LABORATOIRE D'HYDRAULIQUE SAINT-VENANT

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Report on the thesis of Mr. Ondrey KINCL with a view to obtaining the degree of doctor from Charles University

Mr. Ondrey KINCL's thesis dissertation concerns an innovative formulation of the SPH method, based on a new approach recently proposed by Peshkov et al. (2018) to unify the laws of continuum mechanics from Poisson brackets for fluids. This approach offers a common formalism for fluids and solids, where shear forces find a hyperbolic form while satisfying conservation laws and thermodynamic principles. It presents fundamental consequences on the understanding of the physics of continuous media, but also on numerical modeling thanks to schemes appropriate to the propagation of invariants. We can regret that these schemes, widely used with SPH since the work of Vila (1999), were not implemented in this work, probably due to lack of time. This might be a topic of investigation for a possible continuation.

Chapter 1 sets out the foundations of the SPH method quite briefly but clearly. There we find a general conservation law offering a basis for writing the SPH equations in the form of Poisson brackets. Mr. Kincl also proposes a study of convergence, existence and uniqueness of the solutions of regularized Euler equations, based on the previous work of Wendland, in particular. Although the main result must be disappointing – by Mr. Kincl's own admission, this work is very interesting and well conducted. We can only regret the omission of the Violeau and Fonty (2016) reference on the exact evaluation of the smoothing error of the SPH method: can this additional feature improve the proposed proof? A first classical test is finally presented on the basis of a symplectic integrator. It would be interesting to investigate the benefit of such schemes while some authors contest the necessity of variational integrators for SPH compared to higher order conventional schemes.

Chapter 2 is the heart of the theoretical work of Mr. Kincl's thesis. It briefly but clearly presents the equations of Peshkov et al. and the process of their construction. It compares their solution to that of the Navier–Stokes equations for a linearized simply sheared flow. M. Kincl then proposes a conservative and renormalized discrete SPH version. The theory of renormalization of SPH to order one is elegantly revisited. Two examples conclude this chapter: the bending of a beryllium beam and the traditional lid-driven cavity, in order to show the fluid-solid versatility of the model. The quality of the chapter must be highlighted in terms of the scientific content and innovation it presents.

Chapter 3 also deserves the same praise. It is devoted to the modeling of superfluid helium 4. The Poisson bracket method for fluids is used to establish the equations of a theoretical model close to the two-fluid

model of Landau (1958). The pressure is treated there by a linearized barotropic equation of state, as in the Weakly Compressible SPH variant. The latter is then retained for the discretization of the continuous equations with a classical treatment of irreversible terms guaranteeing the second law of thermodynamics. A brief analysis of the acoustics of the second sound is proposed, then an application to the superfluid fountain effect. The model gives very encouraging results despite a gap concerning the consideration of vorticity. Recent publications on how the viscous forces in particle methods can be addressed through particle spin (intrinsic vorticity) might pave the way to circumvent this issue.

Mr. Kincl's work is of high scientific quality, concise, well presented, well documented, pleasantly illustrated. It demonstrates good mastery of scientific content and the writing of an educational scientific document. The content itself is remarkable in its innovation for applications of the SPH method, but also for fluid physics itself. It is also accompanied by at least three articles in high-level specialist journals, an excellent publication rate for a doctoral student.

In conclusion, I give a very favorable opinion to the oral defense of Mr. Ondrey KINCL, with a view to obtaining the degree of doctor from Charles University.

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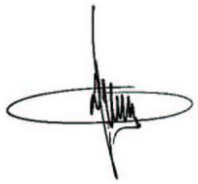

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