Institut Pprime
Recherche en physique et ingénierie

2024 PhD Thesis

Beginning : october 2024 (application till April 9, 2024)

ISAE-ENSMA doctoral grant

Supervisors : Céline Gérard, Loïc Signor, Mikaël Gueguen, Patrick Villechaise

Crystal Plasticity Modeling of the Mechanical behavior under cyclic loading of a stainless steel submitted to ratcheting

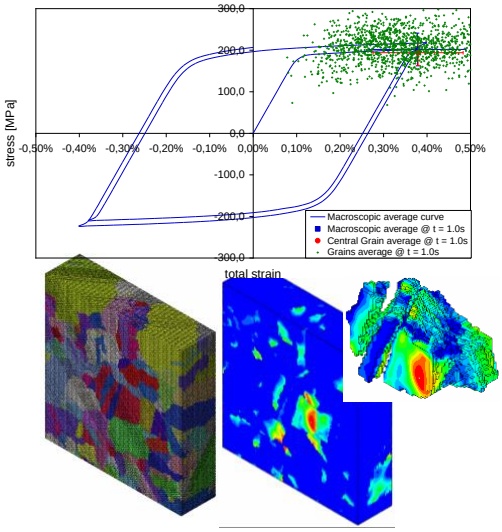
Tools and knowledge to use: Mechanics of materials, Structural calculation, Finite element method, High Performance Calculation, Programming (C++)
Nature of work: Modeling and numerical simulation

Context

Nearly 80% of in-service structure failures are related to cyclic loading. These can be of various types: corrosion fatigue, gigacyclic fatigue, low cycle fatigue or ratcheting. Fatigue phenomenon can lead to crack initiation, even when the loading level is very low, on the order of the elastic limit. The ratcheting phenomenon is characterized by the appearance of uncompensated deformation from one cycle to the next, leading to an accumulation of deformation, and, ultimately to the ruin of the structure by excessive deformation.

Understanding and predicting the mechanical response of metals and polycrystalline metal alloys under cyclic loading by means of modelling and numerical simulations is a major challenge when it comes to controlling the durability of these materials.

In the vast majority of cases, the phenomenon observed is fatigue over a large number of cycles. Numerous experimental and theoretical studies were carried out in the 1990s and 2000s. Models currently available provide a fairly satisfactory prediction of behavior.



Low cycle fatigue, and even more so the phenomenon of ratcheting, occurs much less frequently, but in situations and fields of application where the stakes are particularly high, such as the nuclear industry. However, the ratcheting phenomenon remains largely misunderstood and poorly modeled.

Thesis subject

The aim of this thesis is to understand and model the ratcheting phenomenon by implementing a full-field numerical simulation approach, using the finite element method, of the mechanical response of polycrystalline aggregates under cyclic loading. In this context, the description of local behavior, at the grain scale, will be based on constitutive equations of crystal plasticity (or visco-plasticity) type, including non-linear isotropic and/or kinematic hardening formulated in terms of dislocation density. Particular attention will be paid to the description of latent hardening.

This work will involve, among other things, implementing the numerical integration scheme of the local behavior law within the finite element solver used (Abaqus, Zset or Foxtrot – Academic code developed in-house, etc.) by developing user subroutines or using suitable free libraries (M-Front, https://tfel.sourceforge.net). The implementation of full-field calculations will require the use of parallel computing, performed on a regional cluster.
The model material chosen for this study is an austenitic stainless steel, whose cyclic behavior is well documented. To define the simulated configurations (loading, material parameters) and analyze the results, the PhD student will have the possibility of drawing on data from tests carried out in the laboratory, notably through regular collaborations with industrial partners in the nuclear power sector. (EDF, Framatome). If necessary, additional targeted mechanical tests can be carried out during this thesis. These may be accompanied by microstructural characterization at the grain and sliding system scale (Scanning Electron Microscopy, EBSD, in-situ tests).

Practical framework: This thesis will be carried out at the Pprime Institute –Unit of CNRS UPR3346, more specifically within the Physics and Mechanics of Materials Department, and the "Damage and Durability" team (ENDO), hosted by ISAE-ENSMA. It will make intensive use of the supercomputer facilities of the regional MesoCentre, and, if necessary, of national calculation resources (GENCI).

Candidate profile: This thesis is aimed at students of a Master's degree in Mechanics and/or Materials and/or Numerical Modeling, who are motivated, rigorous and methodical, with definite taste for numerical simulation, multi-disciplinary approaches and teamwork. Good writing skills are expected in French and/or English, as well as a good level of spoken English.

Recruitment framework : ISAE-ENSMA **doctoral grant**
(net monthly salary: 2024 : 1685€ / 2025 : 1769€ / 2026 : 1851€)
Inscription at Doctoral School MIMME (https://mimme.ed.univ-poitiers.fr/)
Possibility of participating in lessons (to be defined according to the initial training).
Beginning: October 2024.
Place : ISAE-ENSMA – Futuroscope site – Poitiers.

Background : The student will work in a stimulating environment, as the research team has a rich history of studying fatigue in metallic materials, in collaboration with industrial partners in the nuclear energy sector, both experimentally and numerically.

Application: APPLICATION DEADLINE: April 5, 2024
Detailed CV, covering letter and Master's transcripts already available should be sent by email to the following address: celine.gerard@ensma.fr
Recommendation letters are not mandatory but are welcome if you have them, as are contacts of teachers and/or internship supervisors if they allow you to do so.

For more information, do not hesitate to contact Dr. Céline Gérard
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