# Effects of microstructural internal lengths on the mechanical behavior of a ferritic steel: micromechanical modeling based on a statistical method using EBSD and nanoindentation

Layal Chamma[1], Jean-Marc Pipard*[2], Artem Arlazarov[2], Thiebaud Richeton[3], and Stephane Berbenni[3]

[1]Laboratoire d'Etude des Microstructures et de Mécanique des Matériaux – Université de Lorraine, Centre National de la Recherche Scientifique, ArcelorMittal, ARCELORMITTAL – France

[2]ArcelorMittal Global Research and Development, Maizières-lès-Metz – ArcelorMittal, ARCELORMITTAL – France

[3]Laboratoire dÉtude des Microstructures et de Mécanique des Matériaux – Université de Lorraine, Centre National de la Recherche Scientifique, Arts et Métiers Sciences et Technologies, Centre National de la Recherche Scientifique : UMR7239 – France

**Abstract**

Microstructural internal lengths play an important role on the local and macroscopic mechanical behavior of steels. These internal lengths correspond, in particular, to the grain size and to the thickness of the layer of "geometrically necessary dislocations" (GNDs) accumulated at grain boundaries (GBs) due to crystal lattice incompatibilities, produced during plastic deformation. In this study, a single-phase polycrystalline ferritic steel with low carbon content (Al-k) was investigated through the analysis of undeformed and pre-deformed samples. The GND density was estimated from two-dimensional EBSD (2D) maps by considering the available five components of the Nye tensor. Instrumented nanoindentation tests were then performed with a Berkovich tip and a load of 1 mN. The total dislocation densities were estimated using a mechanistic model from the nanohardness measurements. A combined study using both 2D-EBSD and instrumented nanoindentation was then proposed to quantify the existence and the evolution of the internal length for the GB affected zone. Then, it was possible to extract a statistical internal length at each plastic strain from both experimental methods. The results confirmed the statistical existence of a gradient of dislocation densities at GBs, and an evolving internal length during plastic deformation. Furthermore, these experimental results showed that the ferritic grains in Al-k steel could be divided into two mechanically different regions. The first region is located near the GBs, where a dislocation density gradient was clearly observed to spread over the characteristic distance. The second region is the interior of the grain where no marked variation in average dislocation density was found. The experimental measurements were used to feed a new Internal Length Mean Field (ILMF) approach capable to directly integrates the evolution law of the internal length. In addition to the prediction of the macroscopic behavior, a good estimate of the evolution of dislocation densities was obtained.

*Speaker

**Keywords:** Internal Lengths, Dislocation densities, grain boundaries, 2D EBSD, nanoindentation, micromechanics, ferritic steels.