Water conservation while using irrigation devices of multiple supports in the conditions of the Moscow region

Conservación del agua mientras se utilizan dispositivos de riego de múltiples soportes en las condiciones de la región de Moscú

Conservação de água durante o uso de dispositivos de irrigação de múltiplos suportes nas condições da região de Moscou

Recibido: 20 de noviembre de 2018. Aceptado: 11 de diciembre de 2018

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Abstract

The paper focuses on problem of water quality around irrigated soils. It was discovered that flushing of the fertile layer occurs on terrains near protected watersheds because of destroying irrigation procedures. The modernization of irrigation machines has been suggested as a solution for above-mentioned problem. The technological features of circle irrigation machines (IM) in the conditions of complicated soil relief are defined by their supportings including: tow-grip crossing capacity and slipping of carts on the slope. The operating results have been given according to evaluation of IM work in difficult conditions with the picture of their changes in the diagram dependences. The above-mentioned devices are improved to create environmentally friendly and energy-saving solutions in order to enhance the reliability of IM while watering sloping lands In the area of softening of complex soils that refers to the safety and quality of maintenance while the reduction in the amount of water and energy consumption as well as the cost of irrigation system structure, the scientific concepts are searching for tools to providing highly efficient IM work. The main goal of the work is using the obtained results of research in a practical way as to create and

Resumen

El documento se centra en el problema de la calidad del agua alrededor de los suelos irrigados. Se descubrió que el enrojecimiento de la capa fértil se produce en terrenos cercanos a cuencas protegidas debido a la destrucción de los procedimientos de riego. La modernización de las máquinas de riego ha sido sugerida como una solución para el problema mencionado anteriormente. Las características tecnológicas de las máquinas de riego en círculo (IM) en las condiciones de alivio de suelo complicado se definen por sus apoyos, que incluyen: capacidad de cruce con agarre de remolque y deslizamiento de carros en la pendiente. Los resultados operativos se han dado de acuerdo con la evaluación del trabajo de IM en condiciones difíciles con la imagen de sus cambios en las dependencias del diagrama. Los dispositivos mencionados anteriormente se han mejorado para crear soluciones respetuosas con el medio ambiente y que ahorran energía para mejorar la confiabilidad de IM mientras se riegan las tierras con pendiente En el área de ablandamiento de suelos complejos que se refiere a la seguridad y la calidad del mantenimiento, mientras que la reducción de la cantidad de consumo de agua y energía, así como

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modify IM in order to exercise the irrigation tools conveniently and also generally determine the efficiency of machinery while reducing energy and water consumption as well as providing soil cooling technologies using water from irrigation.

Keywords: irrigation machine (IM); slipping of carts; sloping lands; tow-grip crossing capacity; water-harvesting formation.

el costo de la estructura del sistema de riego, los conceptos científicos están buscando herramientas para proporcionar un trabajo de IM altamente eficiente. El objetivo principal del trabajo es utilizar los resultados obtenidos de la investigación de manera práctica para crear y modificar la IM con el fin de ejercer las herramientas de riego de manera conveniente y también, en general, determinar la eficiencia de la maquinaria al tiempo que reduce el consumo de energía y agua, así como también proporciona suelo Tecnologías de enfriamiento utilizando agua de riego.

Palabras claves: máquina de riego (IM); resbalones de carros; terrenos en pendiente; capacidad de cruce con agarre; Formación de captación de agua.

Resumo

O artigo enfoca o problema da qualidade da água em torno dos solos irrigados. Descobriu-se que a descarga da camada fértil ocorre em terrenos próximos a bacias protegidas por causa da destruição de procedimentos de irrigação. A modernização de máquinas de irrigação tem sido sugerida como uma solução para o problema acima mencionado. As características tecnológicas das máquinas de irrigação circular (IM) nas condições de relevo complicado do solo são definidas pelos seus apoios, incluindo: capacidade de passagem do cabo de reboque e escorregamento dos carros na encosta. Os resultados operacionais foram fornecidos de acordo com a avaliação do trabalho de IM em condições difíceis, com o quadro de suas mudanças nas dependências do diagrama. Os dispositivos mencionados acima são aprimorados para criar soluções ecologicamente corretas e de baixo consumo de energia, a fim de aumentar a confiabilidade do IM durante a irrigação de terras em declive na área de amolecimento de solos complexos que se referem à segurança e qualidade da manutenção enquanto a redução do quantidade de água e consumo de energia, bem como o custo da estrutura do sistema de irrigação, os conceitos científicos estão à procura de ferramentas para fornecer trabalho altamente eficiente IM. O principal objetivo do trabalho é usar os resultados obtidos da pesquisa de forma prática para criar e modificar IM, a fim de exercitar as ferramentas de irrigação convenientemente e também determinar a eficiência do maquinário, reduzindo o consumo de energia e água, bem como fornecendo o solo. tecnologias de refrigeração usando água da irrigação.

Palavras-chave: máquina de irrigação (como primário); deslizar de carrinhos; terras inclinadas; capacidade de cruzamento de aderência; formação de captação de água.

Introduction

This is a complex technical issue to provide efficient use of circular irrigation systems, while saving energy and water savings and irrigation-resistant technology. The extensive use of circle irrigation machines are faced with the problem of their ecological discordance in the quality of watering process, their energy, supporting and tow-grip properties, complicated soil relief of irrigated terrains that are led to reduction of IM efficient usage. Areas that have significantly changed soil degradation due to great lengths, dynamics, and the start and stop mode of the IM movement and the frequency of crossing a path (Scott & Lousberg, 1995; Scott & Kulberg, 1997; Kah , 1998; Schneider & Leinweber, 2003).

Development of the above-mentioned issues demands solving a set of closely connected scientific and practical tasks based on complex investigations. Chowdary et al (Chowdary et al, 2006). conducted experiments showed that different ponding heads and ring diameters of irrigation machines influence the the process and thus affect the obtained data. Mohamoud and

Keller and Bliesner used rainfall simulators or sprinkler machines to determine infiltration equation parameters (Keller & Bliesner, 1990; McCann & Stark, 1993). Although such methods simulate water application by sprinkler irrigation systems but it's difficult to simulate the high application rates of center pivot systems. Chu et al. indicated when water application rate increase from 25 to 125 mm per hour, degradation rate doubles (Chu et al, 1987). DeBoer and Chu found that soil degradation parameters derived from low application rate tests overestimated runoff values for sprinklers with higher application rates (DeBoer & Chu, 2001). DeBoer and Chu in research on continuous moving sprinkler irrigation system concluded that in addition to soil type, plow operations, initial moisture content of soil and irrigation method also waste considerable amount of water during irrigation (Ryazantsev & Antipov, 2016a).

On the basis of our investigation results, the methodical means of estimating bearing soil capacity depending on frequency and quality of watering, methods of calculating, technical decisions to increase IM supporting, gripping and profile features, ensuring energy saving and soil friendly watering process, innovative technologies of making leveled and directed tracks while using IM, new means of mechanization were performed and implemented into the production.

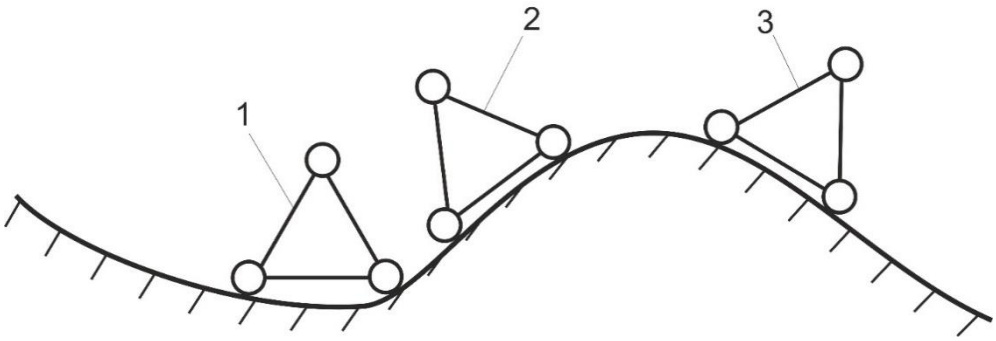
Efficiency and Capacity of Circle MI

The efficiency or capacity per a working day for one circle IM (e.g. «Fregat» and «Kuban - LK1»), by considering all water and time losses, is determined by the following equation:

$$\omega_{ch} = \frac{3{,}6 \cdot Qt_{ch} \cdot K_{ch}}{m\beta} \quad (1)$$

Where in Q – water consumption, L/sec;
m – Water standard, m3/ha;
β – rate, considering water loss on vaporization in the rain cloud area during irrigation;
tch – IM operating time per working day, hr;
Kch – rate of working time use per a working day.

According to the research of circle IMs on the complicated soil relief, their lower efficiency is often caused by decreasing rate of working time use (Kch). This decrease is determined by losses of supporting crossing capacity of the machine carts on the recessed ground level (because of increased rutting) and on the raised ground level (because of insufficient tow-grip properties of chassis system or gear power), and also by excessive slip while moving down the slope (because of poor brake system) (Figure 1).



1 – on the recessed ground level, 2 – on the raised ground level, 3 – on the slope
Figure 1. IM cart direction scheme on the complicated soil relief (Ryazantsev & Antipov, 2015).

The mentioned facts are caused to premature emergency stops of IM because of distortion of its pipeline and, as a consequence, protecting system switching-on.

In its turn, the rate Kch is determined as Formula (2):

$$Kch = K1+K2+K3+K4-3 \quad (2)$$

Where: K1 – technical service rate;
K2 – technological process reliability rate;
K3 – technological service rate;
K4 – operational reliability rate.

Rate K2 is a determining factor to increase in non-productive time losses and to decrease in reliability of technological watering process during IM operating on sloping lands.

To handle it easier, we will mark the sum of rates K1+K3+K4 as the united rate K5, and considering$K_2 = \frac{T_{ch}}{T_{ch}+n_i t_i}$, Tch – network time, h; ti – downtime of IM due to hydroprotection system switching-on; ni – quantity of IM stops due to hydroprotection system switching-on.

Then Formula (2) will be considered as

$$K_{ch} = K_5 + \frac{T_{ch}}{T_{ch}+n_i t_i} - 1 \quad (3)$$

According to the standards, the average result of the united rate K5 (e.g., IM «Fregat»), is about 0.90, and the commissioning process of IM takes about 5 hours on the average after the hydroprotection system was started (Ryazantsev & Antipov, 2016b).

The graphic changes of K2 (Rate of the technological process reliability) and Kch (Rate of working time use) with regard to quantity of IM stops (commissioning process duration), taking into account Formula (3) have been shown in Figure 2.

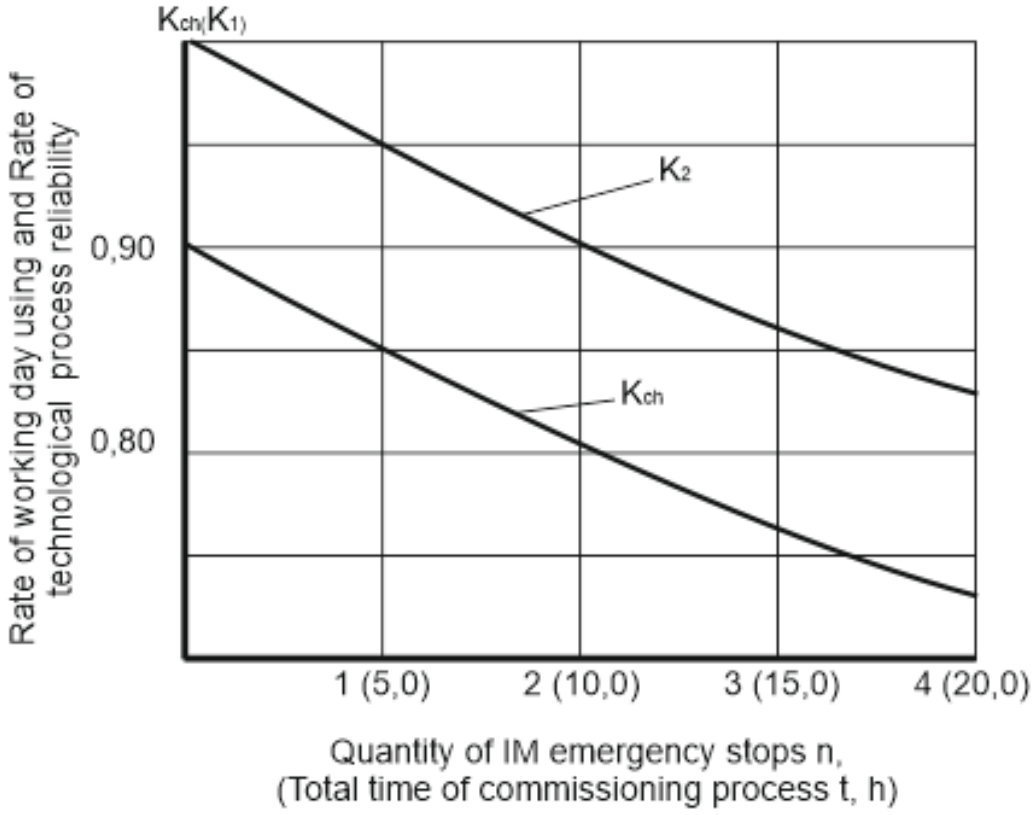


Figure 2. Correlation: Rate of working day use and Rate of technological process reliability vs Quantity of IM emergency stops

For example, after 4 emergency stops of IM (1 and 2 – due to losses of supporting and tow-grip crossing capacity; 1 – due to excessive slipping of IM carts) the rates K2 and Kch reduce from 1,0 and 0,90 till 0,83 and 0,73, or by 17% and 19% correspondingly.

As a result, the specified points lead to reduced IM efficiency and distortion of the irrigation schedule, expressed with the duration of irrigation, to be determined by Formula (4), and with crop yields decrease.

$$T_{rpm} = 0{,}112\frac{R_к}{v\beta K_{ch}} \quad (4)$$

where Trpm– time of one turnover of IM, hr;

Rk – distance from the fixed pivot till the last cart, m;
v – Speed of last cart, m/min;

For case study, with the irrigating standards m=500 m3/ha the model IM Fregat (16 carts, Q=70 L/sec) makes one turnover for 140 hours on the average on the even surface, and for 185 hours with the above-mentioned conditions (4 emergency stops of IM) (Ryazantsev, 1992).

The IM efficiency is traced more clearly in Figure 3, where it is about 3.9 hectares on the condition of uptime work (Kch=0,90) during eight hours working day, and it is reduced to 2.8 hectares, or by 39%, with frequent emergency stops (e.g., 4 stops).

Efficiency tends to decrease by taking other irrigating standards. But if water volume standards reduces (e.g., till 300 m3/ha), the productivity of one machine grows (Ryazantsev & Antipov, 2015).

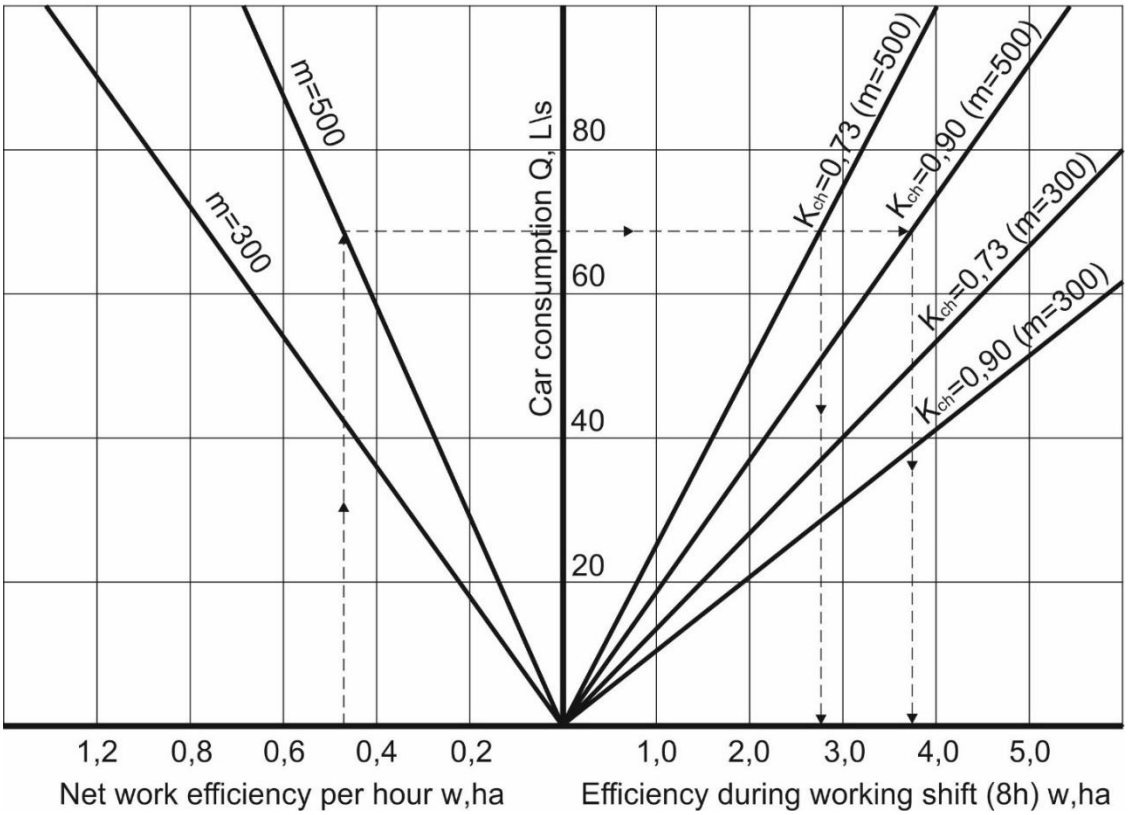


Figure 3. Correlation: IM working day efficiency vs Rate of working day time use (with other permanent rates)

Thus, it is necessary to develop eco-friendly and energy-saving machines with steady supporting, tow-grip and slip-resistant properties by optimizing their features and by improving running and braking systems to ensure reliable operation of the circle IM in the conditions of complex soil relief.

Reliability and efficiency of the circle IM under the mentioned conditions are determined by the following eco-energy factors and are based on the wide experience of research and its implementation by means of mechanization:

1. In the recessed ground level - bearing capacity of irrigated soil (P0) and allowable pressure of IM running systems (q) (condition of bearing crossing capacity)

$$q \leq P0 \quad (5)$$

An increase in soil bearing capacity can be controlled by irrigation timetable (the irrigation standards, intensity and the diameter of rain drops, the volume of water runoff on the surface). The value P0 is determined by the

empirical correlation (Ryazantsev & Tsentsiper, 1988), and by the type of irrigating devices and their positioning scheme (Ryazantsev & Olgarenko, 2005a; Ryazantsev, 1984).

To reduce the pressure of IM running systems on the soil (up to 100 kPa, and more) it is recommended to use low-pressure tires (Ryazantsev & Erokhin, 1994), or caterpillar and stepping gears (Ryazantsev & Afanasiev, 1989a; Ryazantsev & Afanasiev, 1990). In addition, their position on the device is very important (Ryazantsev & Afanasiev, 1989a).

To reduce thrust and therefore energy consumption when working on IM, it is recommended that you consider it with your carts, depending on the running system models, with different leveling devices,
If the mentioned solutions are not effective, it is possible to move IM from the fixed pivot and continue its way along the new track (Ryazantsev, 1989b).

2. When climbing the sloping lands – tow-grip properties of IM running systems, from condition (6), and in case, they grip with the ground strongly enough – gear power of carts

Condition of tow-grip crossing capacity (П):

$$П = \phi c - f > i, \quad (6)$$

Where in ϕc - gripping rate
f – Slip resistant rate;
i – The angle of slope.

Results and Discussion

To ensure reliable climbing of IM and to reduce slip-resistance, it is recommended to apply running systems suitable for areas with the recessed ground relief. To ensure maximum absorption properties, it is best to position the positioning devices of the soil receptors in each wheel with the opposite direction (Ryazantsev & Kirilenko, 2007).

In conditions of sufficient adhesion with the ground, maximum reduction of their internal energy losses is recommended for effective use of IM gear power while overcoming the slopes, which is defined by energy conversion efficiency (ECE).

Thus, for electrified IM in order to eliminate parasitic power, it is achieved by setting the reduction gear on each wheel of carts, changing wheel-gear onto wave ones). It allows to increase gear ECE up to 2 times (from 0,50 till 0,90) (Ryazantsev & Olgarenko, 2006).

For stable climbing movement of hydro-gear IM, it is recommended to improve their kinematics in order to ensure guaranteed traction force (Ryazantsev & Olgarenko, 2005b).

3. When moving down the slopes – by the type of IM running systems, their slip-resistant properties and reliability of braking systems.

It is recommended to use electrical gear IM with self-braking gears, and hydro-gear IM with improved braking systems to prevent involuntary slipping of carts on the slope.

At the same time, the prevention of excessive slipping of carts is provided by the tires with soil grab devices, oriented against their movement

Conclusion

Our research has shown that the introduction of eco-friendly and energy-saving solutions while the use of the IM circle in complex terrain allows their reliability and performance to be provided, usually related to the smooth surface..
For many years, our fundamental research and the results of the analysis of the problem under consideration are the basis of new scientific concepts that provide a promising solution for improving the IM circle for work on soil relief..
The big and important scientific problem for national economy and agricultural sector was solved on the basis of the theoretical generalization made in our work.
The novelty and originality of the most technical and technological decisions for improving circle IM have been confirmed by numerous patents.

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