Enhanced efficiency in the virtual stress boundary (VSB) method

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TL;DR – We made the VSB method more efficient without reducing accuracy.

The hybrid Lagrangian-Eulerian nature of the material point method (MPM) indicates that nonconforming boundaries are often an unavoidable component of numerical simulations. Accurately and efficiently imposing boundary conditions in the presence of these nonconforming boundaries remains a classic challenge. Traditional approaches to impose nonconforming Neumann boundary conditions rely on boundary tracking and reconstruction, both of which necessitate precise knowledge of the material boundary's position. In contrast, the recently developed virtual stress boundary (VSB) method offers a novel approach by imposing nonconforming Neumann boundary conditions without requiring the exact boundary position. This is achieved through a problem transformation that replaces the boundary traction with an equivalent virtual stress field. The problem transformation introduces a modification to the governing equations, which ultimately enables the imposition of boundary traction using only particle-wise quadrature. The VSB method has been shown to incur lower computational costs than traditional approaches while providing comparably accurate results with good convergence properties.

This presentation will cover a recently published update for the VSB method, which eliminates cell-wise quadrature from the original formulation. It will be shown that this simplification further improves the VSB method's efficiency without compromising accuracy or convergence behavior. Additionally, this presentation will highlight recent advancements in coupling the VSB method with high-order variations of the MPM, such as the generalized interpolation material point (GIMP) method and the B-Spline MPM.

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