Department of Mechanical Engineering
The University of Hong Kong

"Distinguished Research Seminars by two Fellows of the Royal Academy of Engineering"

Slip, dislocations and stored energy density in polycrystal crack nucleation and growth

Date: 20 March, 2024 (Wednesday)
Time: 3:00 p.m. – 4:00 p.m.
Venue: LE6, Library Extension Building
HKU

Speaker: Professor Fionn Dunne
RAEng/Rolls-Royce Research Chair
Rolls-Royce Nuclear UTC Director

Abstract:
Short, microstructurally-sensitive crack growth in engineering alloys may contribute a significant fraction of fatigue life but is not yet fully mechanistically understood. Nucleation site, crack path tortuosity and rates of initiation and growth remain key questions to address and solutions at the microstructural length scale could offer the potential of substantive improvement in safety-critical component design.

In this presentation, studies based on integrated small-scale experiment, high-resolution characterisation and discrete dislocation and crystal plasticity modelling will be presented to address hypothesised aspects of the mechanistic bases of the above phenomena. Quantification of slip, lattice curvature and dislocation density, and stored energy density have provided insights in to strain localisation, crack nucleation site [1] and crack paths, and propagation rates in a range of engineering alloys [2]. As a particular example, the crystallographic nature of short crack growth in HCP zirconium alloy is addressed, and its relationship to slip activation and crack tip stored energy density considered by comparison of experimental measurements of crystallographic growth rates and crack paths with crystal plasticity modelling.

[1] Nikoletta Prastiti et al. Discrete dislocation, crystal plasticity and experimental studies of fatigue crack nucleation in single-crystal nickel. Intl. Jnl. Plasticity, 126, 2020. https://doi.org/10.1016/j.ijplas.2019.10.003.
[2] Yilun Xu et al. Microstructural fracture mechanics: stored energy density at fatigue cracks. Jnl. Mech. Phys. Solids. 146, 104209, 2021. https://doi.org/10.1016/j.jmps.2020.104209.

Biography:
Professor Fionn Dunne researches in micromechanics of microstructure-level deformation and the mechanistic drivers of fatigue crack nucleation and growth, including Titanium cold dwell fatigue. A particular focus is bringing together quantitative characterisation (DIC and EBSD) with computational discrete dislocation and crystal plasticity. He was RAEng/Rolls-Royce Research Chair, Rolls-Royce Nuclear UTC Director, served on MOD's Research Programmes Group, and currently on MPI's Intl. Sci. Advisory Board. He led the HexMat EPSRC programme grant (£5m), and is partner on the USAF MAI Dwell Programme. He was elected Fellow of the UK's Royal Academy of Engineering in 2010, and awarded the IoM3's Harvey Flower Prize 2016.

A Novel Continuum Dislocation Density Field-Based Crystal Plasticity Theory

Date: 20 March, 2024 (Wednesday)
Time: 4:00 p.m. – 5:00 p.m.
Venue: LE6, Library Extension Building
HKU

Speaker: Professor Esteban P. BUSSO
Center for Materials Modelling and Characterisation
School of Science
Harbin Institute of Technology
China

Abstract:
In this work, a novel dislocation density field-based crystal plasticity formulation, that incorporates up-scaled continuum dislocation density fields to represent all possible char-acters of the dislocation density, is presented. The continuum dislocation field theory, for-mulated assuming large strain kinematics, is based on an all-dislocation concept, whereby individual dislocation density types are described as vector fields. The evolutionary be-haviour of the dislocation density fields is defined in terms of a glide component derived from the classical general conservation law for dislocation density fields proposed originally by Kroner and Acharya, a rotation one given by the curl of the dislocation velocity vec-tor as proposed originally by Ngan and co-workers, and a statistically stored dislocation source/sink component.

The proposed formulation has been numerically implemented within the finite ele-ment method using a modified up-wind stabilisation approach, which results on eight extra independent nodal degrees of freedom per slip system, associated with the upscaled dislocation densities of pure edge and screw character. Furthermore, the required bound-ary conditions are simple: initial total dislocation density and dislocation flux or velocity, without the need for higher order boundary conditions. Full details of the numerical implementation of the crystal plasticity theory are given.

The theory is then used to investigate classical boundary value problems involving 1D and 2D dislocation pile-ups, and the development of boundary layers in a deforming single crystal strip under constrained conditions. The main general understanding that emerges from the case studies is that, as either the dislocation pile-ups or the boundary layers develop with deformation, geometrically necessary dislocations are generated and lead to an overall behaviour that is size-dependent. Furthermore, it is shown that, in the absence of sources or sinks, which are statistically stored in nature, that total number of dislocations in the pile-up problems is preserved. The numerical predictions of the 1D pile-up and strip simple shear problems are in good agreement with published solutions.

Biography:
Esteban P. Busso is currently Professor of Micromechanics and Co-Director of the Centre for Micromechanics at the Harbin Institute of Technology (HIT), in Shenzhen, China. In 2019, he has been awarded China's National 1000 Talent Plan Award (Topnotch Talents Category), the Shenzhen's Government High Talent Certificate Award, and the Guangdong Province's Pearl River (Zhujiang) Talent Award. In August 2014, Dr. Busso was elected a Fellow of the British Royal Academy of Engineering. He is also a Fellow of the British Institute of Materials, Minerals and Mining and of the Societé Francaise des Matériaux, a Chartered Engineer in the UK and a member of the Royal Academy's Aerospace Committee. He was till May 2018, the Scientific Director of the National Aerospace Research Centre of France (ONERA) in the areas of Materials and Structures. From 2005 till 2013, he was a Professor of Mechanics of Materials at the *Ecole des Mines de Paris* and Director of the *Ecole's Centre des Matériaux* and, from 1994 till 2005, he was a Professor of Mechanics at Imperial College's Department of Mechanical Engineering in London, UK. Dr. Busso obtained his MSc and PhD in Mechanical Engineering from the Massachusetts Institute of Technology (MIT) in Cambridge, USA, in 1986 and 1990, respectively. He has also worked in industry in the UK, Japan, and South Africa.

His research involves micromechanics studies of deformation and fracture of materials and interfaces, with an emphasis on the development of multiscale and multiphysics concepts in mechanistic models to predict deformation and fracture processes. Dr. Busso has been an editorial board member of several international journals, such as *Philosophical Magazine*, the *Int. Journal of Plasticity*, and the ASME *Journal of Eng. Materials and Tech*. He has authored and edited 12 scientific books, and has published over 175 peer-reviewed articles.

ALL INTERESTED ARE WELCOME
For further information, please contact Professor A.H.W. Ngan at 3917 7900.