v-p Form Material Point Method for Weakly Compressible Problems

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Abstract

Weakly compressible material point method (WCMPM) suffers from volumetric-locking and numerical oscillation in modeling fluid flow and fluid-structure interaction (FSI) problems. Hence, Mast et al employed the Hu-Washizu multi-field variation principle in the material point method (MPM) to mitigate the volumetric-locking. However, their proposed algorithm requires the inverse of two large matrices (15×15) and 30 float numbers to obtain and store the polynomial coefficients respectively for each node or cell in order to construct a linear field. To overcome these disadvantages, a v-p form material point method (vp-MPM) is proposed. In the v-p formulation, a linear equation with only four variables is solved to determine the polynomial coefficients of a linear pressure field. The required memory is reduced to only four float numbers, which are needed to store the coefficients for each node or cell. Thus, the v-p formulation requires much less calculation and memory than the Hu-Washizu multi-field formulation. Besides, a limiting process is proposed to further suppress the numerical oscillation. In order to extend the method to the fluid-structure interaction problems, the v-p formulation is incorporated into the improved coupling of finite element material point method (ICFEMP). Three numerical examples including an elastic wave propagation, a dam breaking and a water column interacting with an elastic obstacle are studied to verify the vp-MPM. Numerical results show that the pressure distribution is greatly improved by the vp-MPM and the obtained surface profile is much smoother than that of the MPM and GIMP. For the vp-GIMP, only about extra 30% cost is needed for the smoothing procedure compared with the GIMP.

Keywords: **v-p formulation, material point method, weakly compressible, volumetric-locking**