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SELECTION AND JUSTIFICATION OF THE THE SHORT-BOTTOM NOZZLES' PARAMETERS FOR SURFACE RAIN BY THE SPRINKLER MACHINE «KUBAN-TK»

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ABSTRACT

In recent years, research and development works have been carried out in our country to create a modification of the sprinkler machine "Kuban-L" with a set of equipment for controlling the sprinkling height (including the surface one), which allows reducing the average rain intensity and reducing the loss of irrigation water for evaporation and demolition by the wind. There are a number of issues that need to be clarified, despite the high degree of this product's development such as the distribution of the quality of the rain's spray along the length of the machine, the formation of parameters for reducing the intensity of rain, its energy characteristics, etc.

The object of research is a set of equipment for controlling the height of the sprinkling of the sprinkler machine "Kuban" ("Kuban-TK"). The purpose of the research is to substantiate and clarify the technical and agrotechnical parameters of this equipment. In the course of the research work, the collection, analysis, and previous studies were carried out, engineering calculations and variant studies of the most important parameters of the equipment's set for sprinkling height control were carried out. As a result of the researches, the following parameters were established: the consumption of the sprinkler machine "Kuban-TK" equipped with the kit - 200 l/s, the average rain intensity - up to 0.8 mm / min., the diameter of the rain drops - up to 1 mm. The results of the research work can be used in the finalisation of the specified set of equipment.

Keywords: flow rate, deflector nozzles, construction, flow-pressure characteristics, set of wing racks, placement in space, design parameters, rain intensity, nozzles' diameter.

INTRODUCTION

In recent years, research and development work has been carried out in our country to create a sprinkling modification of the sprinkler machine "Kuban" with a set of equipment to control the sprinkling height (including the surface level), which allows to reduce the average rain intensity and reduce the loss of irrigation water for evaporation and wind drift. Despite the high degree of this product's development, there are a number of issues that need to be clarified. It includes the distribution of the quality of the rain's spray along the length of the machine, the formation of parameters for reducing the intensity of rain, its energy characteristics, etc. This paper presents the results of the researching work on these issues which were obtained in the Federal State Research Institution All-Russia

Scientific and Research Institute for Irrigation and Farming Water Supply Systems "Raduga". They will be used while adjusting the technical documentation for the kit for putting it into production.

The purpose of ground sprinkling is, first of all, environmental protection of the environment by reducing the humidity of the air and the less energy impact of rain on the soil. We have started researches from 2004 and found that a simple reduction of the nozzles, with which the sprinklers are equipped, is not acceptable as a constructive solution; we took into account the experience of creating prototypes of kits that change the parameters of the rain of the standard machine "Kuban". One of the reasons is the decrease in the volume of the rain plume, which reduces their mutual overlap and equalization of the water content of the rain flow. This leads to a decrease in the area covered by a rain cloud under the whole machine, and, consequently, to an increase in the intensity of rain; to reduce the uniformity of distribution of the precipitation layer over the irrigated area [4], [5], [6], [7], [10]. The second reason for the unacceptability of simply transferring the rain belt at a rate of 200 l/s per car is the high rate of raindrops.

The data on the distribution parameters of the flow rate of the irrigation belts of a standard machine "Kuban" and the sprinkler machine one which is equipped with a set of rain intensity reduction presents in [Table 1]. Since the sets of nozzles are different, according to calculations, it turns out that for a regular car all the flow is issued at an expiration rate in the range of 24-18 m/s. For a surface 18.3% of the flow rate is issued at a speed exceeding 24 m/s. This occurs in a design that does not use special chokes and pressure regulators. High speeds break up the water film more strongly, create a fine spectrum of raindrops. On the one hand, this is a guarantee of the irrigation water's losing in the air, on the other hand, the energy of rain is substantially replaced. Let's compare these figures: the diameter of a drop of 0.5 mm, 1 mm and 2 mm gives a soaring speed in relative numbers as 1: 1.3: 1.9 for diameters, this ratio is 1: 2: 4; for the volumes enclosed in these drops of water, this ratio is 1: 8: 64, and for units of kinetic energy acting on the structure of the soil and the plant, these ratios are 1: 14: 219. This is at a drop rate of 3.1 m/s; 4.3 m/s; 6.2 m/s, and the outflow of water at the surface version of irrigation exceeds several times. Therefore, high velocities are a blessing for crushing droplets, since the impact force of the droplets is first of all transmitted through the mass, and, secondly, through the square of velocity.

There are two ways to reduce the intensity of rain in the version of the surface sprinkling: to reduce the consumption of the machine or to distribute the working bodies - the sprinkler heads - in space [1]. This is achieved by design, by combining the design sizes of the wings and the hydraulic parameters of the rain plume of the nozzle. In this case, it is possible to foresee the nature of the rain cloud's formation: in the form of discrete torches, as in the case of the model Valley Reindger (USA) or in the form of a monolithic cloud, where the overlap ratio of the torches is quite high [2], [3].

Placement of nozzles in space leads to increase in their number and fragmentation of unit consumption, which is reflected in the diameter of the nozzles. On the one hand, this is clogging of the nozzles, but with high-quality water purification, the uniformity becomes stable, little dependent on the wind speed with a flat plot of rain intensity [8].

Table 1

The parameters of the flow distribution in the rain belt frontal sprinkler machines

Source: obtained by the authors according to research results

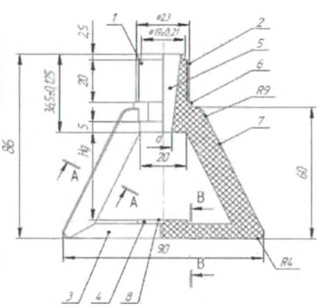
Options	Rain Belt Machine	The rate of flow of water from the nozzle nozzles, m/s					
		28-26	26-24	24-22	22-20	20-18	18-16
Average values H/d	Reducing of the intensity	85-90	7540	5950	4600	3680	3060
	Staff	-	-	4060	3300	2500	-
Probability of distribution, %	Reducing of the intensity	6,7	11,6	15,7	22,4	32,8	10,8
	Staff	-	-	32,5	17,0	49,6	-
Limits of the average-cubic diameter of droplets, mm	Reducing of the intensity	0,55-0,75	0,7-0,85	0,75-0,9	0,8-1,0	0,9-1,1	1,0-1,2
	Staff	-	-	0,6-0,9	0,7-1,0	0,8-1,2	-
Span numbers where parameters are observed	Reducing of the intensity	I	I-II	II-III	III-V	V-VII K	VII-VIII
	Staff	-	-	I-IV	IV-V	V-VIII, K	-

Wide-area frontal sprinkling machines, as a rule, are equipped with deflector nozzles, for which there were relevant searches and justifications. A rethinking of the accumulated experience also required to equip the fittings of the surface sprinkling kit [9]. Deflector nozzles have two main specific differences: first, the deflector is separated from the main body, it can be mobile and stationary. Constructive solution is a conical or convex deflector forms a circular torch of rain. The same detached, sometimes mobile deflector in the form of a plane or a concave surface, sets at an angle of 90^0 to the axis of the jet, forms a rain plume of directional or sectorial action. This is the design of the famous spoon-shaped nozzles. The second specific difference of this type of nozzles is constructive solutions, when the deflector is built into the body, or is performed in the body, and the film-forming surface in the form of a hemisphere and a sphere with some truncation elements. This type of nozzle forms a directional torch and has a certain volumetric figure. This design solution is provided by attachments of Seninger, which served as a prototype for attachments for the sprinkler machine "Kuban-TK".

Analyzing various bench tests for a number of years and considering the results of rain overlaying single distributions, taking into account wind speeds of up to 3-4 m/s, we stopped unequivocally on nozzles with a flat deflector oriented in a horizontal plane, isolated from the main body.

Molds have been developed for the manufacture of such nozzles by the researchers of the Federal State Research Institution All-Russia Scientific and Research Institute for Irrigation and Farming Water Supply Systems "Raduga" [Fig.1]. The design of the nozzle includes a connecting section 1 with an external thread 2 for connecting to a water supply pipeline and Δ - shaped holder 3 of the deflector 4. In the connecting part there is a passage 5 in the form of a conical confuser with a constant diameter inlet and a nozzle 6 of the diameter d. The ribs 7 Δ-shaped have a triangular cross-section with an angle of 20° in order to slightly influence the circular torch formed by the nozzle. The deflector 7 with a flat reflective surface 8 located perpendicular to the stream of irrigation water flowing out of the nozzle under pressure, which ensures a horizontal gathering of the torch of rain with a torch angle to 30^0.

The design feature of the nozzle is maintaining a constant inlet diameter of 19 mm with a varying diameter of the inlet or nozzle, which reduces the cost of injection molding technology for small batches of production. As special requirements for the design of the nozzle is complying with the alignment of the longitudinal axis of the flow channel and the center of the circular reflective surface of the deflector (deviation from the alignment of no more than 0.04 mm), as well as a high purity class of the surface treatment of the flow channel and the reflective surface of the deflector - R_z 0,63.



Source: compiled by the authors

Fig. 1. Head of the sprinkler

The main geometrical parameters of the nozzle are the diameter of the nozzle d and the distance from the nozzle to the deflector N. In the process of hydraulic studies in the pressure range at the inlet to the nozzle from 0.1 to 0.5 MPa, it was established that the optimal value of the distance from the nozzle to the deflector is H_g = 35-40 mm. In the process of bench hydraulic studies, the flow rates of sprinkling nozzles of various types were determined and their flow-pressure characteristics were calculated for different nozzle diameters.

Hydraulic studies were conducted at water pressure at the inlet to the nozzle from 0.1 to 0.5 MPa. For the accepted design of plastic nozzle circular action (Fig. 1), the results of studies to determine the flow rate μ are given in [Table 2].

Table 2

Flow rates of the nozzle of circular action

Nozzle's diameter, d, mm		Flow coefficient μ (experimental results)	Note
nominal	actual		
6,0	5,913	0,939	The estimated coefficient of consumption is assumed μ_p=0,90
6,5	6,463	0,925	
7,0	7,180	0,926	
7,5	7,520	0,907	

Source: compiled by the authors according to the data which were obtained as a result of the researches

The flow coefficient decreases slightly with increasing diameter of the nozzles in the range d = 6.0-7.5 mm and varies in the range μ = 0.939-0.907. Previously performed hydraulic studies of plastic sprinkler heads of a similar design gave a flow coefficient in the range of μ = 0.924-0.91; for tested metal nozzles with a brass nozzle, the value of the flow coefficient for these diameters varied in the range μ = 0.971-0.965 and was 5-7% higher than for plastic nozzles due to, apparently, higher quality of manufacturing the surface of the conical nozzle confuser. According to the results of hydraulic studies, the calculated flow-pressure characteristics of plastic nozzles without pressure regulators were obtained [Fig. 2].

After determining the pressure-flow characteristics of the nozzles for surface sprinkling, the hydraulic indicators of the surface sprinkling unit were determined in order to determine the drag coefficients on a specially equipped test bench consisting of pump-power equipment of the pressure and power lines of the test sets, measuring instruments and control valves. A series of experiments was carried out without transit flow and a series with transit flow in the main water supply pipeline at flow rates that occur in practice.

Digital values of the local resistance coefficient were determined by the formula:

$$h_w = \xi \frac{v^2}{2g}, \tag{1}$$

where h_w - measured head loss;

v - constant flow rate over the internal diameter of the rod.

The coefficient of local resistance was used in the calculations to determine the pressure loss in each fitting:

$$h_w = \xi \frac{8g^2}{\pi^2 g d^4} 10^6, \tag{2}$$

where g - node consumption, l/s;

d - the diameter of the vertical bar, mm;

ξ - coefficient of resistance, depending on the location of the nozzle;

π, d - constants.

The pressure at the axis of the central span is determined by:

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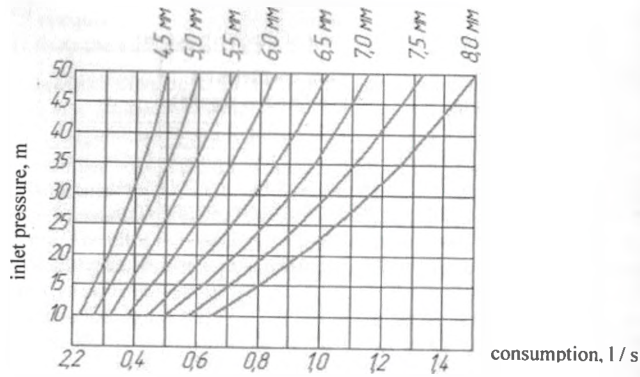

Source: compiled by the authors based on research results

Fig. 2. Flow-pressure characteristics of circular sprinkler nozzles

The limits of the height of the installation of the wing Δh is determined by the formula

$$\Delta h = H_k - h_0 - h_{min}, \quad (3)$$

where $H_к$ - clearance height of the truss span;

h_0 - the depth of the construction of the openings along with the nozzles (vertical) within the limits of the action of $H_к$;

h_{min} – the minimum set height of the installation of the openings (by cutting the nozzle), as a rule, 1-1,2 m.

The height of the installation of nozzles for hydraulic calculation of the layout scheme is taken as follows:

$$h_{cp} = \frac{1}{2}(H_k - h_0 + h_{min}), \quad (4)$$

During the using of the kit for ground sprinkling, the average rain intensity should be no more than 0.7-0.8 mm/min or 2 times less than the sprinkling intensity of the standard sprinkler machine “Kuban-L”.

Engineering calculation of the intensity of rain of the sprinkler machine “Kuban-L” ρ_{cp} (mm/min) is carried out according to the formula:

$$\rho_{cp} = \frac{60Q}{F}, \quad (5)$$

where Q - the flow rate of the machine, l/s (200 l/s);

F - area covered by rain, m^2.

According to previous studies (F = A x L), equal to 8000 m^2, then $\rho_{cp} = \frac{60 \quad 200}{8000} = 1{,}5$ мм/мин

It is necessary to have a rain cloud width equal to 2a=20m to obtain an intensity of 0.7-0.8 mm/min. Bench tests of a specific type of nozzles with nozzle diameters of 4-6 mm with a change in pressure from 10 to 40 m and the height of the nozzles from 1 to 4 m gave a moisture spot with a diameter of:

$$D = 6{,}2 + 0{,}67\, h_i \quad (6)$$

where h_i - set height of nozzles in the range of 1-4 m.

If there is no overlap of rain's torches along the front (with 7 knots), then it should be provided along the direction of the car. The distance between the nodes (rods on the pipeline) is l = 52.5: 7 = 7.5 m. We project the tips from the wing panels to this section of the pipeline [Table 3].

The result of the table is the overlap ratio of the irrigated surface's rain when the machine is moving. The closest parameter to the required one is the layout of the node, more precisely the openings, the number of nozzles is not less than five or we need to increase the number of nodes to 9 pcs. on the span. Obviously this is not the best option. The nozzle diameter of the nozzles becomes a limitation on the number of nozzles on a node for reasons of clogging, unless the price is the price of each nozzle. Reasonings are better kept within the span, for example, 52.5 m long. The consumption of such a span is:

$$Q_{Ln} = \frac{Q}{L} \cdot L_n = \frac{200}{800} \cdot 52.5 = 13.2 \text{ л/с}, \tag{7}$$

Nozzle consumption at 7 nodes with 5 nozzles q_n = 0.375 l/s, with 6 nozzles - 0.314 l/s, with 7 nozzles - 0.268 l/s.

Let's determine the required diameter of the nozzle nozzles by the formula:

$$d_{\text{тр}} = \text{К}\sqrt{\frac{q_{\text{н}}}{\sqrt{\text{H}}}}, \tag{8}$$

where K - a conversion factor of 17.87;
q_n - the desired flow nozzle, l/s;
H - the real pressure in the car, m.

Table 3

Choice of the number of nozzles on the single-node openings

The number of projected nozzles on the node (n), pc.	2	3	4	5	6	7
The distance between them on the projection (в), m	3,75	2,5	1,875	1,5	1,25	1,0
The distance between the extreme projections on the front of the machine (B), m	3,75	5,0	5,625	6,0	6,25	6,5
Cattle relation (ctg x)	0,288	0,385	0,433	0,461	0,486	0,500
Installation angle of the openings in relation to the pipeline (a) degrees	74	69	66,5	65,25	64,30	63,36
Length of the openings (l_0), m	13,44	13,93	14,16	14,31	14,42	14,53
The number of nozzles on the span of 52.6 m with 7 nodes of surface sprinkling ($N_н$), pc.	14	21	28	35	42	49
The total area of the rain torches nozzles ($\sum f_i$)	610	930	1230	1540	1850	2150
Rain ratio ($K_п$)	0,58	0,88	1,17	1,46	1,76	2,15

Source: compiled by the authors according to the researches

CONCLUSION

As a result of the researching work on the generalisation and refinement of the quality of the rain's spray along the length of the sprinkler, the size of the rain's torch, the pressure flow characteristics of the nozzles and the justification of the energy characteristics of rain to determine drainage irrigation rates. The refined values of the coefficients of local hydraulic losses in the elements of the water distribution hub, the flow coefficient of the applied sprinkler of the circular action, the length of the wings and the angle of their installation, and other parameters were obtained and given. In accordance with this, the equipment of the sprinkler machine "Kuban-TK" with a set of surface sprinkling will allow to increase the water flow rates by 30 ... 35%.

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