Multi-scale methods for fracture: model learning across scales, digital twinning and factors of safety

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Fracture and material instabilities originate at spatial scales much smaller than that of the structure of interest: delamination, debonding, fibre breakage, cell-wall buckling, are examples of nano/micro or meso-scale mechanisms which can lead to global failure of the material and structure. Such mechanisms cannot, for computational and practical reasons, be accounted at structural scale, so that acceleration methods are necessary.

We review in this presentation recently proposed approaches to reduce the computational expense associated with multi-scale modelling of fracture. In light of two particular examples, we show connections between algebraic reduction (model order reduction and quasi-continuum methods) and homogenisation-based reduction.

We open the discussion towards suitable approaches for machine-learning and Bayesian statistical based multi-scale model selection. Such approaches could fuel a digital-twin concept enabling models to learn from real-time data acquired during the life of the structure, accounting for "real" environmental conditions during predictions, and, eventually, moving beyond the era of factors of safety.