On the applicability of linear elastic fracture mechanics scaling relations in the analysis of intergranular fracture of brittle polycrystals

Zahid Shabir[a], Erik Van der Giessen[b], C. Armando Duarte[c] and Angelo Simone[d, a, *]

[a]Faculty of Civil Engineering and Geosciences
Delft University of Technology, Delft, the Netherlands

[b]Zernike Institute for Advanced Materials
University of Groningen, Groningen, the Netherlands

[c]Department of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign, Urbana, IL, USA

[d]Department of Industrial Engineering
University of Padova, Padua, Italy

ABSTRACT

Crack propagation in polycrystalline specimens is studied by means of a generalized finite element method with linear elastic isotropic grains and cohesive grain boundaries. The corresponding mode-I intergranular cracks are characterized using a grain boundary brittleness criterion that depends on cohesive law parameters and average grain boundary length. It is shown that load-displacement curves for specimens with the same microstructure and for various cohesive law parameters can be obtained from a master load-displacement curve by means of simple linear elastic fracture mechanics scaling relations. This property is a consequence of the independence of intergranular crack paths from cohesive law parameters. Perfect scaling is obtained for cases characterized by the same grain boundary brittleness number, while it is approximated for relatively large values. The former case corresponds to grain boundary traction profiles that are identical apart from a scale factor; in the latter case, a large grain boundary brittleness number implies similar, apart from a scale factor, traction profiles. By exploiting this property, it is demonstrated that computationally expensive simulations can be avoided above a certain grain boundary brittleness threshold value.