PhD position

Context and goals of the PhD

Modeling of continuous dynamic recrystallization (CDRX)

One of the European Union's objectives in climate change consists of reaching net-zero greenhouse gas emissions by 2050. Such perspective puts the metallic materials industry, as a large contributor to carbon emissions, under tremendous pressure for change and requires the existence of robust computational materials strategies to enhance and design, with a very high confidence degree, new metallic materials technologies with a limited environmental impact. From a more general perspective, the in-use properties and durability of metallic materials are strongly related to their microstructures, which are themselves inherited from the thermo-mechanical treatments.

Hence, understanding and predicting microstructure evolutions are nowadays a key to the competitiveness of industrial companies, with direct economic and societal benefits in all major economic sectors (aerospace, nuclear, renewable energy, naval, defence, and automotive industry).

Multiscale materials modeling, and more precisely simulations at the mesoscopic scale, constitute the most promising numerical framework for the next decades of industrial simulations as it compromises between the versatility and robustness of physically-based models, computation times, and accuracy. The DIGIMU consortium and the RealIMotion ANR Industrial Chair are dedicated to this topic at the service of major industrial companies.

In this context, the efficient and robust modeling of evolving interfaces like grain boundary networks is an active research topic, and numerous numerical frameworks exist. In the context of hot metal forming and when large deformation of the calculation domain and the subsequent migration of grain boundary interfaces are involved, a new promising, in terms of computational cost, 2D front tracking method called ToRealMotion algorithms [1] was recently developed.

This PhD will be firstly dedicated to the extension of existing numerical framework dedicated to the modeling of discontinuous dynamic recrystallization where recovery is not a predominant mechanism to the context of CDRX where progressive evolution of sub-grain interfaces (low misorientation) into grain boundaries (high misorientation) by dislocation accumulation, annihilation and re-arrangement must be considered. Pre-existing developments [2] (see Fig.1) in context of a level-set full-field formulation will be improved and this mechanism will also be integrated to the ToRealMotion front-tracking algorithms.

The developments will be tested/optimized for pre-existing experimental data concerning two aluminum grades and one zirconium alloy. Concerning Al grades, the first one (6016 Al alloy) is of great interest for Constellium in automotive applications and the second one (7010 Al alloy) is of great interest for Aubert&Duval Issoire in aeronautic applications. Finally, Zircaloy-4, used mainly by Framatome in nuclear cladding applications, will also be considered.

The developments will be integrated in the DIGIMU® software.

[1] S. Florez, K. Alvarado, D. Pino Muñoz and M. Bernacki. Computer Methods in Applied Mechanics and Engineering, 367:113107, 2020.

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Partners

Keywords

Digital twins - HPC - Computational Metallurgy - Interface networks - Front tracking and front capturing approaches - Aluminum alloys - Zirconium alloys.

Candidate profile and skills

Degree: MSc or MTech in Metallurgy or Applied Mathematics, with excellent academic record. Skills: Numerical Modeling, Metallurgy, proficiency in English, ability to work within a multi-disciplinary team.

Offer

The 3-year PhD will take place in CEMEF, an internationally-recognized research laboratory of MINES ParisTech located in Sophia-Antipolis, on the French Riviera. It offers a dynamic research environment, exhaustive training opportunities and a strong link with the industry. Annual gross salary: about 27.7k€. She/He will join the Metallurgy μStructure Rheology (MSR) research teams under the supervision of Prof. M. Bernacki, Prof. N. Bozzolo and Dr B. Flipon.

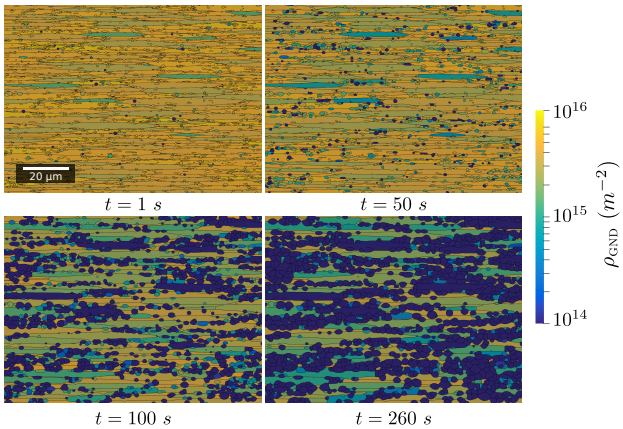

Illustration of the level-set modeling of post-dynamic recrystallization - Zy-4 alloy [2]

[2] G. Victor, B. Flipon, A. Gaillac and M. Bernacki. Simulation of continuous dynamic recrystallization using a level-set method, Materials, In press, https://arxiv.org/abs/2203.08447, 2022.