

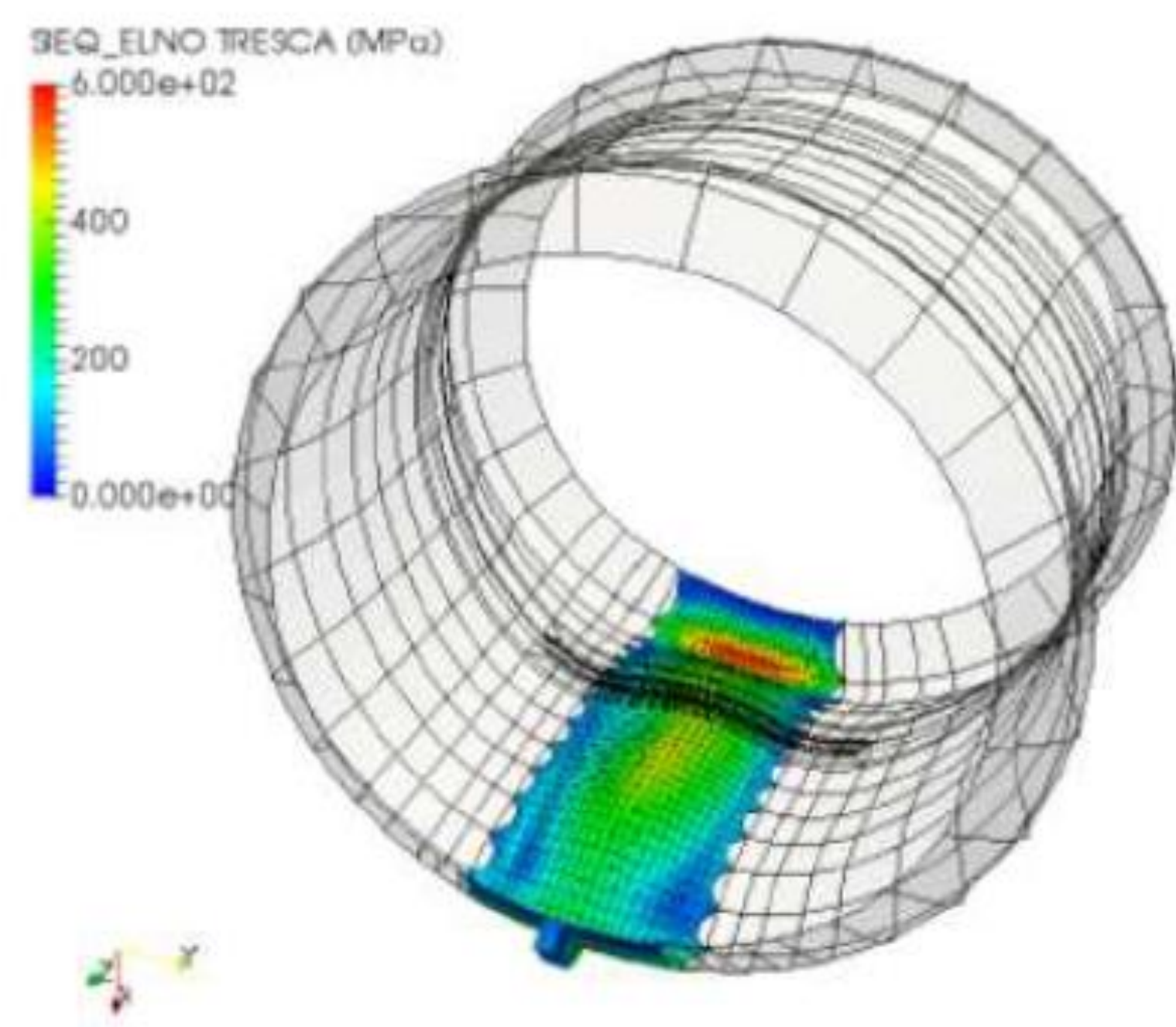
R&D in code_aster

Fatigue initiation & RCC-M code requirements

CONTEXT

Fatigue is one of the most complex degradation modes to predict when structures start ageing and has been identified as a significant degradation mode affecting nuclear power plants world-wide.

Several international codes and standards (ASME, RCC-M, JSME, etc...) offer rules to predict its damaging effect on the locations of the various components of a plant. In addition, a vast amount of PhD theses have investigated the various aggravating effects (mean stress/strain, PWR environment, surface finish, etc...) which has resulted in the definition of sometimes more advanced fatigue criteria than the simplistic but conservative criteria used in nuclear codes and standards.



INTHERPOL Fatigue experiment analyses – EDF R&D MMC

FATIGUE CRITERIA IN CODE_ASTER

Code_aster integrates today a versatile toolbox of fatigue criteria to integrate:

- on the one hand code type calculations according to the RCC-M code
- on the other hand a set of fatigue criteria, either uni-axial or multi-axial, enabling even the creation of a user defined criteria.

As regards the non-codes & standards fatigue criteria, these include per default the Dang Van and Mataka criteria, but also a toolbox of physical parameters (deviatoric tensor, shear tensor, etc...) allowing the user to design easily their own.

FUNCTIONS IN CODE_ASTER

CALC_FATIGUE, POST_FATIGUE, POST_RCCM

PHD THESES



N. Haddar – Fatigue thermique d'un acier austénitique 304L: simulation de l'amorçage et de la croissance des fissures courtes en fatigue isotherme et anisotherme – ECP – 2003

A. Le Pecheur – Fatigue thermique d'un acier inoxydable austénitique: influence de l'état de surface par une approche multi-échelles – ECP – 2008

J. Colin – Deformation history and load sequence effects on cumulative fatigue damage and life predictions – Toledo Univ. – 2009

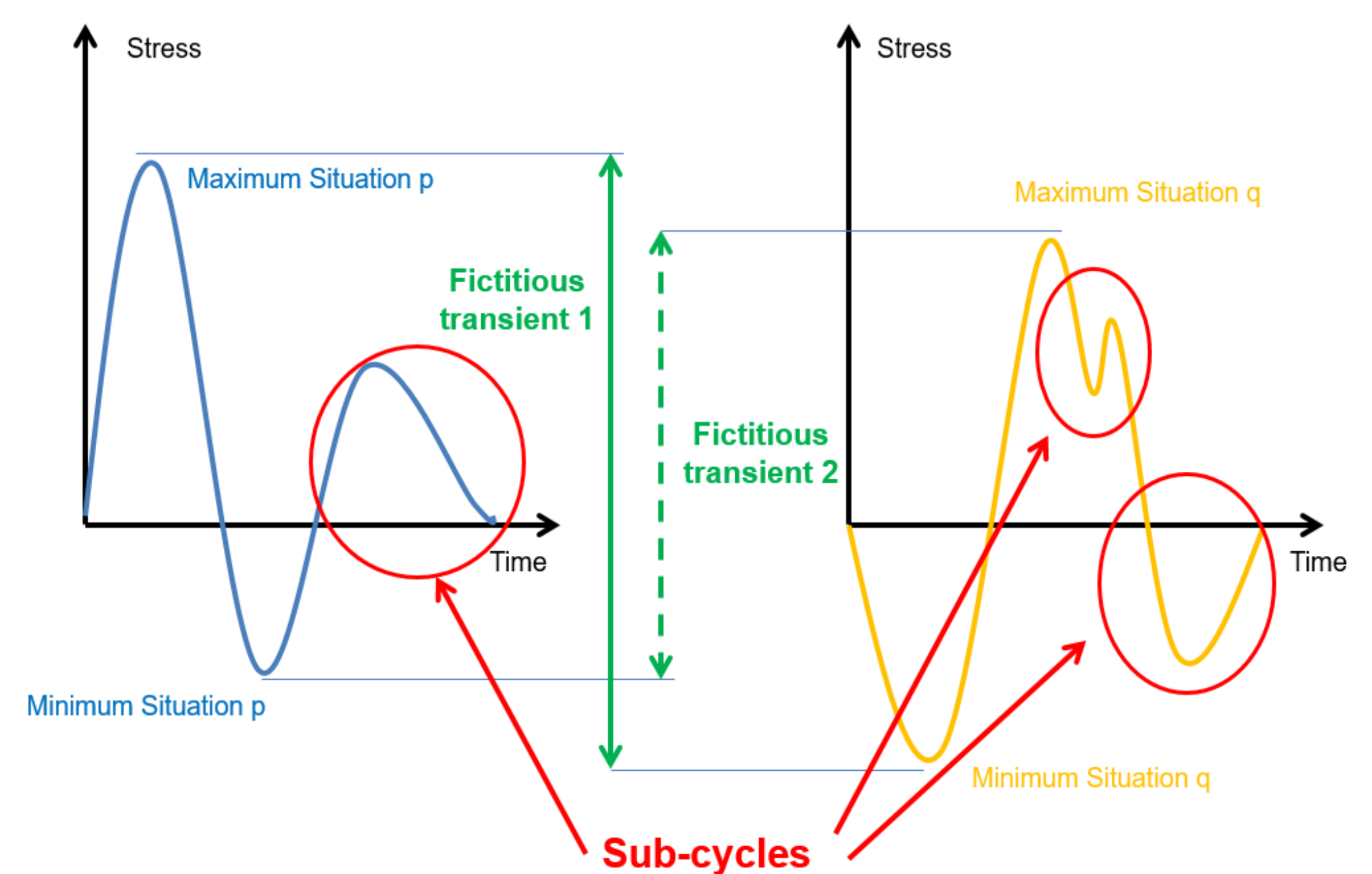
G. Barbier – Fatigue biaxiale à grand nombre de cycles: étude expérimentale et modèle d'endommagement à deux échelles probabilistes – ENS Cachan – 2009

N. Huin – Environmental effect on cracking of a 304L austenitic stainless steel in PWR primary environment under cyclic loading – ENSMA - 2013

RELATED ENGINEERING CHALLENGES

The POST_RCCM was updated to meet the latest requirements of the code, especially along the four following aspects:

- Development of RCC-M ZE-200 calculations module;
- Instant Time combination;
- Transient and load combination (including seismic loading);
- Environmental fatigue.



Schematic view of transient combination according to RCC-M

As concerns the evolutions on environmental fatigue, these are in line with NUREG/CR-6909 prescriptions and the latest RCC-M RPP N° 3 and the operator POST_RCCM provides the very general following formula:

$$F_{en} = e^{[(A+Be^*)S^*O^*T^*]}$$

where F_{en} is the environmental correction factor, computed for each transient combination

A and B are two constants

ϵ^* is a function of the strain rate

S^* is a function of the sulfur content of the base metal

O^* is a function of the dissolved oxygen in the water

T^* is a function of the temperature

This enables to lead calculations including environmental effects and satisfy the latest requirements in the codes & standard. Furthermore, since these formulas are still under discussion internationally and may be subject to change, code_aster leaves the option to manually define the various coefficients, hence maximizing user input control capabilities.

SOME PUBLICATIONS

B.M. Lei, V.X. Tran et al. – *Toward consistent fatigue crack initiation criteria for 304L austenitic stainless steel under multi-axial loads* – International Journal of Fatigue, Elsevier, [10.1016/j.ijfatigue.2015.02.001](https://doi.org/10.1016/j.ijfatigue.2015.02.001), 2015

T. Métais, S. Plessis and J. Miralles – *Validation of the new post-rccm option from code_aster through benchmark comparisons with other industrial codes* – Pressure Vessels and Piping conference, ASME PVP2017-65336

T. Métais, S. Plessis, J. Miralles and J.C. Le Roux – *Evolution of fatigue post-processing methods in the EDF open-access FEA code_aster* – Pressure Vessels and Piping conference, ASME PVP2016-63126