Hydro-Aerodynamics of a Turbulizer Corrector Two-Phase Spray Face

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HYDRO-AERODYNAMICS OF A TURBULIZER CORRECTOR TWO-PHASE SPRAY FACE

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Annotation. This article explores the hydro- and aerodynamic forces acting on a thin layer of fluid that erupts from a turbulent rectifier ring loop developed by the authors. The stages of the decomposition process of a two-phase (air + droplet) torch in which large droplets are formed in this technological process, the physical nature of the Weber number in this process, and the probabilistic nature of highly dispersed droplets are thoroughly covered.

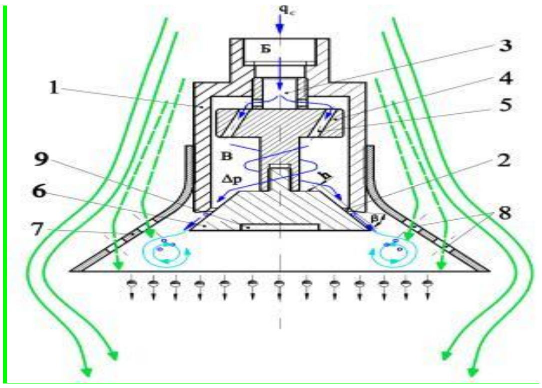
Key words: working fluid, turbulizer rectifier, turbulization efficiency, droplets, Weber number.

Introduction. The issues of agricultural reform and food security are undoubtedly important, and great attention is given to the consistent development of the agro-industrial complex and its engine, i.e., the driving force of diversified farms[1], as well as supporting the farming movement in the agricultural sector; research is underway to phase out cotton and grain production in cluster form.

Cotton has been grown for more than 2,000 years, with 32-34 million hectares in 84 countries. It is one of the leading economies of the United States, India, Brazil, Pakistan, Egypt, and Uzbekistan [2]. Defoliation plays an important role in accelerating the ripening of cotton and its short-term harvesting by machines.

According to the research of leading scientists of the world and Uzbekistan [3,4,5,6,7,8,9], the optimal size is 10-15 microns for disinfection of flying insects living under the leaves of agricultural plants, pests of plants and plants. Drops of 30–150 microns are optimal for decontamination, defoliation and dehydration processes, and for weed control, it is necessary to form droplets of 100–300 microns using spray tools [3, 4].

Methods. The highly dispersed droplets formed by the proposed corrector begin to form under the influence of the kinetic energy of local and main aerodynamic air currents flowing through a nozzle (2), symmetrically generated by a fan, in addition to working fluid flowing out of an annular hole [10, 11.12]



1 – sheath; 2 – ring slot; 3 – central tube; 4 - disc adjuster; 5 - sloping ditch; 6 - flow expander; 7 - conical turbulizer; 8 - hole; 9 - adjustment groove; q_c– transmitted working fluid; α, β – accordingly flow expander, expansion angles of the spray torch; h– annular slit width; Δp – working fluid pressure.

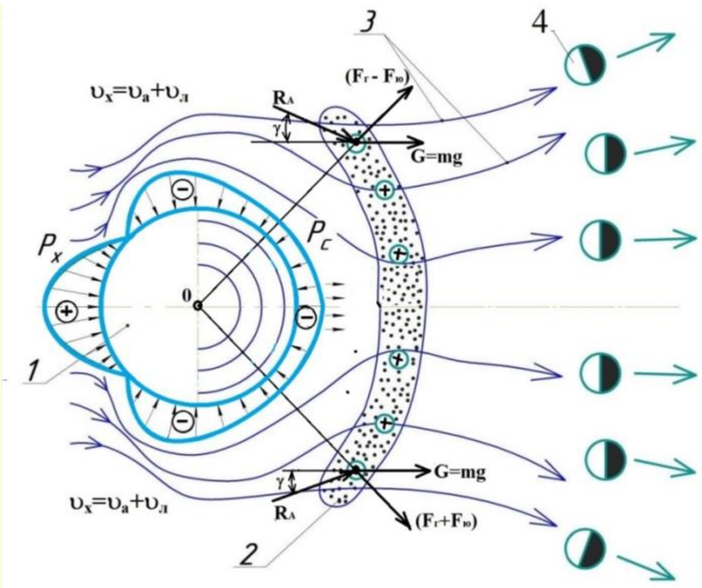
Figure 1. Technological process scheme of turbulizer

The mathematical model of the kinetic energy of the local and main turbulent air currents acting on the thin liquid membrane of the liquid flowing out of the above-mentioned rectifier ring hole can be expressed as follows [13]:

$$E_{ум} = \mathrm{E}_{с} + E_{ло} + \mathrm{E}_{х} = \frac{m_c \upsilon_c^2}{2} + \frac{m_{ло} \upsilon_{ло}^2}{2} + \frac{m_x \upsilon_x^2}{2}, \tag{1}$$

Here, $\mathrm{E}_{с}, \mathrm{E}_{х}, E_{ло}$ - the kinetic energy of the hydrodynamic, primary, and local air turbulence flows leading to the disintegration of the thin liquid membrane, J, respectively.

The local large air droplets separated from the thin liquid membrane are affected by the gravitational force G and the aerodynamic drag force *R* of the local air flow. The R>G condition must be met when forming highly dispersed droplets (Figure 2) [14,17].



1- primary drop; 2- two-phase liquid membrane; 3- local airflow power lines; 4- highly dispersed droplets; P_x, P_c- air and fluid pressure, respectively; $F_г$, R_A- hydrodynamic and aerodynamic forces, respectively

Figure 2. The multi-stage turbulent decomposition process of the primary drop

We can express the differential equation of motion of droplets of mass m_T in the air stream as follows [15,16]:

$$\frac{m_T du}{dt} - R + G = 0. \tag{2}$$

The two-phase spray consists of a fake local airflow and the first large droplets. It serves to form highly dispersed droplets under the influence of aerodynamic forces of the local and main air flow ($F_г$+R)) (Fig. 2).

The local air currents transmitted through the cylindrical holes opened in the turbulizer form a two-phase (drop + air) annular curtain 2 from primary droplet 1 separated from the thin working fluid fragments. The primary droplets are exposed to the gravitational force *G*, hydrodynamic force $F_г$, surface tension force $F_ю$, aerodynamic force R_A, momentum transfer force $F_{им}$, resistance $F_{қар}$ and inertia $\mathrm{F}_{инер}$ forces to form highly dispersed droplets whose diameters are close to each other (Figure 2) [17]

$$F_{г} = \pi d_0^2 \Delta p\left(\frac{2+3\cos\varphi-\cos^3\varphi}{12}\right), \quad (3)$$

Here, d_0– diameter of the primary drop, m; φ – angle of change of flow axis, grad.

$$F_{ю} = \pi\kappa d_{теш}; \quad (4)$$

$$F_{им} = (\pi/3)\rho_c w_{ло}^2 \cdot d_{теш}^2; \quad (5)$$

$$F_{кар} = (\pi/8)d_0^2 \cdot c_T \rho_c w_{ло}^2; \quad (6)$$

$$F_{инер} = \frac{(\rho_{с} + 0{,}5\rho_x)Q_{ло}^2}{3\pi(6/\pi)^{2/3}V_{ло}^{2/3}}, \quad (7)$$

Here, κ - surface tension coefficient, N/m; $d_{теш}$ – the diameter of the cylindrical hole in the turbulizer, m; ρ_c – working fluid density, kg/m^3; ρ_x – air density, kg/m^3; $w_{ло}$– local air flow rate, m/s; c_T – the surface of the primary drop, m^2; $V_{ло}$– the volume of local air flow, m^3.

In the first stage, the balance of forces acting on the fluid flow is determined by the following expression:

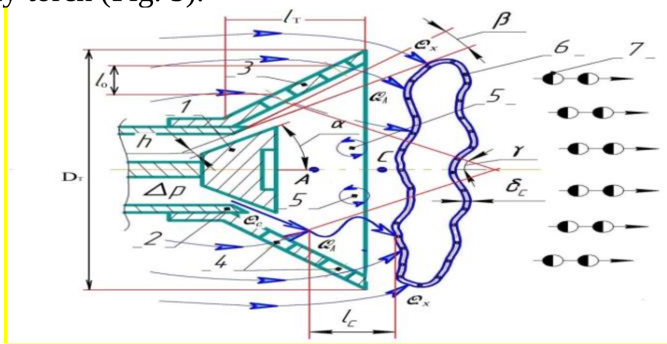
$$F_{г} + \mathrm{F}_{им} = F_{ю} + F_{кар} + F_{инер}. \quad (8)$$

We describe the concentration of air in the coefficient

$$\chi = \frac{m_{ю}}{Q_{л}}, \quad (9)$$

where $m_{ю}$ is the mass of highly dispersed droplets released per second and Q_l is the mass of local air transmitted to the turbulizer condensing chamber per second.

The number of holes drilled in the turbulizer is large, which creates a strong turbulization effect in the condensing chamber around points A and C, allowing the formation of highly dispersed droplets in a short spray torch (Fig. 5).



1- current expander; 2- speakers; 3- turbulizer; 4- cylindrical holes; 5- turbulization effect, 6- two-phase flare; 7- highly dispersed drops

Figure 3. Scheme for determining the turbulence effect

Results and Discussion. The number of holes in the turbulizer is determined by the following expression:

$$z_T = \frac{\pi D_T}{\ell_0} = \frac{3{,}14 \cdot 40}{8} = 15{,}7 \approx 16(count) \quad (10)$$

Here, D_T– turbulizer diameter, mm; ℓ_0 - range of cylindrical holes, mm.

The local air flow rate (m^3/s) transmitted through the cylindrical bores of the turbulizer is determined by the following expression:

$$Q_{л} = \mu_x z \frac{\pi d_{теш}^2}{4}\sqrt{2\frac{\Delta p_x}{\rho_x}} \cdot \cos\gamma = \mu_x z \frac{\pi d_{теш}^2}{4}\upsilon_x \cos\gamma, \qquad (11)$$

Here, μ_x - air consumption coefficient, $\mu_x=1$; z – number of cylindrical holes in the turbulizer, pcs; γ – the angle of inclination of the holes in the conical turbulizer relative to the axis of the turbulizer, degrees; Δp_x – air pressure, Pa; ρ_x – density of air, kg/m^3; υ_x – the velocity of the air flow along the axis coming out of the spray speaker, $\upsilon_x = 52...54$ m/s equivalent.

In the calculations, the coefficient μ_x is assumed to be 1 because the air density is small relative to the working fluid density.

Figure 7 shows a graph of the change in the local air flow transmitted through the cylindrical holes of the turbulizer according to expression (14) depending on the parameters γ and z.

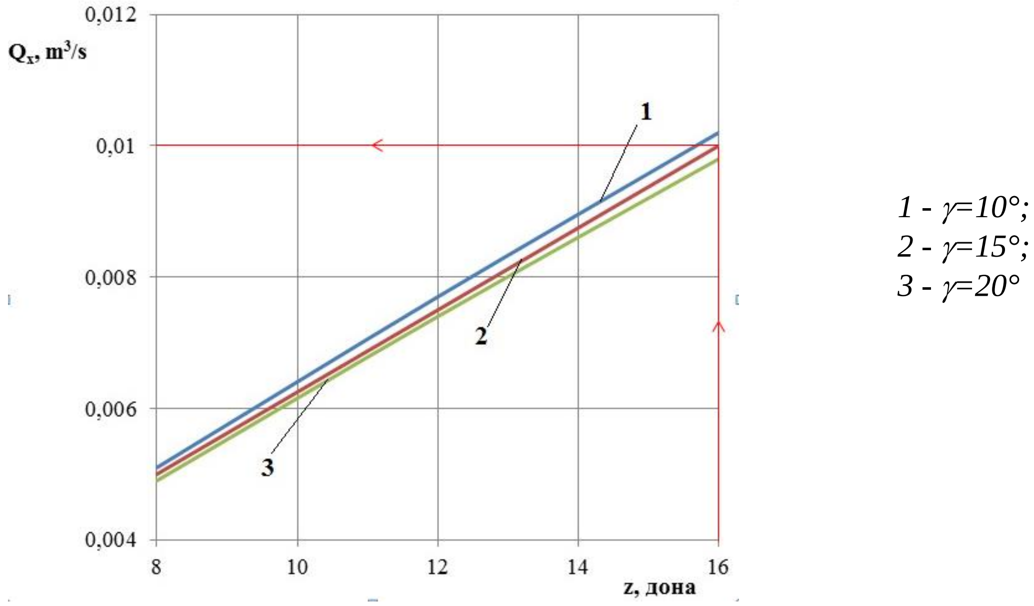


Figure 7. Graph of the dependence of the local air flow through the cylindrical bores of the turbulizer on the parameters γ and z

The disintegration capacity of the working fluid turbulizer inside the condensing chamber is assessed by increasing the Weber number ($10 \le We_{кр} \le 10^5$).

Suppose that the local air pressure acting on the surface of a large primary droplet is equal to $P_x = \rho_x \upsilon_T^2 / 2$. According to Laplace's expression, the force of surface tension acts on a liquid sphere $P_c = 4\kappa / d_0$. The value of this pressure ratio is called the Weber number, which is defined by the following expression [14]:

$$P_x / P_c \approx We = \rho_c \upsilon_T^2 d_0 / 8\kappa = 1{,}45 \cdot 75{,}5^2 \cdot 0{,}006 / 8 \cdot 0.073 = 85 \qquad (15)$$

Here, ρ – working fluid density, kg/m^3; υ_m – drop velocity, m/s; κ – surface tension coefficient (for water κ=0,073 N/m).

The Weber number is *We = 42* for conventional OBX-600 fan spray nozzles, *We = 85* for the proposed two-phase spray torch breaker for the proposed turbulizer nozzles, and the accepted basic working hypothesis proved correct.

We see that the sizes of highly dispersed droplets formed by two-stage accelerated decay around points A and C under the influence of a strong turbulization effect have the property of randomness. The main parameters of such drops and distribution laws are determined on the basis of the theory of probability.

Conclusion. Based on theoretical developments, the strong local air flow rate around point A to achieve a stable turbulization effect Q_{lo} involves the number of cylindrical holes in a conical turbulizer $z = 16$, and the angle of inclination of the cylindrical holes relative to the turbulizer axis $\gamma=15°$ allowed us to obtain the expected turbulization effect through the centre. In this case, the local air flow consumption, which allows us to obtain a turbulization effect, is equal to $Q_{lo} = 0.01$ m^3/s.

We see that the size of the highly dispersed droplets formed by the two-stage accelerated disintegration around points *A* and *C* under the effect of a strong turbulization effect has the property of randomness. This shows that the basic parameters of such drops and the laws of distribution obey the laws of probability theory.

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