Equation-free multiscale modeling of metallic lattices with geometrical and material nonlinearity and variability

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ABSTRACT

An nonlinear equation-free concurrent multiscale numerical framework, being the generalization of the quasicontinuum method [2] is proposed in this contribution to model 3D metallic lattice structures. The proposed equation-free multiscale method (EFMM) relies on the use of fully-resolved domains (FRD) in which all of the 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 geometry description is that cross section variations along the lattice struts (that are experimentally observed as a result of 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 movement of a reduced number of material points at the CGD corners. One of the originalities of this work is the consideration of a *separate interpolation of each type of degrees of freedom* 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 plasticity, by the development and implementation of a 3D co-rotational beam finite element [1] with embedded plastic hinges [3], are unprecedented and original contributions. The EFMM is applied to metallic BCC lattices with various sizes and loading conditions. By comparing to direct numerical simulation (DNS), it is shown that both material and geometrical non-linearities can be captured at a fraction of the DNS cost (the computational time is reduced by 97.27% while introducing an error of only 3.76%).

REFERENCES

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