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An Alternative Updated Lagrangian Formulation for Finite Particle Method

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ABSTRACT

The Finite Particle Method (FPM) is a typical meshfree particle method, which is developed on the basis of standard smooth particle hydrodynamics (SPH) method. Like other collocational meshfree particle method, the conventional updated Lagrangian FPM with Eulerian kernels suffers from tension instability problem. To tackle this problem, an updated Lagrangian formulation with Lagrangian kernels for the FPM method is proposed. With this formulation, the configuration is updated for each increment step, but the initial neighboring particles for particle approximation are kept. To avoid saving the information of the initial configuration in the numerical procedure, a step-by-step transformation scheme is proposed for updating the kernels with the configuration. Numerical examples are provided to demonstrate that the proposed numerical method is (i) effective in eliminating tension instability problem; (ii) can provide as good solution as a total Lagrangian scheme at a similar computational cost; and (iii) has potentials in solving fluid-solid interaction problems and problems with very large distortion.

KEY WORDS: Finite Particle Method; Updated Lagrangian Formulation; Tension Instability; Solid Deformation.

1. INTRODUCTION

The Finite Particle Method (FPM) discussed in this work is a meshless particle method developed on the basis of the Smoothed Particle Hydrodynamics (SPH). Initially proposed to solve astrophysical problems [1] and hydrodynamics problems [2-4], the SPH has also been used as an alternative approach to model dynamic response and plastic flow of solids [5-8] in recent years. As a pure meshless particle method, SPH has certain advantages in solving solid mechanics problems with very large deformation. But the conventional SPH method suffers from some known deficiencies. Two major issues in SPH-like methods are often encountered (see, for instance, Belytschko *et al.* [6], Monaghan *et al.* [9, 10], Liu *et al.* [11]): (1) Poor accuracy of particle approximation near boundaries, which is mainly due to an inconsistent boundary treatment and incompleteness of particle support domains; (2) loss of numerical stability leading to the phenomena of hourglass and/or tension instability.

Concerning the first issue stated above, Chen *et al.* [12] proposed a modified formulation based on a Taylor series expansion. The new formulation is termed a Corrective Smoothed Particle Method (CSPM) which can improve significantly the precision of particle approximation near or on the boundary. Bonet *et al* [13] also presented a modified SPH formulation that can ensure preservation of linear and angular momentum. Liu and his co-workers [14][15] developed the so-called Finite Particle Method (FPM) also based on a