Sedimentation of aerosols and drift of single particles at resonance oscillations in tubes

D.A. Gubaidullin, R.G. Zaripov and L.A. Tkachenko

Institute of Mechanics and Engineering, Kazan Science Center, Russian Academy of Sciences,
Kazan, 420111, Russia
Keywords: aerosol, coagulation and sedimentation, drift particles, oscillations.
Presenting author email: damirgubaidullin@gmail.com

In the present work, coagulation and sedimentation of a small-dispersed aerosol and dynamics of particles are considered in tubes with various geometry on the end near to resonant frequencies.

Experimental investigations of oscillations of an aerosol were carried out for different length of tubes in a shock-wave and shock-free wave modes near to subharmonic and natural resonances. Di-ethyl-hexyl-sebacate $C_{26}H_{50}O_4$ was used as the working fluid to generate aerosol. The majority of droplets have the geometric diameter 0.863 μm. Number concentration of drops for all experiments monotonously decreases with time and with growth of the excitation frequency. In the case of a closed tube, this process is defined by the coagulation of aerosol and sedimentation of droplets on the tube walls. In an open tube, the discharge of aerosol to the environment is observed in addition to the coagulation of aerosol and sedimentation of droplets on the tube walls. The dependence of the time scale of coagulation of aerosol in the closed tube and time scale of the clearing of aerosol in an open tube on the excitation frequency likewise exhibits a nonmonotonic pattern with a maximum and a minimum when passing the resonance. It is established, that presence of a flange slows down process of the cleaning of an aerosol. Reduction of internal diameter of a flange results in increase in the time scale of cleaning. In so doing, the time scale of the clearing of aerosol in the case of an open tube is reduced by a factor of two and more compared to the time of coagulation in a closed tube. It has been found that a decrease in the tube length and increase of oscillation intensity result in a decrease in the time scale of coagulation and time scale of cleaning of aerosol. It is shown, that with increase of intensity of the oscillations, the caused increase of amplitude, this time decreases. For the closed tube this dependence has nonlinear character, and for an open tube - almost linear. It is revealed that in a shock-free mode (for small amplitudes of displacement piston) the time scale of the coagulation of aerosol in the closed tube by 2-4 times, time scale of the clearing of aerosol in an open tube by 6-12 times and a partially open tube by 5-10 times lower than at natural sedimentation.

To study the mechanism of coagulation of the aerosol and the forces acting on the droplets and particles of aerosol in the wave field in the tube, the dynamics of single particles is considered. Dynamics of a single particle with various physical and geometrical parameters is experimentally investigated at the longitudinal oscillations gas in closed and open tubes in a shock-wave mode. Along an axis of a tube the particle moves from the closed (open) end to the piston, near to a wall – to the return side, making longitudinal oscillations with increase in the oscillations swing that is caused by acoustic streaming. In a radial direction, the oscillating particle moves from an axis to a wall of the tube up to a boundary point. Outside of a tube, the particle moves from the open end to an exterior wave field practically without oscillations with nonlinear increase of coordinate from time. It is revealed, that the increase in lengths of a tube and excitation frequency of gas in up to - resonant modes gives in growth of an oscillations swing of a particle and increase of its average velocity. Nonmonotonic character for dependence of oscillations swing and average velocity of a spherical particle from excitation frequency of gas is detected. At approach to a resonance oscillations swing and average velocity are incremented, attain the maximum value on a resonance frequency and decrease behind a resonance. Effect of a weight and diameter of a particle on its oscillations swing and average velocity is investigated. Shift of a curve maximum for dependence of a particle average velocity from oscillation frequency aside magnifications of frequency is shown at increase of a weight or diameter of a particle.

It is experimentally investigated the process of the particle drift over time in different sections of the tube and the external wave field at different frequencies and amplitudes of excitation of the gas in the shock-free wave mode. A particle placed near the open end of tube begins to move to the piston under the influence of the internal wave field. Its oscillating motion with amplitude and frequency significantly is lower than amplitude and frequency of oscillations of the gas due to friction of the fishing line and the weight of the particle. The particle is placed outside the tube close to the open end moves in an external wave field. It was not observed noticeable oscillations of a particle. A linear dependence was distances of time. Increase the amplitude of excitation of the gas increases the amplitude of oscillations and average velocity of the particle. Revealed the position of the particle, placed inside the tube in the vicinity of the open end, wherein the particle oscillates harmonically with no drift in any direction along the axis.

The study was performed by a grant from the Russian Science Foundation (project No.15-11-20022).