Propagation of acoustic disturbances in N-fractional gas-liquid systems

D.A. Gubaidullin, A.A. Nikiforov, E.A. Teregulova and R.N. Gafiyatov

Institute of Mechanics and Engineering, Kazan Science Center, Russian Academy of Sciences, Kazan, 420111, Russia
Keywords: aerosol, waves, damping, heat and mass transfer.
Presenting author email: anikiforov1@yandex.ru

To-date, a large interest is the study of wave dynamics of dispersed media. A significant number of works on acoustics gas-liquid systems devoted to theoretical study of harmonic disturbances. Various problems of acoustics, gas mixtures and mixtures of liquids with bubbles of gas is considered in the well-known monograph (Nigmatulin, 1989). In the monograph (Temkin, 2005) the short review of results on research of acoustic disturbances in monodisperse gas-suspensions without phase transformations is given. In (Kandula, 2010) comparison of nonlinear and linear theories for the description of dispersion and sound dissipation in the diluted suspensions is carried out. In (Gubaidullin and Nikiforov, 2010) presented results of a theoretical study of propagation of acoustic disturbances in two-phase mixtures of liquids with vapor and gas bubbles for the cases of plane, spherical, and cylindrical waves. The propagation of acoustic waves in two-fraction mixtures of gas with vapor, droplets and solid particles of different materials and sizes in the presence of phase transitions is investigated in (Gubaidullin *et al*, 2011). In (Gubaidullin *et al*, 2012) investigated the dynamics of the weak perturbations in two-fraction mixtures of the liquid with vapor–gas and gas bubbles of different sizes and compositions taking into account the phase transformations in one of the fractions.

In this work propagation of acoustic waves in N-fractional mixtures of gas-liquid systems (gas with drops or liquid with gas bubbles, when the dispersed phase is presented by the inclusions of N different materials and sizes) is investigated. The mathematical models is presented, the dispersion relations and a wave equations are received and dispersion curves are calculated.

As an example on the received dispersion relation, dispersive curves for a three-fractional mix of air with particles of sand, ice and soot are calculated. In figures 1 dependence of decrement of attenuation on wavelength from the nondimensional oscillation frequency for a three-fractional mix of air with particles of sand of radius $r_a = 10^{-6}$ m and mass concentration $m_a = 0.05$, ice of radius of $r_b = 10^{-5}$ m and mass concentration $m_b = 0.1$ and soot of radius of $r_c = 8 \cdot 10^{-6}$ m with the various mass concentration (solid line $m_c = 0.15$, dash line $m_c = 0.35$, dash dot line $m_c = 0.55$) are shown. It is visible that with increase in the mass concentration of soot particles dissipation of waves grows. Decrement of attenuation on wavelength with increasing mass concentration of the soot particles increases not the entire range of nondimensional oscillation frequency. In this case, the decrement of attenuation increases less than in monodisperse gas suspension at the same the growth the mass concentration of the dispersed phase. As shown in figure 1, the difference between the size and thermophysical parameters of particles of each of fractions leads to emergence of three inflection curves for dependence of decrement of attenuation on wavelength in the frequency range inversely proportional to typical relaxation times of the phase velocity $\omega\tau_{va}$, $\omega\tau_{vb}$ and $\omega\tau_{vc} = 1$, here τ_{vj} is the relaxation time of phase velocities (Gubaidullin *et al*, 2011).

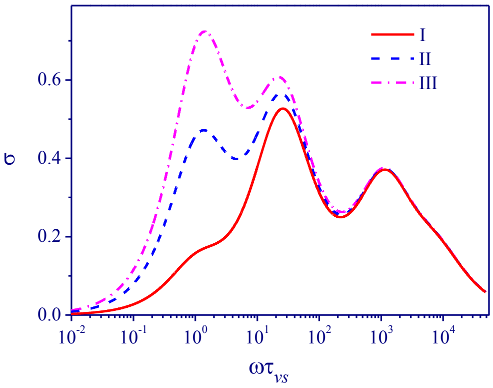

Figure 1. Dependence of decrement of attenuation on wavelength from the nondimensional oscillation frequency.

This work was supported by the Russian Fund of Foundation Investigation under grant 13-01-00135 and within the framework of the Federal target program "Scientific and scientific and pedagogical shots of innovative Russia for 2009-2013" (project №14.B37.21.0644).

Nigmatulin, R.I. (1989) *Dynamics of Multiphase Media*, Washington: Hemisphere.

Temkin, S. (2005) *Suspension acoustics: An introduction to the physics of suspension*, Cambridge University Press.

Kandula, M. (2010) *Journal of the Acoustical Society of America*, **127**(3), EL115-EL120.

Gubaidullin, D.A., Nikiforov, A.A. (2010) *High Temperature*, **48**(2), 170-175.

Gubaidullin D.A., Nikiforov A.A., Utkina E.A. (2011) *Fluid Dynamics*, **46**(1), 72-79.

Gubaidullin, D.A., Nikifirov, A.A., Gafiyatov, R.N. (2012) *High Temperature*, **50**(2), 250-254.