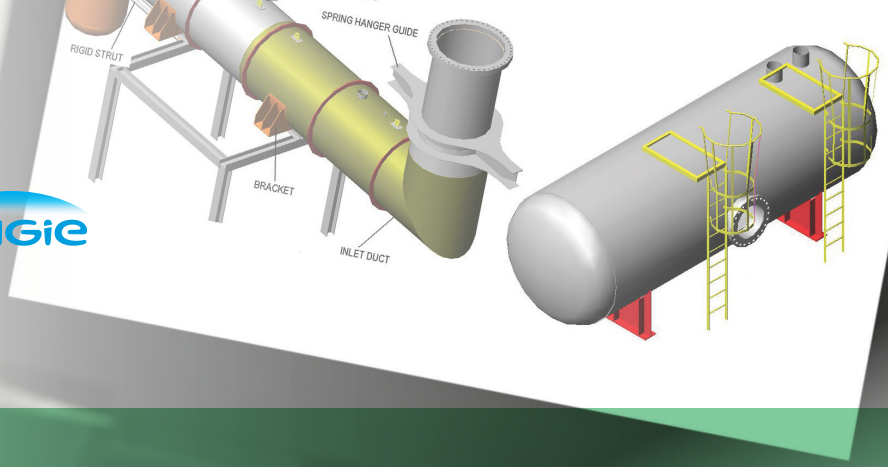
TRACTEBEL

ENGIE



Damage & Fracture Mechanics Expertise

Nuclear & Industries

Top-notch simulation studies giving deep focus to your equipment repair

The Fracture Mechanics activity of Tractebel Piping & Structural Integrity Group relates to the assessment of postulated or detected flaws in critical piping and components. This activity is especially useful to justify detected flaws during In-Service Inspection (ISI) campaigns (ASME B&PV Code Section XI) and to enable an optimisation of the inspection programme and the Non-Destructive testing (NDT) qualification

Services

Based on its long-standing experience in Fracture Mechanics, Tractebel has developed top-class studies with dedicated tools in 3D, using FEM (Finite Element Method) and XFEM (eXtended Finite Element Method), with linear elastic or elastic-plastic calculations.

Tractebel is expert in the use of XFEM, specifically dedicated to crack propagation analyses.

This method offers the following advantages:

Ease of use

- Crack propagation through the elements
- Multiple propagating cracks

Accuracy

- Stress singularity captured with near-tip field enrichment

Flexibility/Adaptability

- No restriction of crack geometry
  - Non-planar
  - Change of topology during propagation
- No restriction on loading

Tractebel's expertise covers:

- Development of flaws justification methodology
- Computational Fracture Mechanics
- Structural Integrity Assessment
- Technical coordination

Software / Tools

Tractebel mainly uses the following computer programmes for fracture mechanics analysis

Software tool	Brief description
Morfeo Crack	eXtended Finite Element Method (XFEM) software for the modelling of cracks in a mesh-independent fashion
SYSTUS	General Purpose Finite Element Software
ANSYS	General Purpose Finite Element Software
TEEPAC	Specific Fracture Mechanics software developed by Tractebel

Codes and Standards

Tractebel uses the following Fitness-for Service Codes for the justification of flaws: ASME B&PV Code Section XI, A16 (RCC-MR), RSE-M, R6.

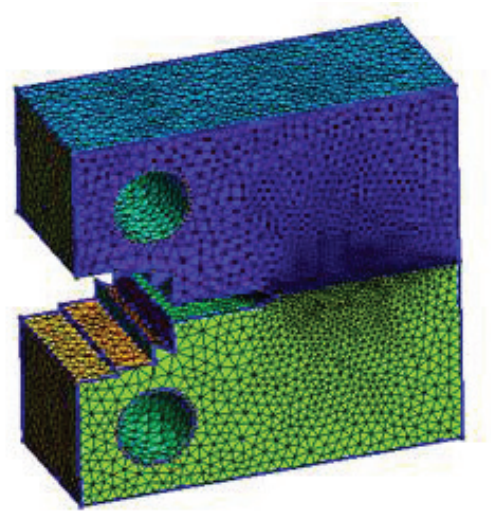
Tractebel is a member of the ASME Code Section XI Working Groups and Committees. In this capacity, Tractebel has itself developed a Code Case related to Specific Flaw Characterisation Rules (introduced in ASME Code edition 2015 via Code Case N-848), several ASME Code changes, and has issued many publications in technical journals and conference proceedings.

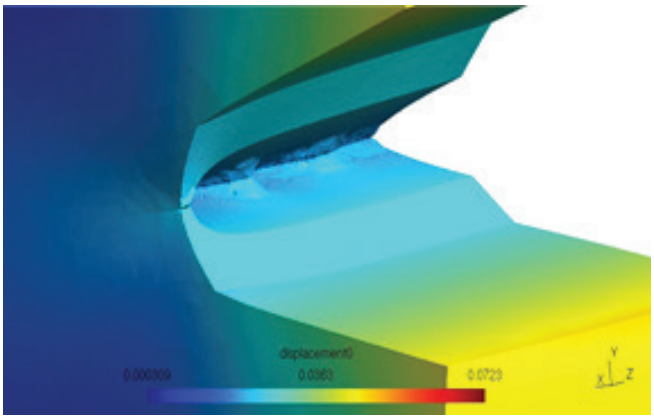
Target sectors

These specialised services are offered worldwide to assist Owners and Operators in the following sectors:

NUCLEAR, OIL & GAS, RENEWABLE ENERGY, THERMAL, POWER, TRANSMISSION AND DISTRIBUTION, GAS & LNG, INFRASTRUCURE, MINING, AERONAUTICS, AEROSPATIAL, DEFENCE, CHEMICAL, AGROCHEMICAL.

Expert simulation studies focused on critical equipment flaw analyses, justification and repair solutions





Some references

Fracture Mechanics Expertise

Belgium (ENGIE Electrabel): Structural Integrity Assessment of Reactor Pressure Vessels with Hydrogen Flakes

The in-depth testing and unexpected detection of hydrogen flaking in Doel 3 and Tihange 2 Reactor Pressure Vessel shells seriously questioned the safe operation of the affected units. The situation was particularly unusual in terms of the quantity, density and orientation of the flaws. Moreover, the ASME Code (or other existing Codes) could not be effectively applied in this first-of-its-kind case.

As a consequence, Tractebel developed a new methodology: innovative while in line with existing Code requirements, case-specific, sufficiently wide to be accepted and, above all, conservative. The quality of the methodology and the excellence of the subsequent Fracture Mechanics calculations were recognised by many different Safety Authorities and International Experts Committees.

As a result of Tractebel's analyses, the Safety Authority granted the authorisation to restart the two nuclear units.

Argentina (NA-SA): Pressurised Thermal Shock Analyses

Tractebel performed the Pressurised Thermal Shock Analyses of the reactor pressure vessel of Atucha II Nuclear Power Plant. These analyses dealt with 3D thermal-hydraulic transients as well as with elastic-plastic Fracture Mechanics calculations in order to determine the maximum allowable RTNDT of the material ahead of the Plant commissioning.

Belgium (ENGIE Electrabel): Fracture Mechanics Analysis of New Steam Generators

Tractebel verified the resistance of new steam generators against brittle fracture for all transients using Fracture Mechanics analysis in compliance with ASME Code Section III Appendix G (with a postulated ¼ thickness flaw).

France (Lyonnaise des Eaux): Bolt Cracking Analysis

Observing cracking at the first fillet of some bolts in the servomotor of a hydraulic power station, the Client asked Tractebel to investigate the phenomenon. Thanks to Finite Element Stress Analysis and Fracture Mechanics investigations, Tractebel was able to identify the cause of the crack initiation and to justify the nature of the failure.

The results allowed the client to change and optimise the design of the bolts to avoid the same phenomenon in future.

Belgium (ENGIE Electrabel): Flaw Tolerance in Flywheel

Using Finite Element Method, Tractebel studied a postulated axial straight crack in a pump flywheel in overspeed. Tractebel accurately calculated the critical crack depth, regarding brittle fracture, at several crack locations (middle and corner of the keyway) taking into consideration both linear (elastic) and nonlinear (elastic-plastic) behaviour.

Sweden Optimisation of Inspections on Swedish BWR's

Reactor Pressure Vessels in Nuclear Power Plants must be inspected both frequently and at many different vessel points. This comes at a high cost. In Sweden, Tractebel has helped their Customer decrease the inspection costs by using Fracture Mechanics analyses, i.e. postulating a set of defects and analysing their propagation.

PUBLICATIONS

Tractebel experts regularly publish/participate in scientific papers on Fracture Mechanics in different journals and conference proceedings. Some recent examples include:

- Lacroix, V., Bouydo, A., Chaouadi, R., Towards a Process for the Assessment of Mixed Mode I+II Fracture Toughness (Proceeding of ASME Pressure Vessels & Piping conference 2018, Prague, CZ, July 2018 - Peer Reviewed, 2018)
- Lacroix, V., Dulieu, P., Hasegawa, K., Li, Y., Bamford, W., Rules for Flaw Interaction for Subsurface Flaws in Operating Pressurized Vessels: Technical Basis of Code Case N-877 (Proceeding of ASME Pressure Vessels & Piping conference 2018, Prague, CZ, July 2018 - Peer Reviewed, 2018)
- Lacroix, V., Mares, V., Strnadel, B., and Hasegawa, K., Combination Criterion for Multiple Laminar Flaws in Steel Components (Key Engineering Materials, ISSN 1662-9795, Vol. 741, pp 63-69, 2017)
- Lu, K., Li, Y., Hasegawa, K., and Lacroix, V., Remaining Fatigue Lives of Similar Surface Flaws in Accordance with Combination Rules (Journal of Pressure Vessel Technology 139, 021407, 2017)
- Katsumata, G., Li, Y., Hasegawa, K., and Lacroix, V., Remaining Lives of Fatigue Crack Growths for Pipes Containing Subsurface Flaws and Subsurface-to-Surface Flaw Proximity Rules (Journal of Pressure Vessel Technology, 138(5), 051402 (Apr 29, 2016), doi: 10.1115/1.4032816, 2016)
- Lacroix, V., Dulieu, P., and Couplet, D., Alternative Characterization Rules for Quasi Laminar Flaws (Proceeding of the ASME Pressure Vessel & Piping Conference, PVP2014-28200, Anaheim, USA, July 2014. – Peer Reviewed, 2014)

TRACTEBEL
tractebel-engie.com
nuclear@tractebel-engie.com