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Enhanced Non-Uniform Transformation Field Analysis

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We propose an extension of Non-Uniform Transformation Field Analysis (NTFA) [1] to address modeling of heterogeneous materials undergoing debonding. We denote the proposed method as Enhanced Non-uniform Transformation Field Analysis (ENTFA). Departing from the NTFA-based homogenization proposed in [2], we enhance it by introducing a consistent tangent matrix, and we formulate the enhanced approach for both single and multi-scale analyses. In the multi-scale setting, we adopt a suitable representative volume element of the micro-scale and model debonding with cohesive interfaces obeying the interface law in [3]. As in [2], the interfaces are partitioned into sub-interfaces, and the inelastic relative displacement field within each sub-interface is approximated by piecewise linear functions. This allows the inelastic relative displacements to be represented using reduced inelastic variables, which are solved for through a Newton-Raphson iterative approach based on the obtained consistent tangent matrix. This not only facilitates the derivation of the homogenized stress-strain constitutive relation at the macro-scale, but also allows to robustly trace complex snap-back phenomena in single-scale analyses by the application of an arc-length control technique. Several numerical tests demonstrate that ENTFA leads to a significant reduction of the computational time over reference non-linear finite element analyses, while retaining a satisfactory accuracy.

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