Large Stress Calculations with Material Point Methods

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A 1D bar with fixed ends and a constant nonzero initial stress is not a dynamic system; the velocity, stress, and density of the bar should be at their initial values for all times. However, both MPM and DDMP have problems calculating such a system, when the initial stress is large. This causes difficulties when modeling phenomena such as thermal expansion of a material with boundary constraints.

The root cause of this issue is the numerical errors in the calculation of the sum of the gradient of the shape functions. Summing over all of the shape function gradients is supposed to be zero, with numerical errors, the value is very small, but never exactly zero. Given that a nodal force is calculated by the sum of the shape function gradients weighted by the particle stresses and volumes, the error in the nonzero sum of the shape function gradient is, therefore, multiplied by the initial stress, greatly amplifying the error in the nodal force, resulting in unexpected dynamics in a pre-stressed 1D bar.

It is possible to modify the nodal force calculation to include an auxiliary stress field in order to reduce the numerical error. Preliminary results suggest that this relatively easy fix is effective in improving the simulation stability of a pre-stressed 1D bar when using either MPM or DDMP.

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