Study of vortex pneumatic sprayer for liquid disinfection

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Abstract. The production of high-quality livestock products can be achieved by upgrading livestock breeds and complying with zootechnical requirements of ensuring sanitary well-being in animal houses. Different ways are applied to gain the proper clean condition of livestock houses and equipment, disinfection preparations for working surfaces. Besides, non-compliance with the requirements for operating devices and standards for disinfectant consumption leads to increased antimicrobial resistance of microorganisms [1]. The efficiency of disinfection depends mainly on the technical capabilities of the units, mainly on the spray devices. Many researchers solve complex problems by optimizing spray devices' design and technological parameters to improve their spray quality [2]. The authors developed a vortex pneumatic sprayer for liquids for the disinfection process. The dispersion composition of disinfectant liquid aerosols was obtained in different operating regimes of the proposed sprayer design. Based on experimental data, dependencies of the influence working pressures of disinfectant liquid and compressed air in their supply channels on the dispersion were obtained. The flow rates of the vortex pneumatic sprayer during its operation in various regimes were determined. Dependencies of disinfectant liquid flow rate through the sprayer were constructed at different pressure ratios in supply channels of working fluids (disinfectant liquid and compressed air) and the angle between them. Optimal design parameters of the vortex pneumatic sprayer for aerosol disinfection of livestock houses and equipment were determined.

1 Introduction

The techno-economic efficiency of the disinfection process of livestock houses and equipment depends mainly on the design characteristics of the sprayers. The following parameters determine the sprayer performance: the spray dispersion, coating degree of the surface to be treated, the uniform distribution of the disinfectant [1; 2]. Despite the diversity of sprayer designs, there is a pressing issue to reduce the cost of disinfectant liquids and increase the dispersion efficiency, the consumption of the working fluid, and its losses [3; 4]. It is known that the fine droplets improve the penetrating capacity of the aerosols [5]. Fine dispersion is achieved by increasing pressure in the supply line for the hydraulic sprayers and requires high energy costs. Therefore, pneumatic sprayers are the most promising devices for the dispersion of disinfectant liquids. The dispersion is changed by controlling the pressure in the supply line, and the flow rate varies slightly [6].

Centrifugal (vortex) sprayers make it possible to carry out a high-quality disinfection process with lower pressure in the supply line. Moreover, they have a larger diameter of the outlet openings (nozzles) than other types of sprayers, leading to lower requirements for cleaning feed liquid and an increased service life associated with the nozzle wear and uniform covering treated surface [7]. When vortex pneumatic sprayers disperse fluids, the jet exits the nozzle in the form of a swirling flow of aerosols, forming an annular trace on the working surface [8; 9].

The work aims to investigate the influence of the design of the developed vortex pneumatic sprayer on the characteristics of the disinfectant liquid at different operating regimes.

2 Materials and methods

In the previous study [10], the most important factors influencing the dispersion of the spray liquid have been identified:

1. Spray design parameters.
2. Working pressure of the spray liquid (P_{liq} , MPa).
3. Working pressure of the compressed air (P_{air} , MPa).
4. Angle between input channels (α, degrees).

The vortex pneumatic sprayer, as shown in Figure 1, was manufactured to determine the influence of the factors mentioned above on the dispersion of the disinfectant liquid. The sprayer includes body 1 with a cylindrical vortex chamber 2 and two channels arranged at an angle α to each other. A radial channel 3 is used to supply disinfectant liquid, tangent channel 4 – compressed air. A conical cover 5 forms a conical vortex chamber 6 with a conical angle of 120 degrees. An output hole 7 for aerosols is arranged on the top corner of the conical vortex chamber.

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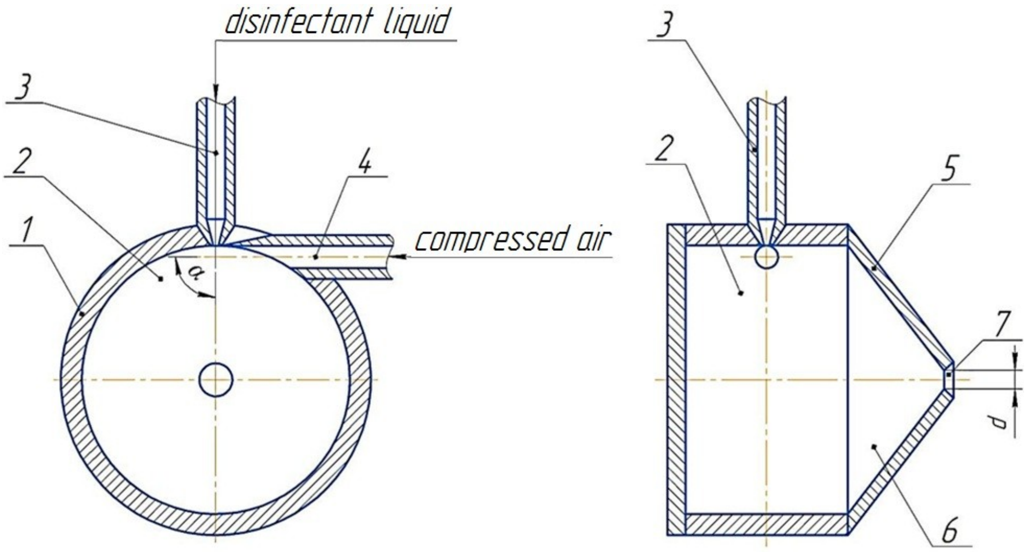

Fig. 1. Vortex pneumatic sprayer for disinfectant liquid: 1 – body; 2 – cylindrical vortex chamber; 3 – disinfectant liquid channel; 4 – compressed air channel; 5 – conical cover; 6 – conical vortex chamber; 7 – hole; *α* – angle between the input channels; *d* – diameter of the output hole.

In the proposed design of the sprayer, the liquid is dispersed in two stages: first utilizing a compressed air jet and then increasing the rotation speed and centrifugal forces in the conical chamber [11].

3 Results and discussion

Experimental studies have been carried out to determine optimum design parameters and dispersion composition of aerosols for different operating regimes of the vortex pneumatic sprayer [12]. The droplet size of aerosols *D* (Table 1) is determined at different pressure ratios in the pneumatic and liquid channels $\frac{P_{air}}{P_{liq}} = \mu$ and by changing the angles between the input channels *α*.

Based on the averaged size values of aerosols D_{sr}, we constructed the dependencies (Fig. 2) against different pressure ratios in the pneumatic and liquid channels *μ* for different angles between the input channels *α*.

Table 1. Experimental sizes of aerosol droplets *D* at different values of *μ* and *α*.

$\frac{P_{air}}{P_{liq}} = \mu$	*D*, μm, at *α* = 45º	*D*, μm, at *α* = 60º	*D*, μm, at *α* = 90º
0.5	86	78	69
1.0	71	64	54
1.5	57	50	40
2.0	44	36	26
2.5	35	26	15
3.0	28	20	8

Figure 2 shows that when the pressure ratio μ increases, the droplet size of the aerosols decreases. It is caused by increasing the efficiency of pneumatic dispersion of disinfectant liquid due to rising the pressure of compressed air in the pneumatic channel [13].

The flow rate of disinfectant liquid *Q* (Table 2) was determined at different pressure ratios in the pneumatic and liquid channels $\frac{P_{air}}{P_{liq}} = \mu$ and at angles between the input channels *α* during experiments.

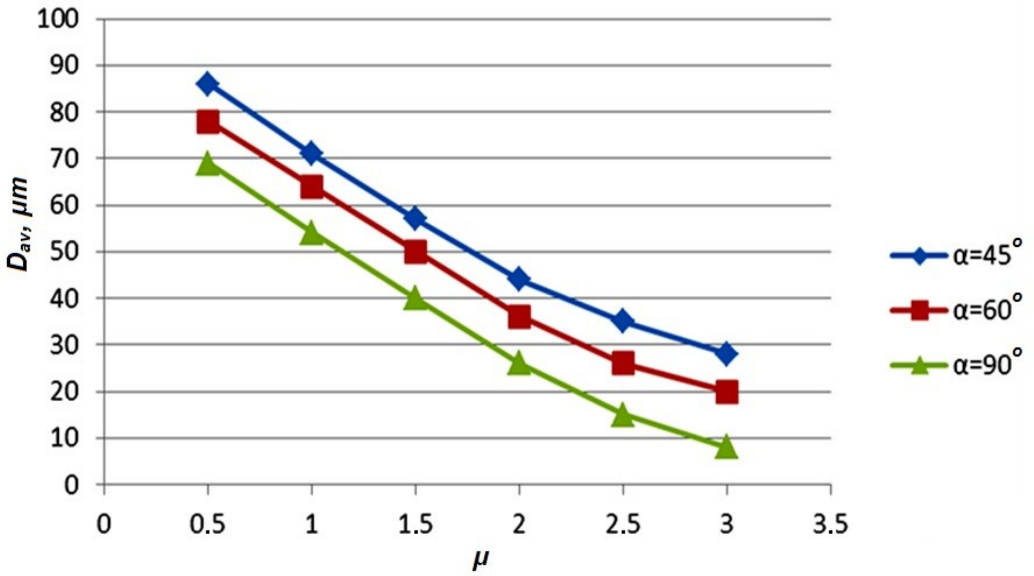

Fig. 2. Dependence of the average droplet size of aerosols against different pressure ratios in the pneumatic and liquid channels μ under changing the angles between the input channels α

Table 2. Experimental values of flow rate Q for disinfectant liquid at different values of μ and α.

$\frac{P_{air}}{P_{liq}} = \mu$	Q, ml/min, at α = 45°	Q, ml/min, at α = 60°	Q, ml/min, at α = 90°
0.5	0.32	0.32	0.29
1.0	0.31	0.30	0.27
1.2	0.29	0.27	0.24
1.4	0.26	0.24	0.21
1.6	0.24	0.21	0.17
1.8	0.21	0.17	0.09
2.0	0.17	0.12	0.05

Figure 3 represents the dependencies of the obtained flow rates of disinfectant liquid Q from different pressure ratios in the pneumatic and liquid channels μ and angles between the input channels α.

Figure 3 shows that as the pressure ratio μ increases, the flow rate of disinfectant liquid decreases. It has to do with the partial closing of the channel for supplying disinfectant liquid by increasing the pressure of compressed air in the pneumatic channel [5; 14; 15].

The results showed that the optimum design parameters of the sprayers are the following: the angle between the pneumatic and liquid input channels α is 90°; the diameter of the output hole d is 2.0 mm.

The developed design of the vortex centrifugal sprayer provides controlling the dispersion of the spray at a constant flow rate, uniform covering the surface to be treated, increasing the disinfection efficiency.

4 Conclusion

A new design of a vortex pneumatic sprayer was developed, which ensures obtaining monodispersed aerosols and reliable experimental data affecting the dispersion quality of disinfectant liquids.

The design and technological dependencies of the vortex pneumatic sprayer were determined, which form aerosols with defined dispersion characteristics under different operating regimes.

The graphical dependencies for the droplet size of the aerosol and the flow rate of disinfectant liquid from the technological parameters of the vortex pneumatic sprayer are constructed, providing the operating regimes with the required dispersion.

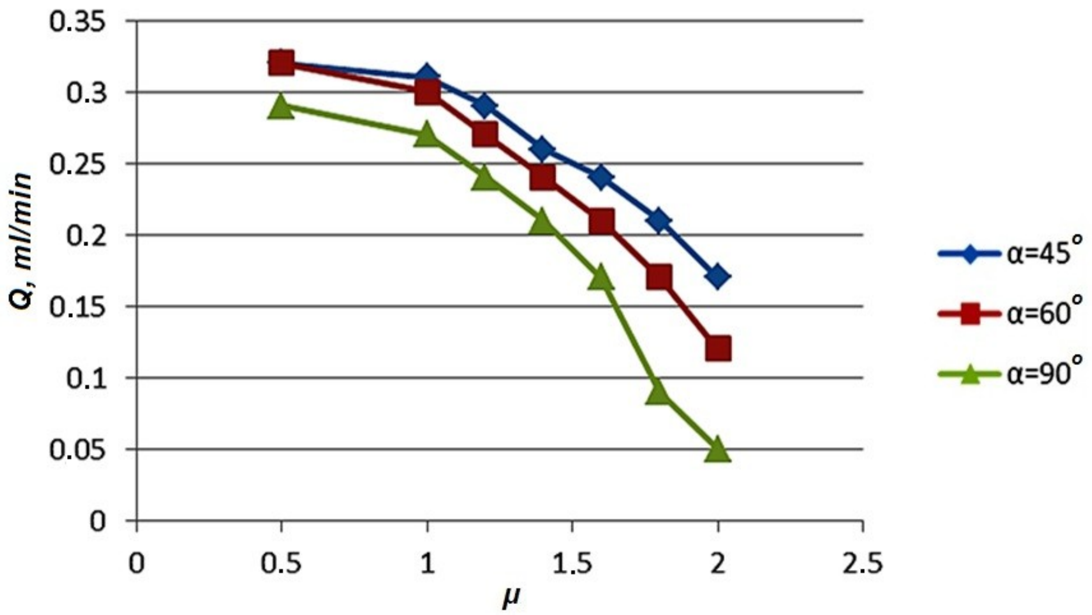

Fig. 3. Dependence of disinfectant flow rate Q through the sprayer against different pressure ratios in the pneumatic and liquid channels μ under changing angles between the input channels α.

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