Contact smoothed particle hydrodynamics method with enhanced spatial accuracy

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The smoothed particle hydrodynamics with the Riemann problem solution at interparticle contacts [1] (CSPH) is widely used to model compressible flows with discontinuities. This Godunov-type scheme provides stable and monotonous solutions, despite its high numerical viscosity. As it was demonstrated [2], the numerical viscosity of the method linearly depends on the particle size and can exceed the physical viscosity of materials, leading to excessive smearing of shock wave fronts and rapid damping of sound waves. Furthermore, the assumptions made for approximation of the right-hand sides of equations using CSPH method result in a further reduction in accuracy. To address the issues mentioned, we have improved the contact evaluation for CSPH technique with using MUSCL (monotonic upstream-centered scheme for conservation laws) value reconstruction at the interparticle contact [3]. The core of this method is in calculating the gradients of physical quantities, which allow to extrapolate hydrodynamic variables to the contact plane between particles and to improve the quality of the Riemann problem solution. We have also introduced a kernel gradient correction scheme to enhance the accuracy of the right-hand side approximations of the governing equations. The developed approach is suitable for modeling not only fluids, but also elastic-plastic media. The method is validated on a set of problems, including Sod's test, cumulation, and viscous flows.

[1] Parshikov A N and Medin S A 2002 *J. Comput. Phys.* **180** 358
[2] Parshikov A N, Medin S A, Rublev G D and Dyachov S A 2024 *Phys. Fluids* **36** 013101
[3] Xiaoyan H, Song J and Ruili W 2016 *Math. Meth. Appl. Sci.* **39** 1093–1100