Spectral analysis of Bazarov's piston

S. Velasco, B. Jiménez de Cisneros, J.M.M. Roco* and J.A. White
Departamento de Física Aplicada
Universidad de Salamanca
37008 Salamanca

We consider a hard-disk gas contained in an adiabatically isolated cylinder with a movable, frictionless, adiabatic piston under constant external pressure. The power spectrum of the position of a piston at equilibrium is investigated. The analysis is made by means of molecular dynamics simulations and hydrodynamics. For different piston masses we obtain results for the main times scales involved in the problem: the piston frequency and its damping constant.

The model (see Fig. 1) consists of a simplified version of the *adiabatic* piston. It presents the advantage that it has a well-defined thermodynamic solution.[1] On the other hand, this model does not present the time evolution from mechanical equilibrium to full thermodynamic equilibrium characteristic of the *adiabatic* piston.[2]

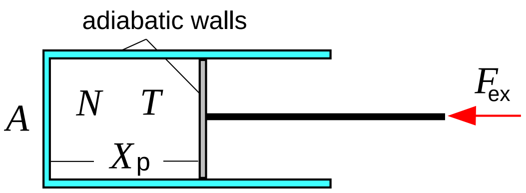

Figura 1. Bazarov's piston.

From a theoretical viewpoint, an analysis of the system near equilibrium is performed by assuming that the fluid displacement is approximately described by $\xi(x,t) \approx \sin(kx)f(t)$ where k is an effective wavelength of the system. An equation for the wavelength is derived in terms of the mass of the piston M and hydrodynamic parameters. Comparison with simulation shows that this equation is very accurate in predicting the piston frequency. Finally, an equation of motion for the piston is obtained in terms of an effective mass that is itself a function of the wavelength k.

Previous work[2] showed that the power spectral density $S(\omega)$ of the position of the *adiabatic* piston at equilibrium presents a three peak structure with a thermal mode associated to the *slow* motion of the piston from mechanical equilibrium to full thermodynamic equilibrium and a sound mode related to the damped oscillating behavior of the piston. A similar behavior is found for the sound mode in Bazarov's piston but the thermal mode characteristic of the *adiabatic* piston is absent in Bazarov's piston. This behavior is shown in Fig. 2 where we note that one must keep the same ratio between piston mass and the mass of the particles in both systems and this implies half piston mass in Bazarov's model compared to the *adiabatic* piston. Finally we would like to note that a second harmonic arises in the spectrum as a consequence of the asymmetry of the effective potential in Bazarov's model.

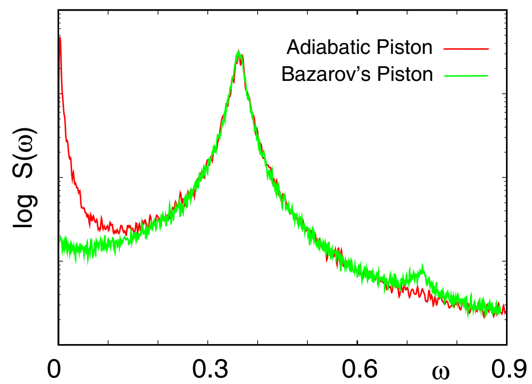

Figura 2. Power spectral density of the position of the piston at equilibrium. Bazarov's piston with $M = 50$ vs the *adiabatic* piston with $M = 100$.

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* roco@usal.es

[1] *Application of thermodynamic extremum principles*, C. Fernández-Pineda and S. Velasco, Am. J. Phys. **69**, 1160 (2001).

[2] *The 'adiabatic' piston at equilibrium: Spectral analysis and time-correlation function*, J.A. White, F.L. Román, A. González, and S. Velasco, Europhys. Lett. **59**, 479 (2002).