PhD proposal

Analysis of the cyclic behavior of metallic materials with bimodal grain size distribution

Material Physics Group, Rouen, France

Supervisors : C. Keller and F. Barbe

Key words :
AISI 316L, cyclic behavior, grain size distribution, thermomechanical treatment, flash sintering, crystalline plasticity.

Context :
Grain size refinement is one of the most promising solution to improve the mechanical properties of metal alloys. Ultrafine or nanocrystalline materials exhibit, hence, larger yield stress or irradiation resistance. However, these materials generally show a lack of ductility which may be detrimental to their potential industrial applications. Several solutions have been considered to improve the ductility of ultrafine grain materials: grain boundary engineering, precipitation or grain size distribution. The first way is linked to the increase in twin boundary density through thermomechanical processes, which, in turn, improve the ductility due to the coherent character of these particular grain boundaries. The second way is based on the increase of the production of dislocations by anchoring on the precipitates. Thanks to this mechanism, the strain hardening capacity is increased even for the low grain sizes. The third way focuses on introducing a second population of coarse grains inside an ultrafine grain matrix to increase ductility.

This PhD project is focused on this third way. A first PhD revealed the interest of a bimodal distribution of grain size for a material with industrial vocation - steel 316L. This first work validated the powder metallurgy as a convenient elaboration route to develop alloys with bimodal grain size distribution. The mechanical tests showed a significant increase in ductility for a given yield stress for a bimodal grain size distribution. Numerical simulations in crystalline plasticity on polycrystals with an explicit representation of the microstructure were also performed with different grain size distributions and spatial coarse grain arrangements. These simulations revealed the influence of the grain size distribution on the stress and strain fields.

Objectives of the PhD :

1. **Elaboration** : up to now, powder metallurgy has been employed to elaborate samples with bimodal grain size distributions. However, samples have low dimensions and may exhibit oxides segregation. For this PhD, new routes based on thermomechanical treatments will be investigated.

2. **Mechanical characterization** : first analyses revealed an increase in ductility in tensile condition for bimodal grain size distributions. Nevertheless, the strong strain localization in the coarse grains may enhance an early embrittlement for cyclic conditions. The cyclic behavior of the samples with bimodal grain size distribution will be hence characterized.

3. **Numerical simulations**: in order to take into account the grain size distribution in numerical simulations, crystalline plasticity models have been modified to consider the effect of grain boundaries on the strain hardening without a gradient formalism. The PhD will be focused on the investigation of the effect of the grain distribution on the strain mechanisms.

This PhD is then based on both experimental and numerical approachs. The Material Physics Group have large facilities both on microstructural characterization (SEM-EBSD, TEM) and mechanical testing (several servo-hydraulic machines). The applicant should be graduated with a master degree in material science or in mechanics of materials. Skills in mechanical testing and electron microscopy will be appreciated. Fluent english (written and oral) is needed.

Dead line for application : June 8th 2018

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