Understanding the mechanisms of micro-propagation of cracks in steels with microstructure gradients obtained by Ultrasonic Shot Peening

Receiving laboratories: The proposed study concerns both microstructural approaches and mechanical aspects of the problem; therefore, in order to have an optimal working environment, the thesis will be carried out in two research laboratories: LEM3 at Metz and PPRIME Institute at Poitiers.

Thesis co-supervisor(s) and supervising team: Dr. Mandana ARZAGHI (P'), Dr. Roxane MASSION (LEM3), Pr. Yves NADOT (P'), Pr. Thierry GROSDIDIER (LEM3)

The improvement in the properties of components is often strongly related to the performance of their surfaces which can be subjected to severe thermo-mechanical loadings. Functionally Graded Material (FGM) belongs to a class of advanced materials with varying properties over a changing dimension. Surface treatments such as Surface Mechanical Attrition Treatment (SMAT) or Ultrasonic Shot Peening (USP), significantly improve the mechanical properties at the surface and over several hundreds of microns within the sub-surface. This is due to the severe plastic deformation and associated formation of a refined microstructure where the presence of grain and twin boundaries (nanoscale) contributes to a significant increase in mechanical strength.

In the domain of fatigue, rotative bending tests on steels having a surface microstructure gradients have confirmed the potential for improving properties under cyclic loads. Post-rupture analyzes also highlighted the importance of surface finish on crack initiation and propagation.

The objective of the present thesis is to better understand the mechanisms of micro-propagation of cracks in microstructure gradient steels having different characteristics regarding the grain / phase boundaries. To this end, three steels with different stacking fault energies will be processed by USP and characterized for their structure evolution: size of the microstructural elements, the amplitude of the micro-stress gradients and the nature of the grain boundaries by MET, DRX and EBSD. Uniaxial fatigue tests in air, at ambient temperature and force controlled will be carried out on macroscopic specimens, with or without USP treatment, in order to plot and interpret the SN curves (particular attention will be paid to the initiation and micro crack propagation mechanisms). These macroscopic investigations will be followed by in-situ fatigue tests in a SEM (new facility under development) in order to determine the mechanisms that govern the micro-propagation of cracks.

Funding and starting date:

The project is supported and financed by LabEx DAMAS and PPRIME Institute. In accordance with the relevant standards applied at the university defined in the “fixed-terms contract”, a net monthly salary of about 1600 euros including social security and retirement contribution will be provided for a period of 36 months. Desired starting date: October 2017.

Contact information:

Dr. Mandana ARZAGHI (P') : mandana.arzaghi@ensma.fr, Tel (33) 5 49 49 82 25

Dr. Roxane MASSION (LEM3) : roxane.massion@univ-lorraine.fr, Tel (33) 7 82 87 31 31