
DIC-Coupled Experimental-Numerical Modeling for Localized Strain Heterogeneity in Polycrystalline Alloys

Adil Kılınc^{*†1}, Qi Hu¹, Jean-François Witz¹, Denis Najjar¹, Vincent Magnier², and Ahmed El Bartali¹

¹Centrale Lille, F-59000 Lille, France – Univ. Lille, CNRS, Centrale Lille, UMR 9013 - LaMcube - Laboratoire de Mécanique, Multiphysique, Multiéchelle, F-59000 Lille – France

²École polytechnique universitaire de Lille, F-59000 Lille, France – Univ. Lille, CNRS, Centrale Lille, UMR 9013 - LaMcube - Laboratoire de Mécanique, Multiphysique, Multiéchelle, F-59000 Lille – France

Abstract

In polycrystals, under the effect of monotonic or cyclic stress, the grains deform in a heterogeneous manner, inducing localizations of plasticity in the microstructure. These localizations of plastic deformation are the origin of material damage (such as slip bands and the initiation and propagation of microcracks) and contribute to the progressive degradation of the material.⁽¹⁾

Identifying strain heterogeneity at the microstructural scale of polycrystalline alloys remains a significant challenge, particularly when considering contributing factors such as grain size, orientation, twins, and defects. Crystal plasticity models, while useful, are often complex and computationally expensive. Therefore, there is a need for well-structured, simplified models that can effectively explain deformation localizations at a finer scale while being cost- and time-efficient.

This study focuses on developing coupled models and the necessary algorithms to bridge the gap between experimental and numerical tensile testing results of polycrystalline alloys, specifically 316L stainless steel. In the first stage, a digitally representative 2D model is created using optical and electron microscopy images, complemented by digital image correlation (DIC) techniques to capture the strain localization observed in both experiments and numerical simulations.

These algorithms and techniques aim to align experimental and numerical results by employing Ludwik's constitutive law, which facilitates the representation of elasticity and plasticity phenomena at the mesoscale using simplified terms for yielding and hardening coefficients. Several assumptions regarding the transition from macroscale to microscale are also incorporated.

The method built upon detecting elasticity and hardening for each grain from the deformation flow was grounded in the approach well-studied by Hu et al⁽²⁾ and later study by Kılınc et al⁽³⁾.

*Speaker

†Corresponding author: adil.kilinc@centralelille.fr

Initial models, simulated at the grain-wise scale using finite element analysis, showed good agreement with experimentally obtained strain fields, particularly in terms of localized deformation zones and statistical data. This finding suggests that it is possible to represent a polycrystalline alloy's microstructure in a 2D model using simplified terms for hardening coefficients and elasticity detection without resorting to complex crystal plasticity models.

BIBLIOGRAPHY

(1) MEYERS, Marc André; CHAWLA, Krishan Kumar. Mechanical behavior of materials. Cambridge university press, 2008.

(2) HU, Qi. Estimation of multiple-scale energy balances during a cyclic loading test of a 316L stainless steel by coupled field measurements. 2023. PhD Thesis. Centrale Lille Institut.

(3) KILINÇ, Adil. Identification of Heterogeneous Properties of a Metallic Polycrystal by Stereoscopic Measurements at Microscale. In: *16ème Colloque National en Calcul de Structures*. 2024