Spectral Analysis of Regular Material Point Method and its Application to Study High Pressure Reverse Osmosis Membrane Compaction and Embossing

Authors: *Sreejith N. A.*, Hariswaran Sitaraman, Nick Deak, Marc Day

Material Point Method (MPM) is gaining widespread interest in applied continuum mechanics. The fact that all the continuum properties are stored on the particles (or material points) and the governing equations are solved on these material points makes MPM extremely suited to problems involving severe material deformations, such as crack propagation, soil movement, and fluid flows.

Despite its popularity, only a few studies have focused on the numerical properties of MPM. This presentation introduces a global spectral analysis of the regular material point method. Contrary to previous studies, the analysis focuses on the numerical properties of the method in the spectral space. The amplification factor is derived as a function of the non-dimensional wave numbers. It provides insights into the stability and dissipative properties of the method for various CFL and Fourier numbers. The effect of the grid shape functions, number of particles per cell and their locations inside the grid cell are also analyzed.

The EXAGOOP MPM solver (https://github.com/NREL/Exagoop.git) is developed at the National Renewable Energy Laboratory as a part of the NAWI UHPRO project and is based on the AMReX framework. A single-level, uniform cartesian grid is used as the background mesh, while the particle class in AMReX is used to manage the material point operations. Linear hat and B-splines are used as grid shape functions, while the time integration is performed using explicit Euler time integration. EXAGOOP is both CPU and GPU compatible and has been demonstrated to work well on multiple compute architectures. The performance of EXAGOOP on various computing architectures is presented along with its application to study compaction and embossing of high-pressure reverse osmosis membranes. The MPM solution accurately reproduces the membrane deformation. The deformed pore size and structure simulated using MPM also agree well with experimental SEM images.