Measurement of the droplet size distribution of a full cone nozzle

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Abstract

The droplet size distribution and the spray angle of a full cone nozzle are measured at varying differential pressures and volumetric flow rates. Due to the large diameter of the spray even at short running lengths a sheet of the spray is peeled out from the spray cone. The droplet size distributions are obtained by two different methods: fast-exposure-photography and laser diffraction analysis. The results are compared. The spray angle of the nozzle strongly influenced by the flow at the trumpet opening is calculated by the analysis of pictures recorded with a CCD camera. The nozzles characterized here are geometrically similar models of a nozzle used as the main sprayer in an industrial dust scrubber. Data are presented in non-dimensional relationships.

Introduction

The measurement of the droplet size distribution of a full cone nozzle is difficult because the spray is normally very dense. This may be the reason for sparse data on that subject in literature. The knowledge of the drop sizes is very important when it comes to design and optimization of gas scrubbers systems or other wet cleaning devices. The gas cleaning efficiency of the scrubber strongly depends on the droplet size distribution.

Materials and Methods

The model of an industrial full cone nozzle in the reduction scale of 1:10 and 1:6 is analyzed. Two different measuring techniques are used in order to determine the droplet size distribution of a high dense full-conical spray. The first method is fast-exposure-imaging using backlighting technique to acquire photos of high contrast, which later on are analyzed with image processing software. The second method is the laser diffraction analyzer (LDA) to obtain the droplet size distribution. Mean values of the droplet size distribution of the model nozzles as (d_{10}, d_{50}, d_{90}) are plotted in a diagram of related droplet sizes versus the Weber-number allowing for an extrapolation toward Weber-number-conditions expected in large scale nozzle. For this purpose the nozzle was operating at different atomization pressures (0.2-9 bar) and volume flow rates (0.5-7.5 m^3/h). The effect of viscosity is expected to be low.

The spray of the nozzle is very dense and therefore it is not possible to measure single droplets with a CCD-camera or the LDA directly. In order to solve this problem a device with a small slit (10 mm) was positioned below the spray cone, allows for the measurement of only a single sheet of the spray cone. This spray curtain is photographed in segments, each with a field of view of 84×84 mm^2 starting in the middle and ending at one outer rim of the spray. In all of these measurements the assumption has been made, that the spray is symmetric. The same is done with the LDA which measures the droplet size distribution at nine positions in an area of 10×10 mm^2. For the fast-exposure-photography the backlighting method was used. An array of about 1800 super bright LEDs forms a homogeneous plane backlight source, illuminating the droplets during a period of 10 µs. The camera acquires pictures with a sampling frequency of 60 Hz. These pictures are processed to Q_3 and q_3 plots with the image editing software "ImageJ" and a self written macro-tool.

For the measurement of the spray angle, a video camera is used. The videos produced by this camera are converted into single pictures later on evaluated with the software "ImageJ" to extract the spray angle. In the first step the colored pictures are converted into 16-bit gray scale images. Then the images are inverted and the angle is calculated (figure 3). For each of the seven different pressures a total number of about 200 pictures are analyzed and the mean angle is calculated. In order to predict the angle of a large-scale nozzle, the angle is plotted versus the pressure-Reynolds-number. This enables to extrapolate the spray angle at the operating conditions of the large-scale nozzle.

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Results and Discussion

The results of the first measurements with the CCD-camera and the LDA are shown in figure 1. The atomization pressure for this measurement was 8.5 bar and the volumetric flow rate was 7.5 m³/h. The differences in the results between the two measurement methods are significant. The d_{50} for the CCD-camera measurement shows a value of about 650 µm and the measurement with the LDA has a d_{50} of 250 µm. Small droplets are not easily detected with the CCD-camera because the resolution of the pictures is not high enough (1 Megapixel), which can be seen in the steplike curve in figure 1. So it is likely that the small fraction of the spray is underrated. The function of the LDA has been checked with another nozzle with a known Q_3 and shows expected results. Eventually the results of the LDA can be trusted and the results of the photo-analysis not.

The results of the patternator experiments are shown in figure 2. The results of the single positions have been weighted with this results.

The measurements of the spray angle show a decreasing angle for increasing pressures. The angle starts with a value of 120° at a pressure of 0.9 bar and falls to a value of 86° for a pressure of 8.7 bar which corresponds to a stronger or earlier detachment from the trumpet curverture.

Acknowledgement

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References

[1] Straßburger, F., "Abbildung eines realen Nasswäschers anhand von Strömungssimulationen und experimentellen Düsencharakterisierungen", Diplomarbeit am Lehrstuhl für Mechanische Verfahrenstechnik Fakultät Bio- und Chemieingenieurwesen, Technische Universität Dortmund.

[2] Kohnen, B. T., Straßburger, F, Walzel, P., "Optimierung eines bestehenden Wäschers durch Simulation", ProcessNet-Jahrestagung 2009 (08.09.2009 - 10.09.2009), Mannheim

[3] Kohnen, B., Mönter, A.-K., Walzel,. P., "Untersuchungen am Modell eines bestehenden Wäschers", Poster, Jahrestreffen der Fachausschüsse Mehrphasenströmungen und Wärme- und Stoffübertragung (03.03.2009 - 05.03.2009), Bad Dürkheim

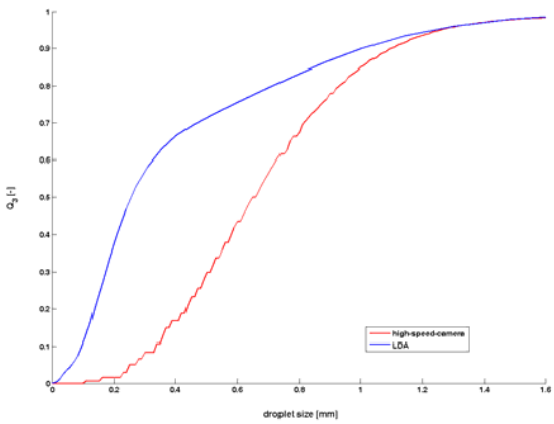

Figure 1. Density function Q_3

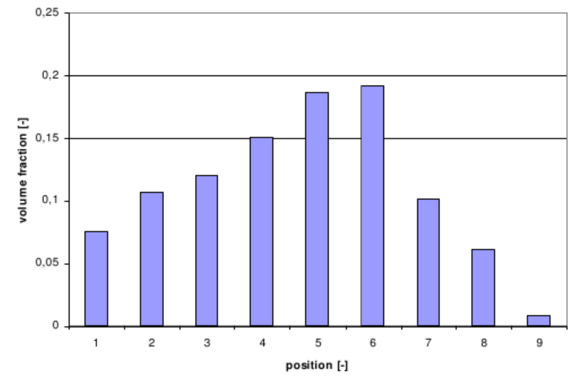

Figure 2. Results of the patternator measurements

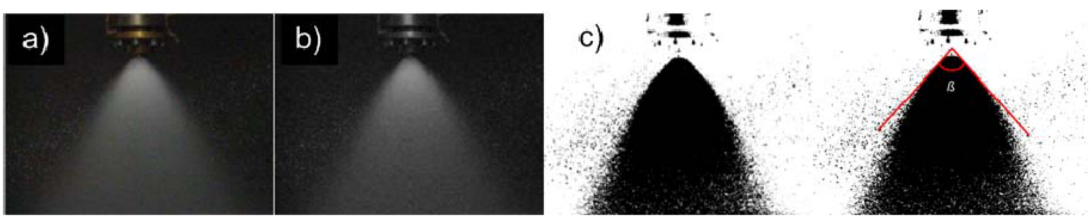

Figure 3. Processing of the images for the spray angle measurements