Reasoning of parameters and working modes of automated leveler with long-span relief sensor

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Abstract. Current state of irrigated farming is characterized by significant changes: technical level of reclamation objects deteriorates, productivity reduces and huge irrigated areas are out of use. Such situation demands reconstruction of technical policy in irrigated farming. One of the prioritized approaches intended for higher efficiency of use of irrigated lands is realization of high-quality leveling of irrigated areas. World and home practice of farming has proved that leveling of a field is key reclamation measure which is intended for elimination of small hills and depressions available in the field, it changes the culture of farming. Leveled fields provide uniform distribution of moisture which significantly improves crop capacity of all agrarian cultures. Such fields guarantee higher productivity of equipment used in cultivating and reaping of harvest.

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Introduction

In Kazakhstan where agriculture is very important for national economy, its stability is not possible without development of AIC's branches of the country [1, 2].

Development of agricultural sector depends greatly on fields' surface leveling. Realization of excavating-leveling and agricultural works while preparing fields for sowing depends greatly on the operation on final smoothing of field surfaces which must comply with high requirements. Depending on the volume and requirements to the quality of field surface final leveling is performed by different types of reclamation and construction equipment including longspan levelers which have relatively high leveling capacity. Their leveling capacity mainly depends on the length of the span which must be approximately 2 times more than the length of uneven sections [3].

The aim of this study is to provide increase in productivity and quality of field surface leveling through the use of hydraulic servosystem of leveler's work unit.

Tasks:

- to develop scheme of automated leveler with longspan relief sensor to increase productivity and quality of workflow process of field surface leveling;
- to give grounds to main parameters of the elements of longspan relief sensor of automated leveler;
-to investigate stability hydraulic servosystem which controls work unit of automated leveler;
-to analyze transfer processes of changes in the depth of cutting by work unit of automated leveler.

Materials and methods

In general, methods of the study suggest use of theoretic and experimental approaches. Theoretic methods are based on the use of theoretic mechanics laws, mathematic analysis, mathematic statistics and theory of automated regulation. Reliability of theoretic provisions is proved by the results of experiments. Experimental approach suggests realization of laboratory-field surveys of experimental sample of automated leveler with longspan relief sensor which based on the use of strain-gauging methods, tests described in normative documents.

Results:

- key parameters and the modes of work of automated leveler with longspan relief sensor;
-results of calculation of transfer processes with on-off jump of the front support of longspan relief sensor;
-results of experiments.

Main part

World and home practice of farming has proved that leveling or smoothing of the field surface is a key reclamation measure intended for elimination of available on the field unevennesses in the form of small hills and depressions.

In modern conditions pre-sowing leveling is done by longspan levelers which is not always efficient: necessary accuracy of leveling is not provided because of the absence of automatic control system which moves work unit in vertical direction [3-5]. In spite of numerous existing technologies and machines today there is no uniform approach to specification of optimal parameters of excavating-leveling machines, it is still not clear which criteria must be used in choice of machine's type and improvement of complex technical process of field surface leveling.

One of the ways of solution of such problem is development of construction of leveler whose work unit can be controlled by servosystem with longspan relief sensor.

Figure 1 demonstrates diagram of automated leveler with longspan relief sensor, its theoretic parameters and modes of operation. Figure 1 presents automated leveler diagram

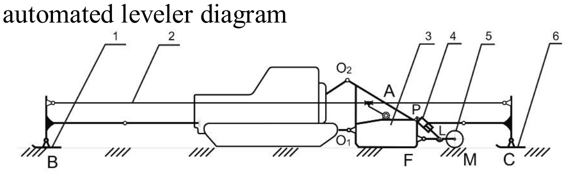


Figure 1. Diagram of automated leveler with longspan relief sensor

Proposed construction of relief sensor in the form of stretched thread 2 connected with front and back supports 1, 6 and positioned on machine's side. Permanent position of work unit 3 in regard to *A* point of the sensor is controlled by relay. When point A moves in vertical direction automatic system is activated which moves the shovel (scoop) in the same direction and for the same distance. The system is driven by of hydraulic cylinders 4 through which shovel is pivotally connected to support frame 5.

Taking into regard transfer functions of the system: hydro-cylinders $W_S(P)$, links formed by vertical shift of relay $W_d(P)$ and front support of relief sensor $W_в(P)$, and clear delay units, formed by back support of rs $W_{\tau_1}(P)$, the wheels of support frame $W_{\tau_2}(P)$ the equation in relay system in regard to regulation error has the following form:

$$X(P) = W_в(P)\cdot Y(P) - W(P)L\{\Phi[x(t)]\}, \quad (1)$$

где $W(P)-$ transfer function of linear part of the system 4,5,6]:

$$W(P) = \frac{W_1(P)\cdot W_S(P)\left[W_d(P) - W_C(P)\cdot W_{\tau_1}(P)\right]}{1 - W_2(P)\cdot W_{\tau_2}(P)} \quad (2)$$

The equation of the system in regard to regulated value $Y(P)$ is as follows:

$$Y(P) = \frac{k_1 \cdot k_S}{P(1 - k_2 \cdot e^{-P\tau_2})}\cdot L\{\Phi[k_в \cdot Y_в(t) + k_c \cdot Y(t-\tau_1)]\}, \quad (3)$$

where $k_в$, $k_c -$ coefficients of transmission of longspan relief sensor, of front and back supports accordingly;

k_1 , $k_2 -$ coefficients of transmission of piston's displacement of hydro-cylinders and the wheels of support frame.

Analysis of equations (1) and (3) allows to investigate stability of regulation system and to assess quality of transfer processes and choose parameters which provide necessary quality of regulation.

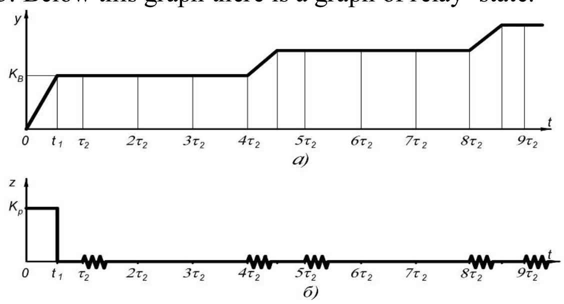
Calculation of transfer processes was done by the fit method (by steps) [6, 7, 8], because on reaching of the limit of the dead zone of relay K_0, and on expiration of time periods τ_1 and τ_2 the kind of solution changes. It will be appropriate also to use graph-analytical method of solution because needed function $y(t)$ is an argument of non-liner function $\Phi(x)$.

The kind of transfer processes will be determined by structure of automatic system, in other words, by the kind of equation (3), which we consider unchanged and the ratio of its coefficients. It s assumed that $\tau_1 = 4\tau_2$, primary conditions $y(t) = 0$ with $t = 0$. We shall believe that in the moment of time $t = 0$, $y_в(t) = 1$ and does not change in future. Physical meaning of the solution can be understood by presenting first multiplier in the form of geometric series:

$$Y(P) = \frac{k_1 \cdot k_S}{P}\cdot\left(1 + k_2 e^{-P\tau_2} + k_2^2 e^{-2P\tau_2} + \ldots\right) L\{\Phi[x]\} \quad (4)$$

Transfer processes have been analyzed with different parameters of regulation system: coefficients k_1, k_2 are such that meaning $z = 1$ is achieved for the time less than τ_2 , which corresponds to high speed of hydraulic drive actuation (more than k_S), or low speed of machine's moving (more than τ_2). Real values of coefficients k_2 and k_C are in the range : $0 < k_2 < 1$, $0 < k_C < 1$.

The form of transfer process is given in Figure 3. Below this graph there is a graph of relay' state.



$k_c = 0{,}68$; $k_2 = 0{,}32$; $k_3 = 2{,}66$ sm/sec; $k_1 = 2{,}27$; $k_2 = 0{,}61$; $\tau_1 = 4$ sec; $\tau_2 = 1$ sec; $\mathcal{H}_0 = 0$.

Figure 2. Transfer process of changes in the cutting depth of automated leveler (*a*) and the graph of relay's state (b)

Full displacement of work unit is calculated on finishing of transfer process. With the first step its displacement is $k_в$, the second $-k_1 k_s k_c$, the ninth $-k_в k_c^2$ and so on. Displacement with step $n+4$ is equal to [9, 10, 11, 12].

$$y_{n+4} = k_в(1 + k_c + k_c^2 + ... + k_c^n) = k_в \frac{1 - k_c^n}{1 - k_c}. \quad (5)$$

With $n \to \infty$, $k_c^n \to 0$ and full displacement of work unit is equal to:

$$y_\infty = \frac{k_в}{1 - k_c} = 1 \quad (6)$$

i.e. it is equal to initial displacement of point *B* of relief sensor.

Performed theoretic study has shown that kinds of transfer processes depending on combination of specific parameters vary greatly. However general trend of displacement of work unit is directed for achieving of final shift which is equal to initial shift of the front wheel of longspan relief sensor.

Results

In this section the method of experiments is given which suggests field studies and tests which are based on the use of strain-gauge methods, test methods described in regulatory documents. Methods of experimental studies include 2 stages developed in accordance with general structural scheme.

In order to identify the influence of settings of work unit servosystem on the quality of operation of automated leveler with longspan relief sensor we made a series of experiments.

Delivery of power liquid Q_n was regulated in the range of 1-71,25 liters per minute or 0-4,28 m3 (Figure 8) and the dead zone in regard to deviation of *A* point – in range from 0 to ± 0,06м. The quality of leveling works with different settings of automatic system was assessed by coefficient of evenness of the field surface k_b which shows quality of leveling of surface field after passing of leveling machine.

We got dependency of evenness coefficient on the speed of unit's motion. With less consumption of liquid the knife of the shovel under the influence of automatic system because of low speed of piston move of support frame's hydro cylinder is not able to control *A* point of longspan relief sensor. That is why leveler smoothes soil with little productivity.

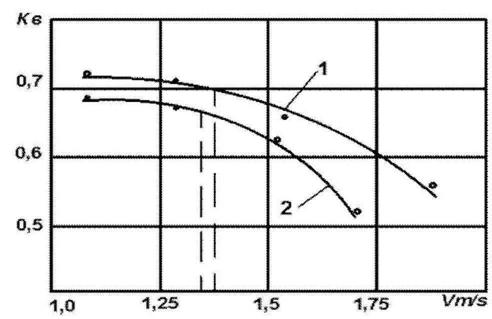


Figure 3 Dependency of the evenness coefficient on the speed of machine's motion

The operation of automated leveler with longspan relief sensor was compared with serial long base leveler P-2,8A. The results of experiments show that leveling capacity of automated leveler is 1,2 -1,8 times higher, productivity grows by 1,7 -1,9 times. The results of processing of obtained oscillogram showed that average value of resistance for automatic leveler is R_l =18,4 kH and for longspan leveler - R_l' =23,6 kH. Reduction of pulling force of the leveler takes place mainly because of the reduction of rolling resistance due to relatively small mass of automated leveler.

Use of automated leveler with longspan relief sensor in combination with tractor DT-75M will reduce labour costs by 1,3 times.

Conclusion

Statics of longspan relief sensor has been considered. The choice of thread is reasoned and the characteristics of compensator's spring have been specified;

Motion of work unit has been analyzed. Functional diagram of the system is built, the system equation was found.

The calculation of transfer processes was done by fit method (by steps). Theoretic study has proved that kinds of transfer processes depending on combination of specific parameters vary greatly.

Proposed scheme of automated leveler with longspan relief sensor which allows to divide debate and measurement-transfer functions of longspan leveler enables to reduce metallic content in its design.

Optimal settings electro-hydraulic system increase leveling capacity of automated leveler in comparison with longspan leveler P-2,8 by 28,5% and reduces its pulling force.

Frequency of actuation of electro-magnets depends on the settings of automatic system and determines the quality of smoothing.

Inference

1. The main reason of low quality of leveling of field surface is low leveling capacity of technical means, including longspan levelers. Leveling capacity of this group of machines is restricted by the base length. Increase in productivity and quality of work of levelers can be achieved due to automatization of work unit's operation.

2. Statics of longspan relief sensor is considered. The choice of thread is reasoned and the characteristics of compensator's spring have been specified;

3. Motion of work unit has been analyzed. Functional diagram of the system is built, the system equation was found.

4. The results of study showed that chosen closed relay system is stable. Physical sense of such stability is that in chosen model the object has no inertia and therefore reversing of its motion is done immediately Since insensitivity zone is ... after the balance of the object is broken the object performs unlimited small fluctuations.

5. The calculation of transfer processes was done by fit method (by steps). Theoretic study has proved that kinds of transfer processes depending on combination of specific parameters vary greatly.

6. Dependencies of settings of automatic system on initial state of relief are found. By experimental method optimal quantity of power liquid consumption is found for different state of relief. Dead zones are defined.

7. The dependencies of the maneuverability values of automated leveler on the machine's motion speed are defined. Experimental data show that increment in speed by 0,5 m/sec results in increment in turn radius by 2-5% and the length of turn changes by 5-10%.

8. The operation of automated leveler with longspan relief sensor was compared with serial long base leveler P-2,8A. The results of experiments show that leveling capacity of automated leveler is 1,2 -1,8 times higher, productivity grows by 1,7 -1,9 times.

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