Modeling Ni/Al High Energy Ball Milled Composites Using Sharp Volumetric Billboards

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Predicting behavior of heterogeneous materials through numerical modeling is a challenging topic due to the extremely high computational cost required to resolve all of the geometrical complexities. To address this problem, various homogenization models have been developed to predict the mechanical behavior of materials. However, accurately predicting highly nonlinear material response with prominent localized behavior remains elusive. The focus of this work is to predict the macro- and micro-mechanical behavior of high energy ball milled (HEBM) Ni/Al composites through sharp volumetric billboard (SVB) based modeling.

This SVB based modeling stems from the volumetric billboard (VB) method, a Google Earth like multi-resolution modeling strategy in computer graphics. This technique is a data-compression strategy developed for real time 3D image rendering. By creating VB series of an object, the data amount is greatly decreased while object shape is visually retained. In our work, we analyze the statistical and physical implications of the VB technique, and enhance it through the SVB scheme. A sharpening filter is created to reconstruct the original material contrast on coarser microstructures. We propose a contrast-based minimization problem and a corresponding numerical algorithm that approximates the minima through a fast sweeping strategy with local volume preservation.

In our work, we focus on reactive composites produced by High Energy Ball Milling (HEBM), a promising strategy to control the initial degree and character of the inter-mixing between various components. We utilize a fine scale microstructure from microtomography, and create levels of detail (LODs) from the SVB scheme. The first and second order probability functions are computed, and both exhibit consistency after large data reduction (1/8 the amount of finer SVB). Then, we use a parallel generalized finite element code, PGFem3D, to compute the mechanical behavior under a tension-relaxation loading profile using crystal plasticity constitutive equations. Two sets of simulations are performed. Firstly, we adopt identical texture to avoid potential side-effects from the crystal orientation mapping among LODs. Secondly, random texture is adopted to simulate the real material texture. The macro- and micro-mechanical robustness of data compression is demonstrated through corresponding error analysis.