Impact of the gas nozzle arrangement on the flow field of a twin fluid atomizer with external mixing

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Twin fluid gas atomization is a common liquid fragmentation operation in chemical engineering. Processes as spray drying, (metal) powder generation or spray cooling are parts of several industrial applications. Beside the physical properties of the atomization gas resp. the process fluid, the design of the atomizer influences the atomization process and the resulting particle size distribution.

Typically the flow field of a twin fluid atomizer with external mixing (here a prefilm free fall atomizer) is generated by discrete nozzles which are located concentrical to the melt stream. In this work the impact of the arrangement of these discrete atomization gas nozzles is investigated. Thereby the focus is on the influence of the number of gas nozzles and a variable spacing between two adjacent nozzles. The total gas nozzle outlet area and the distance between the melt stream and the discrete atomization gas nozzles remains constant.

CFD simulations of the gas flow field as well as experimental investigations of the pressure- and flow profiles in the atomizer vicinity respectively the atomization area are performed.

1. Introduction

In general, the flow field of a twin fluid atomizer with external mixing is generated and influenced by a number of discrete jets. The jets are generated by discrete atomizing gas nozzles which are typically arranged concentrical to the central fluid stream. In fig. 1 a twin fluid atomizer with external mixing (here a free fall atomizer) is shown, which is used for powder production [3]. Liquid and gas are brought into contact outside of the nozzle [1]. In fig. 1 it also can be seen that the discrete gas jets come in contact with the melt by an angle of attack. This angle as well as the nozzle arrangement can be adjusted within nozzle manufacturing linked to process parameters. The knowledge of the potential of the flow field influences can yield some new parameters to improve the efficiency of twin fluid atomizers [2, 7].

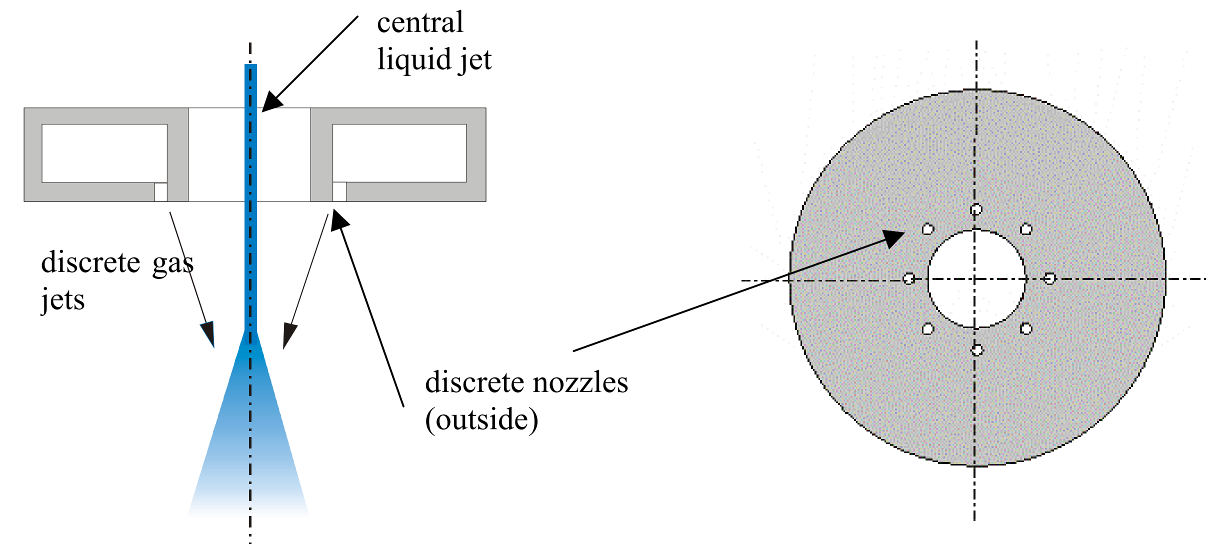


Fig. 1 Twin fluid atomizer with external mixing with discrete gas jet arrangement

2. The external mixing twin fluid atomizer

The free fall atomizer explained before has some disadvantages. One is that the maximum liquid mass flow rate is limited if a reasonable powder size distribution should be achieved with a realistic gas to liquid mass flow ratio. The other disadvantage is that the mass median particle size is depending on the radial position in the spray. Thus the atomizer design limits a narrow particle size distribution. In fig. 2 experimental results are shown for a "free fall atomizer". The spray was investigated by a laser diffraction measuring device 800 mm below the atomizer. In fig. 2 it can be seen that the mass median particle size for different atomizing gas pressures decreases within increasing radial position in the spray. At the edge of the spray the droplets are smaller than in the core.

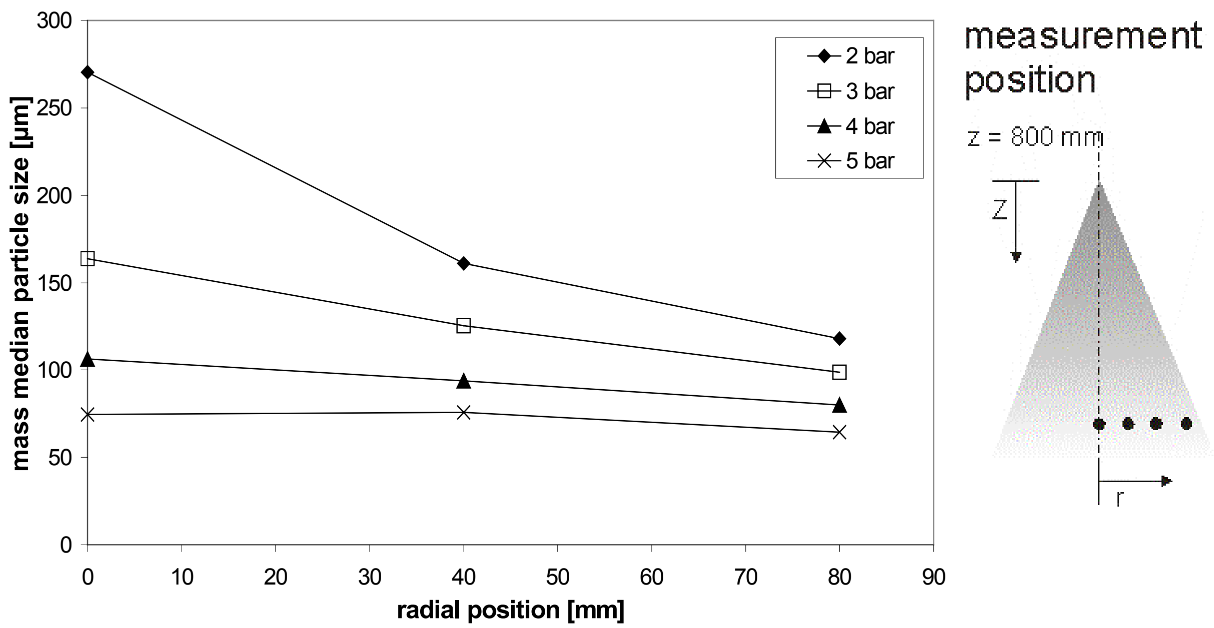


Fig. 2 Experimental results of the free fall atomizer

The liquid mass flow rate was 1000 l/h and water was used as a model liquid. The reason why the particle size decreases with increasing radial position is that the velocity difference between the liquid and the atomization gas becomes greater with increasing radial position.
Experimental results from an "inside atomizer", also a twin fluid atomizer with external mixing verify this fact. In fig. 3 a sketch of an "inside atomizer" is shown. In fig. 4 experimental results are presented. The spray war investigated at a distance of 800 mm to the atomizer, the liquid medium was water and the adjusted liquid mass flow rate was 1000 l/h. In the opposite to the experimental results for the "free fall atomizer", fig. 4 shows that the mass median particle size increases with increasing radial position. This result can be seen for all adjusted atomization gas pressures.

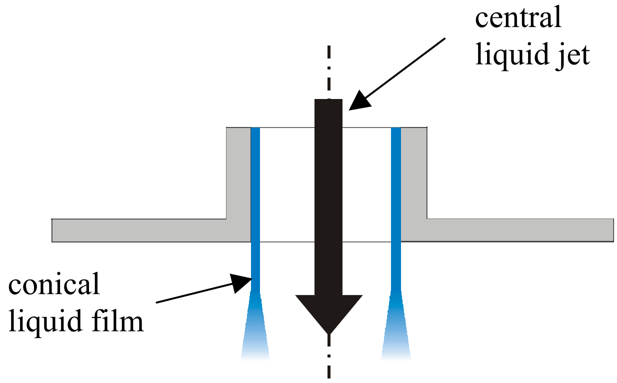


Fig. 3 Prefilming atomizer with central gas jet ("inside atomizer")

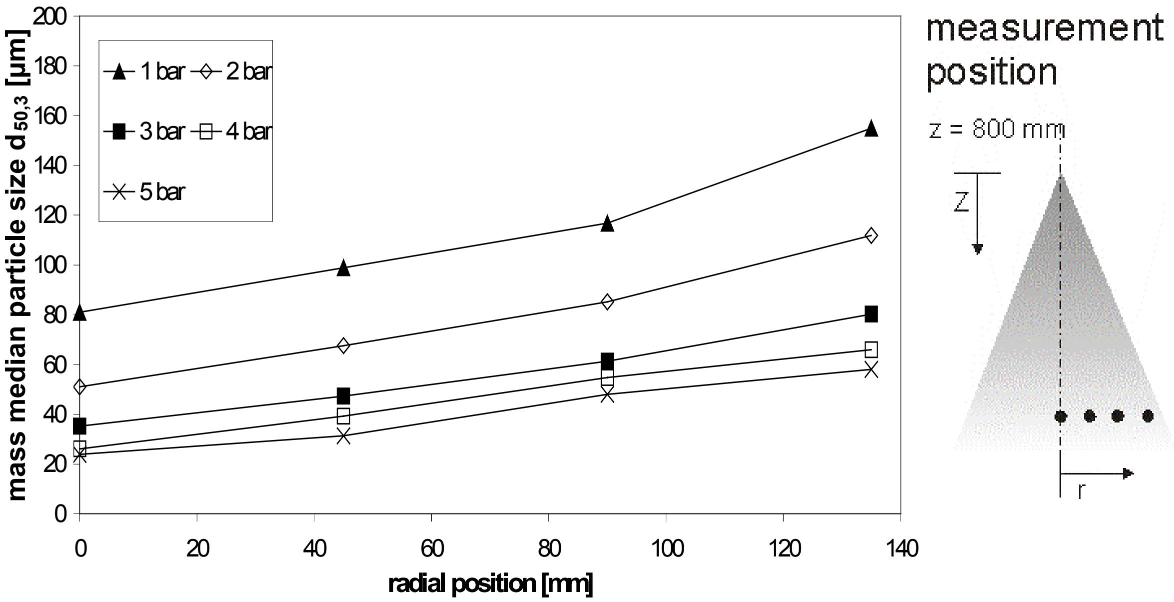


Fig. 4 Experimental results of the "inside atomizer"

Based on these results, a prefilming atomizer with inner and outer atomization was developed as shown in fig. 5. It essentially is a combination of the "free fall atomizer" and the "internal atomizer". The goal is that by this design a more narrow particle size distribution can be obtained compared to the other two atomizers described before. The other advantage is that the atomizer is able to handle higher liquid mass flow rates. In fig. 6 experimental results are shown for different pressure combinations between the inside and the outside nozzle. The results show that the mass median particle size is nearly constant when the pressure ratio between the inside and the outside nozzles is one. The experimental parameters and the detection parameters are as before.

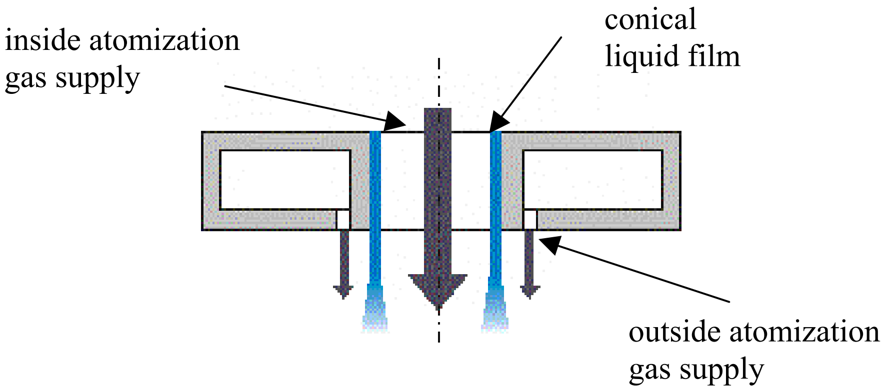


Fig. 5 Sketch of the "Prefilming atomizer"

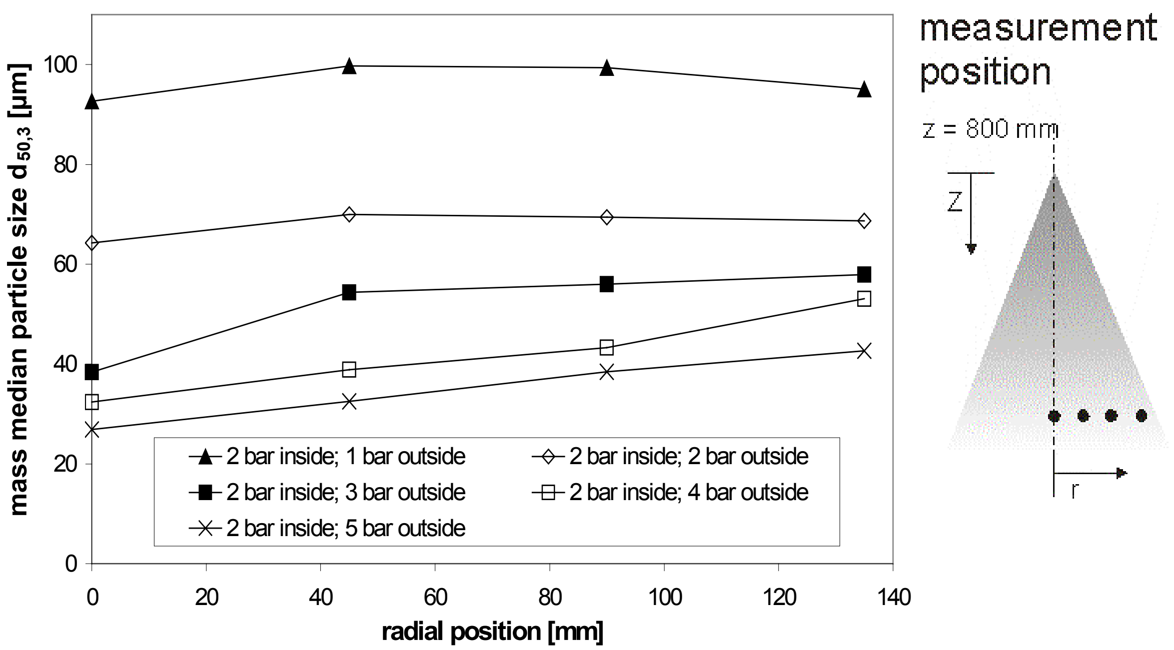
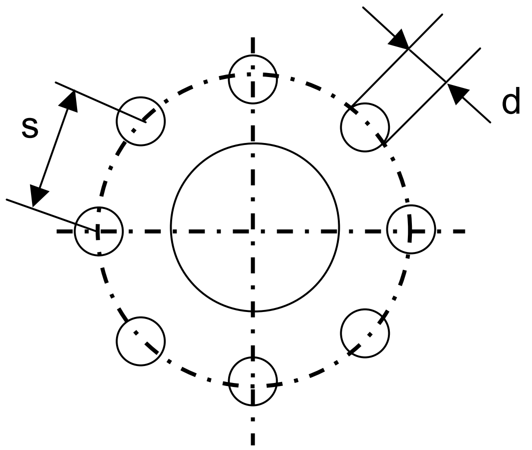


Fig. 6 Experimental results of the "prefilming atomizer"

3. The discrete nozzle arrangement

Numerical and experimental investigations are done to study the influence of the discrete nozzle arrangement on the gas flow field. Hereby only the influence of the spacing between two adjacent nozzles is investigated. The distance between the liquid stream and the nozzles and the total gas nozzle outlet area remain constant. The spacing was adjusted by the number of discrete nozzles. For the investigations, the number of gas nozzles differ from 4 to 64 discrete jet nozzles. In the case of 64 discrete atomization gas nozzles, the arrangement can be considered identical to a slit nozzle, because the relative spacing s/d is nearly unity. In fig. 7 the parameters of the discrete nozzle arrangement design are shown.

In fig. 8 an example for the result of numerical gas flow field simulation (2 dimensional) for a slit nozzle is given where the atomization process is only achieved by the external nozzle. In fig. 8 (left) it can be seen that a low relative pressure area appears in between the coaxial gas jet on the axis at z=0. In fig. 8 (right) the velocity is plotted for this slit nozzle design. The plot shows that the coaxial atomizer gas jet is bended towards the axis. This profile is caused by the inner under pressure area (aspiration pressure). The bending gas jets and the effect of the aspiration pressure is directly used in close-coupled atomizers [5, 6, 8].



s = the distance between the centre positions of two adjacent gas nozzles

d = diameter of one gas nozzle

Fig. 7 Details of the gas nozzle arrangement.

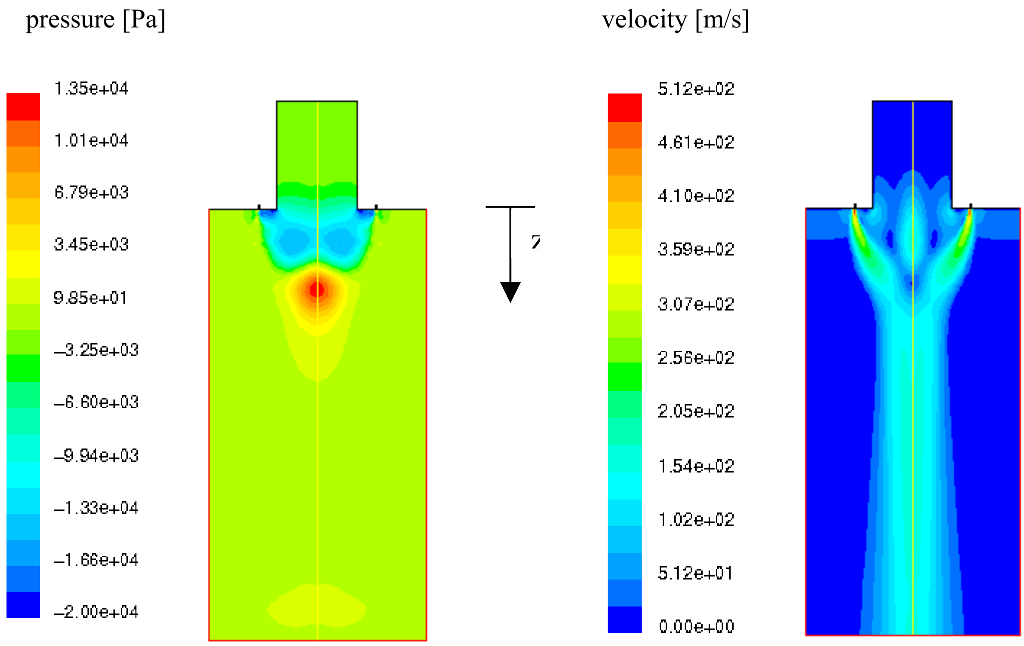


Fig. 8 Simulation of the atomizer vicinity (slit nozzle)

Compared to the simulation results of the slit nozzle, in fig. 9 the numerical results are shown for the three dimensional gas flow field for a discrete nozzle arrangement of 4 nozzles (s/d ratio = 10.6). In fig. 9 (left) on the axis at z = 0 no aspiration pressure area can be seen. It is assumed that the under pressure area can be compensated by gas which flows through the space between two adjacent discrete nozzles. Because of the absence of the under pressure area, the atomizer jets are not bended towards the axis like it can be seen in fig. 8 (right).

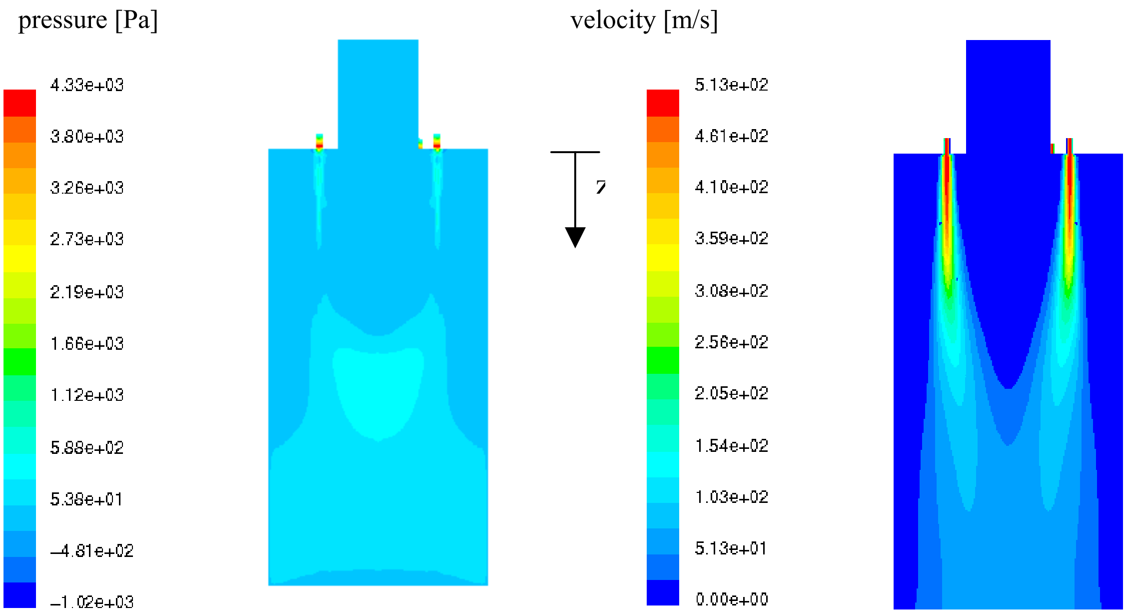


Fig. 9 Simulation of the atomizer vicinity (discrete nozzle)

The magnitude of the aspiration pressure is depending on the s/d ratio. Fig.10 shows the simulated under pressure values at z = 0 for different pre-pressures in the discrete atomization nozzles. As presented in fig. 10, an increasing under pressure can be found with decreasing s/d ratio.

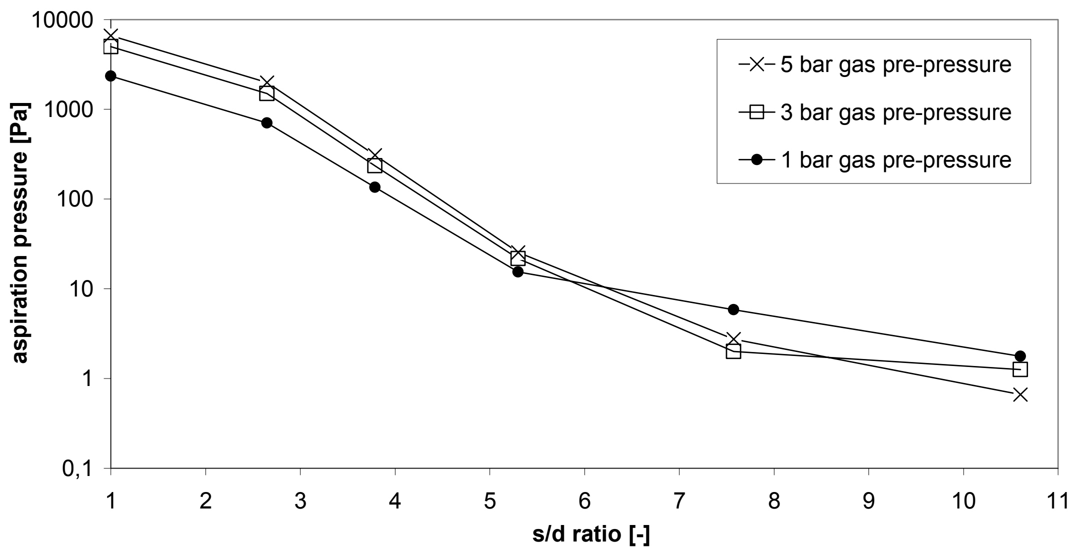


Fig. 10 Aspiration pressure at z = 0 depending on the s/d ratio

4. Summary and outlook

A prefilming atomizer with external mixing has been developed for high liquid throughput. The atomizer can be characterised by a mechanical liquid preforming process. The atomizer gas is applied as a central jet inside the coaxial film flow and simultaneously from the outside of the liquid film by discrete jets. The advantage of this atomizer is a constant particle size distribution over the radial position in the spray and an increased energy efficiency compared to other twin fluid external mixing atomizers. It was found by numerical simulations that the s/d ratio of the nozzle arrangement is affecting the atomization performance. The atomizer flow field profile is influenced by an aspiration pressure area on the axis of the atomizer. The strength of this under pressure area depends on the s/d ratio of the gas jet arrangement.

5. Acknowledgment

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6. References

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