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Droplet Sizes and Droplet Spectrums of Spray Dry Nozzles and Rotary Atomizers under typical conditions of use

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ABSTRACT

In spray dryers mostly pressure atomizers or rotary atomizers are used. When customers are using the pressure nozzle in the spray tower the diameter of the spray tower is smaller than the length of the cylindrical part of the spray tower. If a rotary atomizer is used, than the diameter of the spray tower is larger than the length of the cylindrical part. Both types of tower need different sprays to work in an optimum. The rotary atomizer is able to produce a fine spray at high capacities. The droplets in the spray of a nozzle are normally larger.

In the market different types of pressure nozzles are available. Especially pressure nozzles with a single slot swirl chamber and an orifice plate are established. The nozzles (pressure atomizers) produce a finer spray by increasing the pressure or the spray angle. We have measured the droplet sizes and spectrums of typical used pressure atomizers (nozzles) and a rotary atomizer.

We have measured the sprays and spectrums of pressure nozzles and rotary atomizers. The results show the difference of the sprays and give an explanation why nozzle and rotary atomizers need different types of spray towers. In the results it can be seen also, that the measured Sauter-Diameter $D_{(3,2)}$ and the $D_{(50)}$ value is increasing when the nozzle pressure is increasing. In the literature normally results are presented, were it can be seen, that die Sauter-Diameter $D_{(3,2)}$ and die $D_{(50)}$ value decreases when the nozzles pressure is increasing. Also we have measured nozzles with the standard type (single slot with conical inlet) and also special type of swirl chambers with two slots and conical inlet to make the droplet spectrum more narrow under the restriction that the median diameter $D_{(50)}$ keeps constant.

Atomization with Pressure Nozzles

In spray towers customers are using typically pressure nozzle, called SDX (fig. 1). In the market these types of nozzles have a market share in the business with nozzles of 80-85%. The advantage of the nozzle is, that it is very simple, constructed by an orifice plate (fig. 2) and a single slot swirl chamber (fig. 3).

Fig. 1: Nozzle

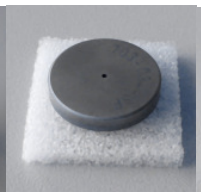

Fig. 2: Orifice plate

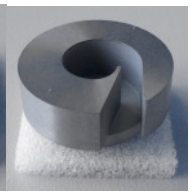

Fig. 3: Swirl chamber

The parts are assembled as in Fig. 4 presented.

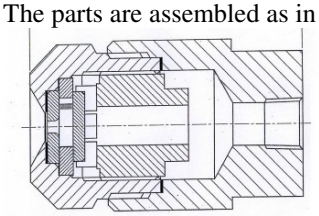

Fig. 4: assembling of orifice and swirl chamber, modification of nozzle body

The customers can vary by using 250 different orifice diameters and 12 swirl chambers. At the end, more than 3.000 combinations, more than 3.000 nozzles are possible.

If the swirl chamber kept constant and the orifice diameter is increasing than the spray angle becomes larger and the volume flow rate at constant pressure is increasing. If the orifice plate is kept constant and the swirl chamber is varying (becoming higher) than the spray angle becomes smaller and the volume flow rate at constant pressure is increasing.

In figure 6 we have presented for a typical spray dry nozzle the volume flow rate of the slurry [l/h], the spray angle (measured, not catalogue data) in correlation to the nozzle pressure from 20 up to 60 bar. With a PDPA laser equipment (fig. 5) we have measured the droplet sizes at the different pressures, which are here characterized by the Sauter-Diameter $D_{(3,2)}$. The orifice of the nozzle or the atomizer was 550 mm away from the measuring point. The laser beam was placed excentric in the spray, not directly through the center of the spray. The measurement range of the expected spectrum of the particles was divided in 50 classes with a linear scaling or step size.

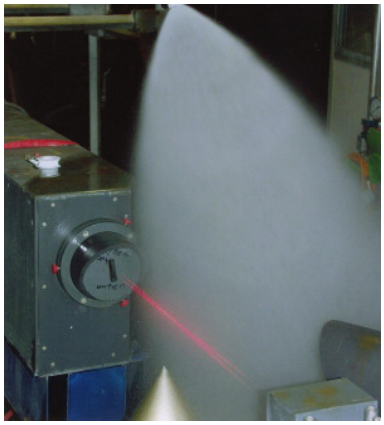

Fig. 5: PDPD laser equipment

Increasing of the pressure from 20 up to 60 bar also increases the nozzles throughput. The spray angle that we have measured is decreasing by increasing the pressure. The presented Sauter-Diameter $D_{(3,2)}$ is increasing by increasing the pressure of the pump. The increasing of the Sauter-Diameter $D_{(3,2)}$ is an effect that we have found during all of our measurements.

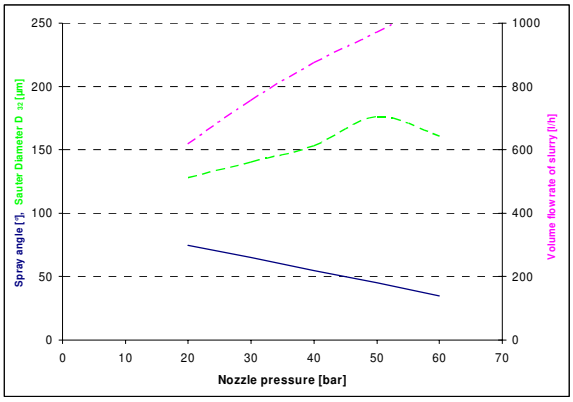

Fig. 6: Spray data of a pressure nozzle, type SDX

Atomization with Rotary Atomizers

The second system that is used in spray towers is a spinning wheel connected by a spindle and a gear with an electro motor. The complete system is called rotary atomizer and is presented in figure 7 and figure 8.

Fig. 7: Rotary atomizer

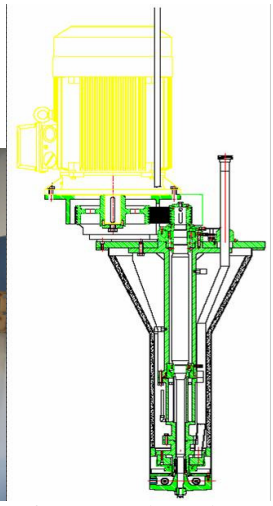

Fig. 8: Cut through

The system is very easy to use and also to be controlled. The advantage of a rotary atomizer is, that the slurry can be atomized in small particles at high capacities. E. g. a Sauter-Diameter in the powder or spray of less than 40 µm is possible at a capacity of 15.000 kg/h.

In figure 9 we have presented at two different rpm the measured droplet spectrums. The maximum rpm of the rotary atomizer was a little bit more than 17.000 [1/min]. For the measurement at a high level of rpm's we have used approx. 85% of the maximum rpm and for the measurement at the lower level we have used approx. 60% of the maximum rpm.

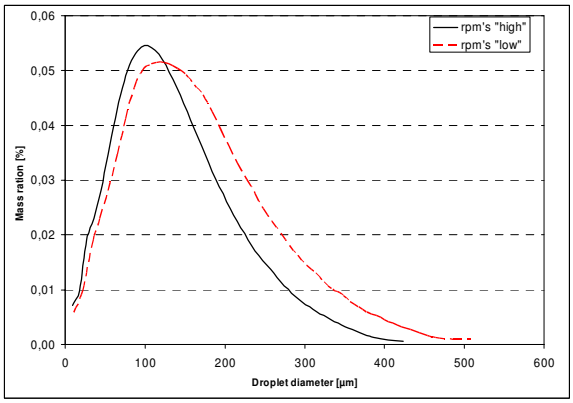

Fig. 9: Droplet spectrum of a rotary atomizer at two different speeds [rpm]

The black line is representing the measured at the high rpm and the red line with brackets is presenting the droplet spectrum at a reduced speed of the atomizer wheel.

Differences in the Results of the Atomization

In the field of spray drying the customers know the differences by using pressure nozzles or rotary atomizers in that way that mostly the atomization by a pressures nozzles gives a large powder sizes in correlation to the atomization by a rotary atomizer. The restriction is, that the customer will get maximum of drying capacity at the tower. This is a result of the design and shape of spray towers, used in the market. Normally the spray tower is able to use a rotary atomizer. Exchanging the rotary atomizer by pressure nozzles allows normally a small quantity of nozzles because of the size of the adapter at the spray tower. The small quantity of nozzles indicated in correlation to the capacity of the rotary atomizer a higher throughput per orifice or nozzle hole. The spectrum of powder or droplets will be moved from fine to large.

In figure 10 and 11 for we are presenting results of measured droplet sprays of a pressure nozzle and a rotary atomizer. The restriction is, that the Mass Mean Diameter $D_{(50)}$ keeps constant. In this case the $D_{(50)}$ value was 120 µm.

In principle at the same $D_{(50)}$ value, the spray of the rotary atomizer is more flat and a little bit more wide than the spray of the pressure nozzle. It is more narrow. The values of the mass ratio at characteristic

diameters like $D_{(10)}$ and $D_{(90)}$ are higher using the rotary atomizer than using a pressure nozzle.

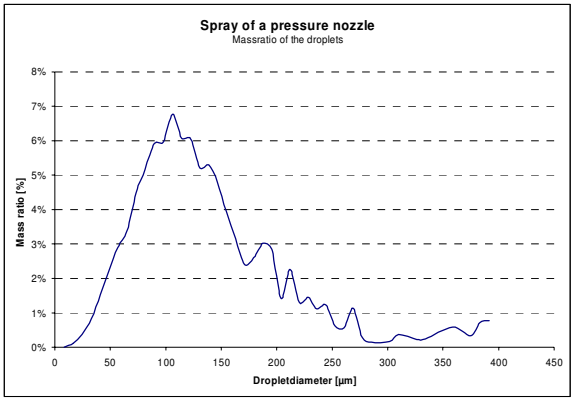

Fig. 10: Spray data of a pressure nozzle

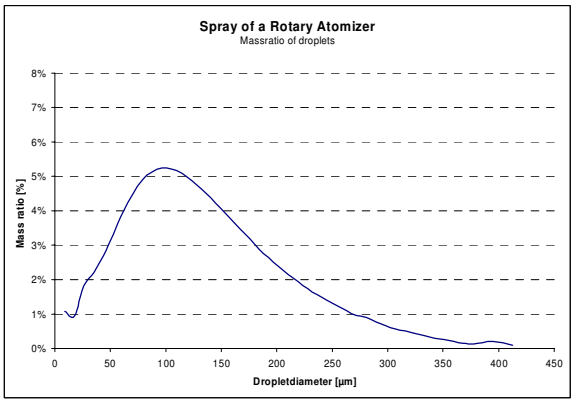

Fig.11: Spray data of a rotary atomizer

In figure 12-14 we have presented for both systems of atomizers the results of analysis. The blue line represents the results of the pressure nozzle and the red line with brackets represents the results of the rotary atomizer.

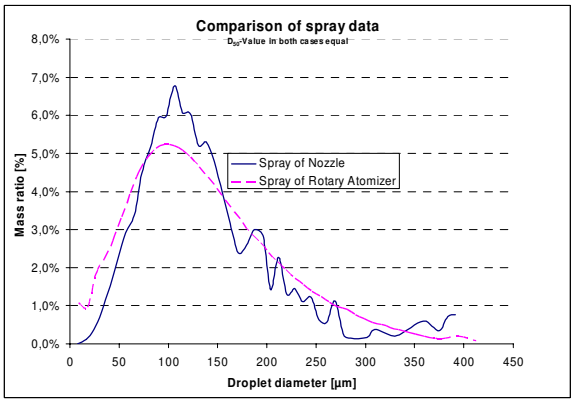

Fig. 12: Droplet diameters and mass ratio

In figure 12 it can be seen that droplet size spectrums vary. The rotary atomizer produces a spray with a higher quantity of fine particles as the pressure nozzle. Also the ration of larger particles is different between rotary atomizer and pressure nozzles. The mass ration for the maximum peak is larger when a pressure nozzle is used.

The presentation of the cumulated mass ratio in figure 13 shows that for both systems of atomizers the $D_{(50)}$ value is the same. Approx. 120 µm is the $D_{(50)}$ value in both cases.

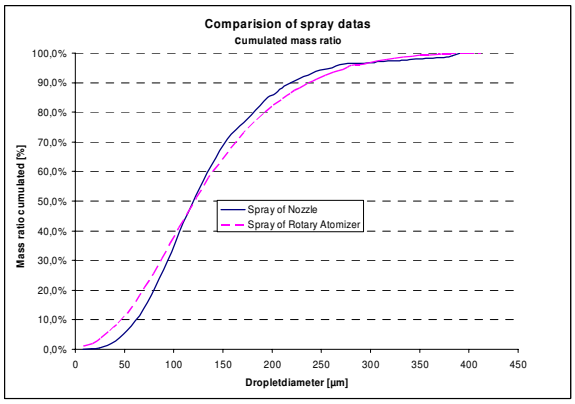

Fig. 13: Cumulated mass ratio

In figure 14 it can be seen that the quantity of droplets varies between pressure nozzle and rotary atomizer. The quantity of small droplets in the spray produced by the rotary atomizer is much more higher than in the spray produced by the pressure nozzle.

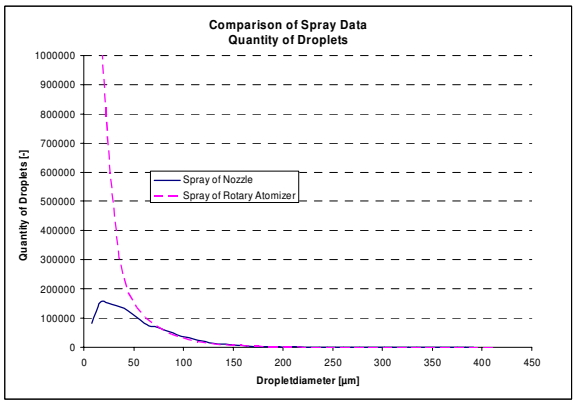

Fig. 14: Quantity of Droplets

Powder and Spray in Spray Towers

To give the reader an overview and the possibility to have a lock in a spray tower, we have presented the results of a CFD simulation in figure 15 and 16.

In figure 15 the spray and powder distribution in a spray tower with nozzles is presented. At the top of the tower the air inlet is a construction of several thin hole plates over the whole diameter of the tower. The velocity of the hot air at the inlet in drying chamber of the tower is approx. between 0,5 and 0,6 m/sec. over the whole diameter.

We have here:

- a soft a homogeneous distribution of the particles,
- no negative effects to the shape of the particles (that they look like potatoes),
- a minimum risk of building powder layers at the wall or the conical part of the tower,
- no rotation of the air in the tower,
- a minimum of agglomeration and
- a homogeneous distribution of heat, humidity and drying.

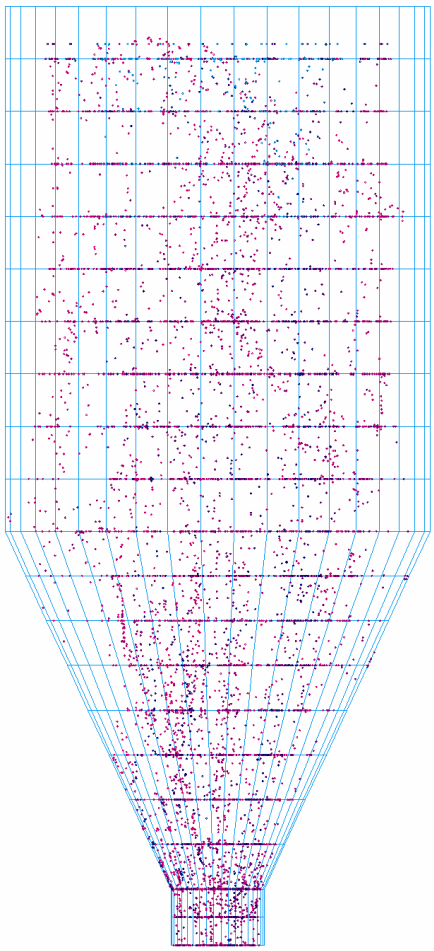

Fig. 15: Powder distribution in spray tower with nozzles and air inlet over complete diameter.

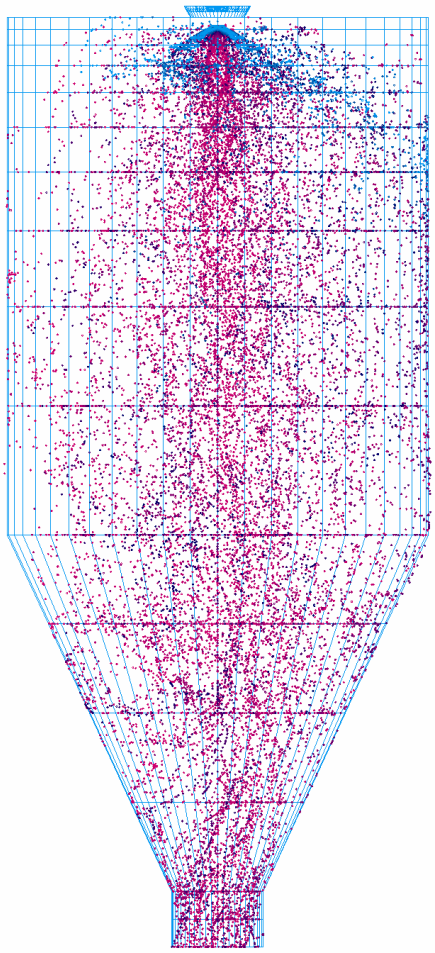

Fig. 16: Powder distribution in spray tower with rotary atomizer an air inlet through small ring.

In figure 16 the spray and powder distribution in a spray tower with rotary atomizer is presented. At the top of the tower the air inlet is a construction of a relative small ring around the rotary atomizer. The velocity of the hot air at the inlet in the drying chamber of the tower is approx. between 29 and 32 m/sec.

We have here

- a turbulent (rotating) and inhomogeneous distribution of the particles,
- the shape of the particles is like potatoes,
- a higher risk of building powder layers at the wall or the conical part of the tower,
- a lot of agglomeration and
- an inhomogeneous distribution of heat, humidity and drying.

Conclusion and summary

Nozzles make a spray, that is more narrow than a spray of a rotary atomizer. The spray of the rotary atomizer consists of more fine particles than the spray of a nozzle. The handling and the quality of both types of powder varies. In the last 4-5 years a trend can be seen in Germany. The customers are trying more and more to use pressure nozzles instead of rotary atomizers. At the end a powder, produced by a pressure nozzle can be sold for a higher price than the same powder produced by a rotary atomizer.

But not every spray tower is able to use both systems of atomization. In special designs of spray towers only rotary atomizers or only pressure nozzles can be used. Customers in the spray dry business can handle and live with the differences in the droplet spectrum and the differences in the powder. Each system of atomization has his advantages and is optimized for the characteristic and design of the spray tower.

If a customer is interested to use both systems of atomization in his tower under an optimum of results, it is possible. But than the design of the spray tower and the air inlet and air distributor has to be changed.