Breakup of stretched liquid threads at low gas relative velocities – Comparison of the laminar rotary atomization to the gravity condition

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Abstract

The gas-liquid-interaction at laminar operating rotary atomizers and its effect on the size distribution of the droplets are investigated. Experiments are carried out at a rotary atomizer and at single nozzles under g-force conditions. The similarity of the systems is satisfied. Based on the achieved results optimized rotary atomizers and drying-gas distributors will be developed and tested in a pilot scale spray tower as a method for the industrial scale production of narrow distributed particles.

Introduction

Laminar operating rotary atomizers distribute the liquid feed into multiple laminar open-channel-flows . After leaving the atomizer the liquid forms thin threads, which are elongated by centrifugal acceleration. Those thinned threads break up to droplets due to capillary instability (Rayleigh-Breakup). The intended breakup-mode leads to narrow distributed droplets. Furthermore the breakup of stretched threads leads to small droplet diameters. Thus small particle diameters can be achieved even by atomizers with large bores what improves the processability of liquids with plugging tendency. High throughput atomizers with multiple stages of bores have already been approved, too . A remaining problem is the droplet size distribution, which is still not that uniform as expected from experiments with liquid capillary breakup at single nozzles in a stagnant gas environment. The current work focuses on the interaction between the liquid threads and the ambient gas, which is supposed to be the reason for a non ideal breakup mode and thus a wider droplet size distribution even in the considered range of moderate relative velocities.

Materials and Methods

As a first approach the theoretical similarity between the breakup of stretched liquid threads at laminar operating rotary atomizers ($a = R\omega^2$) and the breakup of threads stretched by gravity ($a = g$) under air crossflow is shown. Characteristic π-numbers are introduced (1 – 4).

The experiments under gravity conditions are carried out in a range of intense stretching ($4<Bo<30$) and moderate relative velocities of the threads to the ambient gas ($1<We_g<6$). Literature doesn't deal with PSDs in the intended range yet.

A test rig was built to investigate the sensitivity of the liquid threads on the ambient gas at laminar operating rotary atomizers (Figure 1). It consists of a laminar operating rotary atomizer that contains 60 bores which are inclined to the radial direction. High throughputs in the range of laminar jetting can be achieved ($1<V^*<30$). The ambient gas close to the atomizer is accelerated by transparent discs driven separately and placed below and above the atomizer. This setup allows for decreasing the ambient gas' relative velocity to the liquid threads in a controlled manner while the zone of droplet formation is observed through the transparent discs.

Laser diffraction analysis and photographic methods are used for the characterization of the droplet-sizes and breakup-lengths.

Results and Discussion

First results confirm a sensitivity of the droplet-size distribution on the threads' relative velocity to the gas. The achieved experimental results will be used for the development of optimized atomizers and drying-gas distributors. Drying experiments with aqueous solutions and suspensions will be carried out in a pilot scale spray tower.

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Nomenclature

$$d^* = d_{50,3}\left(\frac{\rho_l a}{\sigma}\right)^{0.5}. \tag{1}$$

$$We_g = \frac{v_{rel}^2 \rho_g D}{\sigma}. \tag{2}$$

$$V^* = \frac{\pi}{4} Bo^{0.75}\, We^{0.5} = \dot{V}\left(\frac{a^3 \rho_l^5}{\sigma^5}\right)^{0.25}. \tag{3}$$

$$\eta^* = \eta\left(\frac{a}{\rho\,\sigma^3}\right)^{0.25}. \tag{4}$$

a	acceleration [m·s^{-2}]
$d_{50,3}$	drop diameter [m]
D	nozzle diameter [m]
R	radius of the rotary atomizer [m]
v	velocity [m·s^{-1}]
$\dot{V}$	volumetric flow [m^3·s^{-1}]
ρ	density [kg·m^{-3}]
η	viscosity [Pa·s]
σ	surface tension [N·m^{-1}]
ω	angular velocity [s^{-1}]

References

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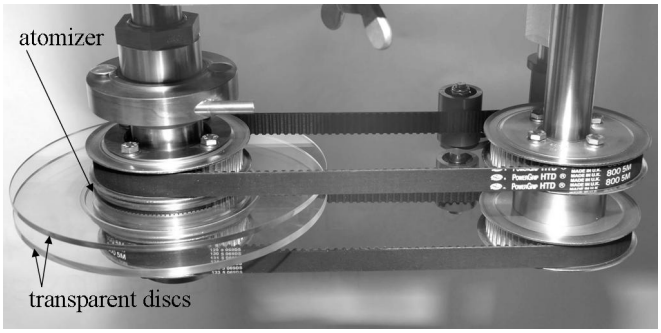

Figure 1. built test rig for the investigation of the gas influence on the laminar rotary atomization