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PARAMETERS OF THE WATER LEVEL CONTROL SYSTEM IN AN IRRIGATOR FOR NON-DISCHARGE IRRIGATION THROUGH SIPHONS.

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Abstract

One method of evenly supplying water to a furrow is siphon irrigation. However, this type of irrigation allows for significant water savings and eliminates the need for drainage irrigation if the process is controlled by automatic regulation. The work describes the equipment in the form of siphons, an irrigator, a device for passing water into the irrigator, as well as the process of maintaining and automatically regulating the water level in the irrigator for an irrigation area of 1 hectare. Simulation of the process showed the correspondence of the main control parameters and the control object. The optimal distance of the sensor from the gate is ~90 m; control parameters for the PID controller used: Kp = 1.5, Ti = 50 s, Td = 12.5 s.

Keywords

intra-farm sprinkler, irrigation, siphons, command level, control system, automatic control, control parameters.

1. INTRODUCTION.

In surface irrigation (cotton) technology, there are devices that allow you to standardise the parameters of the amount of water supplied to the furrows, i.e. to save water. Such devices are siphon tubes. They allow the process of water supply to a whole series of furrows from a temporary irrigator (ok-arik, shokh-arik, outlet furrow) or even from a permanent irrigator with an increased flow rate to tens and hundreds of furrows to be mechanised. At the same time, as is well known, it is necessary to maintain the command level in the specified irrigator. Thus, equipment is formed in the form of siphons, an irrigator, a device for passing water into the irrigator, as well as a process in the form of maintaining the water level in the irrigator or its (level) regulation. This opens up new opportunities and ways to create high-tech methods and devices for automating irrigation work. This

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approach allows us to view the irrigation area as an 'industrialised' object subject to automation, starting from the theoretical foundations and formalisation of processes in the construction of an automated irrigation process control system (ACPS) to the creation of compatibility and integration of the irrigation area's ACPS with higher-order irrigation facilities.

The relevance of this issue is beyond doubt, since surface irrigation, when radically re-engineered with significant water-saving technology (around 40%), can be a very good aid to drip irrigation.

Taking the above into account, let us consider the movement of water through internal watercourses, in gravity-fed surface irrigation, through a network of permanent and temporary sprinklers. It should be noted here that the permanent sprinklers at the head and outlet have flat rectangular gates with manual drive. There are no such gates on the temporary part of the network, except for the possible presence of one at a specific location to which a temporary irrigator is connected. By manipulating the gate, the approximate required water flow to the site is achieved, but always with a reserve, which leads, if not to flooding, then to overspending of water going to discharge.

The path of water flow through the irrigation system from the internal irrigation device is described below.

1. Internal canal.
2. Internal distributor
3. Section distributor
4. Permanent irrigator
5. Temporary irrigator
6. Shoh arik
7. Ok arik.
8. Furrows.

Temporary sprinklers, outlet furrows, irrigation furrows and strips are the last links in the irrigation network and are installed annually. According to their technological purpose and level of automation, these elements of the irrigation system can be divided into three main groups:

-the first group includes irrigation sources and headworks, which are water source facilities.

-the second group includes main canals and inter-farm canals, which are facilities for delivering water to consumers.

-the third group includes intra-farm canals and a network of permanent and temporary irrigators, which are water consumers.

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These technological groups perform different functions in the overall structure of the irrigation system. The third group, namely the permanent and temporary irrigation network, is most closely related to the irrigation process. However, it is precisely here, where irrigation is carried out directly, that there is a significant lag in the provision of electromechanisation and automation equipment. To a large extent, this is due to insufficient research into the conditions for implementing technical measures on internal farm canals.

Currently, irrigation in irrigated areas is carried out by dividing the territory into separate irrigation areas using a network of permanent irrigation channels. Irrigation is carried out according to two schemes: longitudinal and transverse.

In the longitudinal scheme, Fig. 1, water from a sectional distributor with a flat rectangular gate, through a manually operated gate valve, is supplied to a permanent irrigator. From the permanent irrigator, water flows through a shield or plough to a temporary irrigator. From the temporary irrigator, the water is directed into the outlet furrow, and from there it is distributed by the sprinkler directly into the irrigation furrows. The use of such an irrigation scheme, due to the presence of an outlet furrow, leads to excessive labour costs, a decrease in the land utilisation coefficient, and an increase in water losses due to filtration. Another cotton irrigation scheme is the transverse one. In the transverse scheme, water follows the same route, but in this irrigation scheme there is no outlet furrow, which reduces water losses, labour costs for organising outlet furrows, etc.

The above description of the irrigation schemes used on farms gives an idea of the volume and labour intensity of the work performed by irrigators. They must monitor not only the water supply to the furrows and the condition of the furrow heads, but also the water consumption in permanent and temporary irrigators. Therefore, in order to reduce the labour intensity of gravity irrigation, devices are used to mechanise the process of releasing water into the furrow. These devices include portable siphons, which also allow the distribution of water to each furrow to be automated.

2. **METHODS.**

Thus, analysing the two circumstances discussed above, namely the irrigation scheme and siphon water supply to the furrows, we can come to the following conclusion:

1. Eliminate the temporary irrigation network and install siphons in a permanent distributor, or even in a sectional distributor to supply water directly to the furrows.

2. Create a system for automatic maintenance and regulation of the level in the permanent distributor.

3. Create a system without discharge irrigation, i.e. a system for automatic control of the level in the permanent distributor that is capable of ensuring a balance between the water supplied to the permanent irrigator and the water drained into the furrows through siphons. This work is devoted to research on the conclusions mentioned in point 2 above.

By analogy with water distribution in inter-farm canals, we applied a method of maintaining the level by regulating the lower reach. The functional schema of such regulation is shown in Fig. 2.

The system operates as follows. When the water level corresponds to the level set by sensor 3 in the lower reach, i.e. sensor 2 registers the set level, there is no mismatch signal at the output of the comparator CO. Electric motor 5 of the actuator 6 does not operate. If the water exceeds or falls below the set (set) level in the lower reach, sensor 2 measures this changed level, converts it into a signal UO(t) and feeds it to the comparing device CO. The set signal U(Z) from the setter also arrives here. These two signals are compared and a delta mismatch signal is generated: δ=U(3) -UO(t). The 'plus' and 'minus' signs indicate that the set level has been exceeded or, conversely, that it has fallen below the set level. This δ signal acts on block 4. Block 4 is an amplifier with a control element. Block 4 (specifically the control element) generates control signals that activate magnetic starters 4'. Depending on which starter is activated, the IM (gate) motor rotates in one direction or another, raising or lowering the IM working body (gate blade), which in turn leads to an increase or decrease in the water level in the lower reach, where the siphons are installed.

4. **RESULTS.**

The above-described water level control method involved installing one hundred siphons along the length of the sectional distributor, with their outlets leading into furrows, Fig. 1. Gate No. 1 of the sectional distributor was operated according to the above functional diagram.

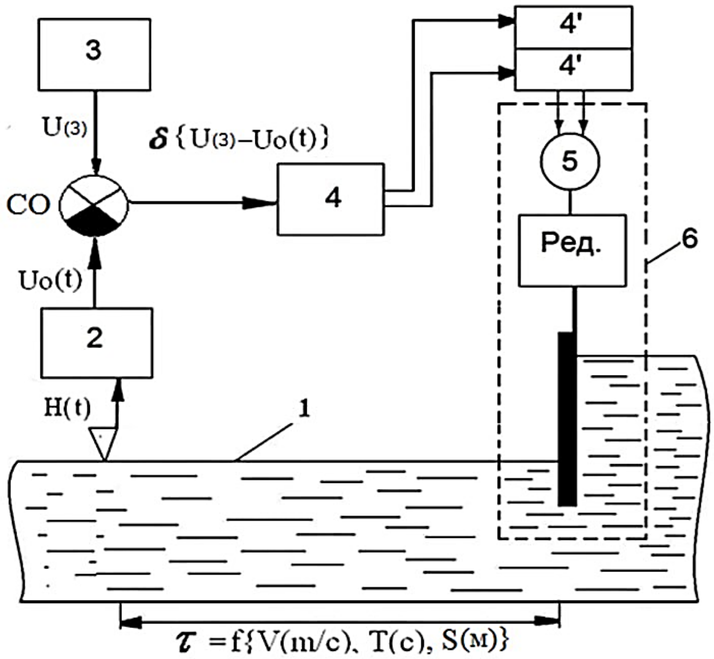
Fig. 2 The functional schema of such regulation

Models of the above method were tested in the Matlab environment based on the problem formulation and the mathematical one-dimensional linearised Saint-Venant model. This allows for the flow delay along the length of the sectional distributor to be taken into account and the sensor installation location and regulator parameters to be determined more accurately:

$$\frac{dh}{dt} + \frac{A_0}{B_0}\frac{\partial v}{\partial x} = 0 \quad \frac{dv}{dt} + g\frac{dh}{dx} + \frac{v}{T_f} = 0 \qquad (1)$$

where h/(x,t) is the water level (state variable),v/(x,t) is the flow velocity,A_0 -is the average cross-sectional area of the channel,B_0 -is the width of the flow surface,T_f -is the friction coefficient,g is the acceleration due to gravity.

Accordingly, for working in Matlab, the channel can be approximated by a



first-order linear system:

$$\frac{dh(t)}{dt} = \frac{1}{T}(K\,u(t) - h(t)) \qquad (2)$$

where h(t) is the level in the lower reservoir, u(t) is the control signal (gate position),K is the channel transfer coefficient,T is the object time constant.

Expressions (1) and (2) provide the basis for formulating a task in MATLAB for controlling the water level in the sectional distributor along the lower reach and calculating the parameters of the PID controller to maintain the command level and

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supply water to the furrows. For this purpose, the following initial data were determined:

Length of the sectional distributor L = 100 m.

Length of the furrow Lb = 100 m.

Diameter of the siphons d = 0.055 m.

Number of siphons N = 100

The conditions for the operation of the automatic controller were selected based on the following indicators and based on:

1. Stepwise impact at the inlet, i.e. the impact of the control element, the gate shield.

2. Initial accepted values K = 1, T = 50 s.

3. Sensor installation locations 10 m, 70 m, 90 m, taking into account that for distributed systems, the optimal level measurement point is determined by the minimum delay function between the input and output.

4. The program's ability to optimise the sensor installation location, taking into account point 3, as well as the fact that for distributed systems, the optimal level measurement point is determined by the minimum delay function between input and output. In our case, the sensor installation involved distances of 10 m, 70 m, and 90 m.

Thus, in the MATLAB environment, the section distributor was discretised along its length using the finite difference method, the section distributor was modelled according to the level (propagation) process, and a PID controller was applied to the lower branch of the distributor.

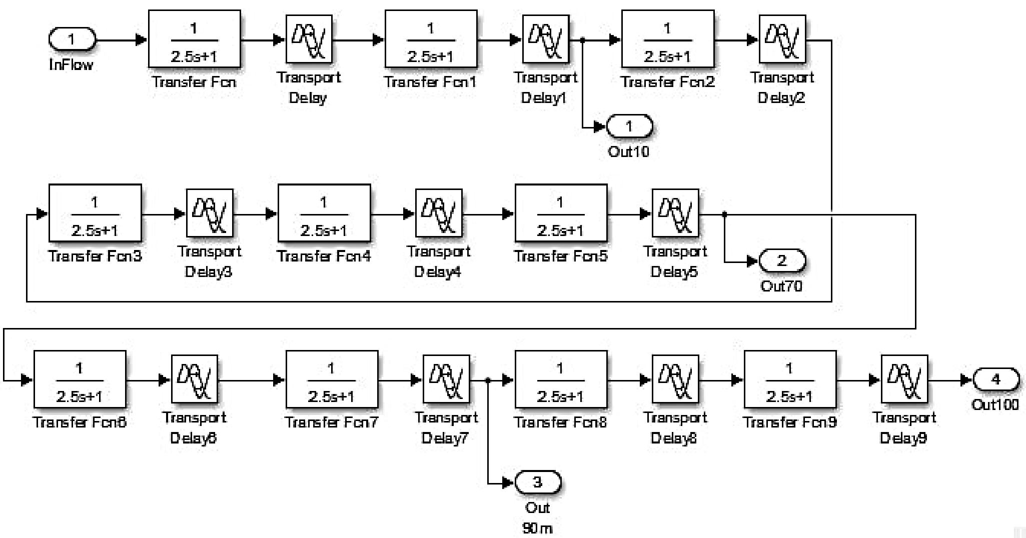

Fig. 3 Simulation model of the control process

The figure shows a simulation model of the control process, divided into 10 sub-sections, for characterising and evaluating the correctness of the sensor installation and the stability of the regulator.

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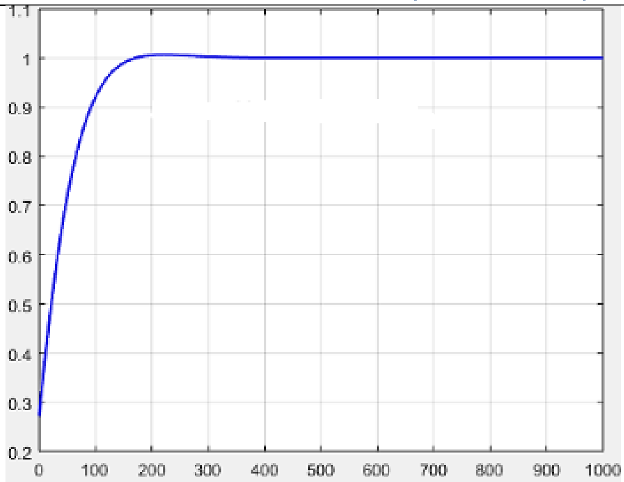

Fig. 4 Transient process in a sectional distributor.

The transient process, Fig. 4, based on the level maintenance test in MATLAB, reflects the correspondence between the main control parameters and the control object. For example, the optimal distance between the sensor and the valve is ~90 m; the type of controller used is PID; control parameters (according to Ziegler–Nichols) are Kp = 1.5, Ti = 50 s, Td = 12.5 s.

5. **CONCLUSION.**

The work carried out to maintain the command level in the section distributor made it possible to structure the technological control facility on the internal irrigation network for non-discharge siphon irrigation (cotton). Equipment was assembled in the form of siphons, an irrigator, a device for passing air into the irrigator, as well as a process for maintaining and automatically regulating the water level in the irrigator. To regulate the process, the lower reach method and an automatic regulator with PID control were used.

For the given irrigation task, the following were determined:

1. Field dimensions – 100 x 100 m;

2.Number of siphons with a flow rate of 1.25 l/s – 100 pcs.;

3. Total flow rate to the sprinkler – 125 l/s;

4. A simulation model was built in the MATLAB environment. Simulation of the process showed that the main control parameters and the control object were consistent. The optimal distance between the sensor and the gate is ~90 m; control parameters for the PID controller used: Kp = 1.5, Ti = 50 s, Td = 12.5 s.

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