Adaptive equation-free multiscale modeling of metallic lattices with geometrical nonlinearity and variability

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ABSTRACT

An equation-free concurrent multiscale framework is proposed to model 3D metallic lattice structures. The proposed equation-free multiscale method (EFMM) is effectively a generalization of the quasicontinuum method [2] and relies on the use of fully-resolved domains (FRD) in which all details of the lattice micro-structure are captured, and of coarse-grained domains (CGD) in which a model reduction is performed by *interpolation* and *summation* steps. The particularity of the lattice geometrical description is that cross section variations along the lattice struts (caused by the manufacturing process) are explicitly represented by their *discretization in several beam finite elements*, both in the FRDs and CGDs. The interpolation step of the EFMM refers to a kinematic approximation of the lattice deformation within CGDs based on the displacement of a reduced number of material points. One of the originalities of this work is the consideration of a *separate interpolation of each type of kinematic variables* within the CGDs, as a function of the connectivity of the lattice beam nodes (i.e. taking the location of different cross sections into account) and their kinematical pattern. This, together with accounting for geometric nonlinearity, by the development and implementation of a 3D co-rotational beam finite element [1], are innovative contributions. Choosing the appropriate sizes of the FRDs and the CGDs for a lattice to be simulated is a trade-off because larger FRDs prevail the accuracy but compromise the efficiency while larger CGDs do the opposite. Since the required sizes of the FRDs and CGDs are generally not known a priori for specific applications, an adaptive coarse-graining strategy is developed. To be specific, the whole lattice is initially considered as a CGD. Two kinds of error indicator are proposed (e.g. the Zienkiewicz-Zhu error indicator [4, 3] and the error indicator based on the discrepancy of strain energy). The error indicator guides on: 1) introducing more material points and rearranging the interpolation for the CGDs; 2) changing the localization-prone parts of the lattice into FRDs. The adaptive EFMM is applied to metallic BCC lattices with various sizes and loading conditions. By comparing to the results of those of the direct numerical simulation (DNS), it is shown that geometrical non-linearities can be captured at a fraction of the DNS cost.

REFERENCES

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