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Local Equilibrium in Liquid Phase Shock Waves

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Porous media can experience shock waves under certain conditions, for instance under ultrasound exposure [1]. Shock waves are also observed in typical Hele-Shaw cells, during Haines jumps [2]. Modelling this is a vital part for understanding these complex phenomena. The question therefore arises; is it possible to use the governing equations for systems without shock waves; the balance laws and the constitutive equations, to model the fluid at the shock front? In this work, we consider the shock front in a liquid to examine the validity of non-equilibrium thermodynamic- and the hydrodynamic (Navier-Stokes) equations. In particular, we investigate the assumption of local equilibrium. Results from non-equilibrium molecular dynamics (NEMD) simulations are compared with numerical solutions of the Navier-Stokes (N-S) equations for supersonic shock waves with a Mach number near 2. The waves generated by the two types of simulations, travelled with nearly the same speed. The average absolute Mach-number deviation of the N-S simulations relative to NEMD was 2.6% in the considered time interval.

Five different methods to compute the surface excess entropy production were compared.

Three of the methods use the local equilibrium assumption as if the shock were a bulk system, and two of the methods assume local equilibrium between excess thermodynamic variables by treating the shock as a Gibbs dividing interface. The methods give excess entropy productions that are in excellent agreement, with an average deviation of 3.5% in the time-interval considered for the NEMD-simulations. For the shock wave studied in this work, we found that local equilibrium holds for the excess surface variables, but also for finer divisions of the planar wave. Our findings confirm the results we found by analyzing a shock wave travelling in a gas-phase [3], namely that local equilibrium holds for the excess surface variables and that local equilibrium is a good approximation for the bulk variables in the classical sense at the shock front also in the liquid phase. This can be regarded as a first step in the direction of computations of shock wave dissipated energy in porous media.

Participation

In-Person

References

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