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Uncovering Bias and Underestimated Errors in Neutron Diffraction Residual Strain Measurements

Typical one-standard-deviation measurement uncertainties in neutron and x-ray diffraction may often fail to account for the complexity of residual strain fields in additively manufactured components. In these methods, measured strains are collected at multiple orientations to describe an underlying strain tensor. However, when only a few measurements are used or the model is overly simplified, the resulting solution may deviate systematically from ground truth. In addition, uncertainties may be underestimated. In such cases, the stability (invariance) and systematic deviation (bias) of the solution cannot be assessed without collecting more data than the minimal inverse solution requires. This research demonstrates how bias and variance are evaluated when calculating strain tensors with complex strain states, using data collected from a solid-state additive component via neutron diffraction. Bias, which is typically unknowable, can be evaluated in this special case, since each measured strain must satisfy common strain transformation. In addition, the analysis will be extended to a reference sample (i.e., ring-and-core) with a known stress state to demonstrate that this phenomenon of underestimated uncertainties is generalizable to the broader neutron diffraction / residual stress community. Suggestions based on the critical number of measurements needed to evaluate systematic effects (underestimated uncertainty) will be made based on the analyses of both the additive and reference samples.

Topical Area

Emerging research and multimodal techniques

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