# Experimental studies of pneumatic disc atomizer for low volume spraying

*Burxon* Utepov [1], *Tuygun* Khaydarov[1], *Nurmamat* Rajabov[1*], *Gulnoza* Murtazayeva[1], *Bakhtiyor* Tulaganov[1], and *Mirzoolim* Avliyakulov[2]

[1]"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, 100000, Uzbekistan
[2]Cotton Breeding, Seed Production and Agrotechnologies Research Institute (CBSPARI), Tashkent, 111202, Uzbekistan

**Abstract.** The article presents the results of experimental studies to determine the dependence of the rotational speed of a pneumatic disc sprayer with coaxial air flow on the flow rate of the working fluid. To refine the parameters of the working body, studies were carried out within the liquid flow rate $q$, corresponding to the first and second spraying modes, at different rotation speeds ω, the working body's radius **r,** and the number of radial channels $n_p$. At the same time, the mass of the rotating part of the pneumatic disk atomizer was determined.
The quality of dispersion of the working fluid obtained experimentally by a multi-disk atomizer in a film version driven by an air flow corresponds to a low-volume liquid atomization mode.

## 1 Introduction

Based on the results of preliminary studies and analytical calculated data, a working body was developed, the schematic diagram shown in fig. 1. [1-3].

The multi-disk atomizer consists of a package of 5 disks made of polyethylene film with a diameter of 130 to 170 mm and a thickness of 350 mm; the number of disks is up to 20 pcs, which can allow work at working fluid flow rates up to 20 l / min. Dosing washers 2…3 mm thick are installed between the discs.

The package of disks and the wind wheel are mounted on the hub 3, which rotates about the hollow axis 1, which serves as a channel for supplying the working fluid to the disks. The whole system is installed in the outlet section of the air nozzle. It is equipped with an aerodynamic fairing 7 (Fig.1). The aerodynamic fairing provides a smooth change in the axial velocity of the air flow and aerodynamic force on the outer part of the wind turbine blades, due to which the rotation of the latter occurs.

*Corresponding author: tiqxmmi1977@mail.ru

 https://doi.org/10.1051/e3sconf/202336504033

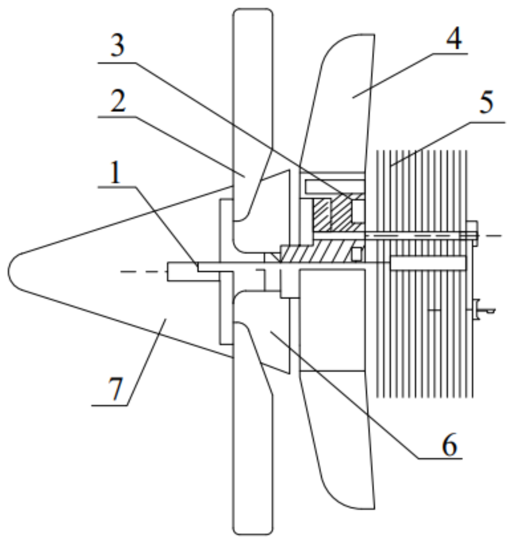


**Fig. 1.** Scheme of the working body

## 2 Materials and Methods

The liquid atomizer works as follows. The air flow created by the centrifugal fan is sent to the blades of the wind wheel, bringing it into rotational motion. The working fluid is fed through the channel of the axis of the sawing device into the internal cavity of the package of polyethylene disks and, through the radial channels of the dosing washers, is distributed over the surface of the working disks in the form of a flat film, which, breaking off from their edges, breaks up into drops.

At the same time, the air flow injected by the centrifugal fan additionally crushes the sprayed droplets and is picked up by the air flow and transported to the object being processed.

## 3 Results and Discussion

Experimental studies were carried out to clarify the working body's parameters. The studies were carried out within the flow rates corresponding to the first and second spraying regimes, q=3…20 l/min and rotation speeds ω = 80-120s-1, working body diameter d = 130…170mm, and the number of radial channels $n_r$ = from 2 to 6 items.

At the same time, the mass of the rotating part of the pneumatic disk atomizer was determined to clarify its design and technological parameters. Table 1 shows the mass structure of a rotating atomizer.

**Table 1.** Bulk atomizer structure

| № in order | Element types | Mass of one element, gr. | Number of elements, pieces. | Total weight, gr. |
|---|---|---|---|---|
| 1. | Polyethylene disc with polyethylene washers: | | 3 to 20 | 20 to 160 |
| | - diameter 130 mm | 6.06 | | |
| | - diameter 150 mm | 7 | | |
| | - diameter 170 mm | 7.9 | | |
| 2. | wind wheel | 270 | 1 | 270 |
| 3. | Aluminum hub | 170 | 1 | 170 |
| 4. | Bearing 18.09.02 | 50 | 2 | 100 |
| 5. | Hub axle | 75 | 1 | 75 |
| Mass of the rotating part | | | | 400 to 600 gr. |

The results and conditions of experimental studies of the working body are shown in fig. 2 and 3.

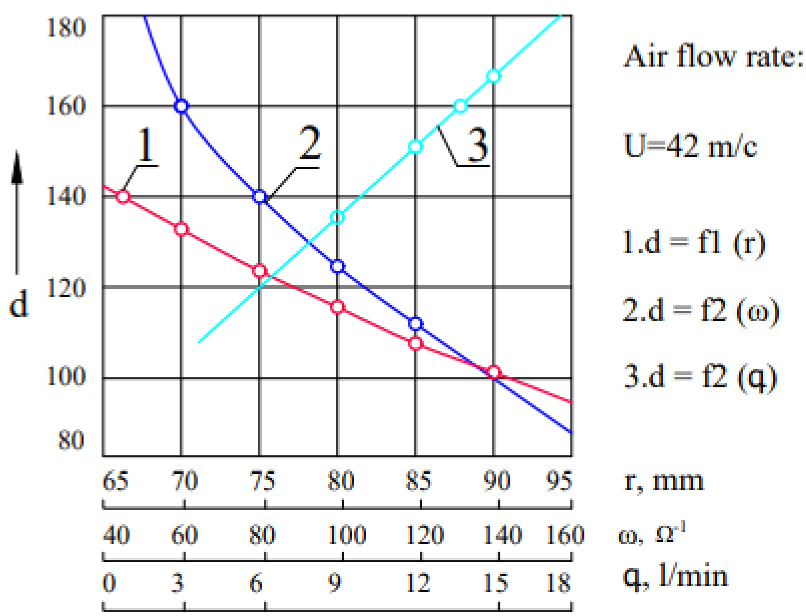


**Fig. 2.** Dependence of the droplet diameter on the main parameters and operating modes of the atomizer

As can be seen from Figure 2, with an increase in the disk's radius and the rotational speed of the atomizer, the diameter of the atomized droplets decreases, and the specific flow rate of the liquid leads to an increase in the diameter of the droplets. When changing the disk radius within r = 65…95 mm, rotational speed ω= 40…160 $s^{-1}$ and specific fluid flow rate q= 3…18 l/min. The median mass diameter of the droplets is $d_{ex}$=85…180 microns, which confirms the theoretical assumptions and meets the requirements for low-volume spraying.

An analysis of the experimental results showed that the size distribution of droplets for the atomizer under study in a wide range is well described by the well-known Rozon-Ramler equation [8].

$$\delta_i = 1 - \exp[-0.693\left(\frac{d_i}{d_m}\right)^{Q2}]$$

where: $\delta_i$ is the fraction of the liquid mass in capillaries smaller than $d_i$, that is, the accumulated liquid mass from the beginning of the integral distribution to $d_i$ (inclusive); $d_i$ is current value of drops in distribution, micron; $Q_2$ is exponent; $d_m$ is constant droplet diameter corresponding to $\delta_i$ =63.21%.

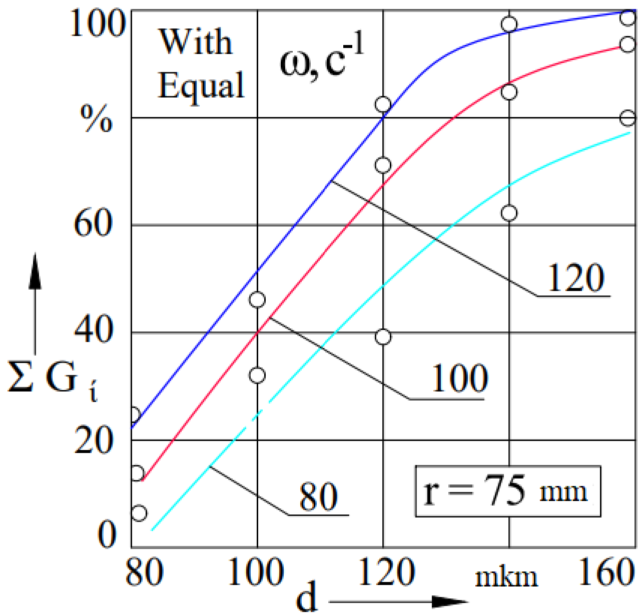


**Fig. 3.** Integral mass distribution of the droplet diameter.

According to the data (GSKTB selkhozkhimmash [4, 5, 11] (Lvov) Ukraine), the exponent $Q_2$ = 2.72 ± 0.045, and the droplet diameter is in the range from 80 to 160 microns.

To assess the quality of spraying, the polydispersity index was also determined. It is equal to the ratio of the droplet diameters corresponding to the values of the liquid mass fraction of 0.9 and 0.1.

$$P = d_{0.9}/\, d_{0.1}$$

This means that 80% of the mass of the sprayed liquid is in droplets with a size range, the ratio of which is equal to $P$. With monodisperse spraying, $P$ = 1, and with increasing polydispersity, P increases. The polydispersity index for the main known atomizers is P=3.1...4.67 (Table 2).

 https://doi.org/10.1051/e3sconf/202336504033

**Table 2.** The index of polydispersity of sprayers of various types

| № in order | Atomizer type | $a_2$ | P |
|---|---|---|---|
| 1 | Thermomechanical aerosol generator | 1.92 | 4.98 |
| 2 | Pneumatic (Venturi nozzle type) | 4.2 | 4.67 |
| 3 | Slotted shape | - | 4.45 |
| 4 | Hydraulic swirl | - | 3.7 |
| 5 | Hydraulic reflex | 2.44 | 3.54 |
| 6 | Disk | 2.72 | 3.1 |
| 7 | Pneumodisc | 2.65 | 3.2 |

Based on the test results, we can gain:

$$P = \left(\frac{l_n 0.1}{l_n 0.9}\right)^{1/a_2} = 21.85^{1/2,65} = 3.2$$

## 4 Conclusions

The obtained value is close to the value of a similar parameter of multi-disk atomizers designed by (GSKTB selkhozmash (Lvov) Ukraina). It is noteworthy that the droplet diameter also increases with increasing liquid flow, which should be considered a positive factor; at high flow rates of the working fluid, the droplets are larger, and with the transition to low rates, the droplet diameters will decrease accordingly.
It follows from the data obtained that the quality of the dispersion of the working fluid by a multi-disk atomizer in a film version driven by an air flow is higher than other disk atomizers.

## References

1. Afanasiy L., Utepov B., and Allaniyazov S. The spraying process simulation of the low-volume sprayer working body. In E3S Web of Conferences **264**, p. 04004 (2021)
2. Afanasiy L., Utepov B., and Allaniyazov S. Formation of an air jet by a fan installation with pneumatic disk sprayer. In E3S Web of Conferences **264**, p.04003 (2021)
3. Lee A., Utepov B., Kan E., and Kuychiev O. Study on the process of droplet formation when liquid flows out of a capillary. In IOP Conference Series: Earth and Environmental Science **939**, p. 012033 (2021)
4. Jadav C. V., Jain K. K., and Khodifad B. C. Spray of Chemicals as affected by different parameters of air assisted sprayer: A review. Current Agriculture Research Journal, **7**(3), 289. (2019)
5. Dunsky V.F., Nikitin N.V. On the transition from droplet outflow of liquid to jet outflow. Journal of Applied Mechanics and Technical Physics. **1**, 17-18 (1980)
6. Patel M. K. Technological improvements in electrostatic spraying and its impact to agriculture during the last decade and future research perspectives–A review. Engineering in Agriculture, Environment and Food, **9**(1), 92-100. (2016)
7. Cavalaris C., Karamoutis C., and Markinos A. Efficacy of cotton harvest aids applications with unmanned aerial vehicles (UAV) and ground-based field sprayers–A case study comparison. Smart Agricultural Technology, **2**, 100047. (2022)

8. Appah S., Wang P., Ou M., Gong C., and Jia W. Review of electrostatic system parameters, charged droplets characteristics and substrate impact behavior from pesticides spraying. International Journal of Agricultural and Biological Engineering, **12**(2), 1-9. (2019)
9. Skyler P. J. Eleventh Report, National Spray Model and Application Technology Working Group Meeting: August 1-2, 2001, Sacramento, CA, **1**(8). US Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. (2001)
10. Maski D., and Durairaj D. Effects of electrode voltage, liquid flow rate, and liquid properties on spray chargeability of an air-assisted electrostatic-induction spray-charging system. Journal of Electrostatics, **68**(2), 152-158 (2010)
11. Duan L., Fang Z., Han X., Dou Z., Liu Y., Wen M., and Zhang, G. Study on droplet impact and spreading and deposition behavior of harvest aids on cotton leaves. Langmuir, **38**(40), 12248-12262 (2022)
12. Khojiyev A., Muradov R., Khaydarov T., Rajabov N., and Utepov B. Some results of moisture and salt transfer in the initial period of plant development. International Journal of Engineering and Advanced Technology (IJEAT), **9**, 6907-6911. (2019)
13. Khaydarov T. A., Razhabov N. K., Utepov B. B. To the theory of movement of air mixture with fibrous materials in a pipeline. Journal Agro Processing, **8**, pp. 59-652020