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TECHNOLOGICITY OF MAINTENANCE OF COMBINE HARVESTERS SYSTEMS DURING STORAGE

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Abstract. The solution of universal, global problems of energy and resource conservation in both mechanical engineering and agro-industrial complex are inextricably linked with the solution of issues of protection of machinery from corrosion.

Modern agricultural machinery, and self-propelled combine harvesters in particular, are operated periodically for one or two seasons a year. Most combine harvesters are stored in the open areas of agro-industrial enterprises, and it is exposed to aggressive environmental influences (fluctuations in temperature, humidity, wind, solar radiation, dust and others). The main type of environmental impact on the equipment is atmospheric corrosion and the corrosion wear caused by materials, parts and components, which leads to its premature failure. Thus, the fatigue strength of steel products when stored for 12 months in the open reduces by 28–58%.

To ensure temporary corrosion protection of combine harvesters, a large number of conservation and working-conservation oils are used. However, the unresolved number of issues of theoretical and practical nature leads to the unjustified use of protective equipment, which either does not provide the required duration of storage of equipment, or increase the cost of its preservation. Standardized methods of testing anti-corrosion lubricants in the vast majority have a number of disadvantages, the most important of which is that the evaluation of protective properties is carried out in units that do not allow to estimate their service life, but only show the corrosion of the metal.

Key words: anticorrosiveness, lubricants, safety, efficiency, combine.

Introduction

The analysis of existing scientific works shows that a significant amount of research is devoted to the problems of bush-roller chains [1], their maintenance and storage of scientists, research and other institutes and organizations.

Summarizing the results of the work shows:

1. The actual consumption of bushing-roller chains type PR-19,05-3180 per 100 combines is 2.5 times higher than the established norm [2]. The reason – violation of operating instructions, as a consequence – their premature rejection, ie. until the pledged resource is exhausted [3].
2. Removal of bushing and roller chains from agricultural machinery creates great inconvenience during current and capital repairs, as well as during off-season maintenance [4]. To test the efficiency of many parts, assemblies and units of most complex agricultural machines, drive chains must be installed, and after inspection and adjustment – removed and put into storage with all technological operations of conservation, which increases labor costs from 7% to 10-13 % of the total regulatory complexity of storage of the combine [5]. The main reasons for the violation are the complexity of technological processes, weak material and technical base of rural enterprises, great inconvenience associated with the removal and storage [6].
3. The using sleeve-roller chains for their intended purpose and during storage, the joints are not insulated from moisture and abrasive particles [7]. Therefore [8], the improvement of service technology is a reserve for increasing the service life of drive chains. To reduce the impact of climatic influences and further aging and wear of bush-roller chain joints, the choice of technological conservation materials, including additives based on non-ferrous metal nanoparticles, is a priority [9].

Formulation of problem

Based on the above to achieve the goal of research in this article, the following research objectives are formulated:

- to carry out a comparative assessment of corrosion resistance of preservative materials, including nanostructured aluminum hydroxide (AlOOH – boehmite) [10];
- to determine the effect of nanostructured aluminum hydroxide (AlOOH – boehmite) on the lubricating properties of preservatives, on the example of sleeve-roller chains [11];
- to determine the regularity of the wear process and the optimal elongation of the sleeve-roller chains of combine harvesters depending on the methods of storage and lubrication during the intended use [12].

Analysis of recent research results

The sequence of the program cycle of experimental researches included a complex technique of research of influence of preservative materials on working capacity of bushing-roller chains of combine harvesters and consecutive elimination of the least effective of them [13].

The method of studying the protective properties of conservative materials included:

- study of corrosion resistance of samples of steel grade 3 in the humidity chamber H-4 [14];
- bench tests of samples of steel grade 3 under open atmosphere conditions [15];
- study of the influence of storage conditions and protective composition on the preservation of sleeve-roller chains [16].

In the laboratory, the study was performed on samples of steel grade 3 in the humidity chamber H-4 [17]. Given the geometric dimensions of the chamber, steel samples for testing were made with a size of 60 × 70 × 2 mm [18]. Before applying the studied conservative materials [19], they were marked [20]. Preservative materials were applied to the prepared samples by immersion and kept for 24 hours at room temperature [21], then placed in a humidity chamber H-4 [22]. Examination of samples and weighing was performed after 24, 48, 72, 120, 240, 360, 420 and 720 hours [23]. Evaluation of the protective ability of preservative materials was performed by gravimetric method and consisted in establishing the loss of mass per unit area of the test sample per unit time [24-26].

Purpose of research

The purpose of research is to develop a more efficient technological process of combine harvester systems during storage.

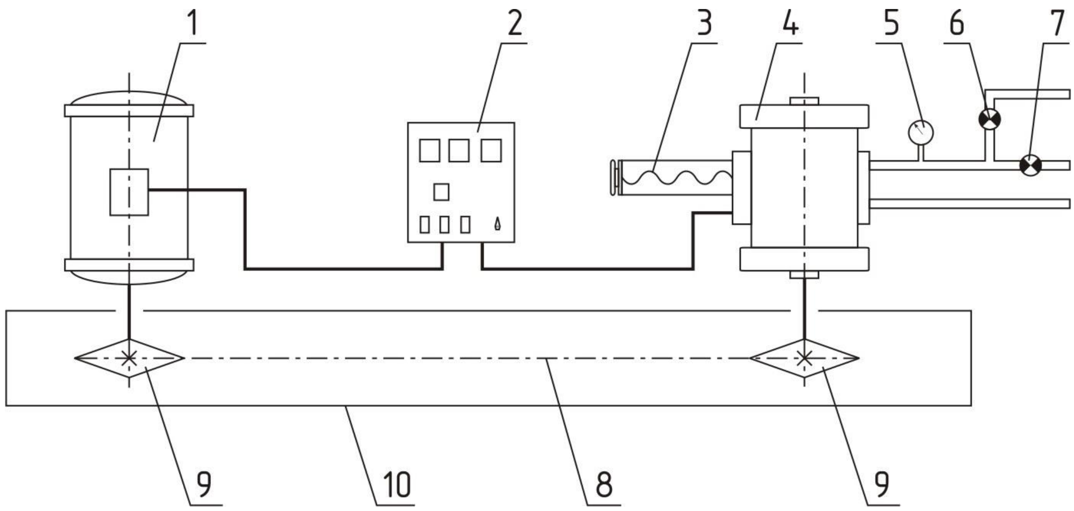
Research results

In order to verify and obtain more reliable results, bench tests of conservation compositions were conducted in open atmosphere conditions. The tests were performed on steel samples similarly to laboratory tests and on samples of sleeve-roller chains. In order to reduce the cost of research, the most effective conservation materials were selected based on the results of accelerated testing. The total duration of the tests was 1 year, which made it possible to simulate the real specifics of storing agricultural machinery. The test sites were inspected daily for the first 10 days and then every 2, 3, 6, 9 and 12 months.

To study the influence of storage conditions and protective composition on the storage of sleeve-roller chains, samples of sleeve-roller chains with a step of 19.05 mm were selected. The installation of chains on the stand simulated the conditions of their storage directly on agricultural machinery in a weakened state. Studies on each storage and conservation option were performed six times over 1 year.

Methods of research of influence of storage conditions and conservation materials on the process of wear of sleeve-roller chains. A characteristic feature of the method is the study on the stand for resource testing of sleeve-roller chains.

A stand has been set up for testing (Fig. 1) testing of chains with a range of 19.05 and 25.4 mm, belts and other products that can be connected in a closed loop. To simulate the operating conditions and ensure forced wear, 100 g of granular quartz sand (particle size – 0.8…1.6 mm) was fed to the sleeve-roller chain every two hours of operation. The number of teeth of the stars Z = 19, the value of the rotational speed of the stars of the chain transmission was recorded by a universal tachometer ATT-9006 with a laser marker. The mode of testing the circuit circuit is as follows: frequency of rotation of the motor and brake shafts – 1700 min^{-1} (chain speed 9.86 m/s), load in the leading branch of the chain – 1000 N. Duration of tests of one circuit – 50 hours.

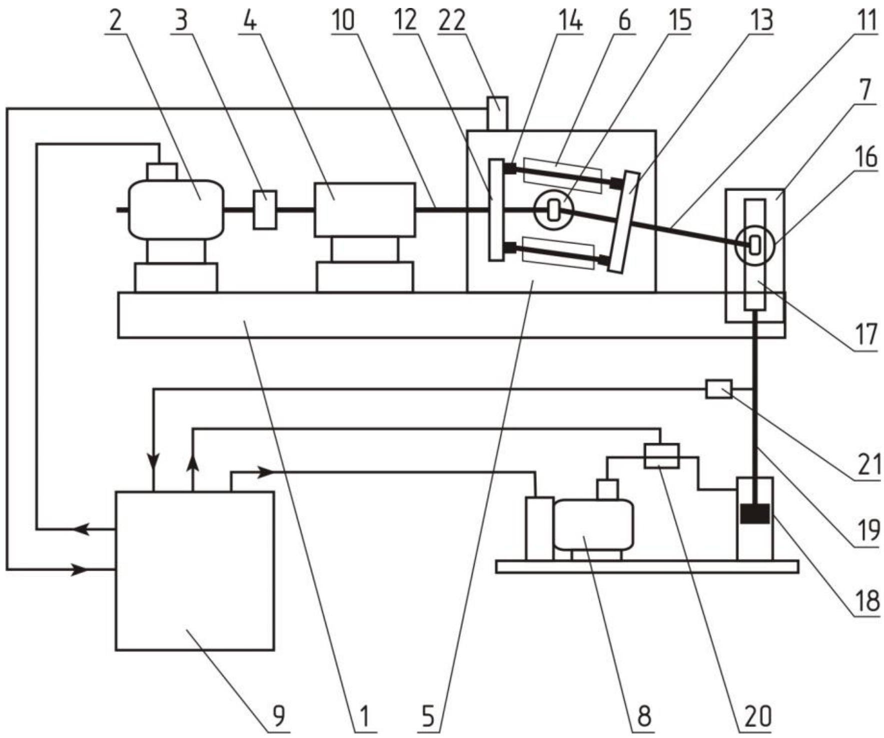


1 – motor shaft; 2 – control panel; 3 – screw; 4 – powder brake; 5 – manometer; 6 – bypass crane; 7 – the inlet crane; 8 – sleeve-roller chain; 9 – asterisk; 10 – protective cover

Fig. 1. Scheme of the stand for resource testing of sleeve-roller chains

The influence of storage conditions and protective composition on the wear of the samples of the chains was assessed by the value of the relative elongation by measuring their average pitch.

Methods of research of influence of storage conditions and preservative materials on fatigue strength of sleeve-roller chains. The main task was to obtain the fatigue characteristic of the sleeve-roller chains, which expresses the decrease in the strength of the chains depending on the service technology and the number of cycles of load change. In order to determine the residual life of the sleeve-roller chains after 50 h of resource tests they were disassembled into sections of 7 links and tested for fatigue strength (at N = 6 · 106 cycles) on a reliable and multifunctional stand (Fig. 2) with remote control for dynamic fatigue strength tests of multi-link and elastically deformed products, including at combined cyclic tensile, bending and torsional loads.



1 – base; 2 – electric motor; 3 – coupling; 4 – bearing support; 5 – protective screen; 6 – tested products; 7 – device for adjusting tensile forces; 8 – compressor; 9 – control unit; 10, 11 – shaft; 12, 13 – flange; 14 – fastening; 15, 16 – hinge of rotation; 17 – support slider; 18 – pneumatic cylinder; 19 – stock; 20 – solenoid valve; 21, 22 – contact sensors

Fig. 2. Scheme of the stand for dynamic tests for fatigue strength of multi-link and elastically deformed products

The stand is designed to work like this. When the stand is turned off, open the protective screen 5, which covers the mechanism of cyclic stretching, and fix it in the product 6 in the form of four segments of 5-7 links of drive single-row roller chains type PR with a range of 12.7-25.4 mm Next, include the compressor 8 and the pneumatic cylinder 18 supply air at an initial pressure of 0.05 MPa, include the motor 2, the speed of which is regulated from the control panel in the range of 1500...2500 min^{-1}, increase the air pressure in the pneumatic cylinder 18 to 0.19–0.4 MPa. Test time – 50…70 hours.

The method of studying the process of wear of the sleeve-roller chains of combine harvesters in operation provided for the study of the dynamics of the wear of drive chains depending on the method of maintenance during their intended use and storage without removal from combine harvesters. The bushing-roller chain from the drive shaft to the lower shaft of the reel variator (81 links) of the combine was convenient for research in the operating conditions. Measurements of chain wear were performed as often as possible, during daily maintenance, during forced downtime of combines due to breakage, wet bread mass, etc.

The analysis of the factors influencing the process of wear of bushing-roller chains and the requirements for the mathematical description of this process showed that the deviation of the state parameter depending on the operating time should be approximated by a random ordered function with increasing realizations and its indicators:

$$u(t) = b + v \cdot t^{a}, \quad (1)$$

where b – the rate of sub-chain; v – the rate of wear of the chain; a – indicator of the degree of function; t – operating time.

As a criterion for optimizing the dynamics of chain elongation used a universal economic criterion - the minimum unit cost per unit of machine operation. In the process of determining it, we found the optimal values of the deviations of the state parameters allowed using the TurboNec program:

$$G = \min_{0 \le D_0 \le 1} \left[\frac{A \cdot Q(D_0)}{T_0(D_0)} + \frac{C \cdot (1 - Q(D_0))}{T_0(D_0)} \right], \quad (2)$$

where $Q(D_0)$ – failure probability, $T_0(D_0)$ – average actual resource of the circuit; A – the average cost of eliminating the consequences of failure; C – the average cost of individual preventive diagnosis.

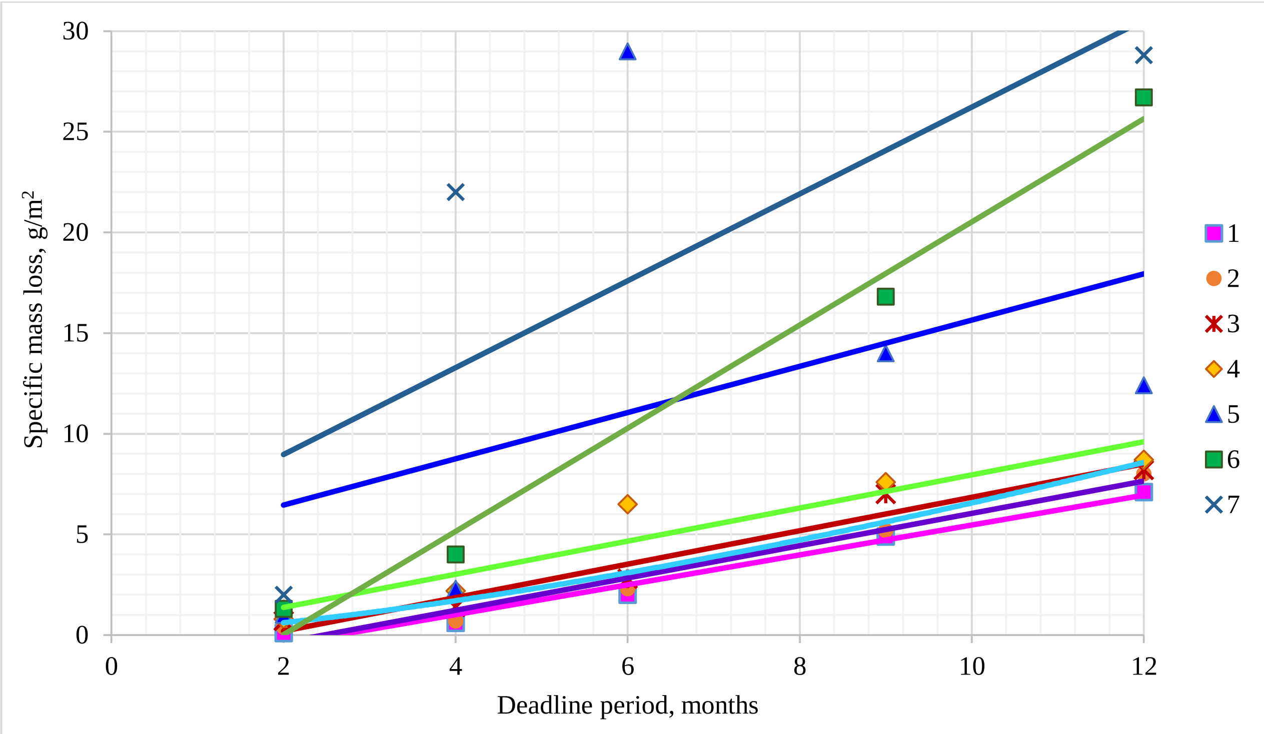
The article defines the criteria for choosing rational ways of servicing bushing and roller chains during storage and using them for their intended purpose.

Accounting for maintenance costs was performed according to two criteria:

1. according to the minimum value of the sum of the given expenses at storage, $\sum C_{Si} \to$ min, UAH;
2. at the minimum cost during the maintenance of chains when using them for their intended purpose, at $C_{Ei} \to$ min, UAH.

Thus, the most rational way to maintain the chain will be the use of conservation material and the technology in which costs will be minimal while minimizing costs during storage and during the use of chains for their intended purpose.

Figure 3 shows a graph of corrosion resistance of samples of steel grade 3, coated with preservatives. Analysis of the test results shows that the best protection of the samples provides the composition of Mayakor, because the value of corrosion losses is 6.8 g/m^2, which is 10% lower than in the compositions Rosoil-700 and NG-222A, whose corrosion resistance is 22 times higher compared to control samples without protection. Warehouses Rosoil-710, ARVK + (I-20 + AKOR-1 (10%)), Rosoil-710 + ARVK also have high protective properties. Depending on the composition, the corrosion resistance of the samples increases by 60…90% against the control samples.



1 – Mayakor; 2 – NG-222A; 3 – Rosoil-700; 4 – Rosoil-700 + ARVK; 5 – Rosoil-710; 6 – ARVC + (I-20 + ACOR-1); 7 – Control samples (without protection)

Fig. 3. Corrosion resistance of steel samples Steel 3 in an open atmosphere

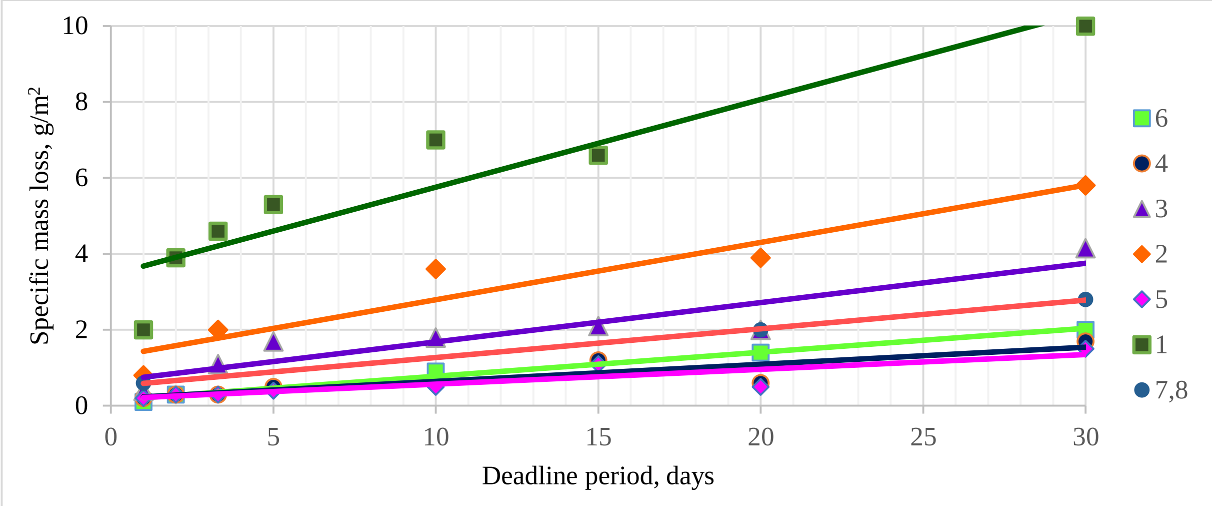
Of particular interest are studies of the corrosion resistance of preservative compositions containing nanopowder based on aluminum hydroxide (*AlOOH* - boehmite). According to the results of previous tests, the most effective conservation materials were selected for this purpose: Mayakor and Rosoil-700. The test results show (Fig. 4) that boehmite increases corrosion resistance by 25...85%.

The explanation for the increase in anticorrosive properties of preservatives with the addition of boehmite is its sorbent properties. The content of 1% *AlOOH* in the preservative material significantly increases the corrosion resistance, which indicates that chemical adsorption processes are taking place. Boehmite absorption of water from the environment, accompanied by the formation of chemical compounds $\mathrm{AlOOH} + H_2O \to \mathrm{Al(OH)_3}$ - Hydrogel.

Chemisorption processes are accompanied by the formation of a bond between the adsorbent molecules and the adsorbate. In this case, chemisorption takes place with the formation of *Al (OH)₃*, this is one of its qualities, which ensures the manufacturability of materials of this type. In a narrower sense, this process can be considered as the chemical absorption of water by the developed surface of the preservative material due to *AlOOH*, ie as chemical adsorption.

The experimental curves are described by the power function $u(t)=v \cdot t^{\alpha}$. Approximation and smoothing are made by means of Excel by the method of least squares, the value of reliability of approximation (R^2) varies within 0,734...0,997 that speaks about high accuracy of the received results.

The curves constructed in the MathCad 13.0 software environment are described by the function $u(t) = b + v \cdot t^{\mathrm{a}}$, the standard deviation $\sigma = 0{,}047\ldots0{,}247$ mm.



1 – Rosoil-700; 2 – Mayakor; 3 – Mayakor + 1% AlOOH; 4 – Mayakor + 3% AlOOH; 5 – Mayakor + 5% AlOOH; 6 – Rosoil-700 + 1% AlOOH; 7 – Rosoil-700 + 3% AlOOH; 8 – Rosoil-700 + 5% AlOOH

Fig. 4. Corrosion resistance of steel samples Steel 3 in the chamber H-4

The testing samples of sleeve-roller chains for fatigue strength (Fig. 4) after the period of off-season storage in the open atmosphere and after resource tests on the stand, straight lines were obtained, which clearly show the decrease in chain strength from the number of load change cycles and the applied conservation composition.

Conclusions

1. For the first time the results of corrosion resistance of steel samples of Steel 3, covered with preservative materials with a content of 1…5% of nanostructured aluminum hydroxide (*AlOOH* - boehmite). It is established that the corrosion losses of the samples are reduced by 25...85%.

2. Comparative tests of chains showed that the best lubricating properties have preservatives NG-222A optimal optimum value of elongation of samples of chains is 6,044, 6,468 mm, respectively, which is 17...25% higher than the optimum allowable value of chain elongation.

3. It is established that the presence of nanocrystalline aluminum hydroxide (*AlOOH* - boehmite) in conservation materials reduces the wear of chain samples by 1.8…2.2 times. The peculiarity of this process is explained by the fact that in the initial period of the boehmite chain exhibits plastic properties similar to graphite, but with increasing temperature in the friction node, boehmite sintering occurs, which turns into corundum with a more stable crystal lattice.

Corundum grinds the surface at the time of loading and heating. It is a solid porous material that helps to retain oil, which explains the increase in wear-resistant properties of preservatives.

4. The regularities of the process of wear of sleeve-roller chains in the conditions of operation are established and it is proved that the service life of chains with the use of preservative materials has increased by 50… 60%. With the help of the mathematical software package MathCAD 13.0 the function of the wear process $u(t)=b+v\cdot t^a$ and the indicators of running-in (b), wear rate (v) and degree of function (a) are determined.

Список літератури

1. *Sergejeva N., Aboltins A., Strupule L., Aboltina B.* Mathematical knowledge in elementary school and for future engineers. Proceedings of 17th International Scientific Conference "Engineering for rural development". Jelgava, Latvia, May 23-25, 2018, Latvia University of Agriculture. Faculty of Engineering. Vol. 17. P. 1166-1172.
2. *Dubbini M., Pezzuolo A., De Giglio M., Gattelli M., Curzio L., Covi D., Yezekyan T., Marinello F.* Last generation instrument for agriculture multispectral data collection. CIGR Journal. 2017. Vol. 19. P. 158-163.
3. *Yata V.K., Tiwari B.C., Ahmad, I.* Nanoscience in food and agriculture: research, industries and patents. Environmental Chemistry Letters. 2018. Vol. 16. P. 79-84.
4. *Masek J., Novak P., Jasinskas A.* Evaluation of combine harvester operation costs in different working conditions. Proceedings of 16th International Scientific Conference "Engineering for rural development". Jelgava, Latvia, May 24-26, 2017, Latvia University of Agriculture. Faculty of Engineering. Vol. 16. P. 1180-1185.
5. *Viba J., Lavendelis E.* Algorithm of synthesis of strongly non-linear mechanical systems. In Industrial Engineering – Innovation as Competitive Edge for SME, 22 April 2006. Tallinn, Estonia. P. 95-98.
6. *Luo A.C.J., Guo Y.* Vibro-impact Dynamics. Berlin: Springer-Verlag, 2013. 213 p.
7. *Astashev V., Krupenin V.* Efficiency of vibration machines. Proceedings of 16th International Scientific Conference "Engineering for rural development". Jelgava, Latvia, May 24-26, 2017, Latvia University of Agriculture. Faculty of Engineering. Vol. 16. P. 108-113.
8. *Zagurskiy O., Ohiienko M., Rogach S., Pokusa T., Titova L., Rogovskii I.* Global supply chain in context of new model of economic growth. Conceptual bases and trends for development of social-economic processes. Monograph. Opole. Poland, 2018. P. 64-74.
9. *Drga R., Janacova D., Charvatova H.* Simulation of the PIR detector active function. Proceedings of 20th International conference on Circuits, Systems, Communications and Computers (CSCC 2016), July 14-

17, 2016, E D P Sciences, 17 Ave Du Hoggar Parc D Activites Coutaboeuf Bp 112, F-91944 Cedex A, France, Vol. 76. UNSP 04036.

10. *Novotny J.* Technical and natural sciences teaching at engineering faculty of FPTM UJEP. Proceedings of 15th International Scientific Conference "Engineering for rural development". Jelgava, Latvia, May 23-25, 2016, Latvia University of Agriculture. Faculty of Engineering. Vol. 15. P. 16-20.

11. *Pinzi S., Cubero-Atienza A. J., Dorado M. P.* Vibro-acoustic analysis procedures for the evaluation of the sound insulation characteristics of agricultural machinery. Journal of Sound and Vibration. 2016. Vol. 266. Issue 3. P. 407-441.

12. *Rogovskii I., Titova L., Novitskii A., Rebenko V.* Research of vibroacoustic diagnostics of fuel system of engines of combine harvesters. Engineering for Rural Development. 2019. Vol. 18. P. 291-298.

13. *Роговський І. Л.* Модель стохастичного процесу відновлення працездатності сільськогосподарської машини в безінерційних системах із запізненням. Machinery & Energetics. Journal of Rural Production Research. Kyiv. Ukraine. 2020. Vol. 11. No 3. P. 143–150.

14. *Тітова Л. Л.* Моделювання перехідних процесів динамічної моделі силової енергетичної установки машин для лісотехнічних робіт. Machinery & Energetics. Journal of Rural Production Research. Kyiv. Ukraine. 2021. Vol. 12. No 1. P. 147-154.

15. *Nazarenko I., Mishchuk Y., Mishchuk D., Ruchynskyi M., Rogovskii I., Mikhailova L., Titova L., Berezovyi M., Shatrov R.* Determiantion of energy characteristics of material destruction in the crushing chamber of the vibration crusher. Eastern-European Journal of Enterprise Technologies. 2021. Vol. 4(7(112). P. 41–49. https://doi.org/10.15587/1729-4061.2021. 239292.

16. *Rogovskii I. L., Titova L. L., Gumenyuk Yu. O., Nadtochiy O. V.* Technological effectiveness of formation of planting furrow by working body of passive type of orchard planting machine. IOP Conference Series: Earth and Environmental Science. 2021. Vol. 839. P. 052055. https://doi.org/10.1088/1755-1315/839/5/052055.

17. *Palamarchuk Igor, Rogogvskii Ivan, Titova Liudmyla, Omelyanov Oleg*. Experimental evaluation of energy parameters of volumetric vibroseparation of bulk feed from grain. Engineering for Rural Development. 2021. Vol. 20. P. 1761-1767. https://doi.org/10.22616/ERDev.2021. 20.TF386.

18. *Rogovskii I. L., Titova L. L., Solomka O. V.* Research of sliding bearings with reverse friction pair and inlaid liners made of thermoplastic composite materials. Journal of Physics: Conference Series. 2021. Vol. 1889. P. 042010. https://doi.org/10.1088/1742-6596/1889/4/04 2010.

19. *Rogovskii I. L., Titova L. L.* Design of landing of assembly machine building units with circulating load rolling bearing rings. Journal of Physics: Conference Series. 2021. Vol. 1889. P. 042004. https://doi.org/10.1088/1742-6596/1889/4/042004.

20. *Rogovskii I. L., Titova L. L., Berezova L. V.* Conceptual bases of system technology of designing of logistic schemes of harvesting and transportation of grain crops. IOP Conference Series: Earth and Environmental Science. 2021. Vol. 723. P. 032032. https://doi.org/10.1088/1755-1315/723/3/032032.

21. *Rogovskii I. L., Titova L. L., Ohiienko M. M.* Research of garden sprayer machines of near-stem and inter-stem strips of orchards. IOP Conference Series: Earth and Environmental Science. 2021. Vol. 723. P. 022035. https://doi.org/10.1088/1755-1315/723/2/022035.

22. *Rogovskii I. L., Titova L. L., Sivak I. M.* Research of machines for mulching near-trunk strips in perennial fruit plantations. IOP Conference Series: Earth and Environmental Science. 2021. Vol. 723. P. 042041. https://doi.org/10.1088/1755-1315/723/4/042041.

23. *Rogovskii I. L., Titova L. L.* Change of technical condition and productivity of grain harvesters depending on term of operation. IOP Conference Series: Earth and Environmental Science. 2021. Vol. 720. P. 012110. https://doi.org/10.1088/1755-1315/720/1/012110.

24. *Rogovskii I. L., Titova L. L.* Modeling of normativity of criteria of technical level of forage harvesters combines. IOP Conference Series: Earth and Environmental Science. 2021. Vol. 720. P. 012109. https://doi.org/10.1088/1755-1315/720/1/012109.

25. *Rogovskii I. L., Titova L. L.* Modeling the weight of criteria for determining the technical level of agricultural machines. IOP Conference Series: Earth and Environmental Science. 2021. Vol. 677. P. 022100. https://doi.org/10.1088/1755-1315/677/2/022100.

26. *Kuzmich I. M., Rogovskii I. L., Titova L. L., Nadtochiy O. V.* Research of passage capacity of combine harvesters depending on agrobiological state of bread mass. IOP Conference Series: Earth and Environmental Science. 2021. Vol. 677. P. 052002. https://doi.org/ 10.1088/ 1755-1315/677/5/052002.

References

1. *Sergejeva N., Aboltins A., Strupule L., Aboltina B.* (2018). Mathematical knowledge in elementary school and for future engineers. Proceedings of 17th International Scientific Conference "Engineering for rural development". Jelgava, Latvia, May 23-25, 2018, Latvia University of Agriculture. Faculty of Engineering. 17. 1166-1172.

2. *Dubbini M., Pezzuolo A., De Giglio M., Gattelli M., Curzio L., Covi D., Yezekyan T., Marinello F.* (2017). Last generation instrument for agriculture multispectral data collection. CIGR Journal. 19. 158-163.

3. *Yata V.K., Tiwari B.C., Ahmad, I.* (2018). Nanoscience in food and agriculture: research, industries and patents. Environmental Chemistry Letters. 16. 79-84.

4. *Masek J., Novak P., Jasinskas A.* (2017). Evaluation of combine harvester operation costs in different working conditions. Proceedings of 16th International Scientific Conference "Engineering for rural development". Jelgava, Latvia, May 24-26, Latvia University of Agriculture. Faculty of Engineering. 16. 1180-1185.

5. *Viba J., Lavendelis E.* (2006). Algorithm of synthesis of strongly non-linear mechanical systems. In Industrial Engineering – Innovation as Competitive Edge for SME, 22 April 2006. Tallinn, Estonia. 95-98.

6. *Luo A.C.J., Guo Y.* (2013). Vibro-impact Dynamics. Berlin: Springer-Verlag. 213.

7. *Astashev V., Krupenin V.* (2017). Efficiency of vibration machines. Proceedings of 16th International Scientific Conference "Engineering for rural development". Jelgava, Latvia, May 24-26, Latvia University of Agriculture. Faculty of Engineering. 16. 108-113.

8. *Zagurskiy O., Ohiienko M., Rogach S., Pokusa T., Titova L., Rogovskii I.* (2018). Global supply chain in context of new model of economic growth. Conceptual bases and trends for development of social-economic processes. Monograph. Opole. Poland, 64-74.

9. *Drga R., Janacova D., Charvatova H.* (2016). Simulation of the PIR detector active function. Proceedings of 20th International conference on Circuits, Systems, Communications and Computers (CSCC 2016), July 14-17, 2016, E D P Sciences, 17 Ave Du Hoggar Parc D Activites Coutaboeuf Bp 112, F-91944 Cedex A, France, 76, UNSP 04036.

10. *Novotny J.* (2016). Technical and natural sciences teaching at engineering faculty of FPTM UJEP. Proceedings of 15th International Scientific Conference "Engineering for rural development". Jelgava, Latvia, May 23-25, Latvia University of Agriculture. Faculty of Engineering. 15. 16-20.

11. *Pinzi S., Cubero-Atienza A.J., Dorado M.P.* (2016). Vibro-acoustic analysis procedures for the evaluation of the sound insulation characteristics of agricultural machinery. Journal of Sound and Vibration, 266 (3). 407-441.

12. *Rogovskii I., Titova L., Novitskii A., Rebenko V.* (2019). Research of vibroacoustic diagnostics of fuel system of engines of combine harvesters. Engineering for Rural Development. 18. 291-298.

13. *Rogovskii I. L.* (2020). Model of stochastic process of restoration of working capacity of agricultural machine in inertial systems with delay. Machinery & Energetics. Journal of Rural Production Research. Kyiv. Ukraine. 11(3). 143–150.

14. *Titova L. L.* (2021). Simulation of transitional processes of dynamic model of power energy installation of machines for forestry works. Machinery & Energetics. Journal of Rural Production Research. Kyiv. Ukraine. 2021. Vol. 12. No 1. P. 147-154.

15. *Nazarenko I., Mishchuk Y., Mishchuk D., Ruchynskyi M., Rogovskii I., Mikhailova L., Titova L., Berezovyi M., Shatrov R.* (2021). Determiantion of energy characteristics of material destruction in the crushing chamber of the vibration crusher. Eastern-European Journal of Enterprise Technologies. 4(7(112). 41–49. https://doi.org/10.15587/1729-4061.2021. 239292.

16. *Rogovskii I. L., Titova L. L., Gumenyuk Yu. O., Nadtochiy O. V.* (2021). Technological effectiveness of formation of planting furrow by working body of passive type of orchard planting machine. IOP Conference Series: Earth and Environmental Science. 839. 052055. https://doi.org/10.1088/1755-1315/839/5/052055.

17. *Palamarchuk Igor, Rogogvskii Ivan, Titova Liudmyla, Omelyanov Oleg*. (2021). Experimental evaluation of energy parameters of volumetric vibroseparation of bulk feed from grain. Engineering for Rural Development. 20. 1761-1767. https://doi.org/10.22616/ERDev.2021. 20.TF386.

18. *Rogovskii I. L., Titova L. L., Solomka O. V.* (2021). Research of sliding bearings with reverse friction pair and inlaid liners made of thermoplastic composite materials. Journal of Physics: Conference Series. 1889. 042010. https://doi.org/10.1088/1742-6596/1889/4/04 2010.

19. *Rogovskii I. L., Titova L. L.* (2021). Design of landing of assembly machine building units with circulating load rolling bearing rings. Journal of Physics: Conference Series. 1889. 042004. https://doi.org/10.1088/1742-6596/1889/4/042004.

20. *Rogovskii I. L., Titova L. L., Berezova L. V.* (2021). Conceptual bases of system technology of designing of logistic schemes of harvesting and transportation of grain crops. IOP Conference Series: Earth and Environmental Science. 723. 032032. https://doi.org/10.1088/1755-1315/723/3/032032.

21. *Rogovskii I. L., Titova L. L., Ohiienko M. M.* (2021). Research of garden sprayer machines of near-stem and inter-stem strips of orchards. IOP Conference Series: Earth and Environmental Science. 723. 022035. https://doi.org/10.1088/1755-1315/723/2/022035.

22. *Rogovskii I. L., Titova L. L., Sivak I. M.* (2021). Research of machines for mulching near-trunk strips in perennial fruit plantations. IOP Conference Series: Earth and Environmental Science. 723. 042041. https://doi.org/ 10.1088/1755-1315/723/4/042041.

23. *Rogovskii I. L., Titova L. L.* (2021). Change of technical condition and productivity of grain harvesters depending on term of operation. IOP Conference Series: Earth and Environmental Science. 720. 012110. https://doi.org/10.1088/1755-1315/720/1/012110.

24. *Rogovskii I. L., Titova L. L.* (2021). Modeling of normativity of criteria of technical level of forage harvesters combines. IOP Conference Series: Earth and Environmental Science. 720. 012109. https://doi.org/ 10.1088/1755-1315/720/1/012109.

25. *Rogovskii I. L., Titova L. L.* (2021). Modeling the weight of criteria for determining the technical level of agricultural machines. IOP Conference Series: Earth and Environmental Science. 677. 022100. https://doi.org/ 10.1088/1755-1315/677/2/022100.

26. *Kuzmich I. M., Rogovskii I. L., Titova L. L., Nadtochiy O. V.* (2021). Research of passage capacity of combine harvesters depending on agrobiological state of bread mass. IOP Conference Series: Earth and Environmental Science. 677. 052002 https://doi.org/ 10.1088/ 1755-1315/677/5/052002.

ТЕХНОЛОГІЧНІСТЬ ОБСЛУГОВУВАННЯ СИСТЕМ ЗЕРНОЗБИРАЛЬНИХ КОМБАЙНІВ ПРИ ЗБЕРІГАННІ

І. М. Кузьмич

Анотація. Вирішення загальнолюдських, глобальних проблем енерго- та ресурсозбереження як у машинобудуванні, так і в агропромисловому комплексі нерозривно пов'язані з вирішенням питань захисту техніки від корозії.

Сучасна сільськогосподарська техніка, і самохідні зернозбиральні комбайни зокрема, експлуатуються

періодично протягом одного або двох сезонів на рік. Більшість зернозбиральних комбайнів зберігається на відкритих майданчиках підприємств агропромислового комплексу, при цьому вона піддається агресивному впливу довкілля (коливанням температури, вологості, впливу вітру, сонячної радіації, пилу та інших). Основним видом впливу зовнішнього середовища на техніку є атмосферна корозія та викликане нею корозійне зношування матеріалів, деталей та вузлів, що призводить до її передчасних відмов. Так втомна міцність виробів із сталі при зберіганні протягом 12 місяців на відкритому майданчику знижується на 28–58%.

Для забезпечення тимчасового протикорозійного захисту зернозбиральних комбайнів застосовується велика кількість консерваційних та робітничо-консерваційних мастил. Однак невирішеність низки питань теоретичного та практичного характеру призводить до необґрунтованого застосування захисних засобів, які або не забезпечують необхідну тривалість зберігання техніки, або збільшують витрати на її консервацію. Стандартизовані методи випробувань антикорозійних мастильних матеріалів в переважній кількості мають велику кількість недоліків, найголовнішим з яких є те, що оцінка захисних властивостей проводиться в одиницях, які не дозволяють оцінити термін їхньої дії, а лише показують величину корозії металу.

Ключові слова: антикорозійність, мастильні матеріали, збереженість, ефективність, комбайн.

ТЕХНОЛОГИЧНОСТЬ ОБСЛУЖИВАНИЯ СИСТЕМ ЗЕРНОСБОРНЫХ КОМБАЙНОВ ПРИ ХРАНЕНИИ

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Аннотация. Решение общечеловеческих, глобальных проблем энерго- и ресурсосбережения как в машиностроении, так и в агропромышленном комплексе неразрывно связано с решением защиты техники от коррозии.

Современная сельскохозяйственная техника и самоходные зерноуборочные комбайны в частности, эксплуатируются периодически в течение одного или двух сезонов в год. Большинство зерноуборочных комбайнов хранится на открытых площадках предприятий агропромышленного комплекса, к тому же она подвергается агрессивному воздействию окружающей среды (колебаниям температуры, влажности, воздействию ветра, солнечной радиации, пыли и др.). Основным видом воздействия внешней среды на технику является атмосферная коррозия и вызванный ею коррозионный износ материалов, деталей и узлов, что приводит к ее преждевременным отказам. Так усталостная крепость изделий из стали при хранении в течение 12 месяцев на открытой площадке снижается на 28–58%.

Для обеспечения временной противокоррозионной защиты зерноуборочных комбайнов используется большое количество консервационных и рабоче-консервационных масел. Однако нерешенность ряда вопросов теоретического и практического характера приводит к необоснованному применению защитных средств, которые либо не обеспечивают необходимую длительность хранения техники, либо увеличивают расходы на ее консервацию. Стандартизированные методы испытаний антикоррозионных смазочных материалов в подавляющем количестве имеют большое количество недостатков, главным из которых является то, что оценка защитных свойств производится в единицах, не позволяющих оценить срок их действия, а лишь показывающих величину коррозии металла.

Ключевые слова: антикоррозионность, смазочные материалы, сохранность, эффективность, комбайн.

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