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TURBULIZATION METHOD OF FORMATION OF HIGHLY DISPERSED DROPLETS

Kh. D. Irisov, I. A. Ashirbekov , A.P. Kartoshkin, A.D. Abdazimov

Abstract. *The article critically analyzes traditional methods of forming drops of defoliants and liquid chemicals. As an object of study, a sprayer with a perforated turbulator was selected, which ensures the formation of fine droplets on a short spraying torch. The degree of crushing of the working fluid, design parameters and operating modes of the proposed sprayer are investigated. Based on theoretical studies, analytical dependencies that reveal the physical properties of the sprayed liquid are analyzed, a description of the device and the principle of operation of the sprayer equipped with a perforated turbulator is given. The above analytical dependencies allowed more purposefully improving the design of the proposed atomizer.*

Key words: *sprayer, crushing, working fluid, method, drops, polydisperse, highly dispersed, turbulizer, perforated.*

INTRODUCTION

The wide introduction of modern cluster farms for the production of high-quality agricultural products into the agro-industrial complex (AIC) requires further improvement of technical means for the use of defoliants and liquid chemicals. This, in turn, requires new theoretical approaches for the deep disclosure of the physical essence of the process of crushing working fluids with a short spraying torch. Spraying of liquid defoliants or other chemical agents is widely used in various branches of the country [1]. At dispersion of working liquids, one of the main difficulties consists in necessity of reception of highly dispersive atomization. However, the majority of modern spraying units are ready to use OVH-600 less efficient polydisperse spraying with an average median-mass diameter of 53-428 mkm [2]. Therefore, creation of new methods of spraying is the most urgent and promising task for today.

OBJECT AND METHOD

The object of research is the degree of crushing of the working fluid, perforated turbulator, its design parameters and operating modes. Fig. 1 shows the basic scheme of formation of initial coarse droplets. From the analysis of the scheme of forces acting on the initial coarse drop it is visible that the integral cylindrical jet 2 in process of distance from edge of a nozzle 1 after short distance Δl passes in the wave-like form with length and under the influence of external forces is exposed to crushing. With the growth of alternating forces G, R_l, T_a and R, the intensity of the wave-like hydraulic jet crushing increases. Future droplets of satellites easily evaporating contaminates the environment [3,4].

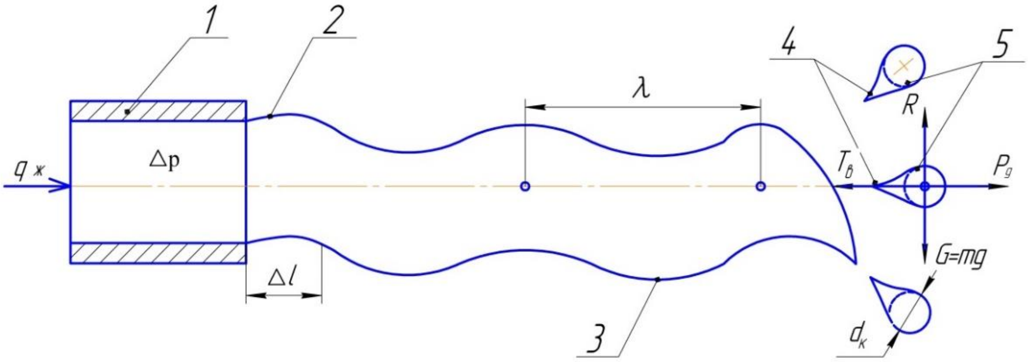


Fig.1. Scheme of formation of initial droplets:

1- Sprayer nozzle; 2-cylinder part of the hydraulic jet; 3-wave jet; 4- future satellite droplets; 5-initial coarse droplets; Δl- length of not crushed part of the cylindrical jet; λ - length of the wave-like part of the jet; G- gravity, T_a-resistance of the air medium, P_l - force from the pressure of the working liquid, R - crushing force of the drop); d_d- diameter of the initial drop; q_l and Δp- flow rate and pressure of the working liquid.

There are available methods of obtaining high dispersion droplets by artificial electrification of sawn liquids, which are most widely used in thermal engines operating on easily crushed and flammable diesel fuel under the influence of high temperatures. However, liquid defoliants or chemical agents used in agro-industrial complex(AIC) with high viscosity and surface tension coefficient are less susceptible to crushing to monodisperse (with the same diameter) drops. The objective of the study is to form highly dispersed droplets.

It is known that the aerodynamic forces of T_a and the strength of the initial coarse droplets formed from thin hydraulic jets proportional respectively [3, 4, 5, 6, 7, 8]:

$$\frac{\gamma_a w_r^2}{2g} u \frac{4\sigma}{d_d}, (1)$$

where γ_a- is the specific weight of the streamlined air kg/m3; w_r - the relative velocity of the droplet movement in the air, m/s; g- the acceleration of the gravity field, m/s^2; σ - the surface tension coefficient of the liquid, kg/m; "d_d- the diameter of the initial droplet, m.

The formula is a condition of non-stability of the initial droplet shape:

$$\frac{\gamma_a w_r^2}{2g} \approx \frac{4\sigma}{d_d}, \ (2)$$

According to M.S.Volynskiy [4], in condition (2), the criterion of crushing the initial coarse droplet is considered the crushing criterion:

$$D = \frac{\gamma_a w_r^2 d_d}{g\sigma}. (3)$$

For most of the liquids studied, the crushing criterion D remains constant. Thus, at D≥0.7, a splitting of the droplets occurs, at D≥14, a splitting of the droplets.

The limiting speed with which the droplet can move in the air without breaking is equal:

$$w_r = \sqrt{\frac{g\sigma D}{\gamma_a d_d}} = \sqrt{\frac{g\sigma D}{2\gamma_a r_d}}, (4)$$

Where, r_d- the droplet radius, m..

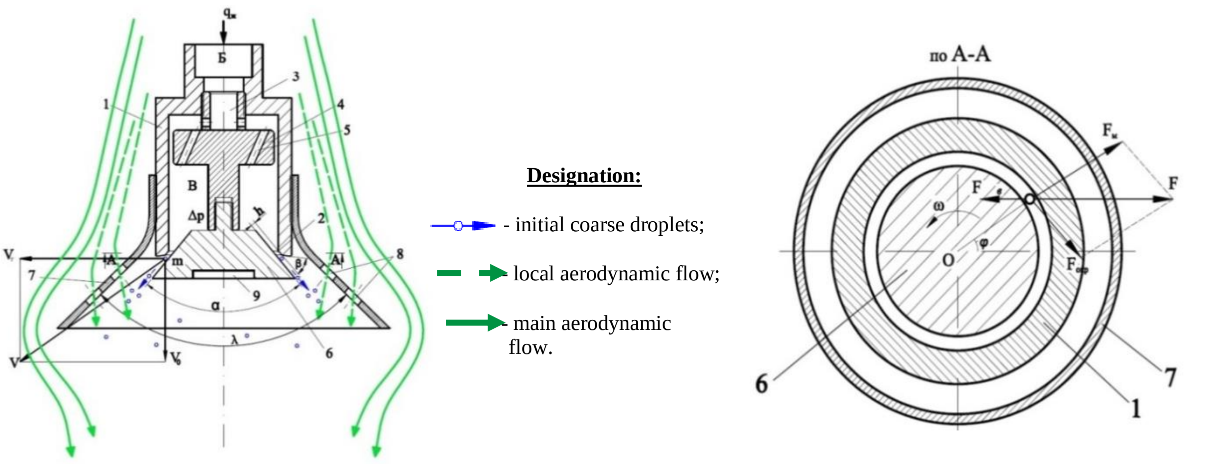


Fig.2. General View and section on A-A of the proposed atomizer:

1 - body; 2 - ring-shaped slot; 3 - central tube; 4 - disk swirler; 5 - inclined channel; 6 - cone-shaped flow expander; 7 - cone-shaped perforated turbulator; 8 - windows for local air flow inlet; 9 - regulating groove (q_l - flow rate of the supplied working fluid, l/min; Fm - centrifugal force, N; F_c - circumferential force, N; F - resulting force, N; F_v - viscosity force of the working fluid, N; angular velocity of thin liquid film in a circular slot; α - angle of opening of cone-shaped liquid flow expander; β - angle of opening of the spray torch; λ - angle of opening of the turbulator nozzle; φ - angle of rotation of thin liquid film in the zone of ring-shaped slot; m - particle of thin liquid film; "V_a- axial velocity of fluid eddy flow; "V_c and V_r - circumferential and resulting velocity of fluid in the zone of ring-shaped outlet slot; h - width of ring-shaped slot).

Well-known disc, rotary and other slot sprayers of modern sprayers are distinguished by their complex design, they give polydisperse spraying.

In order to obtain high dispersion sprayers with the same droplet size, we proposed the design of the atomizer [9,10,11], equipped with a turbulator, the scheme of which is shown in Fig. 2.

The principle of operation of the proposed device is as follows.

The working fluid from the cavity B of the case 1 goes to the cavity of the disk swirler 4 and then tangentially through its inclined channels 5 goes to the swirl chamber C, then under the influence of the working pressure Δp the fluid passes to the zone of the circular slot 2, where under the influence of the kinetic energy of the swirl flow is subjected to intensive dispersion up to highly dispersed drops. Relatively large initial droplets in the nozzle zone of the perforated cone tabulator 7 are subjected to secondary crushing. Further these initial drops in the area of installation of replaceable perforated cone-shaped tabulator 7 under the influence of local and powerful coaxial aerodynamic flow are subjected to tertiary crushing, that is, crushing to highly dispersed droplets and then they under the action of the main powerful aerodynamic flow of the fan of the spraying unit is sprayed towards the treated crops. Due to the use of replaceable perforated cone-shaped tabulator 7, the intensity of crushing of working fluids of different viscosity is increased.

The inclined channels of the 8 replaceable perforated turbulator 7, set at an angleγ, relative to the axis of its symmetry provide inside it a powerful turbulent effect, which stimulates the formation of highly dispersed droplets.

The quality of the technological process of dispersion of the working liquid is regulated by changing the flow rate of the liquid (q_l) through a circular slot with an expanding outlet channel 2 through an adjustable flow expander 6 liquid, and by changing the working pressure of the liquid (Δp) in the hydraulic communications.

Thus, due to the simplification of the device design and additional equipment with replaceable perforated cone tabulator it is possible not only to reduce the metal consumption -

and energy intensity of the crushing process, but also to increase the intensity of dispersion of the supplied small portion of the working fluid to high dispersion drops. The offered device can be mounted on both fan and boom spraying units. Due to the local turbulence of thin liquid film in the area of the nozzle channel of the sprayer the formation of high dispersion droplets on a short spray torch is achieved.

The individual dimensions of the droplets per 1 cm^2 of the surface of the special liquid-sensing droplet number 9950-0028 (Water Sensitive Paper), their distribution, total number of droplets, droplet density were determined using the DepositScan program [12; 13].

RESEARCH RESULTS.

As a result of laboratory tests the following design parameters were determined:

-angle of inclination of the channels in the swirler, 45^0;

- annular gap width, h=0,2-1,0 mm;

- expansion angle of the flow expander, $\alpha=45^0$;

-tilt angle of the channels of a cone-shaped perforated turbulator $\gamma= 20^0$;

- total number of grooves with diameters d_{turb}=4 mm on perforated turbulizer n_{gr}=16 pcs.;

- the total number of turbulization sprayers installed in the nozzle channel of the spraying unit n_s = 4pcs.

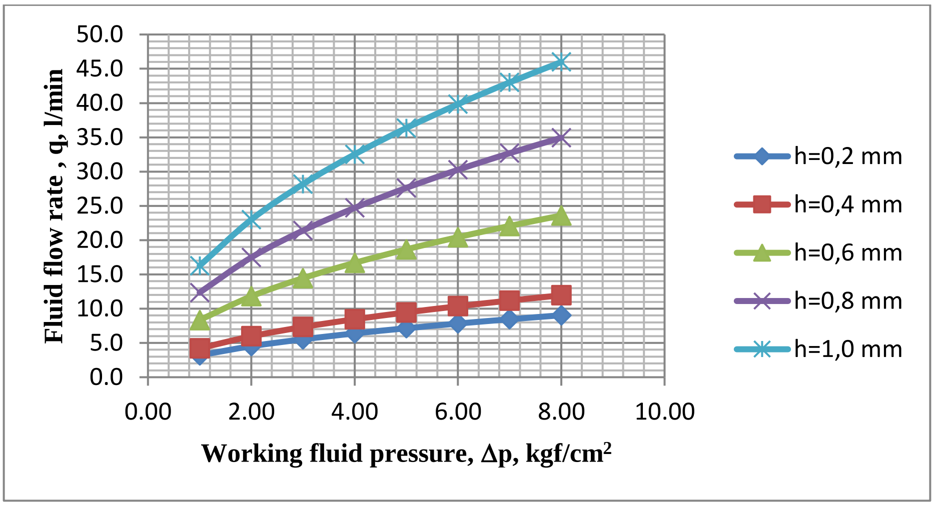
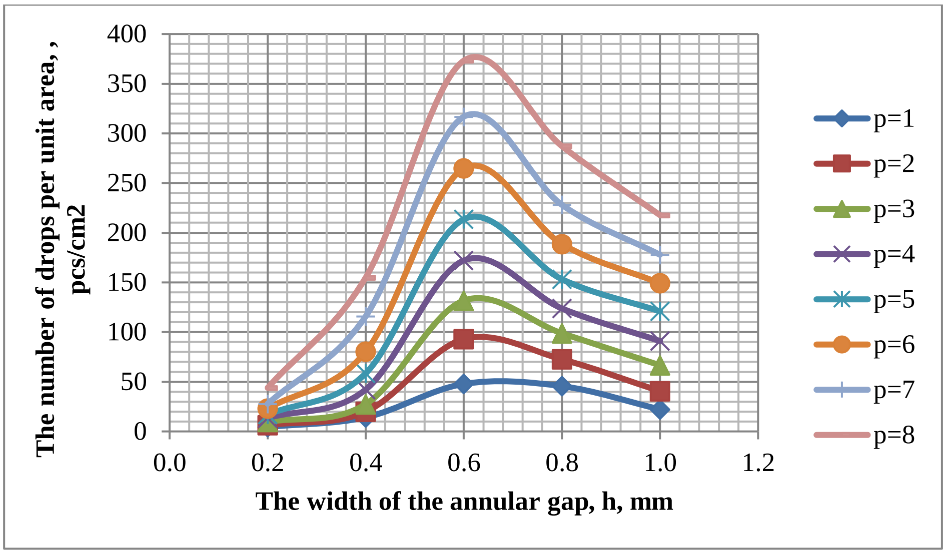


Fig. 3. The results of determining the flow rate of the working fluid through the atomizer (n = 4 pcs.) with a turbulator

Laboratory experiments have shown that due to the formation of highly dispersed droplets, they are reliably deposited on both the upper and lower part of cotton leaves [14]. For example, electrostatic charge of the atomizer supplied to the body 1 in the conditions of turbulent method of formation of high disperse droplets excludes useless loss of working fluid and environmental pollution. Due to the pulling of these droplets towards the surface of cotton leaves and other crops. We have established that the laws of distribution of formed highly dispersed droplets are subject to the law of Gauss or Weibull [15].

Fig.4. shows the dependence of the number of droplets formed from the width of the dosing ring-shaped slot and the average median-mass model diameter of the settled droplets on the surface of the cards from the pressure of the working fluid in front of the nozzle channel of the proposed atomizer. In the course of the study it was established that Δp=5 kgf/cm^2 a and working slot width h=0.6 mm, the flow rate of working fluid was q_l=18,5 l/min, the total number of settled droplets per 1 sm^2 was 213.6 pcs., the average median-mass diameter of droplets was within 52.8-190 mkm. This testifies to the high efficiency of the turbulence method of formation of highly dispersed droplets.



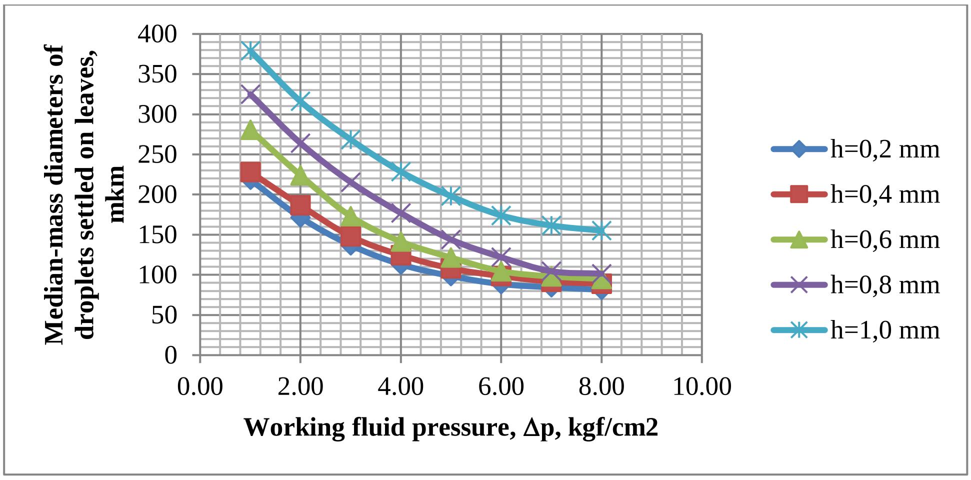


Fig. 4. Graphic dependences reflecting the average diameters of the settled droplets on the surface of model cards (total number of nozzles n=4 pcs.)

CONCLUSIONS

1. Most of the modern spraying units OVH-600 give less effective polydisperse spraying with average median-mass diameters within 53-428 mkm.

2. In order to increase the degree of liquid crushing, a sprayer equipped with a cone-shaped perforated turbulator is offered.

3. The obtained analytical dependences have led to more purposeful improvement of the design of the proposed turbulent atomizer.

4. It was obtained by laboratory experiments that at Δp=5 kgf/cm^2, h=0.6 mm, q_l=18.5 l/min, the total number of settled droplets per 1 cm^2 was 213.6 pcs., droplets of cards, average median-mass diameters of settled droplets were within the range of 52.8-190 mkm, which proves the high technical efficiency of the proposed method of turbulence of formation of highly dispersed droplets.

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