Model reduction in the context of polycrystalline plasticity

Bingqian Li, Piotr Breitkopf, Ludovic Cauvin, Balaji Raghavan

Model reduction in the context of polycrystalline plasticity

Bingqian Li[1], Piotr Breitkopf[1], Ludovic Cauvin*[1], and Balaji Raghavan[2]

[1]Roberval (Mechanics, energy and electricity) – Université de Technologie de Compiègne, Centre de recherche Royallieu, CS 60319, 60203 Compiègne Cedex, France – France

[2]Laboratoire de Génie Civil et Génie Mécanique – Université de Rennes, Institut National des Sciences Appliquées - Rennes – France

Abstract

The plastic behavior of polycrystalline metals is highly influenced by the initial texture of the material and its evolution during loading and/or forming processes (1). Transmission electron microscopy (TEM) investigation and electron backscatter diffraction (EBSD) analysis are commonly employed to examine the textures of polycrystalline materials using pole figure illustrations. However, the increasing volume of experimental data, such as crystallographic observations stored in ODF files, necessitates improved data processing techniques. Indeed, to better understand material behavior, multi-scale experimental characterization is more and more common, especially in academic studies and in the context of new manufacturing processes like additive manufacturing.

In the field of reduced-order modeling, Proper Orthogonal Decomposition (POD) offers a powerful approach to handling high-dimensional data and uncovering its underlying dimensionality (2). This communication aims to introduce a novel application of POD for representing polycrystalline textures in the context of data-driven simulation (3). By applying POD to a set of texture snapshots acquired at different stages of mechanical tests, it is possible to extract the lowest-dimensional basis that captures the primary modes of variation in the data. This basis can then be used to generate an admissible random texture for the same test, significantly reducing the problem's dimensionality. Since ODF files typically describe the orientation of crystals within a specimen using Euler angles, performing POD on periodic data becomes necessary. Different strategies can be considered to deal with periodic data, such as representing one snapshot on a unit sphere and using distance functions. The specific aspects of linear algebra operations on periodic data will be illustrated through various examples, including synthetic ODF files.

The presented results are part of a broader effort (4) to implement model-order reduction in multiscale data-driven simulations with the objective of incorporating experimental information on polycrystalline textures into simulation and design processes.

References

(1) Cauvin, L., Raghavan, B., Bouvier, S., Wang, X., Meraghni, F. Multi-scale investigation of highly anisotropic zinc alloys using crystal plasticity and inverse analysis. Materials Science and Engineering A, 729, 106-118, 2018.

*Speaker

(2) Xia, L., Raghavan, B., Breitkopf, P., Zhang, W. Numerical material representation using proper orthogonal decomposition and diffuse approximation. Applied Mathematics and Computation, Vol. 224, pp. 450-462, 2013.

(3) Kirchdoerfer, T., Ortiz, M. Data-driven computational mechanics. Computer Methods in Applied Mechanics and Engineering, 304, 81-101, 2016.

(4) Jin, J., Cauvin, L., Raghavan, B., Breitkopf, P., Dudda, S., Xiao, M. Towards a Data-Driven Paradigm for Characterizing Plastic Anisotropy using Principal Components Analysis and Manifold Learning. Engineering Applications of Artificial Intelligence, under submission.