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Towards a multi-scale analysis of dynamic failure in architectured materials

Architectured materials are a rising class of materials that provide tremendous possibilities in terms of functional properties. Interest is drawn on the failure of architectured materials in which scale separation ceases to exist. This directly translates to strong interactions between a crack tip and the architecture independently of the considered scale. Moreover, under dynamic loadings, stress-waves come into play and interactions between the crack-tip, the microstructure (architecture) and the stress-waves eventually pilot together the structural behaviour.
In this thesis, three types of architectured materials are considered: one periodic and two Penrose-type quasi-periodic lattices of holes. The analysis is broken into three parts.
To study the influence of the microstructure on crack-propagation at different scales, numerical simulations of failure are analysed; they show improved resistance to crack propagation in the quasi-periodic materials. At the core of the work is also the development of a coarse-graining technique that requires no representative volume element. This technique allowed for a physically consistent multi-scale evaluation of the effective failure properties of the architectures. The inevitability of the consideration of a non-homogeneous effective medium to accurately model microstructural effects at larger scales is also highlighted.
In dynamics, the influence of the architectures on the stress-wave attenuation shows improved attenuation properties of the quasi-periodic lattices.
Moreover, to understand the mechanism(s) governing the dynamic branching phenomenon in a homogeneous material, a criterion based on dynamic fracture mechanics is developed and validated on a novel experimental setup where high-speed-high-resolution imaging is combined with Digital Image Correlation to capture extraordinary phe- nomena. The unquestionable role of T-stress in dynamic branching is put forth.
This thesis brings forth the necessary tools towards a multi-scale analysis of dynamic fracture of architectured materials.

Keywords : *Architectured materials, coarse-graining, brittle fracture, dynamic fracture, crack branching*