MULTISCALE SIMULATION OF STRUCTURAL WELDMENTS

Aditya Jhunjhunwala[1], Ali Koohi Esfahani[2], Machel Morrison[2], and Amit Kanvinde[1*]

[1]University of California, Davis, CA, 95616
[2]Uniiversity of California, San Diego, La Jolla, CA
** Presenting Author email: kanvinde@ucdavis.edu*

Abstract

Simulation of extreme limit states is essential to modern performance-based design of buildings and civil infrastructure that are more resilient to earthquakes and other extreme hazards. While sophisticated simulation techniques are regularly applied in natural hazards engineering, they are limited in ability to capture several important failure mechanisms. A significant limitation, addressed in this research, is the capability to reliably simulate fracture in structural steel weldments. Predicting fracture in weldments is inherently challenging due to the multitudes of material microstructures that occur over small length scales, interacting with steep stress and strain gradients due to geometric discontinuities that are also present in the vicinity of weldments. Moreover, when weldments do not have a sharp, pre-existing flaw, or are subjected to large-scale yielding or earthquake-induced Ultra Low Cycle Fatigue (ULCF – characterized by few cycles of large strain) – all of which occur frequently in modern buildings, conventional fracture and fatigue mechanics are invalidated. Given that fracture often initiates in the weld region, this represents a major obstacle to effective structural performance assessment. This is addressed this through a coordinated program of (1) physical tests and fractography on thermomechanically generated samples of various weld microstructures for discovery of fracture micromechanisms, (2) formulation of new continuum-based fracture criteria for these different microstructures, (3) numerical implementation, and (4) calibration and validation of the developed framework using laboratory testing. A key research challenge is to effectively upscale local models, considering spatial variation of microstructure and interaction between mechanisms to predict fracture at the component/structure scale, while also characterizing the uncertainty in these predictions. The presentation will describe the initiation of a comprehensive research program in the area of fracture model development and materials characterization. The program will culminate in a campaign to facilitate adoption of fracture simulation techniques into engineering research and practice, including standardization of simulation and calibration methods required for their realization, and development of open source software and ready-to-run component models for their convenient implementation.

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