Higher-Order Gradient Plasticity-Damage Model for Microstructural Modeling of Dual Phase Steels

Rashid K. Abu Al-Rub [a*], Mahmood Ettehad [b], and Anthony N. Palazotto [c]

[a] Institute Center for Energy, Mechanical and Materials Engineering Department, Masdar Institute of Science and Technology, Abu Dhabi, UAE

[b] Zachary Departments of Civil Engineering, Texas A&M University, College Station, TX 77843, USA

[c] Department of Aeronautics and Astronautics, Air Force Institute of Technology, WPAFB, OH 45433-7765, USA

Abstract

This paper focuses on the application of a higher-order gradient-dependent plasticity-damage model for microstructural modeling of dual-phase (DP) steels. Damage evolution is governed by the evolution of a nonlocal plasticity measure which is a function of the local equivalent plastic strain rate and its corresponding first-order gradient. Different two-dimensional representative volume elements of the DP microstructure are virtually generated by varying the martensite phase volume fraction, distribution, and size, and volume fraction and size of dispersed hard inclusions. It is shown that the employed modeling framework is capable of addressing three main issues that are not considered by the current studies on microstructural modeling of advanced high strength steels (AHSS); finite element mesh-dependency, size effects, and additional hardening due to evolution of geometrically necessary dislocations. It is concluded that based on the employed mechanical properties of each phase in the DP steel, strength and ductility is governed by damage evolution and not necessarily by plastic strain localization alone. Therefore, it is shown that including nonlocal damage evolution is critical for accurate prediction of the strength and ductility of DP steels. It is also shown that dispersing 5% volume fraction of hard inclusions in the DP steel optimizes both strength and ductility such that a third-generation of AHSS might be attained.

[*] Corresponding author. Tel.: +971-2810-9162; Fax: +971-2810-9901
E-mail address: rabualrub@masdar.ac.ae, rashedkamel@yahoo.com (R.K. Abu Al-Rub)