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# PROGRAM & ABSTRACTS

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# Similarity Parameters for Shock Waves in Dense Fluids

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As it is well known, the structure of a shock wave depends on the initial thermodynamic parameters of the medium and the velocity of the shock. In a dilute gas, if the parameters of the medium inside the shock are related to their initial values and the space coordinate is measured in mean free paths, this may be reduced to dependence on two non-dimensional parameters: adiabatic exponent $\gamma = c_p / c_v$, characterizing the medium, and shock Mach number $Ms = U/a$, ($U$ – shock velocity, $a$ – sound speed in front of the shock).

In a dense medium the above is no longer true: for description of the shock structure the mean distance between the centers of the neighbouring molecules, λ (lambda), must be used instead of the mean free path [1]. Apart from that, another set of non-dimensional parameters must be introduced.

To specify the necessary non-dimensional parameters, a number of Molecular Dynamics simulations of shock waves in noble gases (helium, neon, argon, krypton, xenon), at high initial densities were performed. Interactions between the atoms were described with the Lennard-Jones potential [2]. For simulations the suitably modified program "MOLDY" [3] was used.

The obtained results indicate, that to describe the shock structure in the considered noble gases the following three parameters may be used: $\rho = n\sigma^3$ – non-dimensional density, ~~$\theta = T/(k\varepsilon)$~~ $\theta = TB/\varepsilon$ – non-dimensional temperature, $\omega = U/c_m$ – non-dimensional shock velocity.

The used symbols are: $n$ – number density of the medium in front of the shock, $\sigma$ – "diameter of a molecule" (parameter of the Lennard-Jones potential), $T$ – temperature in front of the shock, $\varepsilon$ – "depth of the potential well" (parameter of the Lennard-Jones potential), $B$ – universal gas constant, $c_m$ – most probable molecular speed in front of the shock.

Figure 1 presents the shock structures (density distributions) for the five noble gases, as obtained from the Molecular Dynamics simulation. The values of the non-dimensional similarity parameters for each of them are: $\rho = 0.5978$, $\theta = 2.5042$, $\omega = 4.665 \pm 0.035$.

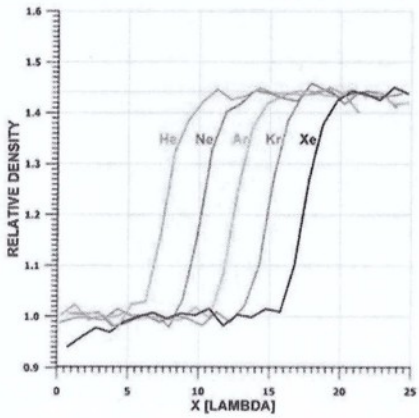


**Fig. 1.** Structures of shock waves in noble gases at $\rho = 0.5978$, $\theta = 2.5042$, $\omega = 4.665 \pm 0.035$.

The presented shock structures are nearly identical, which suggests that $\rho$, $\theta$, $\omega$ are correctly selected similarity parameters for shock waves in dense, noble gases.

For comparison, in Figure 2 two shock wave structures, in dense argon and xenon, for the same initial, non-dimensional densities $\rho$ = 0.5978, non-dimensional temperatures $\theta$ = 2.5042, and shock Mach numbers $Ms$ = 2.14, are shown (it should be noted, that for these shocks the non-dimensional shock velocities $\omega$ are not equal – their values are 4.656 and 4.329 respectively).

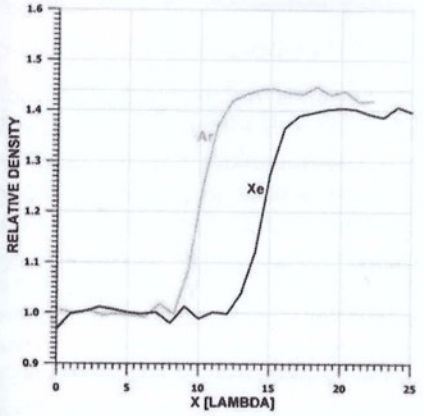


**Fig. 2.** Structures of shock waves in argon and xenon at $\rho$ = 0.5978, $\theta$ = 2.5042, $Ms$ = 2.14.

The structures of these shocks are evidently different – the density increase in the xenon shock is appreciably smaller than that in argon. This suggests, that the shock Mach number is not a valid similarity parameter for the shock wave structures in dense media, contrary to the case of dilute gases.

Investigation of this problem will be continued and will be extended to the media consisting of more complex, polyatomic molecules.

**References:**


1. Walenta Z.A., Slowicka A.M.: Structure of shock waves in dense media. *Shock Waves*, ed. K. Kontis, ISBN:978-3-642-25687-5 (2012).
2. Allen M.P., Tildesley D.J.: Computer Simulation of Liquids, (Clarendon Press, Oxford, 1987).
3. Refson K.: Moldy: a portable molecular dynamics simulation program for serial and parallel computers. Comput. Phys. Commun. bf 126 (3) 309–328 (2000).