Dynamic Discrete Dislocation Plasticity for Extremely High Strain Rates
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Traditionally, the study of plastic relaxation processes under weak shock loading and high strain rates in crystalline materials has been based on direct experimental measurement of the macroscopic response of the material. Using this data, well-known macroscopic constitutive laws and equations of state have been formulated. However, direct simulation of dislocations as the dynamic agents of plastic relaxation in those circumstances remains a challenge. Current Discrete Dislocation Plasticity (DDP) methods, where dislocations are modeled as discrete line singularities in an elastic continuum, are unable to adequately simulate plastic relaxation because they treat dislocation motion quasi-statically, thus neglecting the time-dependent nature of the elastic fields and assuming that they instantaneously acquire the shape and magnitude predicted by elastostatics. Under shock loading, this assumption leads to artifacts that can only be overcome with a fully time-dependent formulation of the elastic fields. The first part of this talk will be an overview of planar quasi-static discrete dislocation plasticity, including a summary of studies on size effects conducted over the last ten years. It will then be shown that the quasi-static approximation is unsuitable for very high strain rates (~10^6 and higher). Finally, a truly dynamic formulation for the creation, annihilation and arbitrary motion of straight edge dislocations will be presented. The Dynamic Discrete Dislocation Plasticity (D3P) method will be applied in a two-dimensional model of time-dependent plastic relaxation under shock loading, and some relevant results on the decay of the elastic precursor will be presented.

Dan Balint is a Senior Lecturer in Mechanics of Materials in the Department of Mechanical Engineering at Imperial College London. Prior to joining the faculty at Imperial 7 years ago, Dan was a post-doc in the Cambridge Centre for Micromechanics working on discrete dislocation plasticity, and he completed his PhD at Harvard in 2003 on oxide rumpling in thermal barrier coatings. Dan’s current research interests include extending discrete dislocation plasticity methods (DDP) for simulating extremely high strain rate deformation, and incorporating atomic scale detail into DDP for simulating dislocation motion coupled to hydrogen diffusion in problems such as delayed hydride cracking in zirconium alloys.