ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 10 , October 2019

Features of Modeling the Flow of Water in the Furrow

Matyakubov Bakhtiyar Shamuratovich, Isabaev Kasimbek Tagabaevich

Doctor of Agricultural Sciences, acting as Professor, Department of Irrigation and Land Reclamation of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME), Uzbekistan.
Candidate of Agricultural Sciences, Associate Professor, Docent, Department of Irrigation and Land Reclamation of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME), Uzbekistan.

ABSTRACT: The article provides an analysis of the observation and determination of water-saving elements of irrigation techniques, advanced technologies for surface irrigation of cotton, as well as the calculation of a system of hydrodynamic equations describing the movement of water in a furrow. Design dependencies are proposed for determining the average speed of the water flow in the furrow, the Shezy coefficients and the roughness of the furrow (depending on the mechanical composition of the soil). It was found that if the measured values of the average speed for light, medium and heavy soil were 0.185; 0.152 and 0.0945, respectively, then its calculated values were 0.184; 0.151 and 0.0944, respectively. The measurement of the values of the Shezy coefficient for these soil categories 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 measured and calculated roughness values were 0.04 and 0.041, respectively. It should be noted that in this case, the calculated and measured values of the furrow resistance coincided, and the value was 0.08. By abidance to the range of values of these hydraulic parameters, a uniform mode will be observed in the furrows for the values of the filtration coefficient for light soil 0.0000026 m/s; for average 0.0000041 m/s and for heavy soil 0.0000012 m/s.

I. INTRODUCTION

It is known that the main wealth of the people and the source of life is water. Therefore, it is necessary to avoid inefficient water losses in the field, as well as on irrigation canals. It is required to apply anti-filtration measures. In order to improve and increase the coefficient of effective performance of the field and irrigation canals, it is necessary to determine the development of crop irrigation technologies. And also apply water-saving irrigation technologies. An important factor in increasing the coefficient of effective performance and efficiency of water use is the Decree of the President of the Republic of Uzbekistan “On the State Program for the Development of irrigation and improvement of lands on irrigated areas for 2018-2019” No. DP-3405 dated November 27, 2017 [1].

As a result of the implementation of these decrees and decisions, raising the groundwater level on more than 260 thousand hectares of irrigated land in the Khorezm region was brought to optimal levels, on average about 32 thousand hectares the average and severe salinity were reduced, and the reclamation state of 182 thousand hectares of irrigated land were improved [2].

Efficient use of water resources is one of the urgent problems facing farmers who are consumers of water. Therefore, it is advisable to create, improve existing and introduce new modern techniques and technologies, as well as irrigation technologies to save water resources and their effective use at all levels of farms.

II. RESEARCH OBJECTIVE

The 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 the arid zones of Central Asia [3], including the Republic of Uzbekistan. Limitations on the amount of water used for irrigation require the development of innovative methods and technologies, improved crop irrigation technologies that allow rational use and management of water in irrigated agriculture. To ensure the rational use of irrigation water, it is necessary to correctly choose the shape of the cross section of the furrow, the length of the furrow, depending on the mechanical composition of the soil and the slope of the terrain, as well as the mode of water movement and the hydraulic parameter of the furrow [4]. To solve this

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 10 , October 2019

problem, the most convenient and cheapest way is mathematical modeling of the water movement along the furrows, where the main task is to choose the hydrodynamic equations of water movement and take into account the hydraulic resistance in them. The aim 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. As well as determining the optimal elements of irrigation technique (furrow length, water flow and furrow slope) [5].

III. METHODOLOGY

During research, soil analysis, cotton observation, measurements and analyzes were carried out according to the methodology of the cotton growing institute "Methods of carrying field experiments" [6], as well as in the practice of channel hydraulics of water movement described by various equations of hydrodynamics - Reynolds, Bussinesk, Nav`e-Stokes, Saint Venan etc. [7].

Scientific research in pilot plots is given to determine water-saving irrigation technologies that provide the optimal regime for irrigation of cotton.

Field experiments were carried out in 2013-2014. on meadow-alluvial soils of the farm "BoboOmoniyez", light loamy soils (experiment 1), medium loamy soils- (experiment 2) and farms "Abdulla" heavy loamy soils (experiment 3) in the Yangibazar district of the Khorezm region of the Republic of Uzbekistan.

IV. EXPERIMENTAL RESULTS

Information based on efficient use of water resources for improvement of cotton irrigation regime, as well as on the identification and implementation of water-saving technologies and efficient use in irrigation. The determination of cotton irrigation regime was carried out on the basis of the field experience scheme. Moreover, information on the water productivity used to obtain the maximum yield of cotton which is given and the water balance of the cotton compiled field [8].

The equations that determine the character of the movement of water have varying degrees of complexity depending on the number of factors. The most practical is the system of hydrodynamic equations of Saint-Venan, consisting of hydrodynamic equations of motion and continuity, based on the conservation of momentum and mass.
The system of equations of Saint-Venan looks simpler in the case of a wide furrow of rectangular cross section [9]:

$$\frac{\partial h}{\partial t}+\frac{\partial \overline{q}}{\partial x}=q \tag{1}$$

$$\frac{\partial q}{\partial t}+\frac{\partial q^2/h+g\ h^2/2}{\partial x}-g\ h\ I+\frac{\lambda}{2}\cdot v^2=\hat{r},\hat{r}=\begin{cases}\hat{q}v & \text{by} \quad \hat{q}<0\\ \hat{q}v_{in} & \text{by} \quad \hat{q}>0\end{cases} \tag{2}$$

where: q_f - is the specific flow rate (that is, the flow rate divided by the average furrow width B), the flow rate flow rate and the impulse introduced into the furrow should also be divided by B:

$$q=q/B,.r=r/B$$

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

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

$$\frac{\partial \omega\ v}{\partial t}+\frac{\partial v^2\ \omega+g\ S}{\partial x}-g\cdot\frac{\partial S}{\partial x}\Big|_{Z_{fs}=c}+\frac{\lambda}{2}\ v^2\ \chi\ =\ r, \tag{4}$$

We transform equation (4) using the differentiation formula:

$$(\varphi\ \psi)'=\varphi'\ \psi+\varphi\ \psi':$$

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$$\omega\cdot\frac{\partial v}{\partial t}+\left[v\ \frac{\partial\omega}{\partial t}+v\ \frac{\partial v\omega}{\partial x}\right]+v\cdot\omega\cdot\frac{\partial v}{\partial x}+g\ \frac{\partial S}{\partial h}\cdot\frac{\partial h}{\partial x}-g\cdot\frac{\partial S}{\partial x}\Big|_{Z_{fs}=c}+\frac{\lambda}{2}\cdot v^2\cdot\chi\ =\ r \qquad (5)$$

And passing from the static moment S to the water depth h (h is the maximum depth in the gauge), we assume that ω, h and S are one-to-one functions:

$$\omega\cdot\frac{\partial v}{\partial t}+\left[v\cdot\frac{\partial\omega}{\partial t}+v\cdot\frac{\partial v\ \omega}{\partial x}\right]+v\cdot\omega\cdot\frac{\partial v}{\partial x}+g\cdot\frac{\partial S}{\partial h}\cdot\frac{\partial h}{\partial x}-g\cdot\frac{\partial S}{\partial h}\cdot\frac{\partial h}{\partial x}\Big|_{Z_{fs}=c}+\frac{\lambda}{2}\cdot v^2\cdot\chi\ =\ r \qquad (6)$$

From the definition of static moment:

$$\frac{\partial S}{\partial h}\ =\ \omega \qquad (7)$$

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

$$\frac{\partial h}{\partial x}\Big|_{Z_{fs}=c}=\frac{dZ_{fs}}{dx}=-I \qquad (9)$$

$$\frac{\partial v}{\partial t}+v\cdot\frac{\partial v}{\partial x}+g\cdot\frac{\partial h}{\partial x}-gI+\frac{\lambda}{2}\ \frac{v^2}{R_h}=\ \frac{r}{\omega} \qquad (10)$$

Equation (10) is widely known in hydraulics; until the dignity of using the divergent form of the equation became known, it was in this form that it was brought (without the right-hand side $\frac{r}{\omega}$) (3,6-8).

V. RESULTS

On light loamy soils, when cotton was irrigated on furrows with a variable water flow rate (option 2) on light loamy soils, the time to reach the stream (q_f = 0.6 l/s) to the end of the furrow was 1.3 hours, and the duration of soil moistening with a flow rate decreased by two times (q_f = 0.3 l/s) at an irrigation rate of 600 m^3/ha was 2.1 per hour. The duration of irrigation was 3.4 hours.

When watering the cotton on counter furrows (option 3), when water was supplied along the furrow slope, the time to reach the stream (q_f = 0.6 l/s) to the end of the furrow was 1.25 hours, the irrigation duration at a rate of 589 m^3/ha was 2, 25 hours

When supplying water against the slope of the furrow in this embodiment, the running time of the stream (q_f = 0.6 l/s) to the end of the furrow was 1.52 hours, the irrigation duration at a rate of 589 m^3/ha was 3.12 hours.

When watering cotton through furrows (option 4), the time to reach the stream (q_f = 0.6 l/s) to the end of the furrow was 1.4 hours, the irrigation duration at a rate of 600 m^3/ha was 2.9 hours.

Such patterns on the influence of the irrigation regime and the technology of irrigation of cotton on the uniformity of soil moisture along the length of the furrows were obtained in other experiments.

According to the results of studies on the use of water-saving technologies, it can be concluded that the most effective irrigation technologies in all experiments are irrigation of cotton on counter furrows and irrigation on furrows with a variable stream. Over the years of research with these irrigation technologies, the productivity of 1 m^3 of water was 63-86 m^3/c, which is 74-88 m^3/c less than in the control.

It is known that in the system of hydrodynamic equations describing the movement of water in a furrow, one of the main problems is the determination of the hydraulic resistance of a furrow. The hydraulic resistance of the furrows was

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International Journal of Advanced Research in Science, Engineering and Technology
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taken into account with the help of its integral characteristic of the Shezy coefficient or roughness coefficient. To establish reliable calculated dependences of the Shezy coefficient, which gives a result corresponding to the real values of the average water velocity, the results were compared to the calculations of several formulas of Manning, I.I. Agroskin, A.D. Altshul, V.N. Goncharova, N.N. Pavlovsky, F. Forchheimer, I.F. Karasev and other researchers.

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

To conclude the main calculated dependences of the average water velocity along the furrow, the Shezy coefficient and the roughness coefficient, we compose the equilibrium equation for the following forces on the calculated compartment:

1. Mutually balanced forces hydrodynamic pressure: $p_1;\ \ p_2;\ \ \sum p\ = 0;$

2. Projections of gravity: $\chi\ \delta_в\ \gamma\ R\ I$;

3. Friction force on the bottom: $\chi \cdot \delta_в \cdot \gamma \cdot \dfrac{\upsilon^2}{C_0^2}$.

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

According to results, 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 Shezy coefficient value for these categories of soils was 5.19; 4.12 and 3.02 m0.5/s, its calculated values were 5.37; 4.32 and 3.32 m0.5/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 [10].

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.

VI. CONCLUSIONS AND RECOMMENDATIONS

The above judgments allowed us to draw the following main findings and conclusions:
A system of hydrodynamic equations describing the movement of water in a furrow is obtained;
The calculation results showed that under conditions of light, medium and heavy soils, the calculated values according to the proposed formulas of average speed, Chesy coefficient and furrow roughness and measured values of average water speed, resistance and roughness coefficient give good convergence.

As water-saving irrigation technologies, ensuring the optimal regime of cotton irrigation in the field with a field slope of 0.00015-0,00020, it is recommended:
- cotton irrigation on counter furrows, with elements of irrigation technique depending on the soil mechanical composition: furrow length 80 m (light loamy soils), 100 m (medium loamy soils), 120 m (heavy loamy soils) and furrow discharge respectively 0.6; 0.4; 0.2 l/s;
- cotton irrigation on furrows with a variable stream with elements of irrigation technology depending on the soil mechanical composition: furrow length 80 m (light loamy soil), 100 m (medium loamy soil), 120 m (heavy loamy soil) and furrow discharge respectively 0.6; 0.4; 0.2 l/s, which are reduced by half after reaching the jet end of the furrow.

Calculation formulas are proposed for determining the mean velocity, Chesy coefficient, and groove roughness.

ISSN: 2350-0328
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