Experimental study of the droplets evolution upon impulse spray formation

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Abstract

This research is aimed at developing the experimental base and investigating the impulse formation of sprays, considering the evolving droplets in the dispersed flow. The work is urgent in view of the necessity to investigate the spray generation processes for prompt neutralization and deactivation of noxious aerosol and gas emissions as well as for suppressing fires and blast waves in coal mines. The spray formation process was simulated in laboratory conditions by applying a modified hydrodynamic tube-type device using a gas-generating pyrotechnic charge to intensify atomization. Considering the specific character of the impulse liquid atomization, we developed an experimental research complex comprising both the known and dedicated methods and procedures.

The high-speed video visualization of the impulse atomization showed that the spray has a conical symmetric shape, the liquid ejection from the atomizer is completed in 3 ms, the mean flow rate corresponds to ~200 m/s, the cloud is formed in 8 ms.

The laser measurement setup based on the low-angle laser light scattering method using a line of sight forward diffraction technique was employed to study the droplets dispersiveness parameters and spray evolution. The study revealed a limitation on measurements, which is caused by the multiple light scattering in the dispersed flow at the initial stage of its formation. To minimize the effect of the multiple scattering, it was suggested to employ a device in the form of a protective tube twice reducing the optical path length. The protective tube is placed in such a way as to isolate the probe laser beam on the half of the dispersed flow. The experimental investigation showed that under the used conditions the measurements using the protective tube can be run starting from 8 ms after the onset of the liquid atomization, whereas the protective tube is not employed, the measurements can be performed starting from 50 ms. The liquid spray produced by the impulse atomization was found to be fairly stable and stationary at the spray evolution stage.

Also to perform the work, an experimental method has been suggested that permits using the whole ensemble of droplets resulting from the atomization. The method consists in atomizing NaCl solutions, evaporating the solution droplets, and subsequently determining the disperse composition of droplets in the spray from the study results for the dry salt residue. The method is informative so far as the dry residue particle size is directly associated with the content of a nonevaporable impurity in the droplet, and the disperse composition of the initial droplets. As a result of the electron microscopy study of the droplets formed upon the impulse atomization of a 20% NaCl solution, it was found that their morphology may be different, that is, solid polycrystalline/monocrystalline structures and hollow spheroids which are also distinct in structure and sizes of crystals constituting their surface. The evaluation of the particles morphology showed that the droplets at the first several milliseconds after the formation underwent various interactions with the environment and their evaporation rates were significant. In other words, the salt residue particles are a sort of 'artifacts' reflecting the 'marks' of processes that occurred during atomization. In addition, when designing and testing impulse-type atomizing devices, the existence of hollow spheroids can serve as an 'indicator' of a maximally effective interaction between the dispersed flow and the environment at the initial stage of the flow formation and, hence, of a more effective liquid atomization.

As a consequence of the study, a general picture has been described for the droplet evolution upon the impulse atomization.