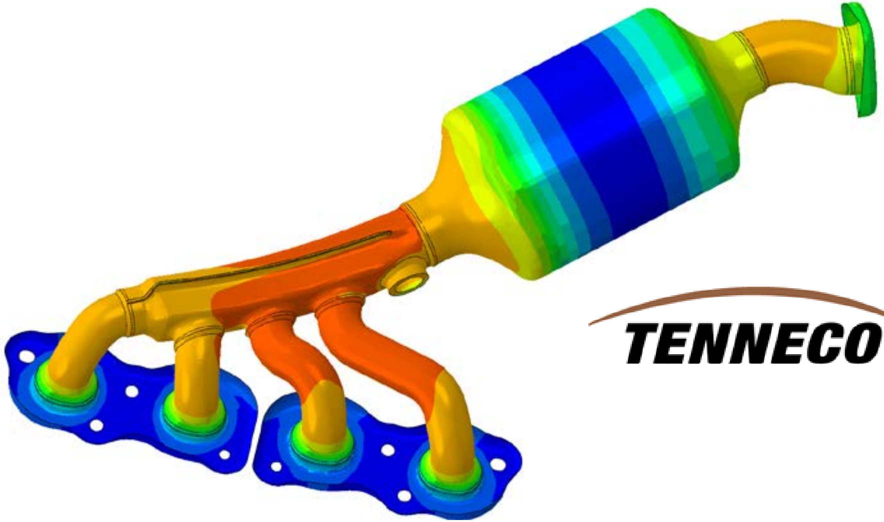
Automotive exhaust system



M4828 Austenitic steel



measured nodal temperatures



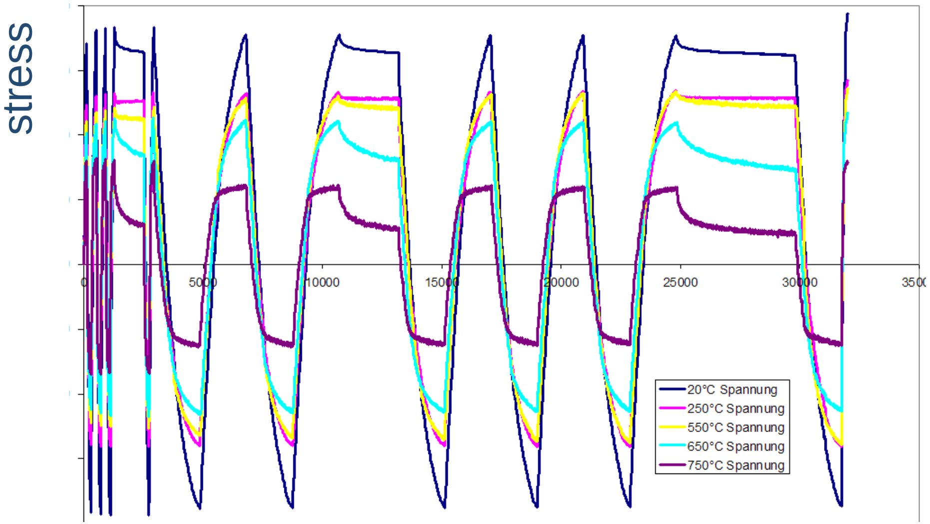
TENNECO

temperature fields resulting from a thermal shock cycle comprising:

acceleration – full throttle - deceleration

Z-set Material & structure analysis suite

Experimental database



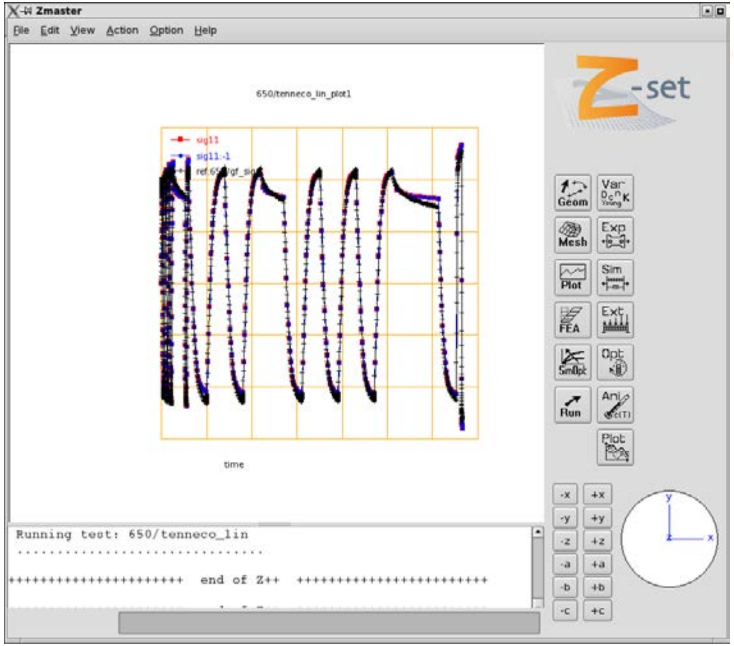
Material properties

- Time dependent plasticity
- Plastic strain
- Stress relaxation due to viscous effects

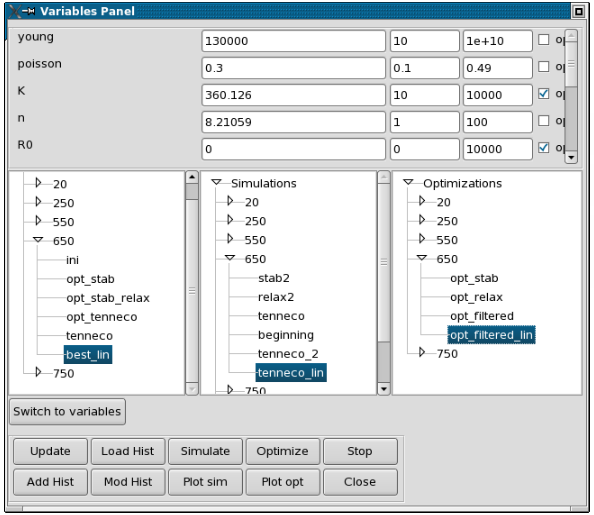
(very pronounced at high temperature)

Temperatures: 20°C, 250°C, 550°C, 650°C and 750°C.

Material model identification GUI



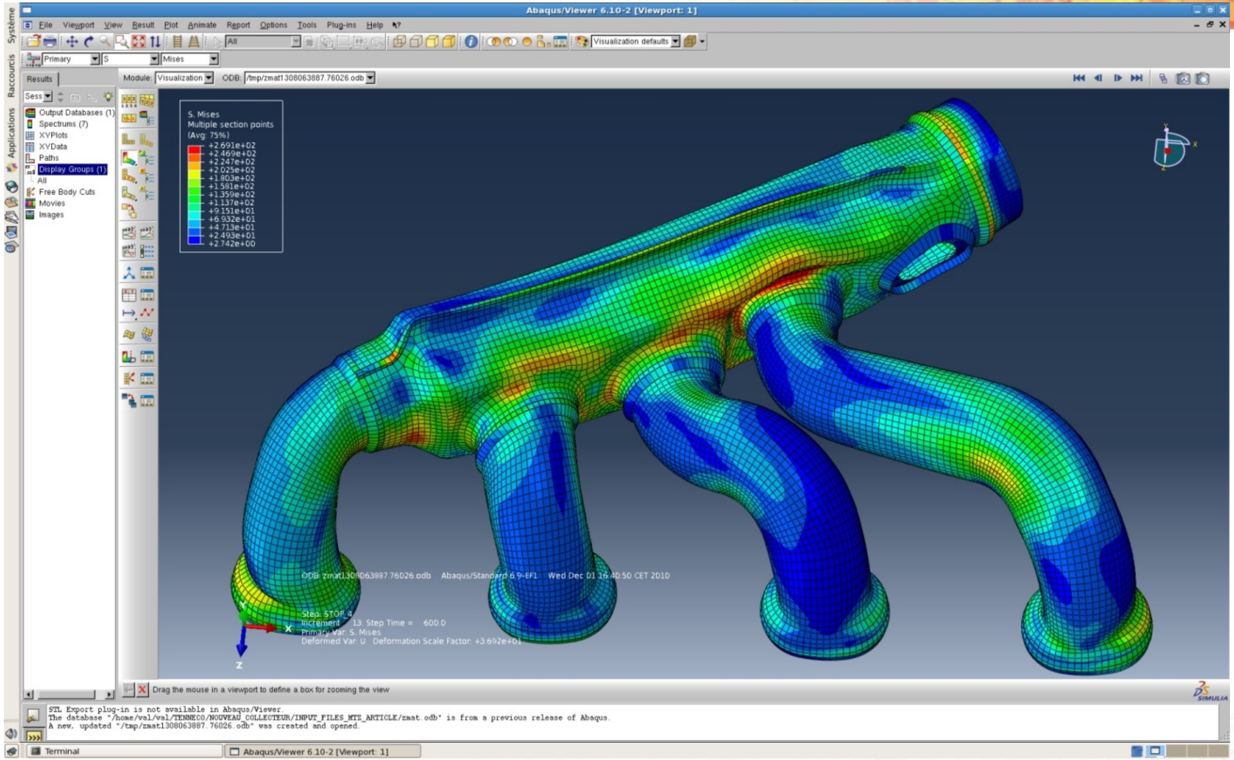
optimisation project management



- templates management
- simulations and variables control
- choice of optimisation strategy

instrumentation panel

Abaqus – Z-mat coupled FE analysis



Von Mises stress isocontour plots (engine shutdown)

Classical **FEA** and design optimization workflow

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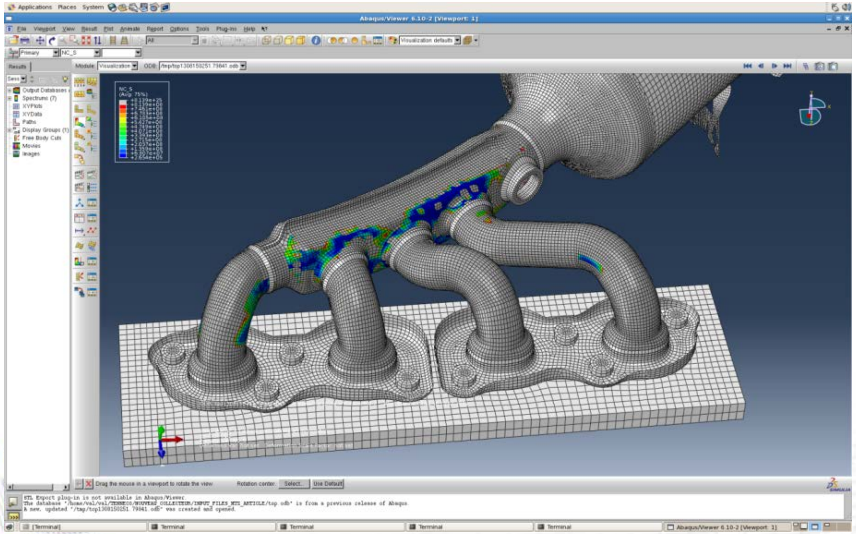
Powerful lifetime assessment models

Z-mat material modeling and FE solutions

Z-post – data processing

- Abaqus mesh / results import & export
- Post-processing data analysis with many algorithmic models
- Advanced durability and life estimation (cycle extraction, counting and damage)
- Efficient multithreading and MPI parallelized



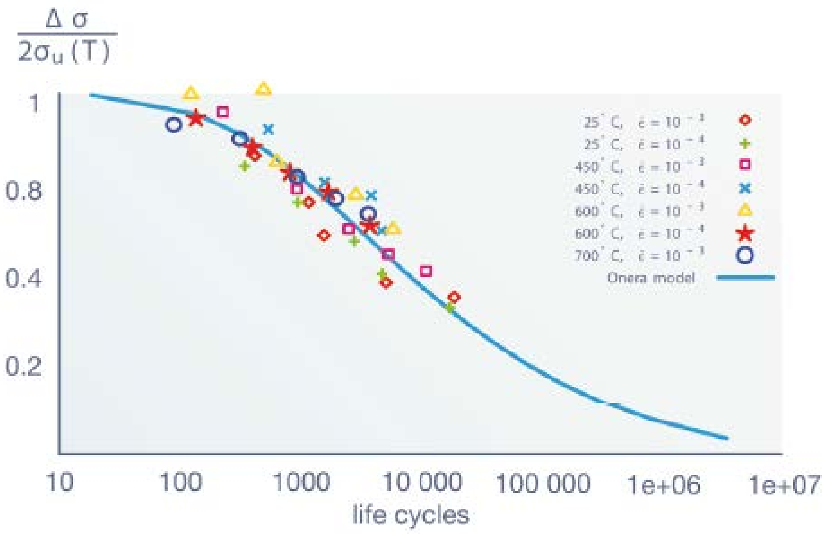
Z-post – data processing

Z-post input file

```
****post_processing
 ***data_source odb
  **open results.odb
 ***local_post_processing
  **file integ
  **output_number 1-10
  **elset nickel
  **process trace sig
 ***global_post_processing
  **process average_in_element sigii
 ***local_post_processing
  **process function msig11
  sig11+(1./3.)(ave_sigii - sigii);
 ***global_post_processing
  **process node_extrapolation
   *list_var msig11t
 ***data_output  odb
   *file pp_results.odb
****return
```

Z-post fatigue models

- Models for both LCF and HCF regimes
  (i.e., the entire S-N curve)
- Multiaxial capabilities
- Modeling of the mean stress influence (Haigh
  diagram, loading factor influence on S-N curve)
- Possible coupling with creep damage to account for
  frequency effects
- Possible nonlinear accumulation of damage for the
  correct representation of experimentally observed effects.



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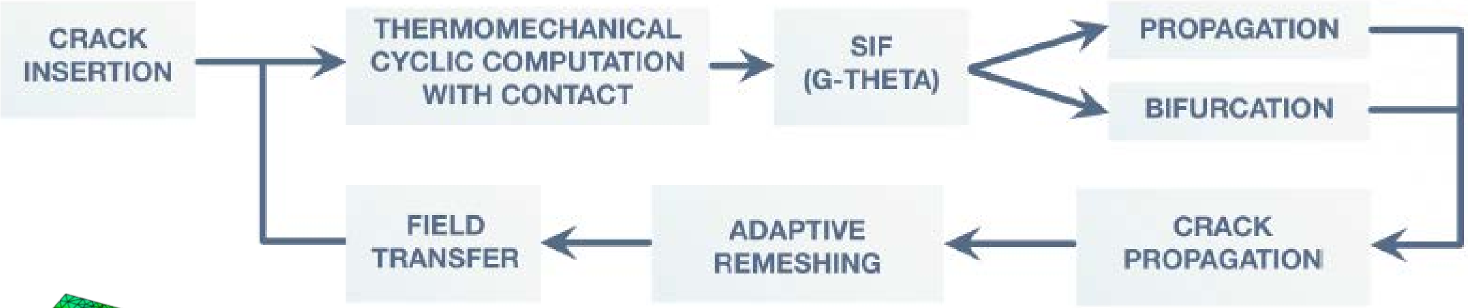
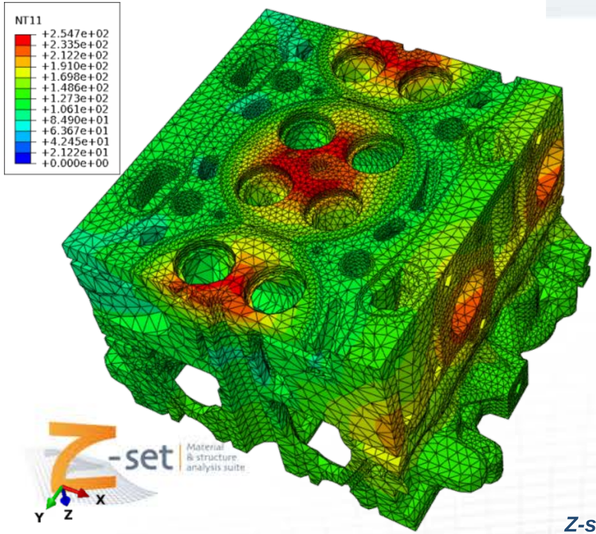
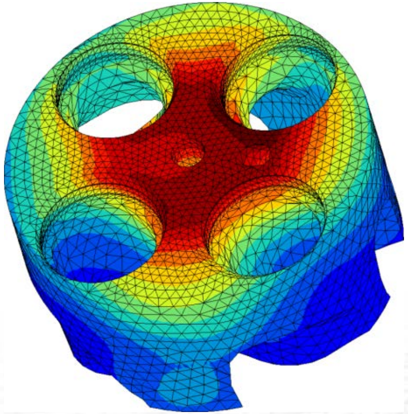
Powerful lifetime assessment models

Z-mat material modeling and FE solutions

3D fracture mechanics simulation





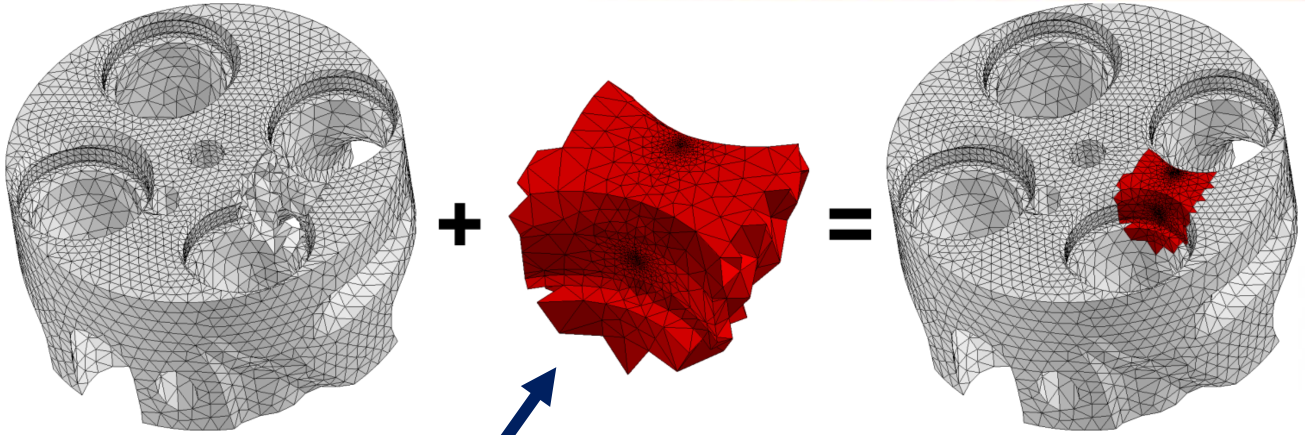


Maximum power thermal field (Tmax)

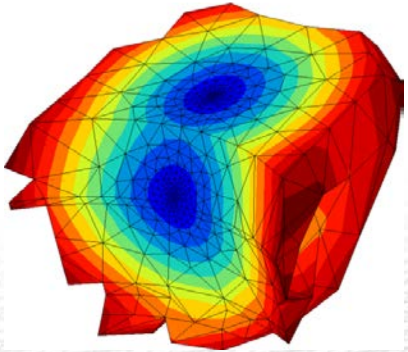
Thermomechanical loading

- Valve seat shrink-fitting
- Node displacements imposed on boundary (submodeling)
- Temperature cycle :
  Room T → Tmax → Room T

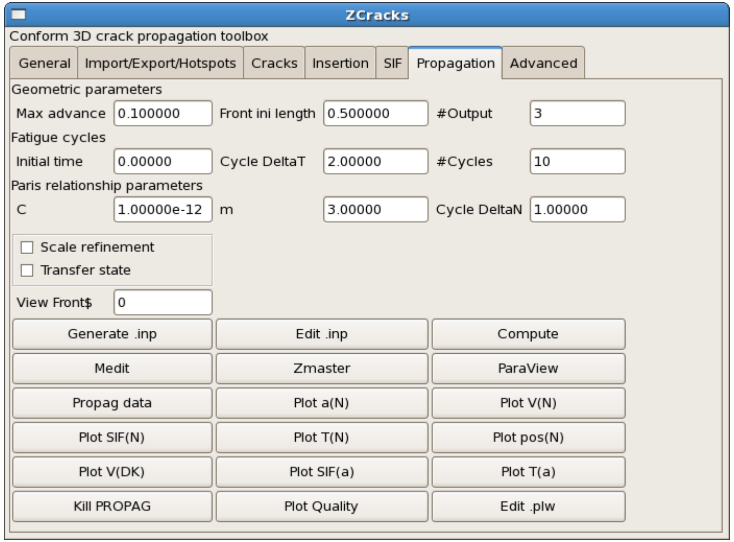
Adaptive remeshing principle



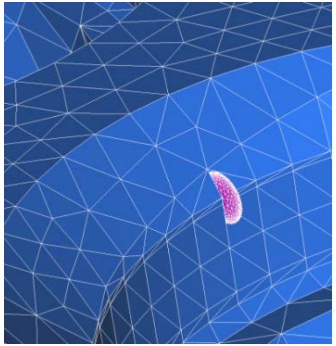
- Automatic patch creation
- Mesh refinement around crack tip
- Automatic calculation of element size map
- Patch interface elements are kept
- Contact zones are preserved

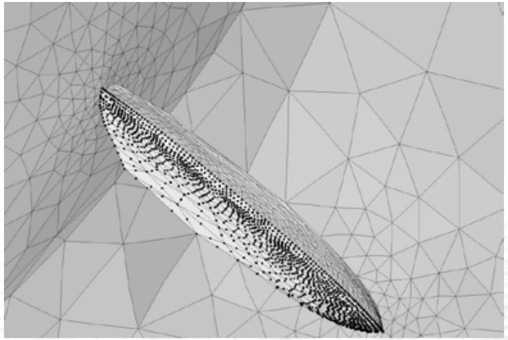


Z-cracks GUI



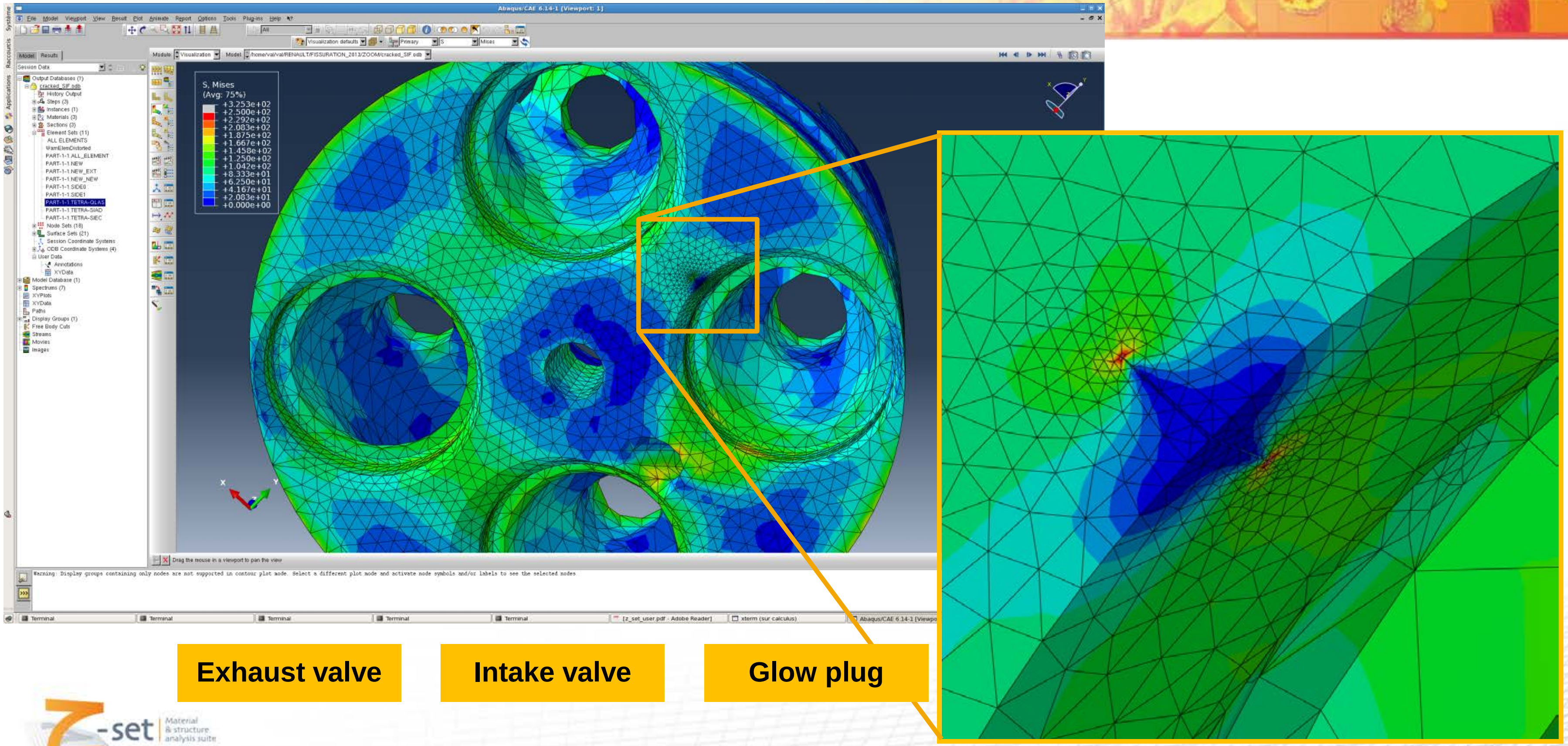
- uncracked mesh import/export features
- crack surface description and insertion
- static crack calculation with SIF and energy release rate outputs
- propagation calculation
- various fatigue propagation laws (Paris law, creep-fatigue or user defined)



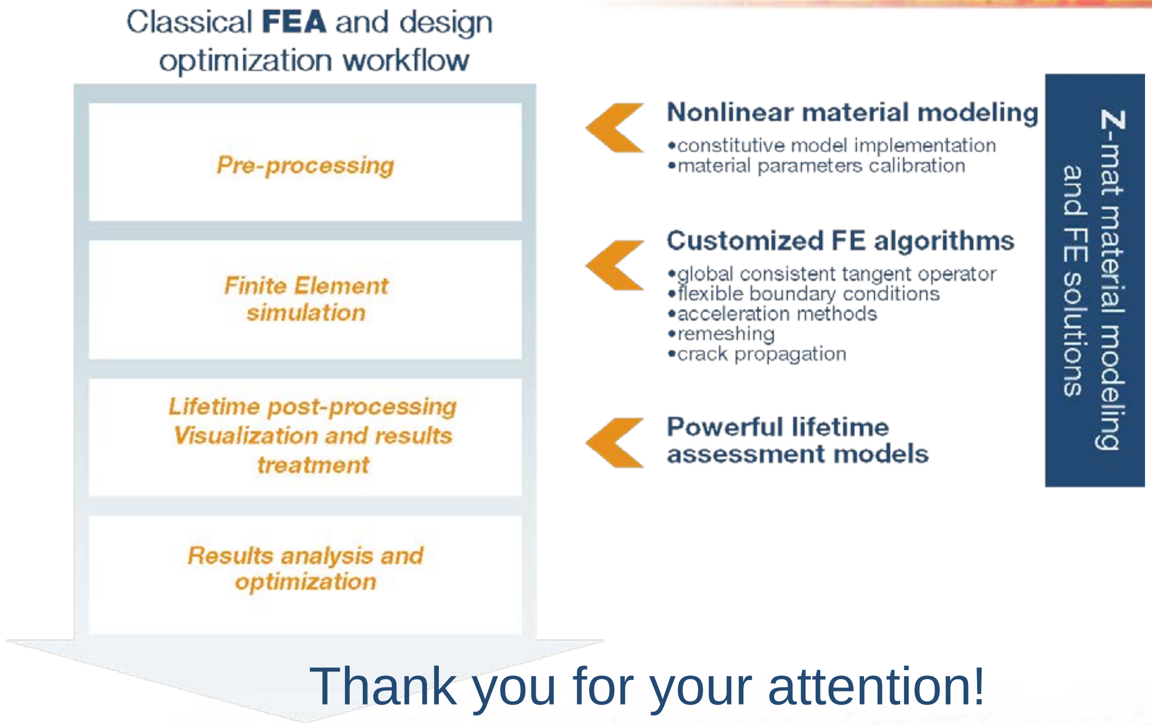


- advanced aspects: elasto-visco-plastic models, complex multiple coalescing cracks, contact..
- visualization tools
- many default settings

3D fracture mechanics simulation



Exhaust valve **Intake valve** **Glow plug**



Thank you for your attention!

You are welcome to visit our stand