A COMSOL® App to Evaluate Mechanical Properties for the Nuclear Industry

Ring tensile tests are employed to evaluate the mechanical properties of fuel cladding materials. New technology allows for the import of measured data into a COMSOL® App to extract vital material information.

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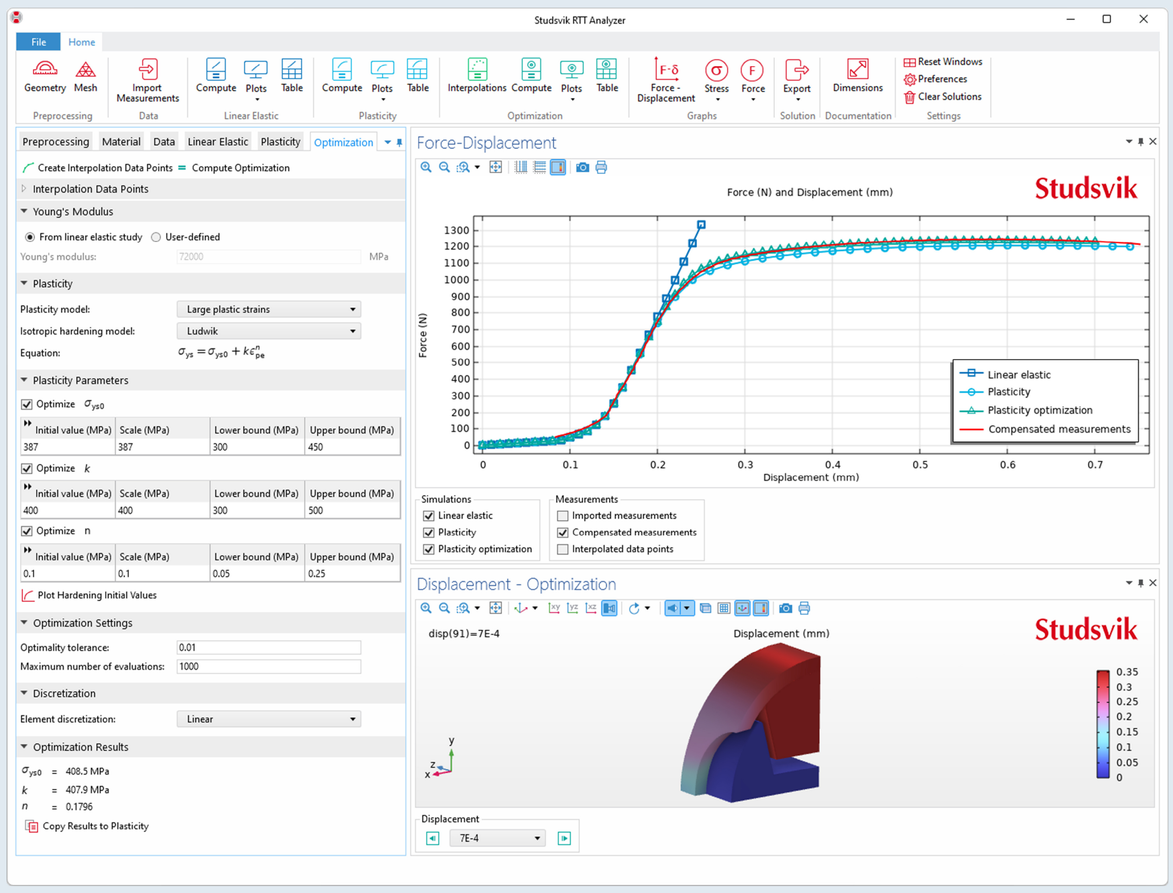

Ring Tensile Tests (RTT)

Structural tubes are extensively utilized in the nuclear industry, and acquiring precise material properties for the hoop direction is imperative due to the predominant internal pressure loading. Studsvik extensively employs RTT for the evaluation of mechanical properties. The specimen is a ring-shaped section cut from the chosen material, featuring two symmetrically placed notches for stress concentration, commonly accompanied by a dog bone-shaped center to reduce bending (Ref 1). The specimen is subjected to an increasing applied load, and force and displacement are recorded. Previously, an algorithm relied on Excel® to calculate yield strength, ultimate strength, and elongation, but only for specific dimensions. This limitation required a new method and COMSOL Multiphysics® provides a convenient solution through a dedicated COMSOL® App.

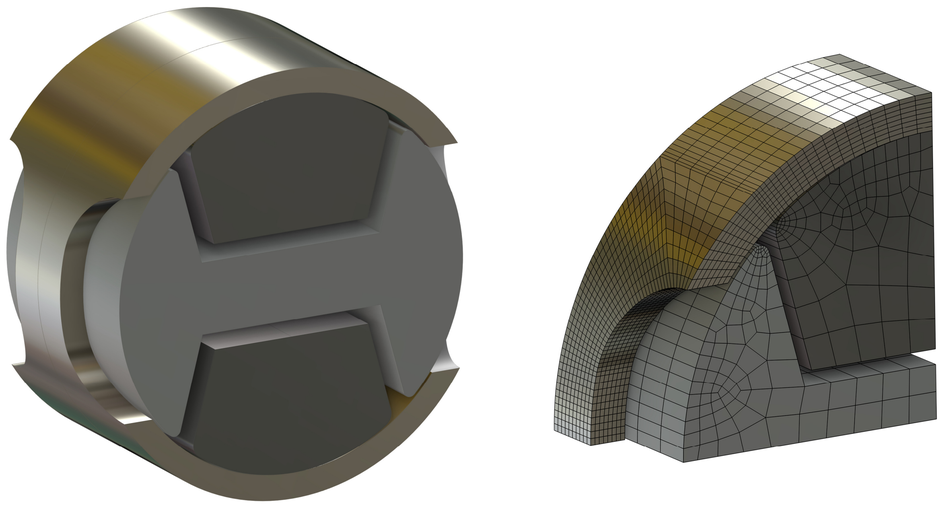

FIGURE 1. Left: The test ring with notches, the bone-shaped center, and the cylinders on which a load is applied (dark gray).
Right: 1/8 symmetry is used to save computational time.

Studsvik RTT Analyzer

The COMSOL® App enables effortless construction of the geometry. The mesh is automatically generated, along with element discretization options. Material parameters, including the friction coefficient can be entered. Due to high test temperatures, input of thermal expansion coefficients is crucial. Users can solve the problem by employing linear elasticity to quickly obtain Young's Modulus. The app offers several isotropic hardening models, as plasticity plays a pivotal role. Measurements can be directly imported, and compensation for rig deformations can be applied. The app provides optimization routines utilizing the Optimization Module with the BOBYQA method to automatically fit the simulated hardening parameters to the measured data.

Accessibility & Results

To enhance accessibility, the application is transformed into a standalone compiled app using COMSOL Compiler™. By utilizing Java® programming code, many model setup tasks are simplified, demonstrating how a complex simulation can be made accessible to a wider audience.
Simulated results should be compared with the measured force-displacement diagram, and upon reaching satisfactory agreement, the stress-strain curve is obtained.
This new Finite Element Method-based approach enables testing with varying dimensions, offering the potential to reduce result uncertainties.

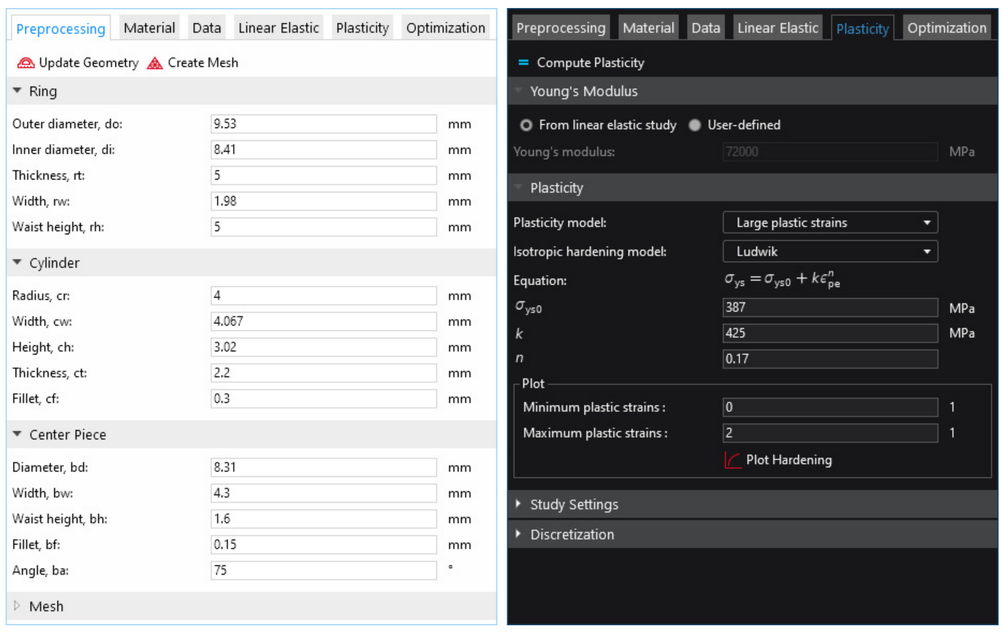

FIGURE 2. Left: Settings for the geometry parameters and the mesh.
Right: Plasticity settings in dark theme. The user can choose from 8 different hardening models or specify an analytic hardening function.

REFERENCES

1. S. Arsene, and J. Bai, A New Approach to Measuring Transverse Properties of Structural Tubing by a Ring Test, Journal of Testing and Evaluation, 1996..

Studsvik deflexional

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