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IMPROVING THE EFFICIENCY OF IRRIGATION OF ARABLE LAND

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Abstract

For optimal use of agricultural land, the mechanism of hypocycloidal trajectory of end point system is suggested to be applied in the circular irrigation system.
It is found that using of the mechanism of hypocycloidal trajectory of end point irrigation system in the form of a shortened hypocycloid with parameters:

– ratio of the radius of guide circle $R_{g.circ}$ to the radius of forming circle r is equal to 4;

– slip coefficient is equal to 0.37;

– radius of guide circle is equal to $(0.76 \cdot a)$, where a - the length of the side of the square, which fits into the trajectory of the Pivots;

will provide utilization factor of arable land which is equal to 0.97.

Key words**:** Arable land, technology of circular irrigation, trajectory parameters, shortened hypocycloid

Abbreviations**:** m –meter.

Introduction

Application of the technology of circular irrigation is widespread in almost all over the world: in Australia, Asia, Western Europe and North America, as the high degree of mechanization and automation of irrigation process, structural simplicity of the equipment allow farmers (fig. 1) [1, 2]:

– to provide uniform and accurate irrigation without overstating norms of water consumption and its losses due to evaporation;

– to increase the cultivated area and get higher harvest with a help of using hydraulic transmission systems.

Currently, at the agricultural enterprises of Kazakhstan standard indicators of water use for irrigation is adjusted in accordance with [3]:

– global climate change in the natural climatic zones of arable land;

– geometry and modern eco-reclamation conditions of irrigated land;

– advanced technologies and technical means of irrigation.

Materials and Methods

In the event of significant increase of irrigated land area innovative solutions are of key importance that help not only to solve the problem of rational use of water, but also to increase the amount of various agricultural products and to reduce the consumption of material and human resources for obtaining them.

This is confirmed by modern experience of management, which shows that on one hectare of irrigated land under modern irrigation technology products can be obtained in 12-15, and in some cases on certain crops up to 20 times more than one hectare of non-irrigated arable land [4, 5].

Preliminary analysis of the area of circular irrigation shows that due to its constructive features about 30% of arable land is taken out from agricultural use. In order to solve this problem it is suggested using kinematical mechanism 1 which would ensure the movement outmost point of irrigation system by trajectory of shortened hypocycloid that is formed by rotational motion around center O of the slip 2 with simultaneous reciprocating motion of the rod 3 along the slip (fig. 1) [6].

In this case the rod 3 is fixed by the retainer 4 on gear radius r, which is rolling over inside the guide gear radius R . The trajectory, which is described by the end point of the rod 3 and the retainer 4 on the rolling radius of the gears is a shortened hypocycloid.Changing position of the retainer 4 on the rolling gear radius r along the guide circle radius R allows to change the slip coefficient $\lambda < 1$.

The equations of motion of the free end of the rod by rotating the slip about the point 0 in parametric form are as follows [7]:

$$\begin{cases} x = (R-r)\cdot\cos\varphi + \lambda\cdot r\cdot\cos\left(\dfrac{R-r}{r}\cdot\varphi\right) + L_{rod}\cdot\cos\varphi \\ y = (R-r)\cdot\sin\varphi - \lambda\cdot r\cdot\sin\left(\dfrac{R-r}{r}\cdot\varphi\right) + L_{rod}\cdot\sin\varphi \end{cases}, \qquad (1)$$

or by performing transformations we will obtain:

$$\begin{cases} x = (R-r+L_{rod})\cdot\cos\varphi + \lambda\cdot r\cdot\cos\left(\dfrac{R-r}{r}\cdot\varphi\right) \\ y = (R-r+L_{rod})\cdot\sin\varphi - \lambda\cdot r\cdot\sin\left(\dfrac{R-r}{r}\cdot\varphi\right) \end{cases}. \qquad (2)$$

As $n = \dfrac{R}{r}$, (3)

where n- integer which is equal to 3, 4, 5 and 6, so we will write equation (2) as:

$$\begin{cases} x = (r\cdot(n-1) + L_{rod})\cdot\cos\varphi + \lambda\cdot r\cdot\cos((n-1)\cdot\varphi) \\ y = (r\cdot(n-1) + L_{rod})\cdot\sin\varphi - \lambda\cdot r\cdot\sin((n-1)\cdot\varphi) \end{cases}. \qquad (4)$$

As equation (4) are the equations in parametric form of some shortened hypocycloid with the number of branches n, the slip coefficient λ_1 and the radius of rolling circle r_1, then we have:

$$\begin{cases} r\cdot(n-1) + L_{rod} = r_1\cdot(n-1) \\ \lambda\cdot r = \lambda_1\cdot r_1 \end{cases} \qquad (5)$$

While solving the system of equations (5) relatively to r_1 and λ_1, we will obtain:

$$\begin{cases} r_1 = r + \dfrac{L_{rod}}{n-1} \\ \lambda_1 = \dfrac{\lambda \cdot r}{r + \dfrac{L_{rod}}{n-1}} \end{cases} \quad (6)$$

Kinematic scheme shows that length of the rod L_{rod} must satisfy the following condition:

$$L_{rod} \geq r \cdot (1+\lambda) + L_{beam} \quad (7)$$

Substituting the boundary condition (7) in the second equation of the system (6), we will determine the slip coefficient λ_1 of shortened hypocycloid trajectory which is formed at outmost point of rod, with a minimum length of the rod L_{rod}:

$$\lambda_1 = \frac{\lambda \cdot r}{r + \dfrac{L_{rod}}{n-1}} = \frac{\lambda \cdot r}{r + \dfrac{r \cdot (1+\lambda)}{n-1}} = \frac{\lambda \cdot (n-1)}{n+\lambda} \quad (8)$$

From equation (8) we define the position of the retainer on the rolling circle radius (slip coefficient λ):

$$\lambda = \frac{\lambda_1 \cdot n}{n - \lambda_1 - 1} \quad (9)$$

Results and Discussion

Rational range of values slip coefficient for maximum trajectory that is formed at outmost point of rod is $\lambda_1 = [0.7 - 1.0]$.

We will define the length of the rod for a rational range of values of the slip coefficient λ_1:

- if $\lambda_1 = 0.7$: $L = r \cdot (1+\lambda) \cong 2{,}6 \cdot r + L_{beam}$; (10)
- if $\lambda_1 = 1.0$: $L = r \cdot (1+\lambda) = 4{,}0 \cdot r + L_{beam}$. (11)

Theoretical researches have been performed to establish potential of this irrigation technology, where rational geometric parameters of shortened hypocycloid which is the most satisfying solution of described problem is defined:

- ratio of the radius of guide circle $R_{g.circ}$ to the radius of forming circle r is equal to 4;
- slip coefficient is equal to $\lambda = 0.37$;
- radius of guide circle is equal to:

$$R_{g.circ} = 0.76 \cdot a, \quad (12)$$

– where a - the length of the side of the square, which fits into the trajectory of the Pivots;

Conclusion

- For optimal use of agricultural land and water resources it is available to use in circular irrigation systems the mechanism for the movement of the end point of circular irrigation system on the trajectory as a shortened hypocycloid.

- It is founded that by providing a trajectory of movement of the end point of irrigation system, further increase of the irrigated area will be more than 24.1% in comparison with the traditional circular trajectory.

- Using of advanced irrigation technology will increase the utilization coefficient of arable land up to 0.97.

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Резюме

С целью рационального использования земель сельскохозяйственного назначения предлагается в системах кругового орошения использовать механизм, обеспечивающий гипоциклоидальную траекторию движения концевой точки системы.

Установлено, что применение механизма с траекторией движения концевой точки системы орошения в виде укороченной гипоциклоиды с параметрами:

– отношение радиуса направляющей окружности к радиусу образующей окружности равно 4;

– коэффициент скольжения равен 0.37;

– радиус направляющей окружности равен $(0.76 \cdot a)$;

позволит получить коэффициент использования пахотных земель равным 0.97.

Түйін

Ауыл шаруашылығы жерлерін тиімді пайдалану мақсатында жер суару жүйесінде қолданылатын механизм ұсынылады. Қысқа гипоциклоидтар келесі параметрлері бар:

- бағыттаушы шеңберінің радиусы құрастыру шеңберінің радиусына қатынасы 4-ке тең;

- жылжу коэффициенті 0,37 тең;

- бағыттаушы шеңберінің радиусы $(0.76 \cdot a)$ тең;

жер суару жүйесіндегі ақырғы нүктенің қозғалысы траекториясының механизмін пайдалану егіндік жерлерді пайдалану 0,97-ге тең коэффициентін алуға мүмкіндік береді.