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Optimizing the parameters of the air disc atomizer for the low volume desalination spraying of cotton crops

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Abstract. The article presents the results of a multi-factorial experiment to justify the parameters of a rotating sprayer. Optimization of the parameters of the pneumatic disk atomizer shows that with the correct choice of the specific liquid flow rate (q_i), disk radius (r) and the number of radial channels (η_r) at a constant air flow rate, it leads to obtaining the required median-mass droplet diameter. Therefore, when justifying the diameter of sprayed drops, it is necessary to consider a combination of the specific flow rate of the liquid and the radius of the disk. To obtain a monodisperse spray of drops with a median-mass diameter d= 80…120 µm, the disc radius should be in the aisles r=75.8…83.4 mm, the specific liquid flow rate qi= 0.61…0.96 l/min and the number of radial channels for pairs of disks in the aisles η_p = 4.59 ... 5.75 things.

1. Introduction

Analysis of the theory of hydraulic, pneumatic and rotary (rotating) atomizers shows that the most promising for the transition to low-volume spraying is the use of smooth rotating atomizers [1, 2, 4, 5, 6, 7].

However, the monodisperse spray mode is realized at very low capacities, which do not satisfy the production conditions. The expediency of increasing the productivity of a smooth spray disc while maintaining the main advantage - monodispersity is dictated by the production need. To increase the cost of monodisperse regimes, additional studies are needed, the results of which should form the basis for the creation of a working body for the Low volume desalination spraying of cotton crops. [8, 9, 10, 11, 12, 13].

2. Materials and methods

In studies of the process of atomization of the working fluid by a rotating atomizer, the method of a full factorial experiment was used. Based on the optimization of mutually independent parameters, the median mass diameter of the working fluid droplets was calculated from the disk radius, the number of radial channels and the specific fluid flow rate. the number of experiments N=8, the number of repeated experiments n=3. [14, 15, 16, 17, 18, 19, 20].

3. Results and discussion

To optimize the parameters of the pneumatic disc sprayer (figure 1), installed at the exit of the nozzle of the OVKh-600 fan sprayer, i.e. to determine the combination of levels of controlled factors, by the method of multifactorial experiment at which a monodisperse liquid spray is provided, the most significant controlled factors were identified based on the preliminary experiments:

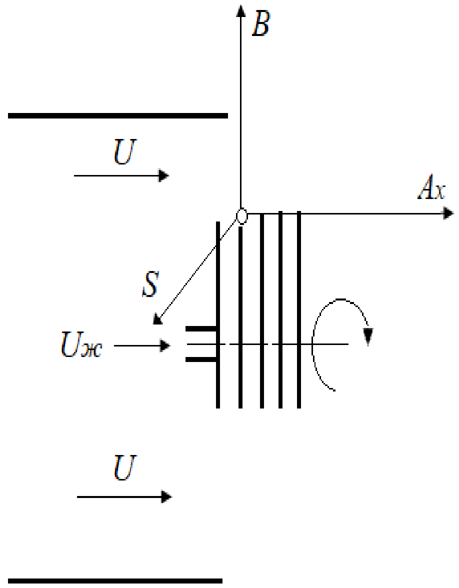

Figure 1. Scheme of installation of a pneumatic disc sprayer at the nozzle exit of the fan sprayer OVKh-600.

η_r - is the number of radial channels, pcs;
r - is the radius of the polyethylene disk, m;
q_i - fluid flow rate per 1 disk, l / min.

For the response (Y), we take the value of the minimum dispersion of droplets during spraying, expressed in microns. Based on preliminary experiments, we select the main levels and steps of varying independent controllable factors (table 1).

Table 1. Levels of factors and intervals of their variation.

Factors	Factor levels			Variation step
	lower (-1)	Basic (0)	Upper (+1)	
x_1, things.	2	4	6	2
x_2, mm	65	75	85	10
x_3, l/min	0.5	1.0	1.5	0.5
Dimensionless values of factors	-1	0	+1	

To obtain a mathematical description of the object from the point of view of minimizing the number of experiments, the most optimal and sufficiently accurate are the symmetrical plan of type B3. With these plans, the factors vary only at 3 levels. This significantly reduces the amount of experiments, which is very important when carrying out complex and expensive experiments related to the manufacture of various variants of disks, etc. and, in addition, in terms of its static properties, this plan is close to the D-optimum. The point of the spectrum of plan B_3 is given in tab. 2

Since the change in the input values У is almost random, it is necessary to conduct parallel experiments at each point of the spectrum of plan B_3 and determine the result of the observation by the formula:

$$у_g = \frac{1}{m}\sum_{e=i}^{m} у_g e \quad (1)$$

and determine the sample variances

$$\boldsymbol{\delta_g^2} = \frac{\mathbf{1}}{\boldsymbol{m}}\sum_{\boldsymbol{e-1}}^{\boldsymbol{m}} \left(у_{\boldsymbol{g}}\boldsymbol{e} - у_{e}\right)^{\mathbf{2}},\ g = 1 \div N, \quad (2)$$

For plan B_3 with n= 3, the number of experiments is N=14. It was decided to carry out m=3 parallel experiments at each point of the spectrum. Before the implementation of plan B_3 on the object, it is necessary to randomize the variation options in each of the series of experiments, i.e. using a table of uniformly distributed numbers, determine the sequence of implementation of options for varying the planning matrix in each series of experiments. The order of implementation of options for variation of the planning matrix is given in columns x_1, x_2, x_3

Table 2. Planning Matrix and Experimental Results.

№ p/p	Random row repetition			Variable Factors			Droplet dispersion, µm repetition			mean
	K_1	K_2	K_3	X_1	X_2	X_3	$У_1$	$У_2$	$У_3$	$У_{cp}$
1	8	4	7	-1	-1	-1	172.78	164.81	170.41	169.33
2	4	12	1	+1	-1	-1	150.39	144.81	155.24	150.08
3	2	5	10	-1	+1	-1	83.6	92.72	82.6	86.31
4	13	6	9	+1	+1	-1	72.56	75.22	76.36	74.68
5	5	14	3	-1	-1	+1	195.38	201.37	197.23	196.99
6	3	1	5	+1	-1	+1	170.08	175.81	168.45	171.45
7	1	8	12	-1	-1	+1	93.99	90.16	94.74	92.96
8	14	9	8	+1	+1	+1	82.07	78.38	84.19	81.54
9	7	13	14	-1	0	0	115.95	110.44	120.64	115.68
10	10	2	11	+1	0	0	101.32	96.72	98.06	98.70
11	6	7	6	0	-1	0	171.05	178.52	169.24	172.94
12	12	11	13	0	+1	0	82.17	77.15	84.29	81.20
13	9	10	2	0	0	-1	101.05	101.05	100.68	102.33
14	11	3	4	0	0	+1	113.98	120.27	122.71	188.97

Processing of experimental data was carried out on a computer. Using this program, outlier variances were determined by formula (2) at m=3 (column of table 2), the reproducibility of the experiment was Sq^2 {Y}= 0.005, and the coefficients **b** were estimated for unsolved models **n** (x, b) of type **I**:

$$\eta\ (x, b) = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_1 x_2 + b_5 x_1 x_3 + b_6 x_2 x_3 +$$
$$+ \boldsymbol{b}_7 \boldsymbol{x}_1^2 + \boldsymbol{b}_8 \boldsymbol{x}_2^2 + \boldsymbol{b}_9 \boldsymbol{x}_3^2, \quad (3)$$

The obtained estimates b were checked for static significance, the predicted response values obtained (columns Yg,), the adequacy of the regression models and the response function were checked. The verification performed showed that the experiment is reproducible, that the regression model η (x, b) is adequate to the response function φ (x1, x2, x3) in the study area. Thus, a regression equation was obtained that describes the required dispersion of drops of atomized liquid

$$У(x, b) = 108{,}917 – 8{,}500x_1 - 44{,}367x_2 + 7{,}867x_3 +$$

$$2{,}667x_1x_2\text{-}18{,}717x_2^2\text{-}4{,}417x_2x_3 \quad (4)$$

An analysis of equation (4) shows that the dispersity of the sprayed liquid droplets decreases with a slight increase in the number of radial channels and disk radius and increases with an increase in the minute flow rate of liquid supplied to one disk. Solving the regression equation for minimization, we chose the value of the main factors based on the correspondence between the sizes of dispersed drops that meet the initial requirements (80 ... 120 µm).

As a result, the values of factors were obtained within the following limits: x_1= 0,2999…0,8763, x_2= 0,0835…0,8461, x_3=0,081…0,779. In kind: ηp= 4,5999…5,7525 things; r=75,835…83,461 mm; qi= 0.6102…0.9595 l/min.

4. Conclusions

As a result of the multifactorial experiment, it was found that in order to obtain the required dispersion of drops within d= 100…125 µm, the main parameters of the pneumatic disc atomizer should have the following values: disc radius r = 75…80 mm, number of radial channels η_p = 4…6 things and specific fluid flow rate q_i= 06…1,0 l/min.

Experimental testing under laboratory conditions of a pneumatic disk atomizer with rational parameters showed that the dispersion of the sprayed droplets was 80-125 microns.

From the data obtained, it is clearly seen that there is a uniform monotonicity of the aerosol phase of the air-droplet jet, which indicates a high quality of spraying.

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