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On Micromechanical Parameter Identification and the Role of Kinematic Boundary Conditions in Integrated Digital Image Correlation

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ABSTRACT

Accurate identification of micromechanical parameters plays a crucial role in numerous areas of the mechanics of materials. On the one hand, micromechanical parameters are required as inputs to constitutive laws that help to predict lifespan and performance of engineering devices. On the other hand, they help to understand complex physical processes in materials occurring across the scales, such as plasticity, damage, or crack growth.

Although relatively accurate procedures exist for identification of macroscopic material properties, micro- or nano-scale mechanical tests are challenging to perform and necessitate more advanced experimental methods. One such method is Integrated Digital Image Correlation (IDIC), which has proven to be a reliable and accurate non-intrusive full-field measurement technique. It has been reported in the literature, nevertheless, that if the loads and restraints applied to a tested specimen are outside the employed Field Of View (FOV), IDIC suffers from inaccuracies [1]. This situation typically applies to micromechanical parameter identification, in which images are usually obtained by electron microscopy or other microscopy techniques, whereas loads are applied on a much larger scale. Kinematic Boundary Conditions (BCs) still need to be prescribed to a measured Microstructural Volume Element (MVE), that is located inside the FOV and used as a model in IDIC. These MVE BCs are unknown, and may introduce significant errors in the identified material parameters when chosen incorrectly.

In this presentation, two goals are pursued. First, the effects of inaccuracies in the prescribed MVE BCs on the accuracy of the identified material parameters are studied in a systematic way. Three virtual experiments are employed to this end, showing that a high level of accuracy is required, and that all microscopic features of the boundary displacement need to be captured. This result motivates the second goal of this contribution, which is an improved boundary condition identification approach, that considers constitutive material parameters as well as kinematic variables at the boundary of the MVE domain as unknowns in the IDIC procedure. It is shown that the proposed methodology improves significantly the precision with which micromechanical parameters can be identified. The overall strategy is demonstrated on three kinds of mechanical tests, various material contrast ratios, and levels of image noise. Finally, a comparison with a state-of-the-art approach reported in [2] is provided.

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