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THEORETICAL AND EXPERIMENTAL RESEARCH OF TECHNOLOGICAL PROPERTIES OF THE AGRICULTURAL BRIDGE AGGREGATES

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Abstract: *The physical objects of the study were an agricultural bridge tool, a structure developed by us with a track gauge of 3.5 m, and the aggregated agricultural implements, used for surface tillage: a tooth harrow, a rotary harrow and an S-shaped spring loosener. The experiments proved good adaptability to work of the aggregate of controlled traffic and bridge farming, and high quality of the technological soil tillage processes in the agrotechnical area of the field. The variation coefficient of fluctuations in the resistance of agricultural implements on the hook of the agricultural bridge tool was no more than 10%.*

Keywords: *Bridge aggregate, soil irregularities, profile, traction resistance.*

INTRODUCTION

The problem of finding new soil tillage tools, machines and implements for their efficient application in the controlled traffic and bridge farming systems is very relevant (Chamen T. 2015; Onal I. 2012; Bulgakov V., Adamchuk V., Kuvachov V., Ivanovs S. 2017; Pedersen H. H., Oudshoorn F.W., McPhee J. E., Chamne W. C. T. 2016; Bulgakov V, Melnik V., Kuvachov V. & Olt J. 2018).

The functional possibilities of using agricultural implements for the surface treatment in the minimum tillage technologies can provide loosening of the surface layer to its structured state without moisture transfer to the surface, the stability of the working tools in depth, high tillage quality, and so on (Derkach O. D., Makarenko D. O., Litvintseva Yu. O., Derkach V. D. 2018; Mitkov V., Kuvachov V., Ihnatiev Ye., Mitkov V. 2016; Mitkov V., Kuvachov V., Ihnatiev Ye., Mitkov V. 2016).

EXPOSITION

The materials published on this topic (Chamen T. 2015; Bulgakov V., Adamchuk V., Kuvachov V., Ivanovs S. 2017; Chamen W.C.T. 1992; Bulgakov V., Kuvachov V., Olt J. 2019; Bulgakov V., Kuvachov V. et al. 2019; Bulgakov V., Kuvachov V. et al. 2019; Kuvachov V., Shulga A. 2018; . Kuvachov V., Shulga A. 2018). may be divided into several categories. To the first one should refer articles of general nature (Chamen T. 2015; Bulgakov V., Adamchuk V., Kuvachov V., Ivanovs S. 2017), which review the essence of the problems and outline the main directions for their solution. In contrast to the publications of general nature, in which the problems are approached as a system, not always taking into account the possibility of practical implementation of the proposed solutions, those works are of significant value the authors of which have tried to implement the bridge aggregates in a practical way (Chamen W.C.T. 1992; Bulgakov V., Kuvachov V., Olt J. 2019). Creation of experimental prototypes of machines encounters all sorts of difficulties; not always the particular samples meet the necessary requirements. Besides, such publications do not completely reflect the results of experimental investigations of the agricultural bridge tools. A special category are inventor's certificates and patents (Bulgakov V., Kuvachov V. et al. 2019; Bulgakov V., Kuvachov V. et al. 2019; Kuvachov V., Shulga A. 2018; Kuvachov V., Shulga A. 2018) Often the authors of such patents are far from practical implementation of their ideas. It often turns out that the ideas of creating new working tools for the bridge and controlled traffic farming are torn away from reality, and even superficial analysis reveals their economic or technical inconsistency. In such a situation detailed analysis of the experimental tests of agricultural machines and tools in the aggregates of controlled and bridge farming, as well as the acquired practical experience, are important for science. The aim of this research is to study the compliance of the parameters of the existing agricultural implements for the surface treatment with the basic principles of efficient implementation of controlled traffic and bridge farming.

METHODS

The methodology of the experiments provided for the use of a contemporary strain gauge, as well as the control and measuring equipment with analog-to-digital conversion of signals received from the information sensors. The experimental data were processed on the PC, applying the probability theory, the regression, and also correlation-spectral analyses. During the experiments it was intended to determine the following characteristics: fluctuations in the longitudinal profile of irregularities of the trail of constant tramline and irregularities of the agricultural background before and after the treatment with the bridge aggregate, moisture and density of the soil, the depth of tillage, and characteristics of fluctuations in the traction resistance of the agricultural implements.

The normalised correlation function $\rho_j(t)$ of fluctuations of the investigated parameters was determined according to equation (Gmurman V.E. 2004):

$$\rho_j(t) = \frac{1}{D_h(n-m)} \sum_{i=1}^{n-m} (n_i - m_n) \cdot (n_{i+m} - m_n) \quad (1)$$

where n – the number of measurements; m – the number of points of the correlation function, $m = 0,\ 1,\ 2, \ldots;$ n_i– the ordinate of fluctuations of the investigated i-th parameter of the measurement, $i = \overline{1,\ m}$; m_n – mathematical expectation of the ordinates of fluctuations of the investigated parameter; D_j – dispersion of fluctuations of the investigated parameter.

The normalised spectral density $s_j(\omega)$ of distribution of the fluctuation ordinates of the investigated parameter by frequency ω was determined according to equation (Gmurman V.E. 2004):

$$s_j(\omega) = \frac{\Delta t}{\pi}\left[1 + 2\sum_{i=1}^{m} \rho_{ji}(t) \cdot cos(m_i \cdot \Delta\omega)\right] \qquad (2)$$

where $\Delta\omega = \frac{\pi}{m \cdot \Delta t}$ – the step of the fluctuation frequency of the investigated parameter.

As the physical objects of research there were used agricultural bridge tools of the design developed by us with a track gauge of 3.5 m and 9.5R32 wheel tires (Fig. 1 a).

a)

b)

c)

d)

Fig. 1. The investigated bridge aggregates:
a) – an agricultural bridge tool of the design developed by us; b) – a tooth harrow;
c) – a rotary harrow; d) – an S-shaped spring loosener of soil

Fig. 1 presents also the aggregated agricultural implements for surface tillage: a tooth harrow (Fig. 1 b), a rotary harrow (Fig. 1 c) and an S-shaped spring loosener of soil (Fig. 1 d). The irregularities of the longitudinal profile of trails of the constant tramline and the treated agricultural background were recorded using an automated profile recorder (Fig. 2 a). The traction resistance of the agricultural implements on the hook of the agricultural bridge tool was determined using the traction strain-gauge link attached to an SA-type dynamometric automatic hitch (Fig. 2 b).

In order to register the measured parameters, such as irregularities of the profile of the agricultural background and the traction resistance of the agricultural implements, a measuring and registration complex was used, based on an analog-to-digital converter and a personal computer PC (Fig. 2 a).

a) b)

Fig. 2. The used control and measuring equipment:
a) – an automated profile recorder with an analog-to-digital converter and a PC;
b) – an SA-type dynamometric automatic hitch with a traction strain-gauge link

Information obtained during the experimental studies on the implementation of the fluctuations of the investigated parameters in the form of digitised data was transferred to the Mathcad software environment. The following statistical characteristics were calculated in it: the average value, the mean square (standard) deviation, dispersion, the dispersion coefficient, the average sample error, the normalised correlation function, the normalised spectral density. The error of direct measurement of the parameters did not exceed 2%. The moisture of soil was determined by the standard thermostat-weight method. During the investigations the average soil moisture in the 0...12 cm layer was 24.4%, and the density was 1.23 g.cm^{-3}. The depth in the research process was measured by a depth gauge in 10 places along the diagonal of the treated area. Experimental testing of the agricultural bridge tool was carried out on a control site, 50 m long. The high-speed operation mode of the bridge aggregate was 3.3...4.4 km.h^{-1}.

RESULTS AND DISCUSSION

Analysis of the obtained experimental data showed that the profile of the constant tramline is significantly smoothed out in comparison with the profile of the treated agricultural background. So, if the mean square deviation of the profile of the treated agricultural background was ± (1.32...1.44) cm, then for the tramline profile this indicator is ± 0.84 cm, that is, 1.6...1.8 times smaller.

By their internal structure the irregularities in the trail profile of the constant tramline are characterised by a function that contains, along with the random components, harmonious ones, expressed by damped periodic fluctuations of the normalised correlation function, which is presented in Fig. 3. Its analysis showed that the length of the correlation link between the ordinates of the profile irregularities of the constant tramline is about 0.18 m, which corresponds to the step of the tire grips of the agricultural bridge tool, the value of which for the tire size 9.5R32 is 0.175 m.

Similar by the nature of their structure are the graphs of the normalised correlation function (see Fig. 3) of fluctuations in the irregularities of the longitudinal profile of the treated agricultural background but different by energy. So the length of their correlation link is somewhat different from the profile of the irregularities of trails of a constant tramline. And this depends upon the type of the technological operation of the soil treatment with a bridge aggregate. For example, after treating the agrotechnical area of the field with a tooth harrow this indicator is greater than for the irregularities of the trails of a constant tramline, and it is equal to 0.34 m. But after treatment, using a tooth harrow and an S-shaped spring loosener, it is, on the contrary, smaller, amounting to 0.12 m and 0.08 m, respectively.

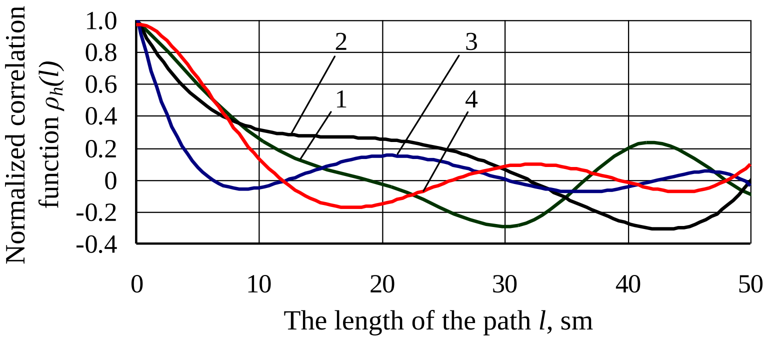

Fig. 3. The normalised correlation functions $\rho_h(l)$ (l) of the background irregularity profiles from the length of the path l: 1 – the trails of the constant tramline; 2 – the agricultural background after the pass of the tooth harrow; 3 – the agricultural background after the pass of the S-shaped spring loosener; 4 – the agricultural background after the pass of the rotary harrow

The obtained characteristics of the irregularities of the treated agricultural background correspond, as a whole, to the characteristics of the irregularities of the fields prepared for sowing agricultural crops. The spectrum of frequencies that make up the random function of irregularities in the trail profile of the constant tramline is determined by the normalised spectral density of their ordinates (Fig. 4). From its analysis it was found that the cut-off frequency for this process is approximately 0.3 cm^{-1}. The main proportion of the fluctuation dispersions in the profile of the tramline trails is concentrated within the frequency range 0...0.3 cm^{-1}. The mean square deviation of the ordinates of the indicated irregularities is consistent with the height of the tire grips of the wheels of the agricultural bridge tool, the value of which for tire size 9.5R32 is 0.03 m.

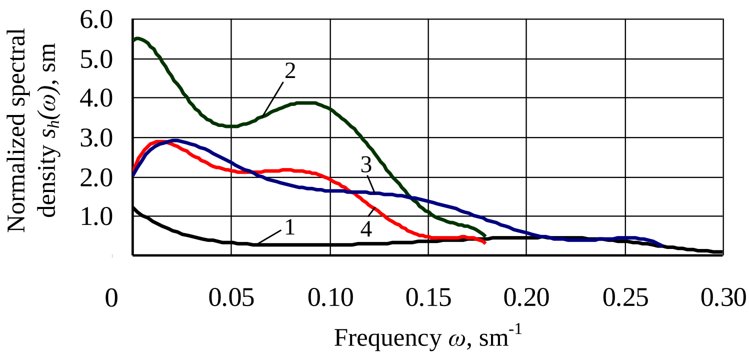

Fig. 4. Normalised spectral densities of the background irregularity profiles versus frequency ω: 1 – the trails of the constant tramline; 2 – the agricultural background after the pass of the tooth harrow; 3 – the agricultural background after the pass of the S-shaped spring loosener; 4 – the agricultural background after the pass of the rotary harrow

The above analysis of the characteristics of profile irregularities of the constant tramline along which the agricultural bridge tool repeatedly is moving indicates that the generator of the formation of these irregularities are the parameters of the tire grips of its wheels. In contrast to the irregularities in the profile of the trails of the constant tramline, formed by the tire wheels of the agricultural bridge tool, the profiles of the treated agricultural background are of a lower frequency (Fig. 4). From the analysis of the normalised spectral density of the irregularities distribution of the treated agricultural backgrounds it was found that the cut-off frequency for these processes is 0.18 cm^{-1}. The basic proportion of the fluctuations in the irregularities dispersion of the treated agricultural background is concentrated within the frequency range 0...0.18 cm^{-1}. Fluctuations in the traction resistance of the agricultural implements during the operation of the bridge aggregates express a random function in which there are no harmonic components (Fig. 5).

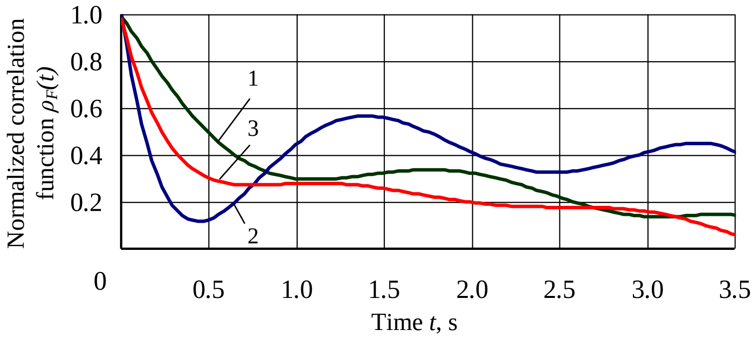

Fig. 5. Normalised correlation functions $\rho_F(t)$ of fluctuations in the traction resistance of agricultural implements from time t for: 1 – the tooth harrow; 2 – the S-shaped spring loosener; 3 – the rotary harrow

It follows from the analysis of the obtained normalised correlation functions (Fig. 5) of the traction resistance fluctuations that the degree of randomness of the process for the S-shaped spring loosener and the rotary harrow is significantly higher. Since the value of their normalised correlation functions $\rho_F(t)$ sharply decreases with increasing time t, this is a witness of a lesser dependence of their traction resistance upon the duration of the process. The basic dispersion spectrum of fluctuations in the traction resistance of the agricultural implements is concentrated within the frequency range 0...8 s^{-1} (Fig. 6). From the analysis of the normalised spectral densities of fluctuations of the traction resistance (Fig. 6) it follows that the nature of the processes is almost the same.

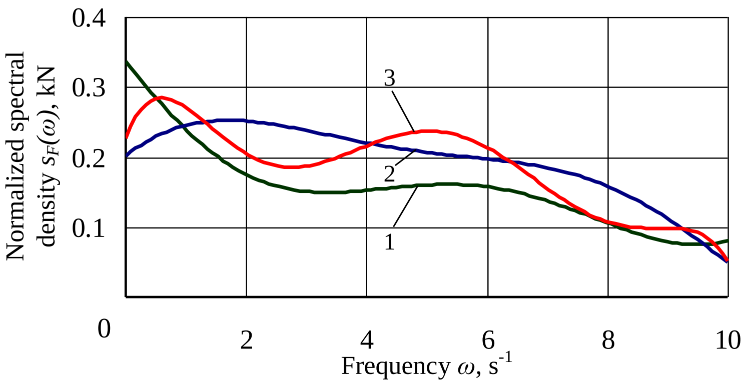

Fig. 6. The normalised spectral densities $s_F(\omega)$ of fluctuations in the traction resistance of agricultural implements upon frequency ω for: 1 – the tooth harrow; 2 – the S-shaped spring loosener; 3 – the rotary harrow

By its energy the dispersion of the traction resistance fluctuations of the investigated agricultural implements is approximately the same, and it amounts to 0.022...0.033 kN2, but the mean square deviation is 0.142...0.163 kN. For three tooth harrows in the bridge aggregate the variation coefficient in the traction resistance was 9.76% with its average value of 1.71 kN. The obtained result is a good sign pointing to high stability (low variability) of the soil cultivation process by the investigated implements. The quality indicators of soil cultivation by means of a tooth harrow, an S-shaped spring loosener and a rotary harrow in the bridge aggregates met the agricultural requirements that are set for this technological operation (Ormadzhi K.S. 1991). In particular, deviation of the actual cultivation depth from the set one did not exceed ± 1 cm, and the height of the ridges on the treated agricultural background was not more than 2 cm.

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CONCLUSION

1. The results of the experimental research of the agricultural bridge tool of an experimental design as part of agricultural implements for the soil surface treatment have proved their good adaptability to work within the units of controlled traffic and bridge farming. The quality of soil cultivation by a dental harrow, an S-shaped spring soil loosener and a rotary harrow is within the current agricultural requirements.

2. Due to the fact that the movement of the agricultural bridge tool is carried out along the compacted trails of a constant tramline, the nature of fluctuations in the profile irregularities of the agricultural background treated by the bridge aggregates is more smoothed out and of a lower frequency. A generator for the formation of the irregularity ridges in the trails of a constant tramline are the parameters of the tire grips of the wheels of the agricultural bridge tool.

3. The variation coefficient of fluctuations in the traction resistance on the hook of the agricultural bridge tool is not more than 10%, which indicates high stability (low variability) of the processes.

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