Convergence analysis of the Affine Particle-In-Cell method and its application to the simulation of extrusion processes

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ABSTRACT

Simulation of extrusion processes represents a major challenge for typical numerical methods. In our application for example, a hot melt is extruded and simultaneously cooled. Due to this quenching, a spinodal phase separation occurs which causes the formation of a characteristic microstructure of the extrudate, consisting of solid-like and liquid-like phases. We model this process using the affine particle-in-cell method (APIC) [3], due to its advantages for simulating both fluid and solid behaviour: pure Eulerian particle methods, such as the classic SPH, would fail for simulating solids, particularly in tension, whereas pure Lagrangian methods generally cannot cope with large deformations caused by the material flow.

In this work we discuss the recently developed APIC, which is a hybrid particle/grid method. The APIC improves upon the original Particle-In-Cell (PIC) method [1, 2] by using a so-called locally affine velocity representation [3] which allows the conservation of linear and angular momentum without the need of potentially unstable FLIP (Fluid-Implicit-Particle) technics. In our implementation of APIC, we use a staggered grid to suppress even-odd instabilities.

We analyse the convergence behaviour and compare accuracy against the original MPM method and one of the most efficient derivations such as the modified update stress last (MUSL) [4]. Since in our application the accurate modelling of velocity and temperature profiles is of great importance, the accuracy of APIC is shown in a series of benchmark simulations involving heat transfer and fluid flow. In addition, the simulation of spinodal decomposition is introduced.

Finally, we present the results of 2D-simulations of an extrusion process using APIC and compare them with experimental observations. Hence, the capabilities of APIC are demonstrated in the simulation of a multi-physics problem.

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