Acoustic waves in vapour-gas mixtures with polydisperse particles and droplets

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The propagation of small disturbances in two-component gas-vapour mixtures with polydisperse particles and drops in the presence of phase transitions is studied. A mathematical model is proposed, the dispersion relation is obtained. The effect of the droplet and particle polydispersity on the dispersion and dissipation of small disturbances is analysed.

Fig. 1 illustrate the effect of polydispersity of droplets and particles on the form of the decrement of attenuation on the wavelength on the nondimensional oscillation frequency $\Omega_{5,3} = \omega_2^{(5,3)}$, where $\omega_2^{(5,3)}$ is the oscillation frequency, $a_{5,3}$ is average radii Gubaidullin and Nigmatulin (2000). The calculations were performed using the dispersion equation Gubaidullin and Fedorov (2012) and the dispersion relation for the case of monodisperse droplets and particles Gubaidullin et al (2011). A mixture of ait with water vapour, water droplets and particles of ash was considered. The relative mass contents of droplets of water $m_a$ and ash particles $m_b$ we will take equal to 0.3. The pressure of the carrier phase $p_1 = 0.1$ MPa, temperature $T_0 = 271$ K. The radii of the droplets and particles were set as follows: curve 1 - $a = 10^{-4}$, $b = 10^{-6}$ m, curve 2 - $a = 10^{-5}$, $b = 10^{-7}$ m, curve 3 - $a \in [10^{-5},10^{-4}]$, $b \in [10^{-7},10^{-6}]$ m. Curve 1 is built on the monodisperse theory with maximum radii from the range, curve 2 is calculated on the monodisperse theory with minimum radii from the range, curve 3 - on polydisperse theory. Distribution functions of droplets and particles sizes: $N_0(a) = a^{-3}$, $N_0(b) = b^{-3}$.

Figure 1. Dependences of the attenuation decrement on dimensionless oscillation frequency

The presence of the two fractions in the mixture leads to the occurrence of two local maxima in the dependences the attenuation decrement per wavelength. Since in real fogs droplets and particles are mainly monodisperse, then, as it seen from fig. 1, the attenuation is not so strong comparably with calculations with monodisperse droplets and particles. It should be noted that the polydispersity, as well as the distribution functions of dispersed phases of sizes, substantially affect the dynamics of wave propagation.

There are experimental data Cole and Dobbins (1971) on the attenuation decrement in the wavelength in the particular case “vapour-gas-droplet” mixture without particles ($m_b = 0$). The radius of the droplets ranged from $10^{-6}$ up to $10^{-5}$ m. Three groups of the experimental points correspond to the three experiments carried out at different mass content of drops, and different temperatures (different concentration of vapour in the gas phase):

1 - $T_0 = 281$ K, $m_a = 0.0076$, $k_V = 0.012$
2 - $T_0 = 276$ K, $m_a = 0.0039$, $k_V = 0.008$
3 - $T_0 = 271$ K, $m_a = 0.0038$, $k_V = 0.006$

Note that because of the complexity of the experiment there is a large spread of experimental data 10-15%. In fig. 2 $\omega_2$ - the dimensionless oscillation frequency, where $\tau = 3\omega_2^{(3,1)} / (2m_b)$.

Figure 2. This is a comparison between theory and experimental data.

Overall, there is good agreement between theory and experiment.