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FORMATION OF ARTIFICIAL RAINDROPS ON THE DEFLECTOR ATTACHMENT OF RAINMAKING MACHINES

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Abstract

The article investigates the formation of artificial raindrops on the deflector attachment of rainmaking machines during their operation and the distribution of artificial raindrops on the soil surface. The dimensions of the resulting artificial raindrops are analyzed depending on the constructive parameters of the attachment. Mathematical expressions of the interdependence of technological and constructive parameters have been developed. The results of laboratory and field tests of the constructed rainmaking machine are presented based on the indicators obtained from theoretical research.

Keywords: Rainmaking machines, deflector attachment, artificial raindrops, deflector segment, water flow, effective precipitation coefficient, rainmaking, water distribution.

Introduction

Climate change observed worldwide is affecting water resources. Central Asian countries mainly draw water from two rivers, the Amu Darya and the Syr Darya. The large water intake canal being constructed in Afghanistan can reduce the water volume of these rivers by up to 25%. In such conditions, it is necessary to make rational use of water resources in agriculture. Presidential Decree № PF-5853 dated October 23, 2019, "On Approval of the Strategy for the Development of Agriculture in the Republic of Uzbekistan for 2020-2030," Decree № PF-6024 dated July 10, 2020, "On Approval of the Concept for the Development of Water Management in the Republic of Uzbekistan for 2020-2030," and Resolution № PQ-144 dated March 1, 2022, "On Measures to further Improve the implementation of technologies for watering Agriculture" have been adopted to effectively address these negative consequences [1]. One of the ways to achieve water resource efficiency in agriculture is through the method of irrigating and irrigating crops by agitation. Although the agitation method has been widely used in foreign countries, it has not been applied extensively in Uzbekistan. One of the main reasons for this is the lack of scientific research on agro-climatic and geographical conditions. Therefore, research on artificial agitation and artificial rain formation is a topical task.

Research and Objectives

F.G. Abramov, A.P. Isaev, Yu. A. Moskvichev, B.M. Lebedev, P.P. Moskalsov, V.Ye. Yeremenko, F.N. Sattarov, I.L. Bezuevskiy, V.K. Sevryugin, and many other scientists have been involved in the development of rainmaking technology and the construction of artificial rainmaking machines [2]. Their scientific works are increasingly being applied in agricultural practices for irrigating and irrigating crops. However, in the process of rainmaking, the evaporation of water, its loss due to wind, and the high energy consumption during the precipitation process remain significant challenges. The main reason for this is the insufficient d evelopment of artificial rainmaking technology. During the rainmaking process, water flow interacts with the deflector attachment, resulting in the formation of artificial raindrops. The quality parameters of artificial rain, such as its distribution over the soil surface and quantity, are crucial in agriculture [3]. The deflector attachment directs the water flow onto the deflector surface, where it interacts to form artificial rain. The dimensions of the artificial raindrops depend on the velocity and thickness of the water flow on the deflector. Due to the elliptical shape of the deflector surface, the velocity and consumption of water flow vary in different segments. Consequently, the rainmaking machine generates a rainmaking area on the soil surface consisting of sectors OO_iO_{i+1} Oa_ia_{i+1} (refer to Fig. 1). Observations of rainmaking processes indicate that the thickness of the water flow remains uniform across all segments, leading to the concept of "continuity of water flow." Therefore, assuming that the water flow distributed along the deflector surface maintains uniform thickness, we conduct research on the velocity and consumption of water flow in various segments and its distribution along the surface.

The trajectory of the water flow along the line OO_8 is depicted in Fig.1. At point O, the initial velocity of the water flow from the nozzle, denoted as
ϑ_o $(\vartheta_o = \vartheta_{A})$, reaches velocity ϑ_B at point a i on the deflector surface, and at point O_i, it attains velocity ϑ_t upon collision with the soil surface. Therefore, velocity ϑ_B serves as the initial velocity of the water flow in the atmosphere from the rainmaking machine.

The water consumption Q_d on the deflector is equal to the sum of water consumption in the deflector segments:

$$Q_d = \sum_{i=1}^{n} Q_{di} = \sum_{i=1}^{n} S_i \cdot \vartheta_{Vi}, \qquad (1)$$

Here, Q_{di} *represents water consumption in segment i of the deflector;* $S_i = \delta \cdot l_i$ *denotes the surface area of water flow in segment i of the deflector (refer to Fig.2); δ represents the thickness of water flow on the deflector;* $l_i = |O_iO_{i+1}||$ indicates *the length of the elliptical arc of segment i of the deflector; φ_i represents the inclination angle of segment i of the deflector relative to the water flow line; n denotes the number of segments on the deflector surface; and* ϑ_{Bi} *denotes the velocity of water flow in segment i of the deflector.*

To calculate, Q_{di} it is necessary to determine the velocity of water flow ϑ_{Bi}, the thickness of water flow δ, and the length of the elliptical arc $l_i$of segment i of the deflector. The value of, ϑ_{Vi} representing the velocity of water flow in segment i of the deflector, is equal to the projection of onto ϑ_B line OO_8 (refer to Fig. 2).

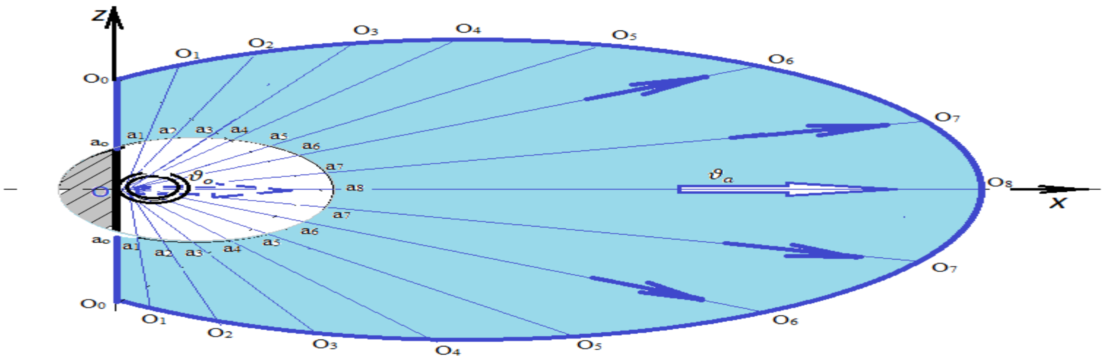


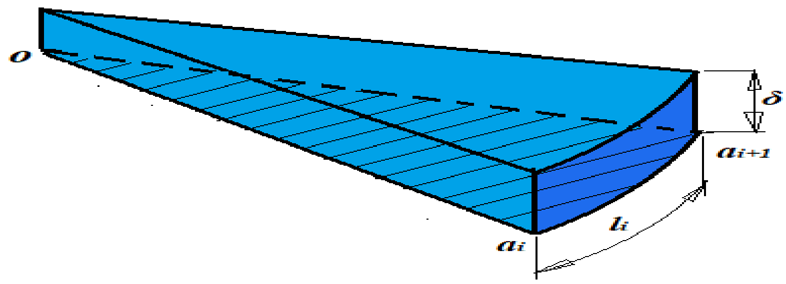
***Fig.1*. Schematic representation of the water flow onto the deflector attachment:** *water dispersion on the deflector surface in blue; division of the water flow into droplets in light blue.*

$$\vartheta_{Bi} = \vartheta_B \cos\varphi. \quad (2)$$

Or, by considering the velocity upon entering the nozzle of the rainmaking machine [4]:

$$\vartheta_{Bi} = \sqrt{\vartheta_A^2 - 2g\frac{D}{2\cos\alpha}(1+\sin\alpha)\cos\alpha - \frac{\pi\gamma\ \vartheta_A^2(1+\sin\alpha)^2}{4\cos^3\alpha\left(\left(1-\frac{1}{2}\sin(D\cos\alpha)\right)-\sqrt{\frac{\cos^2\alpha}{4}-1}\right)}}\cos\varphi,$$

(3)



2 - Diagram. To determine the surface area of water flow on the deflector segment, the following formula (1) can be expressed as**:** $A=\pi\cdot l_i\cdot\delta$

Where: l_i - represents the length of the ellipse arc of the deflector segment. δ - represents the thickness of the water flow on the deflector.

$$Q_d = \sum_{i=1}^{n} S_i \sqrt{\vartheta_A^2 - 2g\frac{D}{2\cos\alpha}(1+\sin\alpha)\cos\alpha - \frac{\pi\gamma\ \vartheta_A^2(1+\sin\alpha)^2}{4\cos^3\alpha\left(\left(1-\frac{1}{2}\sin(D\cos\alpha)\right)-\sqrt{\frac{\cos^2\alpha}{4}-1}\right)}}\cos\varphi.$$

(4)

Let's φ express the necessary expressions to calculate the values of δ and l_i.

The water consumption from the second side of the nozzle is equal to the following:

$$Q_n = S_1 \cdot \vartheta_A, \quad (5)$$

Here, $S_1 = \frac{\pi \cdot d_n^2}{4}$ represents the area of the nozzle orifice, where d_n is the diameter of the nozzle orifice, and $\vartheta_A$is the water flow velocity at the nozzle orifice.

Given that

$$Q_n = Q_d,$$

and if we assume uniformity of water flow thickness on the deflector segments, we can

$\delta =$ Deflector segment, degrees	• Nozzle diameter D=20 mm • Water flow velocity at the nozzle orifice ϑ_A=8 m/s, Diameter of the nozzle orifice d_n=8 mm, δ<1.68 mm			• Nozzle diameter D=25 mm • Diameter of the nozzle orifice d_n=8 mm, δ<1.32 mm		• Nozzle diameter D=30 mm • Diameter of the nozzle orifice d_n=8 mm, δ<1.19 mm	
	The velocity ϑi m/s	The length l_i is expressed in millimeters (mm).	The water consumption Q_{di} is expressed in cubic millimeters per second (mm³/s).	The length $l_i$is expressed in millimeters (mm)	The water consumption $Q_{di}$is expressed in cubic millimeters per second (mm³/s).	The length $l_i$is expressed in millimeters (mm).	The water consumption Q_{di} is expressed in cubic millimeters per second (mm³/s).
90^o	0,000	2,62	20	3,28	20	3,93	20
75^o	2,070	4,88	16970	6,54	17870	6,86	16900
60^o	4,000	4,10	27550	5,20	27460	5,24	24940
45^o	5,660	4,22	40130	5,30	39600	5,45	36710
30^o	6,930	4,49	52270	5,62	51410	6,23	51380
15^o	7,730	6,28	81550	7,87	80300	9,35	86010
-15^o	7,730	6,28	81550	7,87	80300	9,35	86010
-30^o	6,930	4,49	52270	5,62	51410	6,23	51380
-45^o	5,660	4,22	40130	5,30	39600	5,45	36710
-60	4,000	4,10	27550	5,20	27460	5,24	24940
-75^o	2,071	4,88	16098	6,54	17880	6,86	16910
-90^o	0,000	2,62	20	3,28	20	3,93	20
The water consumption (l/s).		Q_{di20}	434000	Q_{di25}	433000	Q_{di30}	432000
The sum of denoted as $\sum Q_{di}$ represents the water consumption at the nozzle, which is 0.433 liters per second (l/s).							

write:

Tabl. 1.

$$\frac{\pi \cdot d_n^2}{4} \vartheta_A = \delta \cdot \sum_{i=1}^{n} l_i \cdot \vartheta_{Bi} \cdot cos\varphi$$

From this, we can derive the following expression to determine δ.

$$\delta = \frac{\pi \cdot d_n^2 \cdot \vartheta_A}{4 \cdot \sum_{i=1}^{n} l_i \cdot \vartheta_{Bi} \cdot cos\varphi} . \qquad (6)$$

The obtained values indicate the total length of the deflector segments: $\sum l_i$ = 53.18 mm for D=20 mm, $\sum l_i$ =67.62 mm for D=25 mm, and $\sum l_i$ =74.12 mm for D=30 mm. If the lengths of the deflector segments are known, it is possible to calculate the water flow thickness (δ) using formula (6). Graphs illustrating the dependency of δ, the thickness of water flow on the deflector, on the diameter of the nozzle d_n based on the values obtained using formula (5) at a velocity of ϑ_B=8 m/s are provided in the fig.3.

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As depicted in the graphs, an increase in the nozzle diameter leads to a decrease in the water flow thickness on the deflector. For instance, when D=20 mm and d_n=6 mm, δ=0.91 mm, while for D=30 mm and d_n=6 mm, δ=1.32 mm. Conversely, a decrease in the nozzle diameter results in an increase in the water layer thickness: for D=30 mm and d_n=4 mm, δ=0.84 mm; for d_n=8 mm, δ=1.68 mm. The increase in water flow thickness leads to a higher water content compared to larger diameter nozzles, resulting in increased water consumption.

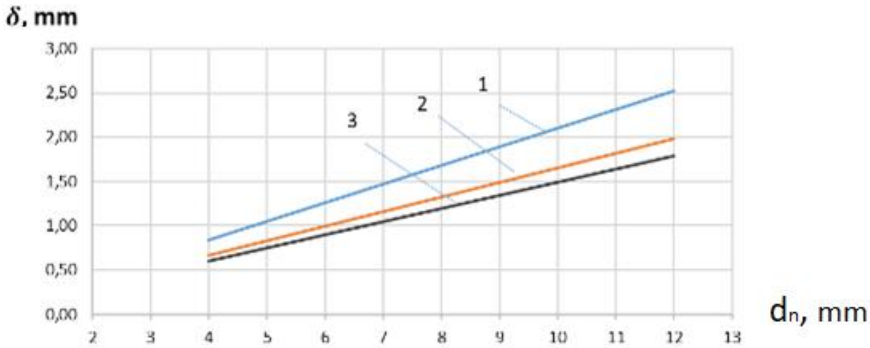

Fig.3*. Graphs illustrating the dependency of water flow thickness on the diameter of the nozzle d_n for deflector segments: *1. D=20 mm; 2. D=25 mm; 3. D=30 mm are presented.*

It is explained that under the influence of surface tension force, water always tends to minimize its volume. When the sum of forces affecting the fluidity increases, the fluid splits, leading to a decrease in its mass and volume, which in turn reduces the forces affecting the fluidity.

It is known that among geometric figures with the same mass, the sphere has the minimum surface tension. Therefore, the water flow in the nozzle tends to acquire a spherical shape under the influence of surface tension force. It is assumed that the diameter of the artificial water droplet produced will not exceed the thickness of the water flow on the deflector. Researchers have often emphasized the necessity to start the fragmentation of the water flow into droplets after it leaves the nozzle and passes a certain distance.

In this case, it is possible to express the following inequality based on the characteristic feature of the surface tension force of liquids:

$$\delta \geq d \qquad (7)$$

Where δ represents the thickness of water flow on the deflector.

From the graphs, it is deduced that for water droplets with diameters of d_s =0.7-2.0 mm, the diameter of the nozzle orifice d_n should be in the range of 6-10 mm. The length of the deflector segment l_i, water flow velocity ϑ_{Bi}, water flow thickness δ, and the distance of the water jet from the line OO_8 of the deflector segment at an angle φ_i are determined based on the values obtained from the formula (5) and the water consumption in the deflector segment (3), and its distribution on the working surface.

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The variation of water consumption Q_{di} in the deflector segment depending on the nozzle diameter D is presented in Table 1. It is noted that the majority of water flow is concentrated in the central segments. For example, for nozzle diameter D=20 mm and initial velocity ϑ_0=8 m/s, the water consumption Q_{di} in the segment at angles $\varphi\, \varphi = 0^0 \div 15^o$ is 81,550 mm³/s, while for angles $\varphi = 75^{\ 0} \div 90^o$it is Q_{d6}= mm³/s. Here, a water droplet with a diameter less than 1.68 mm is formed.

For D=30 mm, the diameter of the water droplet formed at the nozzle decreases to less than 1.19 mm. Accordingly, Q_1=24,958.3 mm³/s and Q_{d6}=86,01 mm³/s.

Conclusion

Theoretical research and analysis of the results make it possible to state the following:

- When the diameter of the deflector orifice is 6-10 mm, a water flow with a thickness of 1.19-1.68 mm is formed on the deflector (7).
- The initial velocity of the water flow ϑ_B=6−8 m/s changes the distance of the jet to 3.6-6.5 meters and leads to a further increase in the range of variation depending on the size of the formed droplet (see formula (5)).
- These values substantiate the requirements of agrotechnical standards (GOST 26967-86) imposed on irrigation machines.

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