

FRANC3D Training Workshop: Part 3

Introduction to FRANC3D

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Workshop Agenda

- Part 1: Introduction to Fatigue and Damage Tolerance
- Part 2: Introduction to Fracture Mechanics Analysis
- **Part 3: Introduction to FRANC3D**
- Part 4: FRANC3D User Interface
- Part 5: Finite Element (FE) Model Import
- Part 6: Crack Insertion
- Part 7: Static Crack Analysis & SIF Computation
- Part 8: SIFs from FE Analysis
- Part 9: Crack Growth
- Part 10: SIF History & Fatigue Life
- Part 11: Miscellaneous Topics

Introduction to FRANC3D

- FRANC3D Development History
- FRANC3D Version 9 Software
- What FRANC3D Can Do
- What FRANC3D is NOT
- Global and Local “sub-model” Terminology
- FRANC3D Benchmarking & Validation
- FRANC3D Documentations
- FRANC3D Tutorials

FRANC3D Development History

- 1988 to 1994
 - FRANC3D v1.0 BEM only
- 1994 to 2001
 - FRANC3D v2.0 BEM & Thin Shell FEM
- 2001 to 2005
 - FRANC3D v3.0 BEM & Thin Shell & Solid FEM (ANSYS)
- 2005 to 2009
 - FRANC3D v4.0 Solid FEM only (ANSYS, ABAQUS, NASTRAN)
 - Completely new code written in C++
- 2009 to 2010
 - FRANC3D v5.0 – Command line interface and other enhancements
- 2010 to 2014
 - FRANC3D v6 – Fretting Fatigue, Fatigue Life, Post-processing & other enhancements

FRANC3D Development History

- 2015 to 2021
 - FRANC3D v7
 - Built in sub-model generation tool
 - Expanded fatigue crack growth rate library
 - Robust automatic method for fatigue life integration
 - Time dependent and combined time and cycle dependent crack growth models
 - Python user-defined crack growth rules
 - Virtual crack closure technique
 - Partial crack front extension
 - SIF path options to improve paths for crack fronts that split or turn corners
 - Curvilinear elliptical crack geometry added to flaw library
 - Dialog for defining local coordinate systems for crack insertion
 - Preliminary capabilities for computing elasto-plastic J-integral from ABAQUS results
 - Crack face traction (CFT) capability allows a user to add CFT to an existing load step with options for setting temperature and thermal expansion properties

FRANC3D Version 8 Software

- 2021 to 2026
 - FRANC3D v8.0
 - Revised load schedule/events with support for combined LCF/HCF loading & dynamic pairing
 - Revised crack insertion and meshing library with support for cracks crossing bi-material interfaces, cracks embedded in bi-material interfaces, symmetry surface cracks, and finite volume “thick” cracks
 - Computation of single crystal fracture parameters
 - Improve support for partial crack front extension
 - Added user-mesh voids
 - Allow crack insertion into a single mesh facet
 - FRANC3D v8.1
 - Improved ANSYS, ABAQUS and NASTRAN interfaces
 - Revised mapping to improve the transfer/mapping of nodal force boundary conditions
 - Improved crack insertion and meshing library
 - Added support for multiple crack growth rate models
 - Added support for inserting multiple symmetry cracks
 - FRANC3D v8.2
 - Added support for additional languages in the GUI
 - Updated symmetry crack insertion capabilities
 - Added support for NASTRAN SOL 401 and ANSYS super elements
 - Improved partial crack front growth

FRANC3D Version 8 Software

- FRANC3D v8.3
 - Added support for modal crack face traction (CFT) using .dtp files for stress and temperature
 - Added Python script for pre-NASTRAN analysis
 - Added more crack growth rate models
 - Added label for “passes through load schedule” in fatigue dialog
 - Added electrostatic energy release rate
- FRANC3D v8.4
 - Revise volume meshing code; old volume meshing is available via Preferences
 - Revised crack growth data stored in .fdb file
 - Modified/fixed midside-to-quarter and quarter-to-midside node position code
 - Made blunt brick option available for ANSYS and Sierra
 - Add Advanced menu to read analysis code contour integral data, with a dialog to plot the data
- FRANC3D v8.5
 - Add support for OpenGL 4.5; this can be set in the Preference dialog
 - Revised both crack insertion remeshing and edit crack geometry dialog
 - Revised pseudo-ellipse (both surface and interior) flaw library geometry creation
 - Add 1D polynomial CFT distribution
 - Add template preference settings to the Meshing tab in Preferences
 - Add HILL and CREEP material data for ANSYS import
 - Add smoothing and coarsening to merge-and-grow to improve the crack geometry

FRANC3D Version 8 Software

– FRANC3D v8.6

- Modifications to the CRACKFACENODES data block in the .fdb file. Version 8.6 files cannot be read into older versions of Franc3d
- version 8.6 will read old .fdb files
- Updates to support thick crack (void) nodes and element faces
- Updates for thick (finite volume flaws) cracks, including J-integral computations
- Update to FE input checks for disconnected quad faces
- Add local vector to Anchor Node in the crack insertion Define Coord Sys dialog
- Add Preference setting to save .crk files for each crack growth step
- Update user-defined crack boundary dialog
- Add multi-spectra dynamic pairing, Growth Rate File menu option and load factor table dialog

– FRANC3D v8.7

- Modifications to differentiate cracks, notches and voids
- Modifications for crack front element types (wedge, collapsed brick and blunt brick); all-tet element template option supported
- J-integral for notch fronts added
- ComputeSif command modified to remove the elasto-plastic J computations, and a new
- ComputeJRings command added
- Symmetry option added for ABAQUS and ANSYS contour integral output for symmetry cracks
- Add Growth Rate File option

FRANC3D Version 8 Software

– FRANC3D v8.8

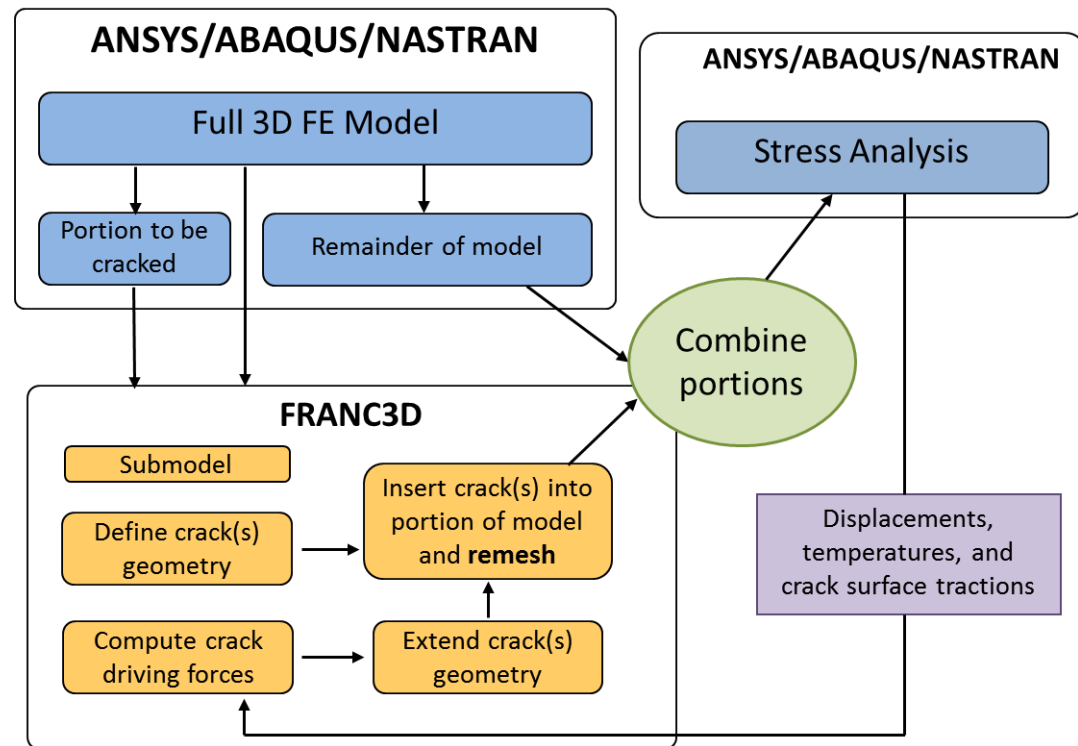
- Advanced Options button added to Fatigue dialog to set the starting crack step and to limit the cycle counting to a portion of the crack front
- Updates for single crystal crack growth
- Add non-proportional kink angle option; allow user to choose ΔK or K_{max}
- Revised crack / flaw / void parametric flaw definitions
- License is released when the model is closed; a license request is issued if the user opens or imports a model

FRANC3D Version 9 Software

- 2026
 - FRANC3D v9.0
 - Updates to Fatigue dialog
 - Updates to Edit Crack Geometry dialog
 - Simplify Grow/Merge command
 - Add partial-circle library flaw
 - Update RLM to version 18
 - Updates to FEM input checks
 - Add template display option
 - FRANC3D v9.1
 - Updates to View/Show Boundary Condition dialog
 - Updates to table dialogs
 - Update user-mesh crack to eliminate need for front-node sets
 - FRANC3D v9.2
 - Updates to Surface/Set Selection dialogs for retained surfaces, symmetry cracks and CFT
 - Revised analysis dialogs – analysis code is set automatically based on the input FE model

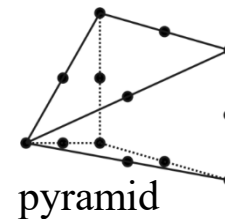
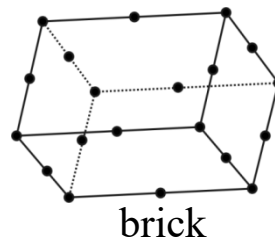
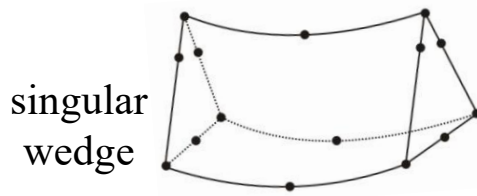
FRANC3D Software

- **FR**acture **AN**alysis **C**ode **3-D** uses the finite element (FE) method to simulate crack growth
- Designed to work in conjunction with commercial finite element codes:
 - ANSYS
 - ABAQUS
 - NASTRAN
- Computes stress intensity factors (SIFs) for arbitrary 3D crack geometry



FRANC3D Software

- Adaptively remeshes a 3D FE model to simulate crack growth; uses explicit crack geometry
- Several elements are used at the crack front:



- Written in C++
- Runs on Windows and Linux systems
- Programming interface that is an extension to the Python programming language

What Does FRANC3D Do?

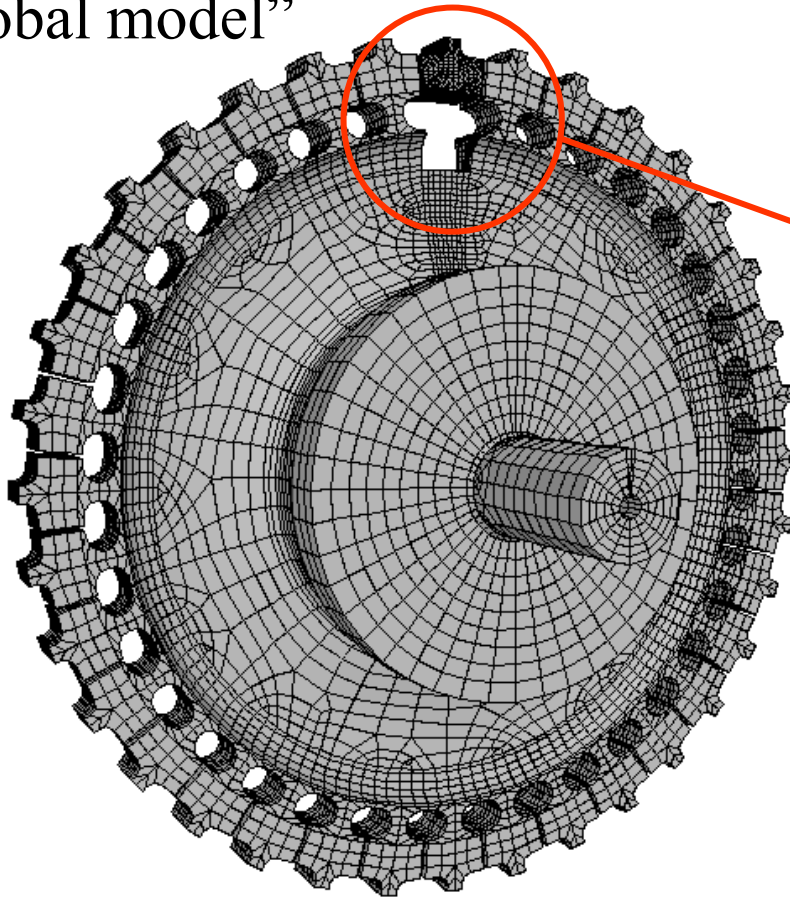
- Inserts a flaw into an *existing* finite element (FE) model and remeshes using **singular crack-front elements**.
- Computes stress intensity factors (SIF's) for all three “modes” of fracture at FE **mid-side nodes** along crack front for *isotropic* and *anisotropic* materials.
- Predicts how a crack will grow (relative extension and angle) using *engineering* growth criteria, extends the crack geometry and remeshes.

What FRANC3D is NOT

- Not a general FE pre-processor or post-processor: external software is required to build uncracked FE models and to visualize results (FRANC3D can display deformations).
- Not a FE analysis program: an external FE code is required (*e.g.*, ANSYS, ABAQUS or NASTRAN) to perform the stress analysis.
- Not a “fast running” fatigue life prediction code with stored analytical or tabular K solutions (*e.g.*, AFGROW, NASGRO or DARWIN).

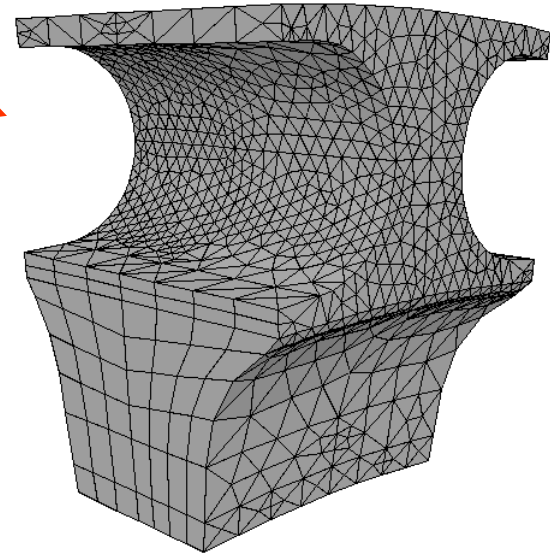
Global and Local “sub-model” Terminology

“global model”



“sub-model”

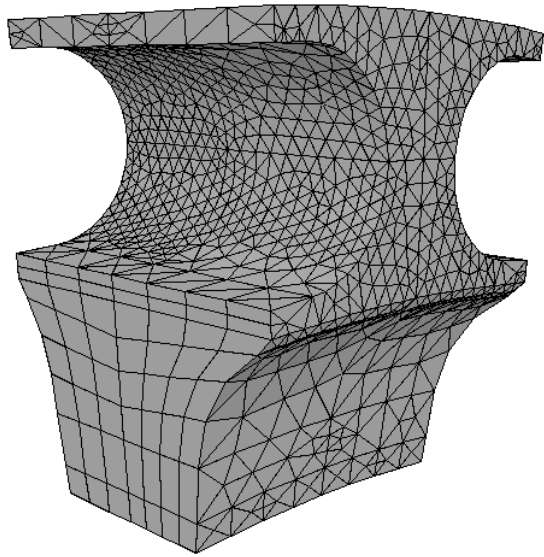
crack growth region



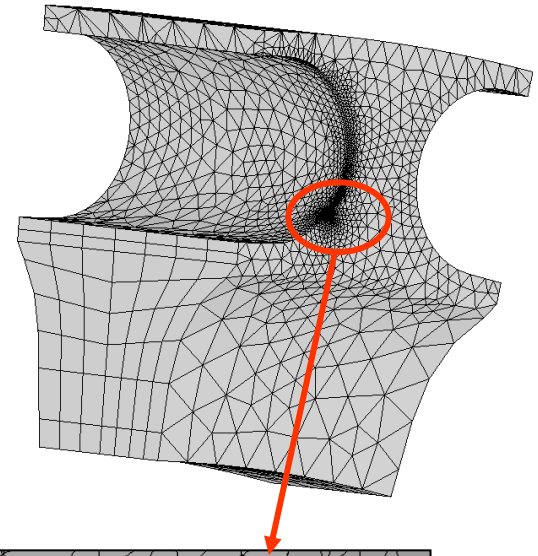
FE software (*e.g.*, ANSYS) or FRANC3D can be used to define the global and (local) sub-model. The sub-model should encompass the expected crack growth with ‘space’ for remeshing.

FRANC3D Modifies the Sub-model

uncracked sub-model

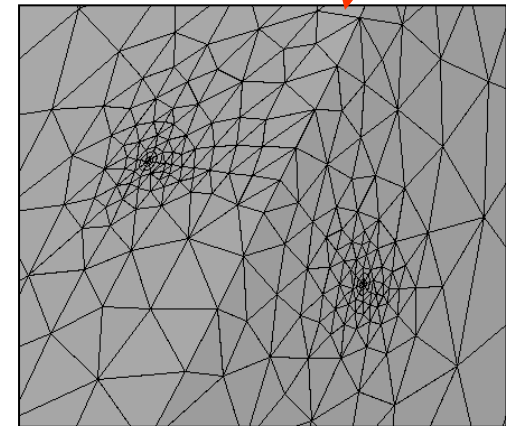


after crack insertion

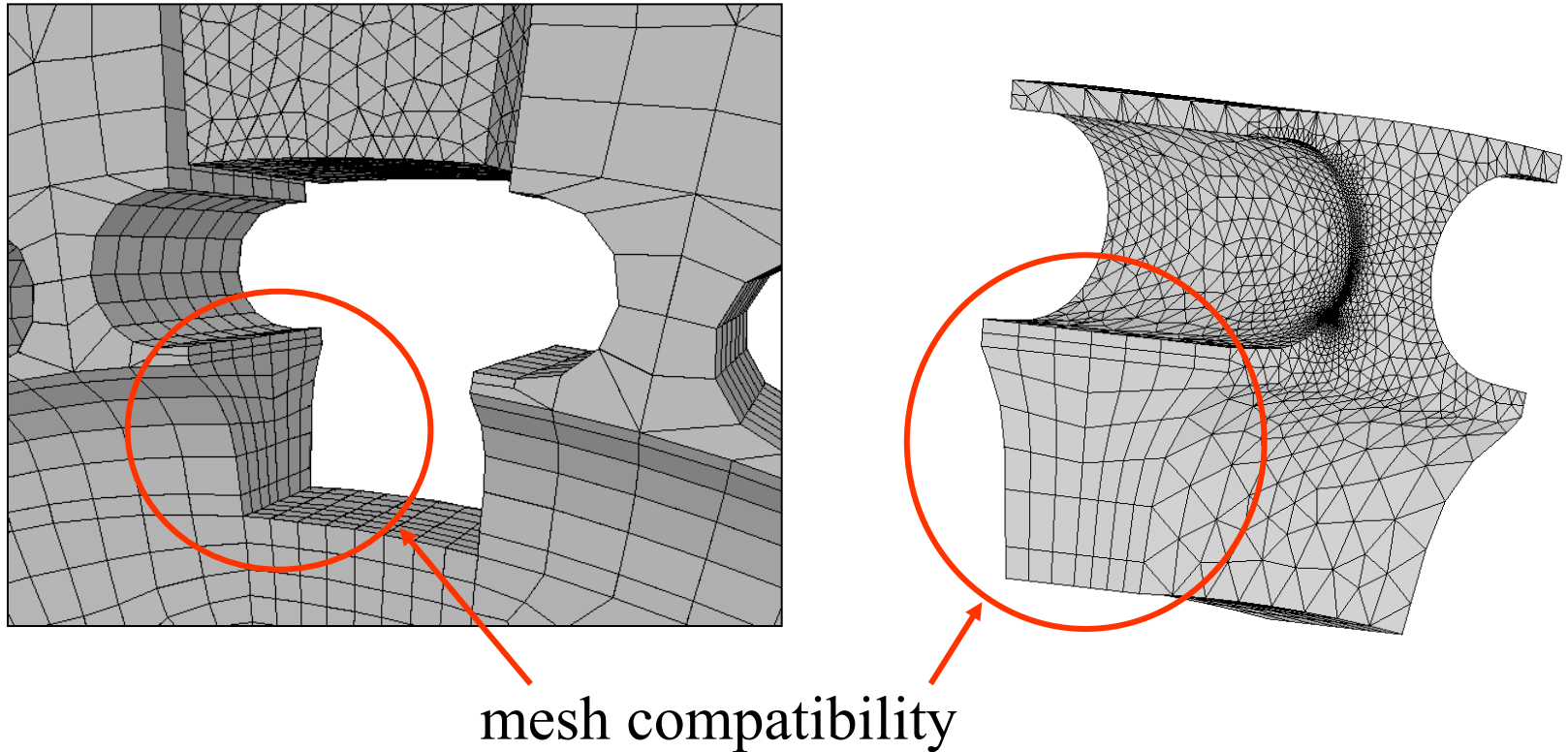


FRANC3D modifies the sub-model by **inserting a crack and remeshing**.

A file that combines the global and remeshed sub-model is output for the FE analysis software.



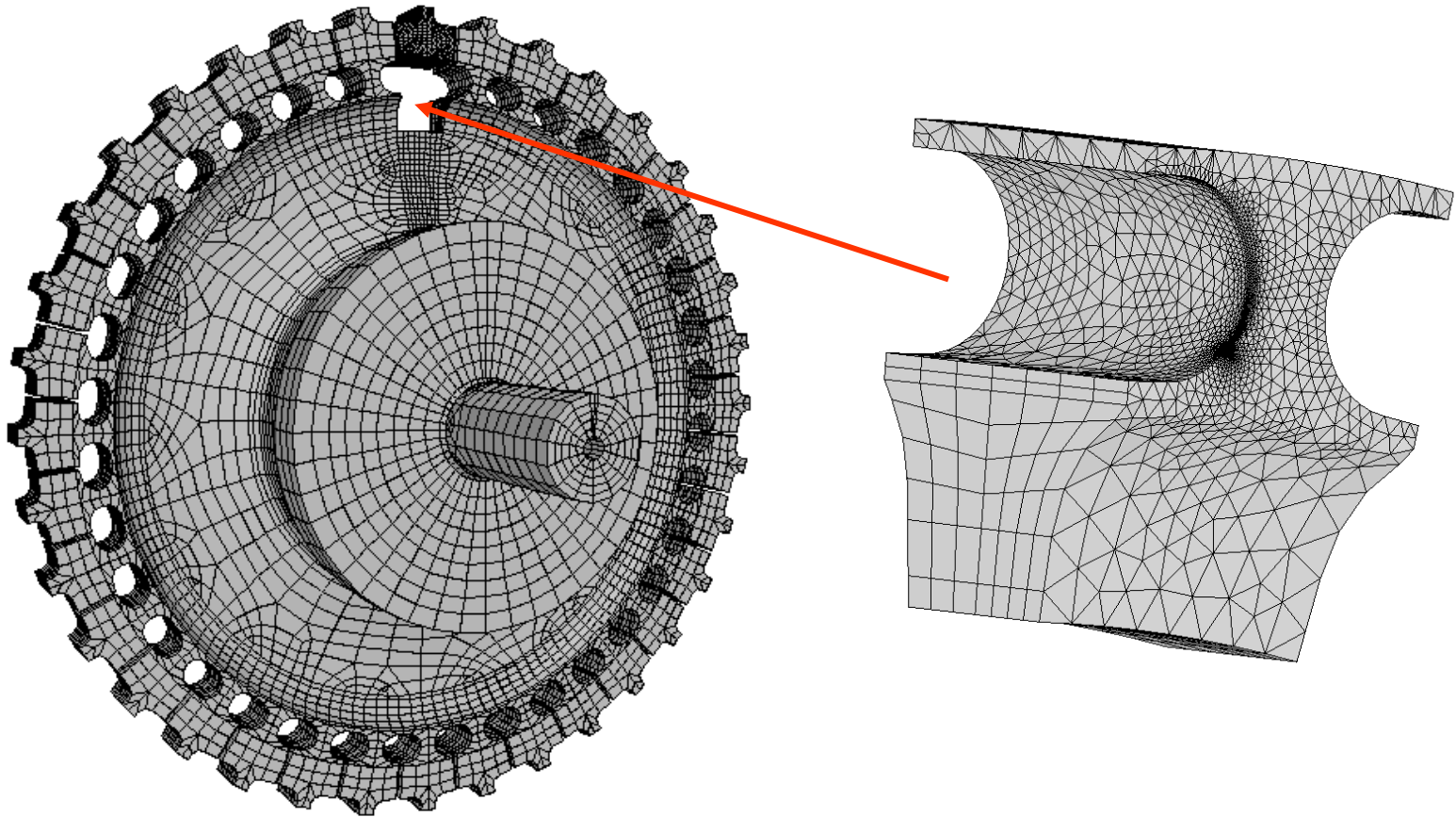
FRANC3D Maintains Mesh Compatibility



FRANC3D retains surface meshes on “cut” surfaces for compatibility between the global and sub-model – the best and preferred approach.

Note that FRANC3D can instruct the FE software to use constraint or contact on these surfaces.

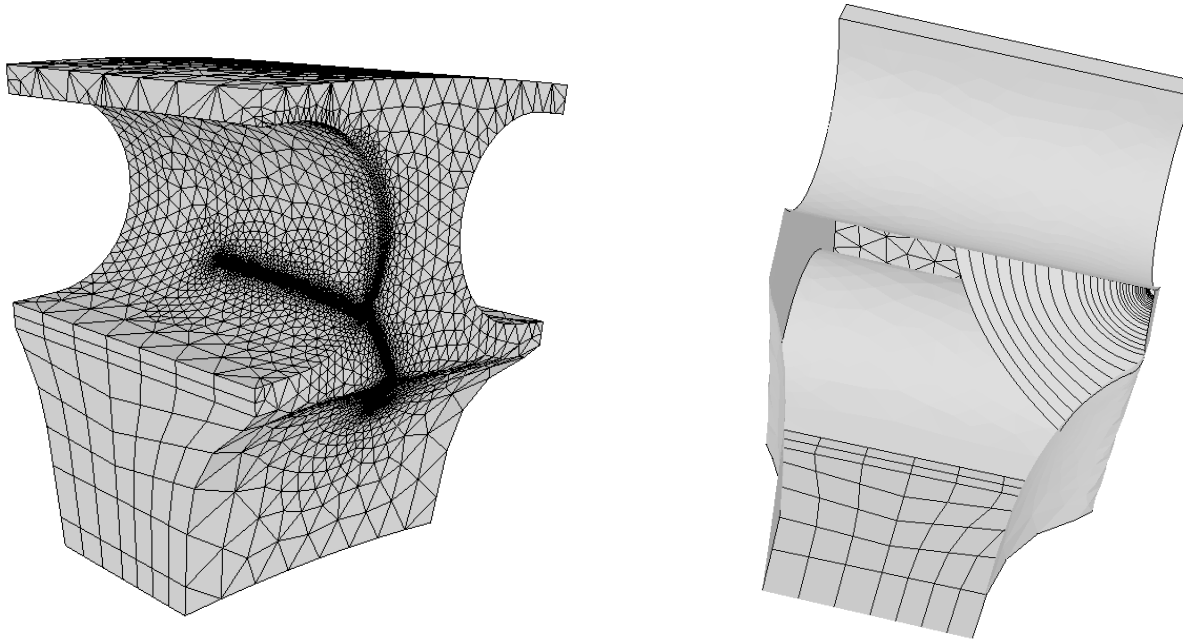
Re-Combined (Full Model) Analysis



FRANC3D does **not** use “global/local” solution approach (although it is possible); FE analysis is performed with the **full** re-combined model.

Crack Growth Process

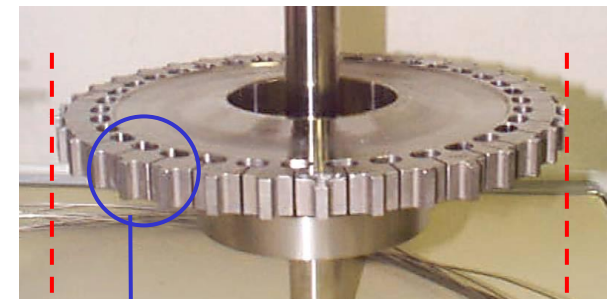
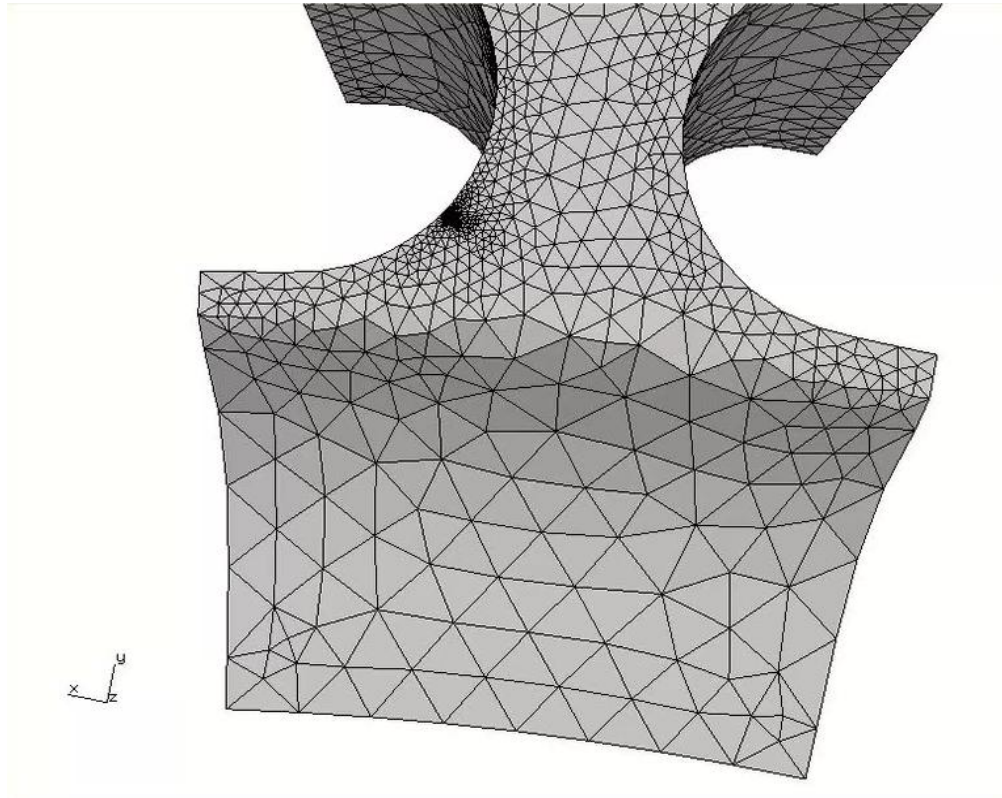
after 33 steps of crack growth



Crack growth is simulated by repeatedly reading and modifying the initial uncracked sub-model; *do not remove or overwrite uncracked FE model files.*

At each crack growth step, the global and modified (local) sub-model are re-combined and the full model is analyzed.

Mini-turbine disk crack growth simulation



264 mm (10.4 in)



Mini-turbine disk (Russ et al, 2004)

FRANC3D Benchmarking and Validation:

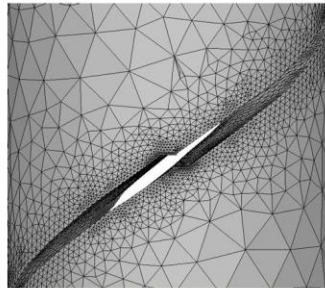
- in-house
- industry examples

FRANC3D Benchmarks

FRANC3D

Benchmark Examples

Version 8.8



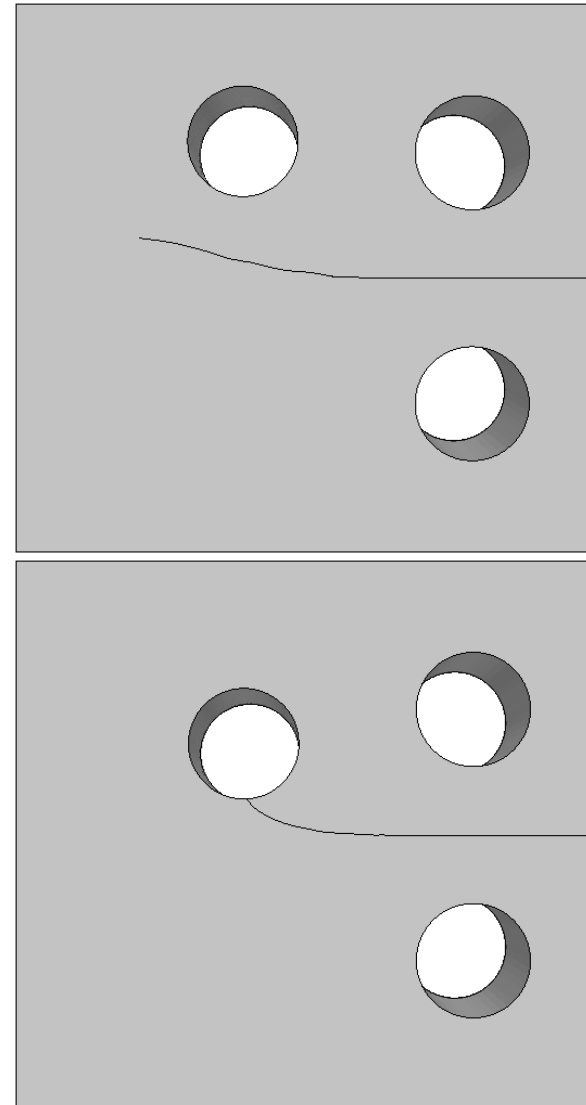
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<https://fracanalysis.com/benchmarks.html>

Other Simulations/Examples

- Compact Tension (CT) is a standard fracture test specimen, which is a 2-D problem modeled as 3-D.
- If a third hole is bored in the specimen, this causes the crack to curve; depending on where the third hole is placed, the crack either grows into or bypasses the hole.

http://www.fracanalysis.com/simulations/ct_specimen.html



Industry Example

Cracking of a Gear Tooth

Simulated

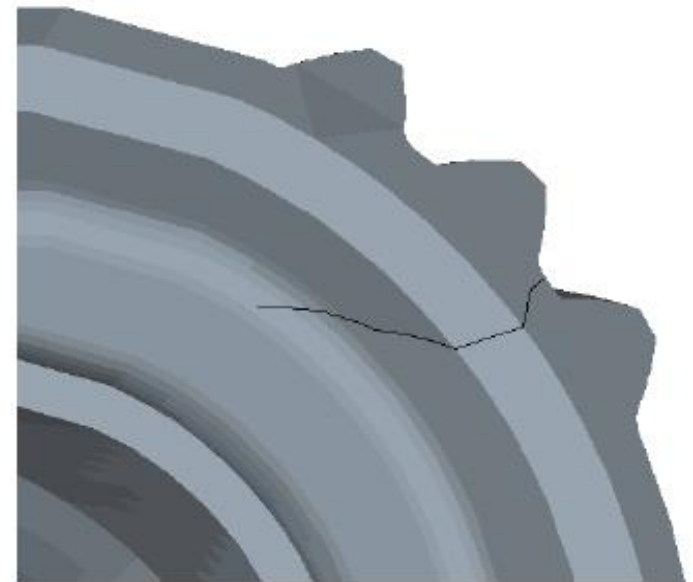
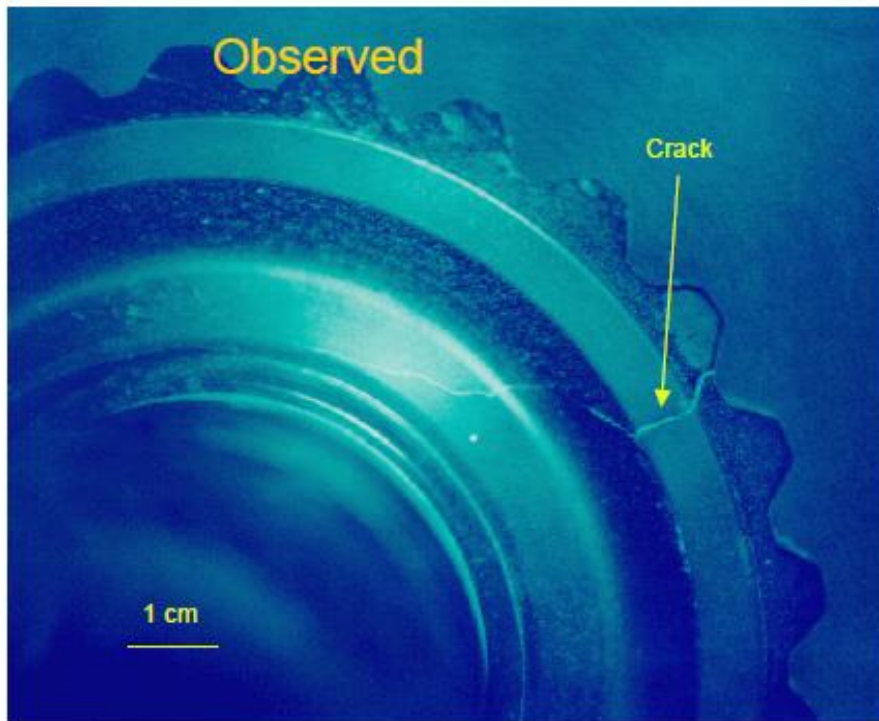


Observed



Industry Example

Comparison: Simulated vs Observed Crack Trace on Gear Hub



Simulated

Industry Example

Observed crack growth

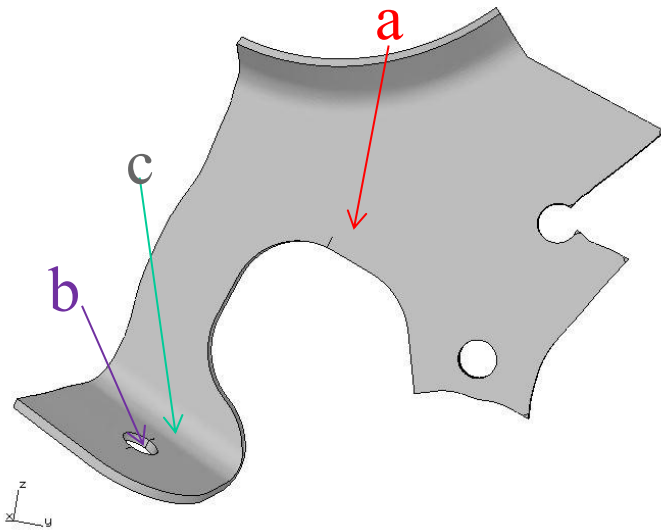


FRANC3D blind prediction

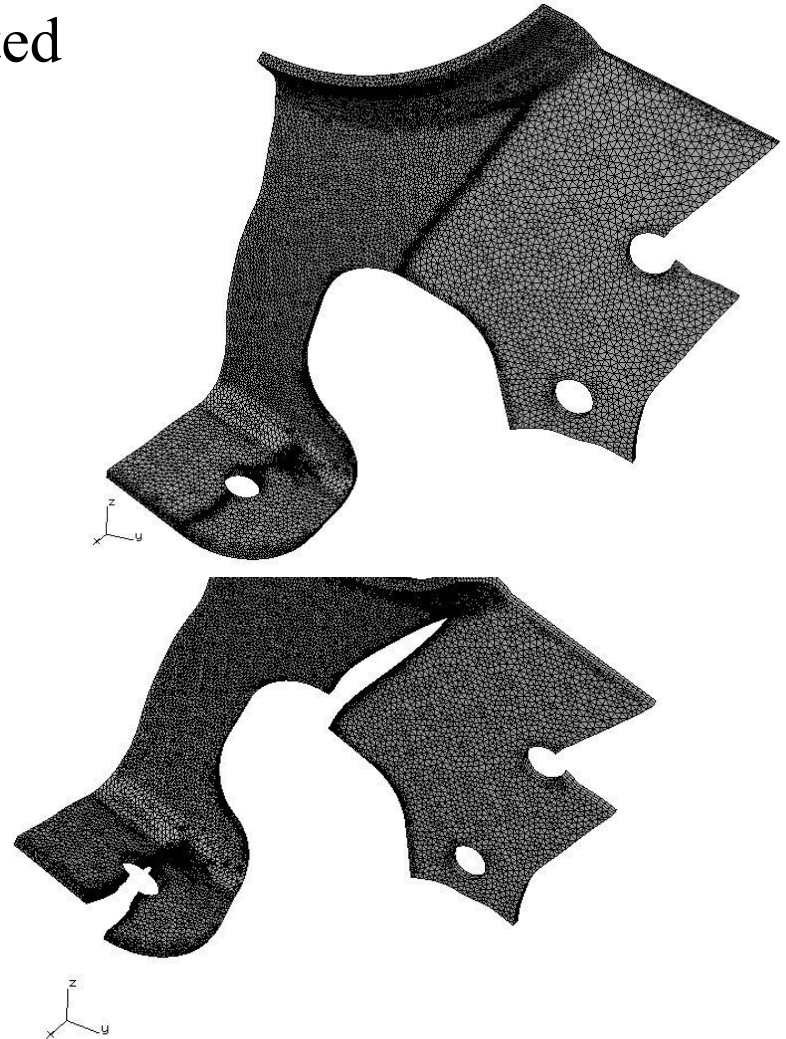


Industry Example

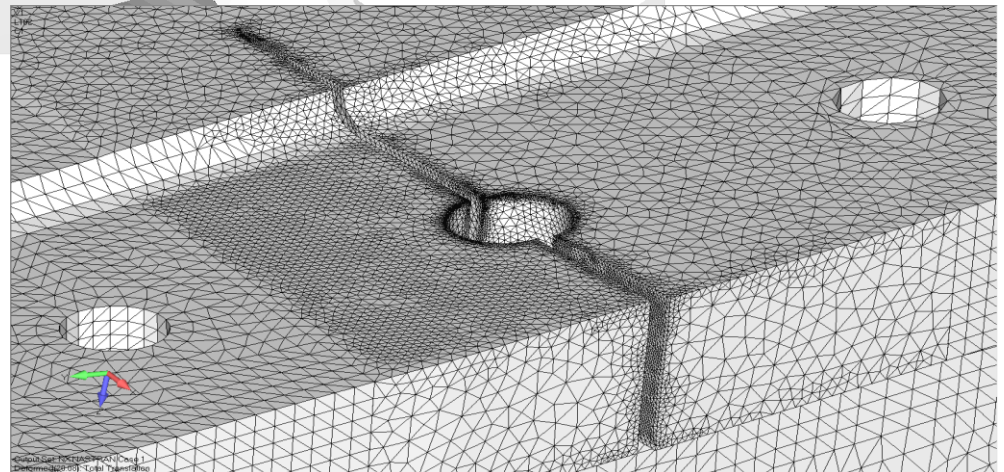
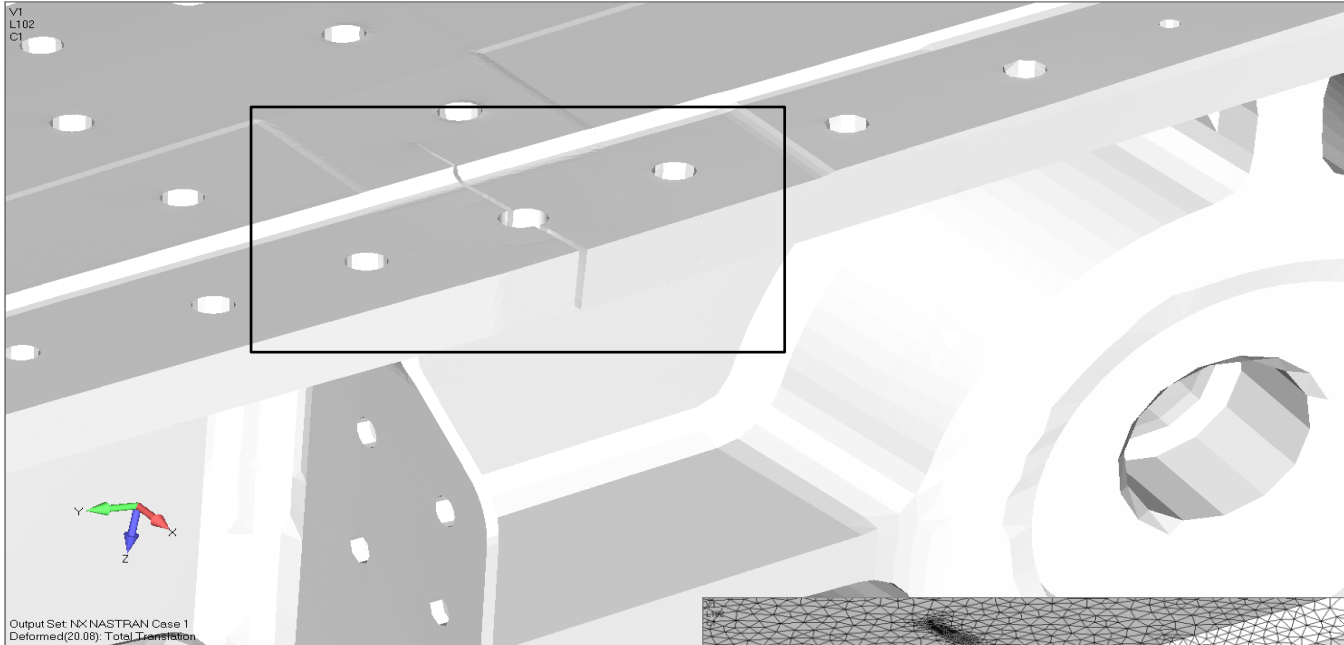
Three cracks inserted and propagated



45 steps of crack growth



Industry Example



FRANC3D Documentation

- FRANC3D Documentation:
 - Installation Guide
 - FRANC3D Brochure
 - Reference Manual
 - User's Guide
 - Commands & Python Reference
 - FRANC3D/ABAQUS Tutorial
 - FRANC3D/ANSYS Tutorial
 - FRANC3D/NASTRAN Tutorial
 - FRANC3D/SIERRA Tutorial
 - FRANC3D Tutorials 2-15
- The Documentation can be viewed or downloaded using the following link:

<https://fracanalysis.com/software.html>

FRANC3D Benchmarks

- FRANC3D Benchmark documentation
- Benchmark Model Files
- Tutorial Model Files
- Test Suite Scripts
- The benchmark material can be viewed or downloaded using the following link:

<https://fracanalysis.com/benchmarks.html>

FRANC3D Training

- FRANC3D Training Slides:
 - 1: Introduction to Fatigue and Damage Tolerance
 - 2: Introduction to Fracture Mechanics
 - 3: Introduction to FRANC3D
 - 4: FRANC3D User Interface (GUI)
 - 5: Finite Element Model Import into FRANC3D
 - 6: Crack Insertion and Meshing
 - 7: Static Crack Analysis
 - 8: Stress Intensity Factors (SIFs)
 - 9: Crack Growth
 - 10: SIF History and Fatigue Life
 - 11: Miscellaneous Topics
- FRANC3D / ANSYS Tutorial #1 Training Material
- The training material can be viewed or downloaded using the following link:

https://fracanalysis.com/franc3d_training.html

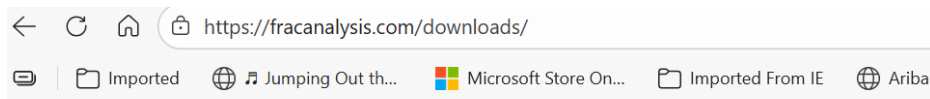
FRANC3D Tutorials

To download Tutorial and Benchmark model files, click on the link: <https://fracanalysis.com/downloads/>

You will be prompted to enter username and password.

Current username: franc

Current password: *****

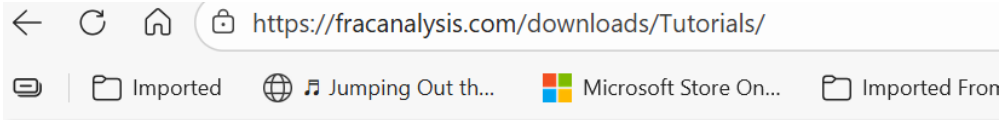


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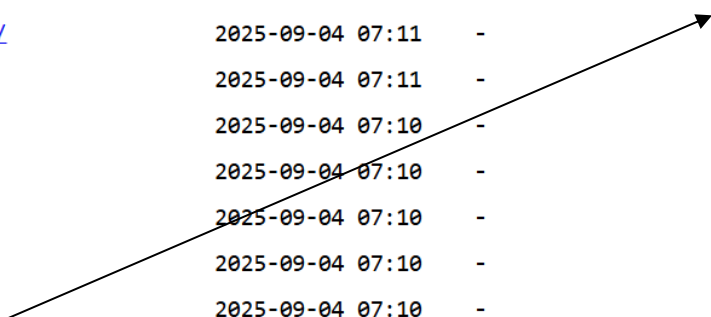
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FRANC3D Tutorials



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