RESEARCH TOPIC FOR THE PARISTECH/CSC PHD PROGRAM

Field: Materials Science, Mechanics, Fluids

Subfield: Non-destructive analysis, residual stresses, fatigue damage, X-ray

Title: Development of non-destructive damage evaluation method using X ray diffraction line profile analysis: from experimental characterization to digital twin

ParisTech School: Arts et Métiers Sciences et Technologies

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(Lab/Advisor website): https://www.msmp.eu/

Short description of possible research topics for a PhD:

This project combines experimentation and modeling and aims to propose a new method for characterizing the mechanical state of a material and its damage accumulation. The mechanical properties of materials, resulting from fabrication processes, are linked to microstructure, residual stresses level and heterogeneities. During a part's life, an accumulation of damage up to failure can be induced by repeated load or temperature cycles or irradiation for example. As illustrated in the figure the heterogeneity of deformations within a microstructure can be deduced from the broadening of X ray diffraction peaks. It is thus possible to set up in-situ and non-destructive monitoring of damage using X-ray diffraction line profile analysis. Digital twins will be created by simulating the microstructure with its mechanical heterogeneities and by adding damage (FE simulation). Using diffraction laws with these digital twins will allow to link mechanical microstructural states to the shapes of diffraction peaks. This method will find its place in the R&D of materials with gradients of mechanical states and in the non-destructive characterization of fatigue damage in industrial domains such as aeronautics or automotive.

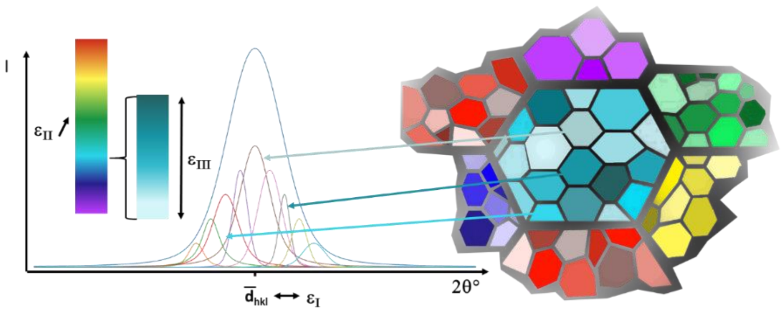

Figure: *Schematic illustration of the heterogeneity of deformation in a microstructure; 3 orders: ε_I, ε_{II}, ε_{III} respectively mean deformation, heterogeneities between grains, heterogeneities though a grain.*

Collaboration with a Chinese laboratory would be welcomed.

Required background of the student

Ideally, the applicant comes from materials science education with knowledge of mechanics of materials. He knows how to carry out experimental manipulations and is comfortable with implementation of digital models using Abaqus and Python.

A list of 5 (max.) representative publications of the group:

1. L. Heraud, L. Barrallier. Fine analysis of superelasticitic transformation and microdeformations by in situ cyclic tensile tests under X-ray synchrotron radiation 10th Edition European Conference on Residual Stresses - ECRS10 Leuven, Belgium, 2018.
2. Depriester et R. Kubler, Calculs Éléments Finis à l'échelle des grains depuis des données EBSD, Congrès Français de Mécanique, 2019.
3. M. Kbibou, L. Barrallier, M. El Mansori, L. Héraud, In-situ characterization of the liquid-solid phase transition in small volume, Surface and coatings technology, 46th ICMCTF (International Conference on Metallurgical Coatings and Thin films), 2019.
4. C. Deleuze, L. Barrallier, A. Fabre, O. Molinas, C. Esbrard, Microstructure characterisation of biphasic titanium alloy Ti - 10V - 2Fe - 3Al and effects induced by heterogeneities on X-ray diffraction peak's broadening, Materials Science and Technology, 2010.
5. A. Fabre, S. Jégou, L. Barrallier, Qualification of the damage induced by friction using X-ray Diffractometry, 2014