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Concurrent multiscale and multiphysics modelling with Direct FE2

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Abstract

Multiscale analysis addresses problems involving two or more vastly different length scales—typically the structural scale and the microstructural scale of heterogeneous materials. The FE² method is a widely adopted concurrent multiscale approach, where finite element analyses are performed at both the macro and micro levels. In conventional FE², the microscale finite element model is nested within each integration point of the macroscale simulation to compute homogenized material responses on-the-fly. However, its implementation complexity often restricts its use to researchers with advanced computational expertise. This presentation introduces Direct FE², an alternative framework that is more accessible and efficient. Direct FE² is implemented using commercial finite element software through two pre-processing steps and executed as a single standard FE job—eliminating the need for custom solvers or nested coupling routines. Because it leverages the full capabilities of commercial codes, Direct FE² has been successfully applied to a range of multiscale and multiphysics problems. Following the theoretical foundations of Direct FE² and its implementation workflow, illustrative applications in structural stress analysis, wave propagation, thermo-mechanical problems, multiscale optimization, etc., will be presented to highlight the framework's versatility and potential for broader adoption in engineering practice.

Keywords:

multiscale multiphysics computational mechanics