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Physics- and AI-Based ICME Methodologies Relying on Multi-Scale Digital Twin of Heterogeneous Materials

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Over the past several years, homogenization techniques in materials engineering have worked their way into industrial applications. The rise of computational power, parallelization methods, GPU programming and solvers have paved the way for daily usage of full-field homogenization over larger and more representative RVEs (i.e., Representative Volume Element). For example, FFT/spectral solvers have demonstrated very high performance thanks to CPU/GPU parallelization while delivering accurate material performance predictions. Problems with loss of ellipticity can be regularized by non-local formulations. However, we are still challenged with the curse of dimensionality when dealing with complex material phenomenon. A full bridging of the structural and the material/RVE scale (FE^2) is cost prohibitive. Single scale phenomenological models fitted against predictions of RVE models or semi-analytical homogenization techniques can lose some of the most valuable information leading to inaccurate or incomplete predictions. However, we have a few more tools in the toolbox that can help us here. First, the use of measurement techniques like CT-scans and their associated software are delivering increasing measurement accuracy at a more affordable price allowing the direct physical measurement of material microstructure. Second, many authors have suggested using AI/ML models with synthetically and physically generated data. We will discuss our experiences combining physical modelling with data and AI/ML techniques. We believe that these elements together will enable true multi-scale driven Integrated Computational Material Engineering (ICME) methodologies across engineering processes in product development to account for material internal structure.