PhD Proposal for CSC 2019:

Fatigue properties under complex loadings for materials processed by surface mechanical attrition treatment

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The safety of mechanical parts in aeronautical applications is of primary importance. Some mechanical parts, for example in an aircraft, are subjected to cyclic loadings due to vibrations and take-off and landing. Many efforts have been made in the literature to reinforce the mechanical resistance of the mechanical parts and to get a better understanding of fatigue properties of materials.

To strengthen the materials, one of the most used techniques is surface mechanical treatment. Among these techniques, surface mechanical attrition treatment (SMAT) is a promising one which enables the nanocrystallization of the top surface of materials. More concretely, SMAT can transform the coarse grained surface layer of a material into nanosized grains by means of high velocity multi-directional impacts. It has been illustrated that SMAT is able to increase the fatigue resistance of materials, which gives a promising industrial application prospect of this technique. It is generally agreed that the enhanced fatigue resistance of SMATed materials is due to the compressive residual stresses and the work hardening generated by this treatment.

Some investigations have been performed in the literature to study the fatigue properties of SMAT processed materials. However, most of these studies have focused on uniaxial loadings, whereas in service the mechanical loadings are much more complex. This PhD project constitutes the continuity of previous fatigue work performed in our research team [1-4]. The goal of this project is to investigate the fatigue properties under complex loadings for materials processed by SMAT. A specific attention will be given to the effects of residual stress and work hardening on the fatigue resistance of materials processed by SMAT. However, understanding their contribution separately is a challenging work because the residual stresses and the work hardening are strongly linked to each other. Thus, on the one hand, the goal of this PhD project is to investigate the fatigue properties under complex loading. On the other hand, it is to quantitatively study the effects of residual stress and work hardening on fatigue life of materials. This PhD work will be composed of two main parts which are respectively as follows:

-Experiments essentially including combined tensile-torsional fatigue tests with different loading paths, evaluations of residual stresses and work hardening using X-ray diffraction, microstructure observations using different microscopes (Digital Microscope and Scanning Electron Microscope), nano-indentation profiles, etc. A particular attention will be given to residual stress relaxation under the effect of complex fatigue loadings, and to the effect of SMAT affected region and surface topography on fatigue life;

- A model of high cycle fatigue will be developed taking into account the damage mechanisms of the materials under complex cyclic loadings to predict the fatigue life. The effect of SMAT on fatigue resistance strengthening will be considered in the model. For this purpose, the model will incorporate the effect of residual stress and its relaxation as well as the effect of work hardening in order to improve the fatigue life prediction.

References:

[1] Zhou J, Sun Z, Kanouté P, Retraint D. Effect of surface mechanical attrition treatment on low cycle fatigue properties of an austenitic stainless steel. Int J Fatigue 2017;103:309–17.

[2] Sun Z, Retraint D, Baudin T, Helbert AL, Brisset F, Chemkhi M, et al. Experimental study of microstructure changes due to low cycle fatigue of a steel nanocrystallised by Surface Mechanical Attrition Treatment (SMAT). Mater Charact 2017;124:117–21.

[3] Zhou J, Retraint D, Sun Z, Kanouté P. Comparative study of the effects of surface mechanical attrition treatment and conventional shot peening on low cycle fatigue of a 316L stainless steel. Surf Coat Technol 2018;349:556–66.

[4] Zhou J, Sun Z, Kanouté P, Retraint D. Experimental analysis and constitutive modelling of cyclic behaviour of 316L steels including hardening/softening and strain range memory effect in LCF regime. Int J Plast 2018;107:54–78.