RESEARCH TOPIC FOR THE PARISTECH/CSC PHD PROGRAM

Field: Materials Science, Mechanics, Fluids

Subfield: Mechanical Engineering, computational mechanics

Title: Improved numerical multiscale approaches for the prediction of the ductility limit of polycrystalline materials

ParisTech School: Arts et Métiers Sciences et Technologies

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Lab location: 7 rue Félix Savart F-57070 METZ

(Lab/Advisor website): http://www.lem3.univ-lorraine.fr/

Short description of possible research topics for a PhD:

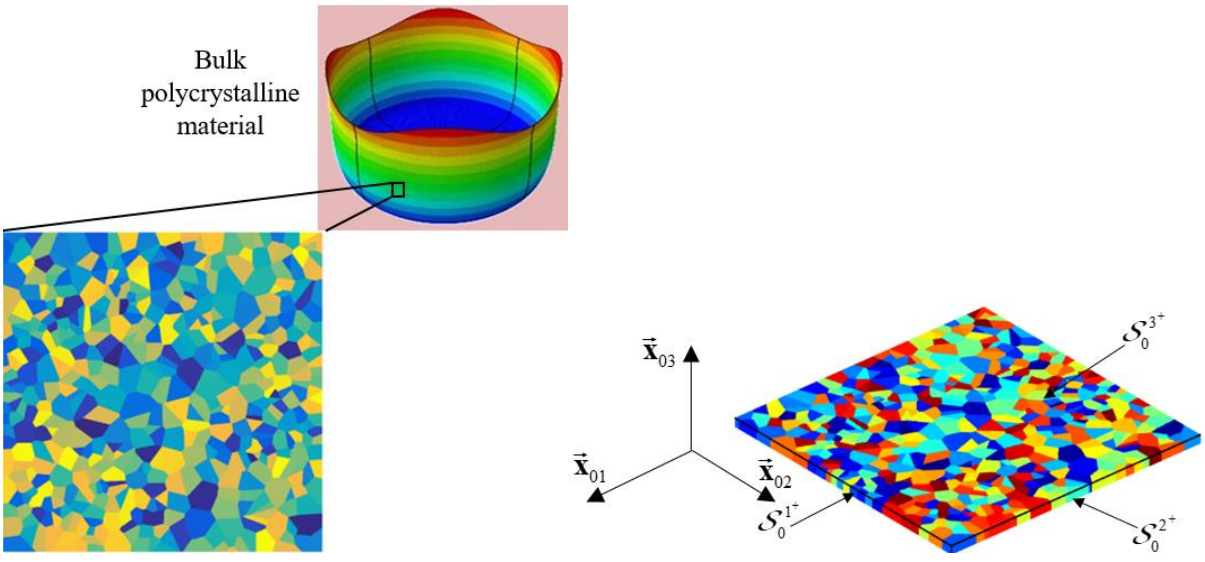
Multiscale approaches are nowadays widely used to predict and analyze the mechanical behavior, and especially the ductility limit of polycrystalline media. Full-field multiscale schemes (based on finite element method or FFT approach) are considered to be the most powerful tools able to predict the mechanical behavior of media exhibiting complex microstructures and/or mechanical behavior. In a previous research project, we have developed and used a full-field multiscale scheme (based on the periodic homogenization technique) to predict the mechanical behavior of heterogeneous materials. The first aim of the present project is to extend this scheme to be able to capture more complex phenomena not considered in the former model (such as second-order effects due to grain size…). The second aim is to improve the description of the single crystal behavior by considering physical aspects not sufficiently investigated so far (such as an adequate description of dislocation density evolution, phase transformation present in TRIP and TWIP steels…). Once validated, these numerical tools will be used, in academic and industrial contexts, to provide guidelines and assistance in the design of new generation of metallic alloys with improved ductility.

Required background of the student:
- Solid background in solid mechanics and numerical methods;
- Good analytical and programming skills (e.g., Matlab, Mathematica, C/C++, Fortran);

- Experience with Finite Element modeling would be an asset.

A list of 5 (max.) representative publications of the group: (Related to the research topic)

1. **M. Ben Bettaieb**, **F. Abed-Meraim (2015),** "Investigation of localized necking in substrate-supported metal layers: Comparison of bifurcation and imperfection analyses", *International Journal of Plasticity*, Vol. 65, pp. 168–190.
2. H.K. Akpama, **M. Ben Bettaieb**, **F. Abed-Meraim (2017),** "Localized necking predictions based on rate-independent self-consistent polycrystal plasticity: Bifurcation analysis versus imperfection approach", *International Journal of Plasticity*, Vol. 91, pp 205–237.
3. M.Y. Jedidi, **M. Ben Bettaieb**, **F. Abed-Meraim**, A. Bouguecha, M.T. Khabou, M. Haddar **(2019),** "Prediction of necking in HCP sheet metals using a two-surface plasticity model", *International Journal of Plasticity,* doi.org/10.1016/j.ijplas.2019.102641.
4. J. Paux, **M. Ben Bettaieb**, **F. Abed-Meraim**, H. Badreddine, C. Labergere, K. Saanouni **(2020),** "An elasto-plastic self-consistent model for damaged polycrystalline materials: Theoretical formulation and numerical implementation", *Computer Methods in Applied Mechanics and Engineering,* doi.org/10.1016/j.cma.2020.113138.
5. J.C. Zhu, **M. Ben Bettaieb**, **F. Abed-Meraim (2020),** "Investigation of the competition between void coalescence and macroscopic strain localization using the periodic homogenization multiscale scheme", *Journal of the Mechanics and Physics of Solids*, doi.org/10.1016/j.jmps.2020.104042.



(a) (b)

Polycrystalline aggregate: (a) Selection of a unit cell from the bulk polycrystalline material; (b) FE mesh of the unit cell generated by the Voronoi tessellation technique.