Fifth Workshop on Compressible Multiphase Flows

Rapport sur les contributions

https://indico.math.cnrs.fr/e/9225

ID de Contribution: **2** Type: **Non spécifié**

Symmetric-hyperbolic conservation laws to model viscoelastic flows as Maxwell fluids

mardi 6 juin 2023 09:00 (1 heure)

Invités Workshop Strasbourg 2023
https://indico.math.cnrs.fr/event/9225/
Conférences invitées:
Sébastien BOYAVAL
Titre : Symmetric-hyperbolic conservation laws to model viscoelastic flows as Maxwell fluids
Abstract: Many Partial Differential Equations (PDEs) have been proposed to model viscoelastic flows. Seminal hyperbolic PDEs have been proposed by Maxwell in 1867 for 2D elastic fluids with stress relaxation, to ensure propagation of 1D shear waves at finite-speed while capturing the viscosity of real fluid continua. But actual computations of multi-dimensional viscoelastic flows using Maxwell's PDEs have remained limited, at least without additional diffusion that blurs the hyperbolic character of Maxwell's PDEs. We propose a new system of PDEs to model 3D viscoelastic flows of Maxwell fluids. Our system, quasilinear and symmetric-hyperbolic, unequivocally models smooth flows on small times, while ensuring propagation of wavesat finite-speed. It is inspired by the K-BKZ integral reformulation of Maxwell PDEs (proposed independently by Kaye and Bernstein, Kearsley, Zapas), but it is purely differential with additional variables for the fluid material properties, therefore more versatile. Our system rigorously unifies fluid models with elasto-dynamics for compressible solids, and it can be manipulated for various applications of the viscoelastic flow concept in environmental hydraulics (shallow-water flows) or materials engineering (non-isothermal flows).

Orateur: BOYAVAL, Sébastien (Ecole des Ponts ParisTech, Laboratoire d'hydraulique Saint-Venant)

ID de Contribution: **3** Type: **Non spécifié**

Helicity in dispersive continuum mechanics

mardi 6 juin 2023 14:00 (1 heure)

New conservation laws are obtained for the equations of dispersive continuum mechanics describing Euler–van der Waals–Korteweg's fluids, fluids containing small gas bubbles, and long–free surface gravity waves (Serre–Green–Naghdi equations). The corresponding mathematical models are characterized by the dependence of the energy on spatial and temporal derivatives of the density. In particular, analogs of helicity invariants are deduced.

Orateur: GAVRILYUK, Sergey (Aix-Marseille Université)

ID de Contribution: **4** Type: **Non spécifié**

A relaxation approach for modeling turbulence in compressible flows

lundi 5 juin 2023 15:30 (1 heure)

In this talk, a thermodynamical approach for modeling turbulence in compressible flows will be presented. Modeling of muti-component flows following a thermodynamical (homogeneous) point of view is known to ensure that the resulting models inherit from several very important mathematical properties such as : hyperbolicity, entropy inequality and uniqueness of the definition of the shocks through Rankine-Hugoniot relations. This last property is difficult to obtain when considering the classical approach for modeling turbulence and it will be shown that thermodynamical modeling can help to tackle this point.

Orateur: HURISSE, Olivier (EDF R&D)

ID de Contribution: **5** Type: **Non spécifié**

A unified arbitrary-rate mechanical relaxation technique for compressible two-phase flows

mercredi 7 juin 2023 09:00 (1 heure)

Our goal in this talk is to describe an extension of the arbitrary-rate mechanical relaxation techniques proposed by M. Pelanti [2] for compressible two-phase flows with non-barotropic equations of state to a barotropic two-phase flow, and a hybrid barotropic and non-barotropic two-phase flow. As in [2], we could derive the same first-order ordinary differential equation for the difference in the phasic pressure Δp = p_1−p_2 of the form
(1) ∂_t Δp = μ (Z_1 + Z_2) Δp,
but with a different expression of the thermodynamic variable Z_k for k representing the phase of a barotropic flow. It follows that the exact solution of (1) can be used as usual for the solution update in the mechanical relaxation step of the algorithm with the finite-rate relaxation parameter μ over a time step, irrespective of the difference in the equations of state to the two-phase flow. We use the state-of-the-art finite volume method for the numerical solution of the homogeneous part of the model system without the relaxation terms. Sample numerical results will be present to show the feasibility of the algorithm for practical applications. A generalization of the current relaxation technique to a three-phase flow (cf. [1]) will be discussed briefly.

[1] M. Pelanti and K.-M. Shyue, A numerical model for multiphase liquid-vapor-gas flows with interfaces and cavitation. Intl. J. Multiphase Flow, 113:208–230, 2019.

[2] M. Pelanti, Arbitrary-rate relaxation techniques for the numerical modeling of compressible two-phase flow with heat and mass transfer. Intl. J. Multiphase Flow, 153:104097, 2022.

Orateur: SHYUE, Keh-Ming (National Taiwan University)

ID de Contribution: **6** Type: **Non spécifié**

Which future for Van der Waals type equations of state?

mercredi 7 juin 2023 11:30 (1 heure)

Despite the criticism that the Van der Waals theory behind them is too simple, despite the many attempts to replace them with more sophisticated models, despite their well-documented shortcomings, it is a fact that the cubic equations of state (CEoS) are still around, and in industry in particular. Derived from the seminal work of Van der Waals, CEoS appear indeed as reference models for people from industry working on the simulation and design of processes involving from non-associating to weakly-associating compounds. Since the 1950's, people working on CEoS have gained experience on this class of models and a number of pertinent improvements have been proposed all through the years to overcome or reduce their shortcomings.
Through this presentation, we will show how the potential of cubic equations of state for describing mixture properties has been boosted by decades of progress.
In this study, we present some arguments to convince the reader that further development of this family of models is necessary and that promising results are expected in return.
With Francisco Paes, Jean-Noël Jaubert.

Orateur: PRIVAT, Romain (Université de Lorraine)

ID de Contribution: **7** Type: **Non spécifié**

On derivation and analysis of traffic and lubrication models

mercredi 7 juin 2023 10:30 (1 heure)

I will present our latest developments on the generalization of the Aw-Rascle model of traffic. These include existence and non-uniqueness results and also singular limit analysis leading to certain hard-congestion model. The latter model has been studied in the context of lubrication forces for the motion of rigid bodies in a viscous fluids. The proof of the singular limit will be presented in one-space dimensional case with periodic boundary conditions. I will also comment on the open problems related to generalisation of this result.

Orateur: ZATORSKA, Ewelina (Imperial College London)

ID de Contribution: **8** Type: **Non spécifié**

On structure-preserving schemes for continuum mechanics

mardi 6 juin 2023 10:30 (1 heure)

In this talk we present two new classes of structure-preserving schemes for hyperbolic and thermodynamically compatible (HTC) systems with involution constraints, which have been studied for the first time by Godunov in 1961 and later in a series of papers by Godunov & Romenski. In particular, we consider the unified first order hyperbolic model of continuum mechanics proposed by Godunov, Peshkov and Romenski (GPR) that is able to describe the behavior of moving elasto-plastic solids as well as viscous and inviscid fluids within one and the same governing PDE system. The homogeneous part of the GPR model is endowed with involution constraints, namely in the absence of source terms the distortion field A and the thermal impulse J need to remain curl-free for all times.

In the first part of this talk we present a new staggered semi-implicit structure-preserving scheme that is able to preserve the curl-free property of both fields exactly also on the discrete level. Furthermore, the pressure terms are discretized implicitly, in order to capture the low Mach number limit of the equations properly, while all other terms are discretized explicitly. Last but not least, the new staggered semi-implicit scheme is also able to reproduce the stiff relaxation limit of the governing PDE system properly, recovering an appropriate discretization of the compressible Navier-Stokes equations.

In the second part of the talk we present a new thermodynamically compatible finite volume scheme that is exactly compatible with the overdetermined structure of the model at the semi-discrete level, making use of a discrete form of the continuous formalism introduced by Godunov in 1961. A very particular feature of our new thermodynamically compatible finite volume scheme is the fact that it directly discretizes the entropy inequality, rather than the total energy conservation law. Energy conservation is instead achieved as a mere consequence of the scheme, thanks to the thermodynamically compatible discretization of all the other equations.

Computational results for several test cases are presented in order to illustrate the performance of the new schemes.

References

[1] S.K. Godunov. An interesting class of quasilinear systems. Dokl. Akad. Nauk SSSR, 139:521–523, 1961

[2] S.K. Godunov and E.I. Romenski. Nonstationary equations of nonlinear elasticity theory in Eulerian coordinates. Journal of Applied Mechanics and Technical Physics, 13:868–884, 1972

[3] E. Romenski. Hyperbolic systems of thermodynamically compatible conservation laws in continuum mechanics. Mathematical and Computer Modelling, 28:115-130, 1998

[4] I. Peshkov and E. Romenski. A hyperbolic model for viscous Newtonian flows. Continuum Mechanics and Thermodynamics, 28:85–104, 2016

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[9] R. Abgrall, S. Busto and M. Dumbser. A simple and general framework for the construction of thermodynamically compatible schemes for computational fluid and solid mechanics. Appl. Mathematics and Computation, 440:127629, 2023

[10] S. Busto and M. Dumbser. A new thermodynamically compatible finite volume scheme for magnetohydrodynamics. SIAM Journal on Numerical Analysis, 61:343-364, 2023

Orateur: DUMBSER, Michael (Università di Trento)

ID de Contribution: **9** Type: **Non spécifié**

Hamiltonian mechanics of superfluid helium-4 with numerical applications

mardi 6 juin 2023 11:30 (1 heure)

At very low temperatures (less than 2.17 K), helium becomes superfluid. For instance, it flows through narrow capillaries with no resistance. Although traditional models describe superfluid helium as a mixture of a normal component and a superfluid component, helium is actually a pure substance, not a mixture, that exhibits two motions. In order to describe the two motions, we use geometric mechanics, that connects classical continuum mechanics with the underlying quantum mechanics. Another aspect of superfluid helium is the presence of quantum vortices, topological defects of the phase of the wave function. Hamiltonian mechanics helps to include quantum vortices and to formulate a numerical scheme based on smoothed-particle hydrodynamics. As an application, we show a simulation of the superfluid fountain effect, where heating is converted to the motion of helium.

Orateur: PAVELKA, Michal (Charles University)

ID de Contribution: **10** Type: **Non spécifié**

Exemples d'études expérimentales d'écoulements diphasiques turbulents : analyse de l'influence de la phase dispersée sur la phase porteuse

lundi 5 juin 2023 14:00 (1 heure)

On présentera ici des exemples d'études expérimentales d'écoulements diphasiques avec et sans changement de phase pour lesquelles on montrera comment la phase dispersée (vapeur ou gaz) peut modifier la phase porteuse (liquide ou gaz). On s'attachera en particulier à quantifier les modifications des structures de la turbulence dans le cas d'un écoulement turbulent cavitant (de type marche descendante ou autour d'obstacle de type plan porteur) ainsi que dans le cas d'un écoulement turbulent d'air et de gouttelettes (effet des particules inertielles sur le sillage de plaques inclinées).
(Collaborateurs : S. Barre, G. Maurice, M. Obligado, S. Smith)

Orateur: DJERIDI, Henda (LEGI / G-INP)

ID de Contribution: **11** Type: **Non spécifié**

Relaxation au sein d'un mélange de trois phases immiscibles

Orateurs: JOMÉE, Guillaume (EDF R&D); HÉRARD, Jean-Marc (EDF R&D)

ID de Contribution: **12** Type: **Non spécifié**

A multi-component multi-temperature model for simulating laminar deflagration waves in mixtures of air and hydrogen

Orateur: HURISSE, Olivier (EDF R&D)