

ME395: Mechanics and Computation Seminar

“Unravelling Hydrogen-metal Interactions: A Challenge Across Scales and Disciplines”

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The exposure to small quantities of hydrogen (in the ppm range) can reduce the ductility, fracture toughness, and fatigue crack growth resistance of metals by orders of magnitude. This remarkable phenomenon, known as ‘hydrogen embrittlement’, is pervasive across the transport, defence, energy, and construction sectors, due to the ubiquity of hydrogen, and constitutes one of the biggest threats to the future of hydrogen as a clean energy carrier. However, understanding and predicting hydrogen-metal interactions have proven to be more difficult than first anticipated. This talk will overview the author’s cross-disciplinary efforts to shed light on the nature of hydrogen-assisted failures. Focus will be on the combination of experiments and modelling across scales and disciplines, to mechanistically resolve the physical processes underlying hydrogen embrittlement, from the (electro-)chemical uptake of hydrogen from gaseous and aqueous electrolyte environments, to the diffusion and transport of dissolved hydrogen in the crystal lattice, and to the hydrogen-assisted nucleation and growth of cracks. The insight gained has led to the development of a new class of physically-based electro-chemo-mechanical models for hydrogen embrittlement that can not only obtain an unprecedented level of agreement with laboratory experiments but also deliver finite element

predictions at scales relevant to engineering practice, bringing the “Virtual Testing” paradigm to hydrogen-containing environments. Finally, focus will be placed on a recent, pressing challenge: with the upcoming use of hydrogen in aviation, there is a need to understand, from first principles, the behavior of metals exposed to hydrogen and extreme environments (temperatures ranging from 20 K to nearly 1800 K). Given the small margins of the aviation industry, this requires a new way of thinking, whereby every hydrogen-material interaction must be appropriately described (and not fitted), from the atom scale, to the dislocation level, and to the macroscopic component performance, through a new generation of mechanistic quantum-mechanically informed, thermo-chemo-mechanical crystal plasticity models.

Prof Emilio Martinez-Pañeda is an Associate Professor at the University of Oxford. Prior to joining Oxford, he was a Reader (Associate Professor) at Imperial College London, where he led an interdisciplinary research group from 2019 to 2023 (2019: Lecturer [US Assistant Prof], 2021: Senior Lecturer, 2023: Reader). Before that, he was an 1851 Research Fellow at the University of Cambridge. His recent research focus has been on addressing fundamental scientific challenges that can accelerate our transition to a net-zero carbon society and assist in tackling our energy and climate crises. Prof Emilio Martinez-Pañeda has been the PI on over 7M GBP of funding in the past five years (ERC Starting Grant, UKRI Future Leaders Fellowship) and his work has been recognized through multiple awards, including the 2021 UK Young Engineer of the Year (Royal Academy of Engineering), the 2022 Imperial College President’s Medal for Excellence in Research, ECCOMAS’s 2024 Zienkiewicz Award, the 2024 IACM John Argyris Award and the 2025 Philip Leverhulme Prize.

Thursday, April 2, 2026
Building 530, Room 127

Refreshments between 4:10 - 4:25pm
Seminar at 4:30 pm