OPENING NEW HORIZONS IN THE PREDICTION OF HYDROGEN EMBRITTLEMENT: MULTI-PHYSICS PHASE FIELD FRACTURE

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ABSTRACT

The phase field fracture method has quickly gained traction as a powerful numerical tool. Advanced cracking phenomena, such as crack branching, merging, initiation from arbitrary sites and complex crack trajectories, can be captured without convergence problems and on the original finite element mesh. We extend this success to hydrogen embrittlement. A general chemo-mechanical framework is presented, suitable for any mechanistic interpretation upon an appropriate definition of the hydrogen-dependent fracture energy degradation law. The potential of the proposed phase field modelling framework is demonstrated by means of representative case studies. First, crack growth resistance curves are computed in a wide variety of scenarios, showing that the model appropriately captures the sensitivity to material strength, loading rate and hydrogen concentration. Secondly, model predictions are benchmarked against experiments on Ni-based alloys and ferritic and martensitic steels. Results reveal a promising agreement. Insight is also gained into the suitability of standardised experiments; slow strain rate testing (SSRT) is revisited, showing that subcritical crack growth compromises its validity. Finally, the capabilities of the modelling framework in enabling Virtual Testing are showcased. Large-scale multi-physics predictions are obtained for technologically-relevant applications. The phase field method easily enables capturing damage evolution from an initial distribution of defects, as measured from in-line inspection or other non-destructive techniques. More recent extensions, such as the consideration of multiple traps or the modelling of fatigue damage will also be discussed. Finally, I will show how the phase field paradigm can also open new modelling horizons in another scientifically-challenging phenomenon of notable technological importance: corrosion damage.

SHORT BIO

Emilio Martínez Pañeda is a Lecturer (US Asst. Professor) and 1851 Research Fellow at Imperial College London, where he leads the Mechanics of Infrastructure Materials Lab. Before, he was a Research Fellow at the University of Cambridge. During his 7-year academic career (PhD Thesis: 2013-2016), Emilio has published 45 scientific papers (h-index: 17), supervised 12 PhD students and attracted and managed over £1M in research funding. Emilio has been the recipient of a number of competitive fellowships such as the 1851 Research Fellowships, the Marie Curie Individual Fellowship, the H.C. Ørsted Fellowship or the Wolfson College (Cambridge) Junior Research Fellowship. His current research interests lie in the field of applied mechanics; more specifically fracture mechanics, multi-physics problems, and hydrogen embrittlement. Emilio's work has been recognized through several awards, including the Simó Prize, the Acta Student Award, the Springer PhD Thesis Prize, the Brunel Award, the Keith Miller Prize, the Extraordinary Doctoral Prize, and the IMechE Prestige Award for Risk Reduction in Mechanical Engineering.