AN ENTROPY-STABLE SMOOTH PARTICLE HYDRODYNAMICS ALGORITHM FOR LARGE STRAIN THERMOELASTICITY

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ABSTRACT

Building upon previous work developed by the authors [1, 2, 3], this paper will present an upwind Smooth Particle Hydrodynamics (SPH) algorithm for a first order conservation law framework in large strain thermo-elasticity. In this work, a system of conservation equations will be expressed in terms of the linear momentum and the minors of the deformation, namely deformation gradient tensor $F$, its co-factor $H$ and its Jacobian $J$. In this paper, in order to account for irreversible processes, the above system will require an additional conservation law and variable describing the total balance of energy in the system. This is known as the first law of thermodynamics which, in general, can be expressed in terms of total energy $E$ or entropy $\eta$. For completeness, both expressions for the first law will be presented and compared. For closure of the system, appropriate thermo-elastic model on the basis of a polyconvex stored energy function will be employed. Such polyconvex model will guarantee the existence of real wave speeds for the entire range of thermo-elastic deformation process.

From the spatial discretisation standpoint, an upwind SPH computational framework will be utilised [1]. In this approach, discontinuity of the conservation variables between any pair of particles leads to a Riemann problem, whose approximate solutions will be derived by means of an acoustic Riemann solver. For this reason, artificial user-defined stabilisation parameters typically used in the classical SPH formalism can be avoided. The overall SPH algorithm will be shown to satisfy the discrete version of entropy dissipation law via the Coleman-Noll procedure. In addition, we will also demonstrate the equivalence of the upwind SPH method and a stabilised non-ordinary state-based Peridynamics if a nodal integration is used. From the temporal discretisation standpoint, an explicit two stage total variation diminishing Runge Kutta time integrator will be employed.

A number of benchmark tests will be presented in order to assess the capability and robustness of the proposed algorithm. Both stresses and temperature converge at the same rate as velocities and displacements. This is in clear contrast to the classical displacement-based formulations where derived variables (e.g. stresses and strains) converge at one order below the rate of displacements. Finally, and for benchmarking purposes, comparisons with other in-house finite volume or finite element methodologies will be provided.

REFERENCES

