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MORPHOLOGICAL ANALYSIS OF THE CONSTRUCTIVE-FUNCTIONAL STRUCTURE OF THE SPRINKLER DEVICE WITH DEFLECTOR NOZZLE

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Abstract

Each element functions as an independent technical object (TO) performing a specific function and facilitating a specific physical process (FJ). This leads to the emergence of two types of connections between elements and, accordingly, two types of systemic management. These elements have specific functional relationships, forming a constructive-functional structure (CFS). The CFS is built based on the correspondence of the function and structure of TOs. This article presents scientific research on methods for improving the CFS of the sprinkler device.

Keywords: Sprinkler device, constructive-functional structure, morphological analysis, technical solution, sprinkler irrigation, deflector nozzle, water pipeline, water pressure.

Introduction

The size of the artificial water droplets produced by existing sprinkler machines varies between 0.8 to 3.5 mm. Due to the water particles rising up to 4-4.5 meters from the ground during the irrigation process, the evaporation of water droplets and the loss due to wind increase. On windy days, the effective irrigation coefficient can drop from 0.76-0.80 to 0.45-0.5. Water resource waste in irrigation can reach 22-24%, and in some cases, up to 40%. At the same time, energy consumption remains high, requiring 350-550 kWh of electricity to deliver 1000 m³ of water to crops. Existing sprinkler machines require high water pressure (0.5-0.7 MPa). Research has shown that reducing water pressure to 0.1 MPa in large-scale sprinkler machines can save 10-30% of energy. The high consumption of water and energy resources, the lack of development of sprinkler machines in our country, and the high cost of foreign machines hinder the widespread adoption of irrigation technology in agricultural production.

Therefore, it is urgent to develop scientific and technical foundations for energy-efficient sprinkler irrigation processes, reduce water resource waste, improve the quality indicators of sprinkler irrigation, and enhance the design and manufacturing practices of irrigation machines and devices.

To adapt irrigation machines to local conditions, it is advisable to build the CFS of the nozzle and shaft to minimize the evaporation of water droplets in the technological process and their loss due to wind, and to implement technical solutions based on morphological analysis to overcome these deficiencies. The functions of the elements of the sprinkler device nozzle are presented in Table 1.

The research method and results show that the element E1-1 (deflector) performs the most functions.

Table 1 **Functions of Elements in the Sprinkler Device Nozzle****

Elements		Function	
Designation	Name	Designation	Description
E_{1-1}	Deflektor	F_1' F_1'' F_1''' F_1''''	Delivers water flow (V_1) to short-distance field surface (V_2). By diverting the flow of water (V_1) at short range, it reduces evaporation(V_3) during the irrigation process at the expense of reducing their flight time. Reduces their wind-induced blowout (V_4)) at the expense of supplying water flow (V_1) across the surface. Reduces the washing of the soil surface(V_5) at the expense of low pressure rainwater flow (V_1)
E_{1-2}	Perforated tube	F_2' F_2''	Adjusts water consumption(V_6). Provides the generation of thick-walled liquid capacitance (V_7) in finite space
E_{1-3}	Surface reverse	F_3'	Drains the water flow (V_1) towards the field surface (V_2)
E_{1-4}	Central canal	F_4'	Limited space water capacity (V_7) is provided by the required amount of water flow (V_1)
E_{1-5}	Confusor	F_5'	Limits the compression (V_8) of the flow of water coming out of the fluid capacity (V_7) in finite space
E_{1-6}	Connecting part	F_6'	Nasadka elements ($E_{1-1\dots1-7}$) to provide the coupling of chips between the rainbows device(E_0).
E_{1-7}	Corps	F_7'	To the elements ($E_{1-1\dots1-7}$) giving shape, ensuring their mutual location

The E_{1-1} element plays a crucial role in the interaction of water droplets with the environment while fulfilling the functions of F_1', F_1'', F_1''' and F_1''''. The evaporation (V_3) and loss due to wind (V_4) (height of droplet rise, flight time, distance) during the irrigation process are intrinsically linked to the constructive dimensions of the deflector. Additionally, the soil washing (V_5) (velocity of droplet flight) necessitates the adoption of proper technical solutions for the deflector. At the top of the hierarchy, the perforated pipe of the nozzle stands in second place, performing two functions. The water consumption and hydraulic pressure values in the water pipe are closely related to the type, installation location, and generated physical-technical effect of the perforated pipe.

Based on Table 1, the constructive-functional structure (CFS) of the sprinkler nozzle is presented in Fig 1. The first level of the CFS includes the functions of the sprinkler nozzle, while the lower level lists the names of the nozzle's elements. The constructed CFS allows for visualizing the interrelations of the nozzle elements. It also illustrates the functions performed by the elements. Three elements (E_{1-1}- deflector, E_{1-3}- surface reflector, E_{1-4}- central channel) directly interact with the water flow (V_1). The evaporation of water droplets (V_3), their wind loss (V_4), and the soil washing (V_5) are associated with the deflector E_{1-1}. The confuser E_{1-5} prevents the compression of the water flow exiting the nozzle.

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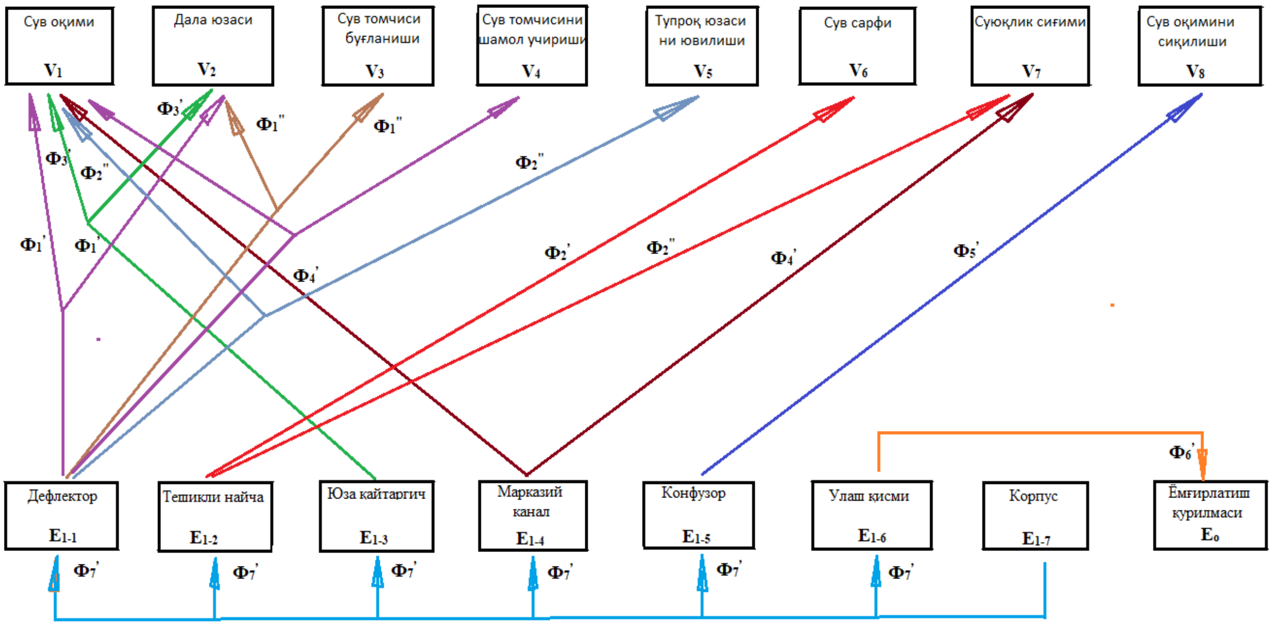

Fig 1: Constructive-Functional Structure of the Sprinkler Nozzle

The elements shown in the table can be designed with various constructions and physical-technical effects. Heuristic methods from an interdisciplinary heuristic fund can be utilized in improving the S_i generation of the sprinkler device.

Optimal technical solutions for technical objects, including the sprinkler nozzle, were found using morphological analysis. The physical-functional analysis of technical objects, their functional criteria for development, constructive evolution, laws of structure and development, morphological analysis and synthesis of technical solutions, interdisciplinary heuristic funds for modifying objects, physical-technical effects, laws of hydrodynamics, the effect of liquid flow from containers, and the laws of kinematics and dynamics were used to conduct comparative analysis of alternative options. The options were iteratively reduced, and the optimal variant of the deflector nozzle was adopted (Table 2).

Table 2 **Technical Solution of the Deflector Nozzle Based on Morphological Analysis**

$F_1^{'}, F_1^{''}, F_1^{'''}, F_1^{''''}$	$F_2^{'}$ $F_2^{''}$	$F_3^{'}$	$F_4^{'}$	$F_5^{'}$	$F_6^{'}$	$F_7^{'}$
1	**2**	**3**	**4**	**5**	**6**	**7**
$A_1^{'}$	$A_2^{'}$	$A_3^{'}$ screen surface reducer	$A_4^{'}$- round-shaped duct	$A_5^{'}$	$A_6^{'}$- rhesbally compound	$A_7^{'}$- round-shaped body
$A_1^{''}$- Ellipsoid deflector	$A_2^{''}$- round-hole flute (symmetrical flow relative to the arrow)	$A_3^{''}$	$A_4^{''}$	$A_5^{''}$- inner wedge		$A_7^{''}$
$A_1^{'''}$	$A_2^{'''}$	$A_3^{'''}$		$A_5^{'''}$		
$A_1^{''''}$	$A_2^{''''}$	$A_3^{''''}$		$A_5^{''''}$		

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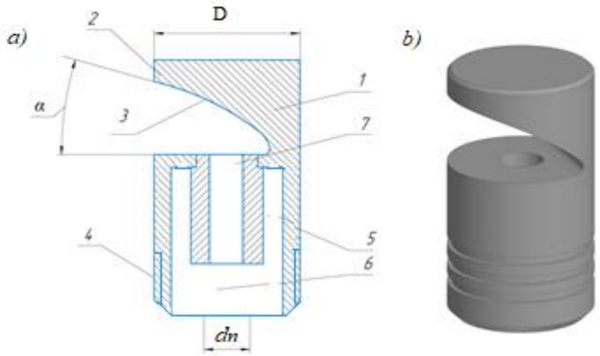
Table 2 presents the variants of technical solutions obtained from the morphological analysis of the KFS of the Si generation sprinkler device. The obtained technical solutions were analyzed from constructive and technological perspectives, unacceptable options were reduced, and the technical solution for the deflector nozzle of the S_(i+1) generation emerged as follows:

Round perforated pipe + elliptical deflector + screen surface reflector + equipped with a round central channel + in a round-shaped body + designed for installation with a threaded connection = short-range sprinkler nozzle.

The drawing of the improved constructive-functional structure of the deflector nozzle is presented in Fig 2. The nozzle allows for low-energy sprinkler irrigation at low pressure.

The task was resolved by replacing the flow of liquid from a thin-walled vessel under pressure P with a thick-walled (nozzle) vessel under pressure P - ΔP, without changing the water consumption rate Q (ε=0.64).

The described short-range sprinkler nozzle consists of: Base 1, with an open bottom and a concave top, a screen surface deflector 3, and a pipe 7, which is connected to a horizontal plane through a threaded connection. The base 1 is designed to be attached to the water supply pipe using a threaded connector 4. The central channel 5 allows water to flow into the base, while the confuser 6, made of thick-walled containers, ensures the required water flow condition between the pipe 7 and the body.



1 - base; 2 - deflector; 3 - screen surface reflector; 4 - connecting part; 5 - central channel; 6 - confuser; 7 - perforated pipe

Fig 2: Overall View of the Improved Low-Pressure Operating S4 Generation Nozzle with Interchangeable Adjustment Pipe

The technological process is as follows: water enters the confuser 6 through the central channel 5 and fills the channel and confuser cavity. Since the pipe 7 is positioned inside the base with a gap between the pipe and the body (formed by the confuser cavity), the water flow entering the pipe does not create a pressure increase. As a result, the water stream exiting the pipe will have a diameter matching the inner diameter of the pipe. The screen surface deflector 3 located at the top of the base ensures the even distribution of the water stream, forming droplets of uniform size.

The proposed S_{i+1} generation nozzle operates at a lower pressure than the Si nozzle, while ensuring a higher water flow rate. This lower pressure when the water droplets exit the nozzle results in less pressure on the soil surface, thus preventing disruption of the soil structure. The screen surface deflector contributes to improving irrigation quality by forming droplets of

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uniform size. The irrigation intensity, water flow, and the size of the artificial droplets can be adjusted by changing the nozzle to one with the required hole diameter.

Conclusion:

The above technical solution involving the designed deflector nozzle ensures that artificial irrigation systems use less energy, distributes the water droplets uniformly over the field surface, and maintains the required irrigation intensity within standards.

The problem of liquid flow Q remaining unchanged while replacing a thin-walled container with a thick-walled (nozzled) container at a pressure of P-ΔP is resolved through the use of the nozzle.

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