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PECULIARITIES OF FURROWS RESISTANCE IN THE MODELING OF SURFACE IRRIGATION

Matyakubov Bakhtiyar Shamuratovich
Tashkent Institute of Irrigation and Agricultural Mechanization Engineers,
Tashkent 100187, Uzbekistan

Abstract: *The article presents a system of hydrodynamic equations describing the movement of water in the furrow. The calculated dependences were continued to determine the average rate of water flow in the furrow, the Chezi coefficients and the grooves roughness. It is established that if the measured values of the average speed for light, medium and heavy soil were 0.185; 0.152 and 0.0945, respectively, its calculated values were 0.184; 0.151 and 0.0944, respectively. The measurement of the Chezy coefficient value for these categories of soils was 5.19; 4.12 and 3.02 m* $^{0.5}$*/s, its calculated values were 5.37; 4.32 and 3.32 m*$^{0.5}$*/s. The values of the measured and calculated roughness were 0.04 and 0.041, respectively. It should be noted that in this case, the calculated and measured values of the resistance of the furrow coincided, and the value was 0.08. At observance of the range of values of these hydraulic parameters in furrows the uniform mode will be observed also for the values of filtration coefficient for light soil of 0.0000026 m/s; for the average 0.0000041 m/s and for heavy soil 0.0000012 m/s.*

Key Words: *furrow, model, surface, irrigation, coefficient, soil, light, medium, heavy, water, elements of irrigation technique.*

1. INTRODUCTION AND OBJECTIVE:

Intensive development of agriculture and climate change on the planet leads to limited use of water resources in the region. This factor is especially evident in arid zones of Central Asia, including the Khorezm oasis [2]. Restrictions on the amount of water used in irrigation require the development of innovative methods and technologies that allow for the rational management of water in the irrigated field. To ensure the rational use of irrigated water, it is necessary to choose the shape of the furrow section, the elements of the irrigation technique and the mode of movement of the water furrow [4, 12]. To solve this problem, the most convenient and cheap way is mathematical modeling of the movement of water along the furrows, where the main task is to select the hydrodynamic equations of water movement and allow for hydraulic resistance in them. The purpose of this work is to identify the features of the hydrodynamic equations and the hydraulic resistance of the furrow to the movement of water in it.

2. RESEARCH METHODOLOGY:

To calculate the irrigation rate, N.N.Ivanov's formulas were used, with the adjustment of Molchanov, Institute of “Uzdavmelisuloyiha, A.M.Alptiev, Blaine-Criddle and others. All field, laboratory studies and phenological observations were carried out according to the methods adopted at UzSRIC (“Methods of agrochemical, agro-physical and microbiological studies in irrigated areas”, 1963. “Methods of field and vegetation experiments with cotton under irrigation conditions” 1969, “Methods of field experiments with cotton (1981) [11, 14]. Field experiments were accompanied by the study of water-physical, agro-chemical properties of soil, water, salt and nutrient of soil regimes in the aeration layer in the annual and long-term cycles, regime of the level and salinity of groundwater, elements of irrigation equipment with different irrigation technology, as well as conducting phenological observations of growth and development are cultivated with cotton, taking into account their productivity, etc.

The reliability of the obtained results of the studied options was proved by statistical processing with the method of dispersion analysis according to B. A. Dospekhov [10].

Experiment 1 and 2. Mode of an irrigation and cotton irrigation technique with light loamy and medium loamy soils on the farm "Bobo Omoniyoz" Yangibazar district, Khorezm region of Uzbekistan. Old-irrigated meadow soils are alluvial and slightly saline.

Experiment 3. Cotton irrigation regime in medium loamy soils in the farm “Abdullah” of the Yangibazar district of the Khorezm region. Old-irrigated meadow soils are alluvial and slightly saline.

Experiments with cotton were carried out according to a single scheme, presented in Table 1 [1].

Table 1
The scheme of field experience with cotton

Numbers	Irrigation technology	Pre-irrigation soil moisture,% of Lowest moisture content		
		Light	Medium	Heavy
1	Production control	By actual measurements		
2	Irrigating with the variables jets	70 - 80 – 60		
3	Counter irrigation			
4	Irrigation through the furrows			

Note: furrow length: l = 100 m, slope i = 0.0002, water flow rate of the furrow: for light soils q = 0.60 l / s; in medium soils, q = 0.40 l / s; in heavy soils, q = 0.20 l / s. In option 2, when the water reaches the end of the furrows will be reduced by 2 times.

In all of the experimental plot was sown cotton variety Khorezm-127. Repeated experiments options - three-time. All replicates were located in one tier. Irrigation and irrigation rates were determined depending on the marginal field moisture capacity of the soil, the elements of irrigation equipment were determined by the method of Laktaev N.T. To study the movement of water in the work used: the movement of water described by various equations, like Reynolds, Boussinesq, Navier-Stokes, Saint-Venant, etc. [5-6]. These equations, depending on the number of factors determining the nature of the movement of water, have varying degrees of complexity, respectively, problems. The most practical is the system of Saint-Venant hydrodynamic equations, consisting of hydrodynamic equations of motion and continuity, based on the conservation of momentum and mass [6, 8]. The system of Saint-Venant equations describing the movement of water in furrows with an arbitrary shape has the form:

$$\frac{\partial \omega}{\partial t} + \frac{\partial Q}{\partial x} = q \tag{1}$$

$$\frac{\partial Q}{\partial t} + \frac{\partial Q^2/\omega + gS}{\partial x} - g\frac{\partial S}{\partial x}\Big|_{Z_{fs}=c} + \frac{\lambda}{2}v^2\chi = r\,,\quad r = \begin{cases} qv & \text{при} \quad q<0 \\ qv_{in} & \text{при} \quad q>0 \end{cases} \tag{2}$$

where: α - coefficient taking into account the uneven distribution of velocities over the living section of moving water in the furrow, usually taken equal to α=1; t – time; x - is the longitudinal (along the channel) coordinate; ω - sectional area of water in the furrow; Q - water discharge, $Q = \omega v$; v is the flow velocity; S - the static moment of the cross section relative to the free surface, equal to the product of the cross-sectional area of water and the depth of its center of gravity in the vertical h_c, $S = \omega h_c$; χ - wetted perimeter; Z_{fs} – the free surface of the water mark; g – gravity acceleration; q – the specific (per unit length of the furrow) flow rate at q>0 («rain intensity») or filtering water from the furrow when q<0; v_{in} - velocity of inflow in the form of inflow from outside water (when filtering water from a furrow in one-dimensional schematization, we assume that the impulse taken out of water is connected only with the average velocity of water in the furrow); $\lambda = \frac{2g}{C^2}$ - hydraulic friction coefficient Darcy-Weisbach [7]; C – Chezy coefficient.

Equation (1) is called the continuity equation; multiplied by the fluid density ρ, it expresses the law of conservation of the mass of an incompressible fluid in the channel. Equation (2) is called the equation of motion; multiplied by the density of water ρ, it expresses the law of conservation of momentum. The meaning of some members of the equation of motion: Q^2/ω - the amount of movement in the alignment, divided by water density ρ, gS - hydrostatic pressure at the site (in units of water column, that is, divided by the density of water ρ), $\frac{\partial gS}{\partial x}$ - pressure change along the channel, $\frac{\partial gS}{\partial x} - g\frac{\partial S}{\partial x}\Big|_{Z_{fs}=c}$ - part of the change in pressure not perceived by the channel, $g\frac{\partial S}{\partial x}\Big|_{Z_{fs}=c}$ - furrow pressure on water, $\frac{\lambda}{2}v^2\chi$ - hydraulic furrow friction.

In the furrow parameter $g\frac{\partial S}{\partial x}|_{Z_{fs}=c}$ greatly simplified: $g\frac{\partial S}{\partial x}|_{Z_{fs}=c}=g\omega I$, and the system takes the form:

$$\frac{\partial \omega}{\partial t}+\frac{\partial Q}{\partial x}=q \tag{3}$$

$$\frac{\partial Q}{\partial t}+\frac{\partial Q^2/\omega+gS}{\partial x}-g\omega I+\frac{\lambda}{2}v^2\chi=r\,,\quad r=\begin{cases} qv & \text{при} \quad q<0 \\ qv_{in} & \text{при} \quad q>0 \end{cases} \tag{4}$$

It looks even simpler in the case of a wide rectangular profile:

$$\frac{\partial h}{\partial t}+\frac{\partial \bar{q}}{\partial x}=\hat{q} \tag{5}$$

$$\frac{\partial \bar{q}}{\partial t}+\frac{\partial \bar{q}^2/h+gh^2/2}{\partial x}-ghI+\frac{\lambda}{2}v^2=\hat{r}\,,\quad \hat{r}=\begin{cases} \hat{q}v & \text{при} \quad \hat{q}<0 \\ \hat{q}v_{in} & \text{при} \quad \hat{q}>0 \end{cases} \tag{6}$$

where: $\bar{q}$ - specific flow rate (ie consumption divided by the average width of the groove B), inflow rate and introduced into the furrow momentum also need, in this case divided into B: $\hat{q}=q/B$, $\hat{r}=r/B$.

Next, we consider equations (1), (2) in the form:

$$\frac{\partial \omega}{\partial t}+\frac{\partial v\omega}{\partial x}=q \tag{6}$$

$$\frac{\partial \omega v}{\partial t}+\frac{\partial v^2\omega+gS}{\partial x}-g\frac{\partial S}{\partial x}|_{Z_{fs}=c}+\frac{\lambda}{2}v^2\chi=r\,, \tag{7}$$

Transform equation (7) using the differentiation formula $(\varphi\psi)'=\varphi'\psi+\varphi\psi'$:

$$\omega\frac{\partial v}{\partial t}+\left[v\frac{\partial \omega}{\partial t}+v\frac{\partial v\omega}{\partial x}\right]+v\omega\frac{\partial v}{\partial x}+g\frac{\partial S}{\partial h}\frac{\partial h}{\partial x}-g\frac{\partial S}{\partial x}|_{Z_{fs}=c}+\frac{\lambda}{2}v^2\chi=r \tag{8}$$

And going from the static moment S to the depth of water h (h is the maximum depth at the site), we assume that ω, h and S are one-to-one functions:

$$\omega\frac{\partial v}{\partial t}+\left[v\frac{\partial \omega}{\partial t}+v\frac{\partial v\omega}{\partial x}\right]+v\omega\frac{\partial v}{\partial x}+g\frac{\partial S}{\partial h}\frac{\partial h}{\partial x}-g\frac{\partial S}{\partial h}\frac{\partial h}{\partial x}|_{Z_{fs}=c}+\frac{\lambda}{2}v^2\chi=r \tag{9}$$

From the definition of the static moment:

$$\frac{\partial S}{\partial h}=\omega \tag{10}$$

$$\omega\frac{\partial v}{\partial t}+\left[v\frac{\partial \omega}{\partial t}+v\frac{\partial v\omega}{\partial x}\right]+v\omega\frac{\partial v}{\partial x}+g\omega\frac{\partial h}{\partial x}-g\omega\frac{\partial h}{\partial x}|_{Z_{fs}=c}+\frac{\lambda}{2}v^2\chi=r \tag{11}$$

$$\frac{\partial h}{\partial x}|_{Z_{fs}=c}=\frac{dZ_{fs}}{dx}=-I \tag{12}$$

$$\frac{\partial v}{\partial t}+v\frac{\partial v}{\partial x}+g\frac{\partial h}{\partial x}-gI+\frac{\lambda}{2}\frac{v^2}{R_h}=\frac{r}{\omega} \tag{13}$$

Equation (13) is widely known in hydraulics; until the advantage of using the divergent form of equation (2) has become known, it was in this form that it was given (without the right side $\frac{r}{\omega}$) [6, 8, 9, 13].

The results of the study and discussions: Given the above, the system of equations describing the movement of water, we can present:

$$\frac{\partial \omega}{\partial t}+\frac{\partial v\omega}{\partial x}=q \tag{14}$$

$$\frac{\partial v}{\partial t}+v\frac{\partial v}{\partial x}+g\frac{\partial h}{\partial x}-gI+\frac{\lambda}{2}\frac{v^2}{R_h}=\frac{r}{\omega} \tag{15}$$

In this system of hydrodynamic equations describing the movement of water in the furrow, one of the main problems is the determination of the hydraulic resistance of the furrow to the movement of water. And the hydraulic resistance of the furrow can be taken into account with its integral characteristic of the Chezi coefficient or the roughness coefficient. To establish reliable calculation dependencies for the Chezi coefficient, which gives a result that corresponds to the real values of the average water velocity, the results of calculations of several formulas by Manning, I.I.Agroskin, A.D.Altshul, V.N.Goncharov, N.N.Pavlovsky, were compared F.Forheimer, I.F.Karasev and other researchers.

The results of multivariate calculations showed that the Manning formula gives good convergence with the data of full-scale studies of the movement of water along furrows, taking into account the decelerating effect of the furrow walls. The braking effect of the furrow is taken into account by the correction factor, which is determined by the modified formula of I.F.Karasev.

To derive the main calculated dependences of the average water velocity along the furrow, the Chezi coefficient and the roughness coefficient, we compile the equilibrium equation of the following acting forces on the calculated section:

1. Mutually balanced forces hydrodynamic pressure: $p_1; p_2; \sum p = 0;$
2. Projections of gravity: $\chi\delta_в\gamma RI$;
3. Friction force on the bottom: $\chi\delta_в\gamma\frac{\upsilon^2}{C_0^2}$.

where, g - gravity per unit mass, m/sec^2; χ - wetted perimeter of furrows $\chi = 2h\sqrt{1+m^2}$, м; $R-$ hydraulic radius; C_0 - Chezy coefficient, determined for the uniform movement of water by the Manning formula in the form $C_0 = \frac{1}{n}R^{\frac{1}{6}}$; $\delta_в$ - furrow roughness height; $\upsilon-$ average water velocity.

We write the dynamics of the amount of movement of the flow of water on the considered area for a point $t = \frac{\delta_в}{\upsilon}$ in time:

$$2\frac{\gamma}{g}\varphi R\delta_в^2\upsilon = \left(\gamma RI - \frac{\gamma\upsilon^2}{C_0^2}\right)\delta_в\chi\frac{\delta_в}{\upsilon}$$

where, $\varphi-$ coefficient taking into account the ratio of the preserved longitudinal mass exchanging between water in the transit zone and in the laminar layer to the average velocity, the size and shape of disturbances relative to the height of the roughness of the roughness, the continuity of disturbances on the walls of the furrow and other factors of mass exchange, not explicitly taken into account.

Processing of data from many years of research allowed us to determine the numerical value of this coefficient for the furrow, which was

$\varphi = 1{,}15 - 1{,}2$
.

This equation gives the formula for the average water velocity, taking into account the decelerating effect of the furrow walls of the following type:

$$\upsilon = C_0\sqrt{\frac{g\cdot\chi RI}{R\left(2\varphi C_0^2 + g\frac{\chi}{R}\right)}}$$

The resulting formula allows us to write a formula for determining the Chezi coefficient taking into account the retarding effect of water in the following form:

$$C = C_0\sqrt{\frac{g\cdot\chi}{R\left(2\varphi C_0^2 + g\frac{\chi}{R}\right)}} = k_C C_0$$

In view of the foregoing, a formula was obtained for determining the calculated value of the roughness coefficient, taking into account the retarding effect of the furrow in the following form:

$$n = n_0\sqrt{\frac{2\psi R^{\frac{2}{3}}}{g\chi n_0^2} + 1}$$

where, n_0- roughness coefficient for the conditions of a flat problem; - roughness coefficient, taking into account the braking effect of the furrow walls; - adjustment coefficient, $\psi = 0{,}012$.

If the measured mean velocity for light, medium and heavy soil was 0.185; 0.152 and 0.0945, respectively, its calculated values were 0.184; 0.151 and 0.0944, respectively. The measurement of the Chezy coefficient value for these categories of soils was 5.19; 4.12 and 3.02 $m^{0.5}/s$, its calculated values were 5.37; 4.32 and 3.32 $m^{0.5}/s$. The values of the measured and calculated roughness were 0.04 and 0.041, respectively. It should be noted that in this case the calculated and measured values of the resistance of the furrow coincided, and the value was 0.08.

If the range of values of these hydraulic parameters is observed, a uniform mode will be observed in the furrows for the values of the filtration coefficient for light soil of 0.0000026 m/s; for the average 0.0000041 m/s and for heavy soil 0.0000012 m/s.

The obtained values allow you to set the time to reach the flow and water flow for satisfactory irrigation, depending on the type of crop and the depth of its roots.

3. CONCLUSIONS AND RECOMMENDATIONS:

The above considerations allowed to draw the following main conclusions and conclusions:

1. A system of hydrodynamic equations was obtained, which describes the movement of water in the furrow;
2. The results of the calculations showed that under conditions of light, medium and heavy soils, the calculated values for the proposed formulas of the average speed, the Chezy coefficient and the roughness of the furrow and the measured values of the average water velocity, resistance and roughness coefficient give good convergence;
3. The proposed calculation formulas for determining the valuesof the average velocity, the coefficient of the Chezy and the roughness of the furrow.

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