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Dependence of the quality indicators of transient processes in the hydraulic drive for rotation of the garbage truck manipulator arm on the wear of friction pairs

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Abstract

This article is dedicated to determining the analytical relationships between the quality indicators of transient processes in the hydraulic drive of the manipulator arm rotation mechanism of a garbage truck, taking into account the wear of friction pairs, which can be used to develop an improved method for the design calculation of the parameters of the manipulator arm rotation mechanism during the loading of municipal solid waste. The drive for the working components of the garbage truck manipulator arm rotation mechanism is hydraulic, powered by the garbage truck's pump station. During the operation of this drive, transient processes inevitably occur, associated with the operation of the control unit, the activation of the positive-displacement hydraulic pump, changes in the load on the actuator, and so on. Graphical dependencies of the quality indicators of transient processes in the hydraulic cylinder of the garbage truck manipulator arm rotation mechanism on the wear of friction pairs were plotted based on initial data corresponding to the parameters of a real production model of the KO 436 garbage truck manufactured by Turbivskyi Machine-Building Plant LLC (Ukraine). These results showed that accounting for friction pair wear significantly affects the quality indicators of transient processes in the hydraulic drive of the garbage truck manipulator arm rotation mechanism. It was established that an increase in the wear of the friction pairs in the garbage truck manipulator arm rotation mechanism leads to a decrease in the quality indicators of the transient processes of its hydraulic drive.

Keywords: transient processes, quality indicators, consideration of wear, hydraulic drive, wear, friction components, arm rotation mechanism, manipulator, garbage truck, municipal solid waste.

Introduction

One of the key directions in the development of modern municipal machinery in Ukraine is the improvement of mobile manipulator-type machines, which include garbage trucks [1]. Within this field, particular attention is paid to improving the wear resistance, reliability, and durability of the design elements of these machines, as these operational characteristics significantly influence their performance. Improving these indicators makes it possible to reduce costs associated with repairs and maintenance, increase the serviceability of the machines, and ensure a longer service life under conditions of long-term and intensive operation [2, 3]. In Ukraine, the majority of work involved in collecting and transporting municipal solid waste (MSW) to sites for further processing, recycling, or disposal is carried out using body-type garbage trucks [4, 5]. An integral part of the design of these specialized vehicles is the loading mechanisms [6–8], which enable the mechanized performance of operational tasks such as gripping, lifting, and tilting waste containers to empty them into the garbage truck's body. The vast majority of such devices are implemented as manipulator mechanisms of various designs [9–13], which are operated by a hydraulic drive [14–16]; during operation, transient processes inevitably occur at startup [17] associated with the activation of a positive-displacement hydraulic pump, the operation of the control mechanism, changes in the load on the actuator, and so on. Currently, there are approximately 3,700 garbage trucks in operation in Ukraine, which, in addition to transporting municipal solid waste, mechanically compact it directly in the truck body. Implementing this process makes it possible to significantly increase the mass of waste transported per trip, reduce the number of transport cycles, and, consequently, lower transportation costs. In addition, compacting MSW contributes to a more efficient use of landfill capacity by reducing the area required for disposal, which provides a significant economic benefit while also positively impacting the environment through a more rational use of land resources. During the process of loading municipal solid waste into the body of a garbage truck, the friction components of the manipulator mechanism—primarily its hinged joints and hydraulic cylinders—are subjected to the highest mechanical loads. The rate of wear on these components is determined by the combined effect of operational factors. The main factors include the significant weight of waste containers, which in some cases can reach 500 kg; the operation of the mechanism under conditions of frequent reversing loads with repetitive reverse-rotational movements of the links; and the performance of a large number of work cycles during a single transport trip. The combined effect of these factors leads to accelerated wear, deterioration of the technical condition of the manipulator's components, increased clearances in the couplings, and, as a result, reduced reliability and operational efficiency of the garbage truck's loading equipment. Operating conditions for the manipulator mechanism are further complicated by the influence of unfavorable environmental factors, including significant fluctuations in temperature and relative humidity, as well as high dust levels in the work area. The combined effect of these factors accelerates the wear of friction assemblies and the mechanism's working parts, leading to a deterioration in their technical condition, a decrease in operational reliability, and a reduction in the service life of garbage trucks. In addition, the deterioration of the tribological properties of the materials used in the parts, as well as insufficient lubrication, cause an increase in friction forces in the hinged joints of the manipulator mechanism. The rapid progression of wear processes in the friction assemblies of the manipulator mechanism not only leads to a deterioration in its technical and operational characteristics but also significantly affects the overall operational safety of the garbage truck. Increased clearances in mating surfaces, increased internal leakage in the hydraulic drive, and higher levels of vibration and dynamic loads can disrupt normal equipment operation, cause individual components to fail, or lead to emergency situations. In accordance with the provisions of Resolution No. 265 of the Cabinet of Ministers of Ukraine [18], one of the priority tasks for the development of the housing and utilities sector is the introduction of modern, high-performance garbage trucks, which serve as the basic technical equipment for the mechanized collection, transportation, and initial compaction of municipal solid waste. Equipping municipal utilities with modern specialized equipment ensures greater efficiency in carrying out technological processes, optimization of transportation and logistics operations, a reduction in operating costs, and a more rational use of material and energy resources. Planning the modernization, maintenance, and repair of garbage trucks is facilitated by identifying analytical dependencies of the quality indicators of the transient processes in the hydraulic drive of the garbage truck's manipulator-arm rotation mechanism, taking into account the wear of friction pairs, which can be used to develop an improved methodology for the design calculation of the parameters of the manipulator arm rotation mechanism during the loading of municipal solid waste.

Analysis of recent research and publications

The scientific article [19] presents an algorithm for determining the key quality indicators of transient processes to optimize the components of a system and improve control quality. The key quality indicators of transient processes that were considered include: relative overshoot, the number of overshoots, and the settle duration. For high-quality transient processes, relative overshoot should not exceed 30%, and the number of overshoots during the settling time period should not exceed 2–3 [20].

The results of the structural analysis of garbage truck components subject to intense wear are presented in the scientific paper [21]. In the study [22], a design for a robotic manipulator was proposed, along with its three-dimensional geometric model in SOLIDWORKS, and a motion analysis was also performed. During the structural optimization of the design, a detailed analysis of the manipulator's key parameters was carried out; in particular, the stresses and strains of its components were evaluated, and the objective functions and system of constraints necessary for improving the design were formed. This approach helps reduce the probability of failures in the manipulator mechanism under conditions of prolonged operation under high loads and ensures more efficient interaction of its components with other systems of the garbage truck, which ultimately increases the productivity of MSW collection and transportation processes.

In the paper [23], the effect of an increase in radial clearance due to wear on the quality characteristics of a servo valve's transient processes was investigated using MATLAB/Simulink. The following changes were analyzed: overshoot, settling time, damping, and dynamic accuracy. It was found that an increase in the servo valve's flow rate as the clearance increases due to wear leads to a reduction in overshoot and a shorter settling time. An analysis of the correlation between wear progression and performance degradation will enable the formulation of maintenance strategies and proposals for design improvements, thereby ensuring the durability and operational efficiency of servo valves.

The authors of [24] proposed a mathematical model for determining the optimal geometric parameters of the manipulator's structural elements, taking into account the maximum boom reach, load capacity, and other kinematic characteristics of the machine. Particular attention is paid to hinged joints operating in a cyclic mode, which is characteristic of manipulator-type machines. It has been established that under such conditions, the hydrodynamic friction mode is practically nonexistent, and the friction process occurs predominantly in the semi-dry or boundary friction modes. In this regard, the properties of the materials, the quality of surface finishing, and the effectiveness of the lubrication system are of decisive importance for ensuring the wear resistance and durability of the hinge assemblies. The operation of sliding bearings under these conditions is accompanied by accelerated wear of the contact surfaces, a decrease in kinematic accuracy, and the occurrence of additional dynamic loads and vibrations. To reduce friction forces, it is recommended to apply special coatings to the contact surfaces (lead, phosphate, or indium-based), use grease, as well as phosphate and anodic coatings, which improve lubricant retention and increase the service life of hinge assemblies.

In the paper [25], the effect of wear on the throttle edges after a certain period of operation on the transient processes of a servo system based on a hydraulic servo-spool valve was experimentally investigated. It was found that the diameter of the hydraulic servo valve opening increases due to erosive wear caused by contamination with solid particles in the oil, which leads to a decrease in the valve's static and dynamic characteristics and a deterioration in performance. A control method with a variable amplification coefficient is proposed to address the problem of erosive wear of the valve opening. After applying variable amplification control, the static and dynamic characteristics of the servo valve closely resemble those of an ideal servo valve, with a maximum deviation between the flow characteristics and the ideal valve orifice of approximately 1%.

In the article [26], a method for optimizing the operation of a robotic cell is proposed, which involves selecting an optimal position for the robotic manipulator within the work area for programs with a specified end-effector motion trajectory. The aim of the study was to reduce the total wear of the manipulator's joints and to balance their loads by preventing excessive mechanical stress on individual joints. Wear was assessed based on an approximation of the integral of the mechanical work of each joint along the motion trajectory, using values of angular velocities and torques. The proposed approach is based on dynamic modeling, which enables the determination of rotational velocities and torques at various positions of the manipulator. The research results show that optimizing the robot's base configuration reduces the total wear of its joints by 22–53%, depending on the motion trajectory configuration.

In the scientific article [27], which investigates the deterioration in the performance of hydraulic servo-spool valves caused by erosive wear of the valve opening, the micromorphological characteristics of the spool's working edge were investigated, the transient process of solid-particle erosion was visualized, and the factors influencing the erosion rate of the working edge were modeled.

The study [28] analyzes the main mechanisms of wear in the hinged joints of forestry manipulators and identifies promising approaches for improving their wear resistance depending on operating conditions. It has been established that the operation of manipulators under significant temperature fluctuations significantly affects the properties of structural materials and lubricants. At low temperatures, the brittleness and stiffness of materials increase, friction conditions deteriorate, and lubricants lose their fluidity or become significantly more viscous, which accelerates wear. At high temperatures, the lubricant thins, is less effectively retained in the friction zone, and fails to provide adequate cooling of the contact surfaces, resulting in increased wear rates. To increase the service life of hinge assemblies, it is recommended to use combined contact-labyrinth seals, which effectively protect them from the ingress of dust, moisture, and other contaminants and ensure that the lubricant is retained in the friction zone.

In the paper [29], the effect of erosive wear of the spool pair on the dynamic characteristics of an electrohydraulic servo valve was investigated. It was found that as wear increases, the following parameters deteriorate: pressure amplification factor, internal leakage, characteristic linearity, and dynamic performance of the control system.

A study [30] justified the feasibility of applying a comprehensive approach to the selection of scientific and technical solutions when designing new hinged joint structures. It is shown that their performance is determined by the combined effect of design features, the properties of the friction pair materials, loading conditions, lubrication modes, and the operating environment. Taking these factors into account makes it possible to create designs with improved reliability, durability, and wear resistance. This comprehensive approach improves both the mechanical and tribological characteristics of hinged joints, optimizes their thermal behavior, and contributes to increased operational efficiency of forestry machines, reduced maintenance costs, and extended service life of manipulator systems.

The paper [31] proposes a method for synthesizing the motion trajectory of a manipulator robot, taking into account its kinematic characteristics and the degrees of freedom of its links. The effect of rod bending on the formation of support reactions and contact loads in the interaction zone between the hydraulic cylinder, the rod, and the ground bushing is examined to assess the distribution of forces and predict the wear rate of friction surfaces. It has been established that, in the absence of a risk of rod failure, contact stresses accounting for about one-third of the material's tensile strength can significantly accelerate wear due to cyclic loading. It has also been shown that the contact pressure and the wear rate depend on the angle of the rod's extension, its velocity, and the manipulator's operating mode.

The paper [32] investigates the design features of the grippers on garbage truck manipulators and evaluates their reliability. Based on the results obtained, a computational model of the garbage truck as an oscillatory system was developed, which made it possible to analyze the vibrations of the frame and the regularities of load distribution in the "gripper–bin–gripper" system. It was found that the highest loads are received by the pull rod and the hydraulic cylinder rod, and their magnitude increases with the increase in the container's mass, whereas the mass of the garbage truck affects only the frequency characteristics of the oscillations. Operational studies have shown that the main causes of garbage truck failures are wear and corrosion of working equipment components, and approximately 32% of hydraulic drive malfunctions are attributable to hydraulic cylinders. Their failures are caused by wear on mating surfaces, deformation of the piston rod and cylinder, uneven loading, and abrasive wear. The spools and housings of hydraulic distributors, as well as the hydraulic cylinder rods, are subject to the most intense wear. The deterioration of technical condition is promoted by hydro-abrasive damage caused by contamination of the working fluid and wear of seals. To restore the performance of the parts, it is recommended to use chrome plating in a cold, self-regulating electrolyte, which ensures the formation of wear-resistant coatings and helps extend the service life of the hydraulic drive components.

In the article [33], an improved nonlinear mathematical model of the hydraulic drive for the mechanism that loads municipal solid waste into a garbage truck during container tipping was developed. Unlike other models, it accounts for the wear of the friction pairs in the main components of the hydraulic drive, which ensures a more accurate representation of real operating conditions. Based on the results of numerical simulations, the dynamic characteristics of the system during the startup phase were investigated, and the effect of wear on its key parameters was evaluated. It was found that increased wear significantly worsens the speed and force characteristics of the hydraulic drive and prolongs the duration of the operational cycle. It was shown that the duration of container tipping increases in a power-law relationship with the degree of wear on the hydraulic cylinder, confirming the nonlinear nature of the effect of wear on the mechanism's performance. The results obtained can be used to predict the operational performance of the hydraulic drive, determine optimal maintenance schedules, and improve the reliability of MSW loading systems.

In the paper [34], an analytical study was conducted of an improved mathematical model of the hydraulic drive for a garbage truck container-tipping mechanism, taking into account wear of the friction pairs. Based on the linearized model, approximate analytical dependencies of the pressure in the hydraulic cylinder's pressure line, the angular velocity, and the container's rotation angle as a function of time were obtained for the first phase of tipping—its rotation to the equilibrium position. A regression equation was also derived, which allows for an approximate determination of the duration of this phase, taking into account the wear of friction pairs. The proposed relationships can be used in the design of new garbage truck configurations and the optimization of hydraulic drive parameters without the need to analyze a full nonlinear mathematical model.

In the paper [35], using a first-order experimental design methodology that accounts for the effects of factor interactions according to the Box-Wilson method, an adequate mathematical dependence was obtained that describes the influence of the properties of anti-friction materials on the wear rate of the friction components in the garbage truck's loading mechanism. In the study [36], using a similar approach, an adequate dependence was established for the variation of maximum dynamic impact stresses in the most heavily loaded section of the garbage truck manipulator's boom, depending on the degree of wear of the hinged joint and the manipulator's load level.

However, during their analysis of the available literature, the authors did not identify any specific analytical dependencies between the quality indicators of the transient processes in the hydraulic drive of the garbage truck's manipulator arm rotation mechanism, taking into account the wear of the friction pairs.

Aims of the article

Determination of analytical dependencies of the quality indicators of transient processes in the hydraulic drive of the manipulator arm rotation mechanism of a garbage truck, taking into account the wear of friction pairs, which can be used to develop an improved method for the design calculation of the parameters of the manipulator arm rotation mechanism during the loading of municipal solid waste.

Methods

The following methods were used in this study: analysis of scientific literature; mathematical modeling of processes in hydraulic drives using the fundamental laws of solid-body mechanics, the theory of hydraulic drives and hydropneumatic automation, and the theory of modeling; synthesis of mathematical interdependencies of the main geometric, force, and velocity parameters of the equipment; a systematic approach to account for the interaction of all the machine's subsystems.

Analytical dependencies of the quality indicators of transient processes in the hydraulic drive of the manipulator-arm rotation mechanism of a garbage truck, without accounting for wear of friction pairs, are determined in [37]:

$$\sigma = \left[\sin\left(\frac{\pi Q_P}{4 l_p^2 S_{C1}^2} \sqrt{\frac{K W_{12} J}{2 \sin \lambda_{av}}} + \frac{\pi}{4} \right) + \frac{Q_P}{2 G R \cos \delta} \sqrt{\frac{J \sin \lambda_{av}}{K W_{12}}} e^{-\frac{\pi \sigma_l}{4 l_p S_{C1}} \sqrt{\frac{J}{2 K W_{12} \sin \lambda_{av}}}} - 1 \right] 100\%; \tag{1}$$

$$N=\frac{l_pS_{C1}}{\pi\sigma_l}\sqrt{\frac{2KW_{12}\sin\lambda_{av}}{J}}\ln\left\langle\left\{1.05-\sin\left[\frac{\pi Q_P}{4l_p^2S_{C1}^2}\times\right.\right.\right.$$
$$\left.\left.\left.\times\sqrt{\frac{KW_{12}J}{2\sin\lambda_{av}}}+\frac{\pi}{4}\right]\right\}\frac{2GR\cos\delta}{Q_P}\sqrt{\frac{KW_{12}}{J\sin\lambda_{av}}}\right\rangle^{-1}+0.75; \tag{2}$$

$$t_{set}=\frac{2KW_{12}}{\sigma_l}\ln\left\langle\left\{1.05-\sin\left[\frac{\pi Q_P}{4l_p^2S_{C1}^2}\sqrt{\frac{KW_{12}J}{2\sin\lambda_{av}}}+\frac{\pi}{4}\right]\right\}\frac{2GR\cos\delta}{Q_P}\sqrt{\frac{KW_{12}}{J\sin\lambda_{av}}}\right\rangle^{-1}, \tag{3}$$

де σ – relative pressure overshoot of the working fluid in the rod-side chamber of the hydraulic cylinder of the arm-rotation mechanism of the waste collection vehicle, %; J – moment of inertia of moving parts, kg·m^2; Q_P – actual flow rate of the hydraulic pump, m^3/s; R – radius of rotation of moving parts, m; G – weight of moving parts, N; S_{C1} – rod-side chamber area of the hydraulic cylinder, m^2; l_p – distance between the centers of rotation of the manipulator arm and the hydraulic cylinder rod, m; λ_{av} – the average angle of inclination of the hydraulic cylinder axis relative to the horizontal,°; δ – angle between the arm axis and the horizontal, °; σ_l – the coefficient of working fluid loss due to flow from a high-pressure region to a low-pressure region m^5/(N·s); K – compressibility coefficient of the working fluid, Pa^{-1}; W_{12} – the volume of the piping between the hydraulic pump and the rod chamber of the hydraulic cylinder, m^3; N – the number of pressure overshoots of the working fluid in the rod-side chamber of the hydraulic cylinder of the arm-rotation mechanism of the waste collection vehicle manipulator during the settling time, times; t_{set} – the settling time of the working fluid pressure in the rod-side chamber of the hydraulic cylinder of the arm-rotation mechanism of the waste collection vehicle, s (Fig. 1).

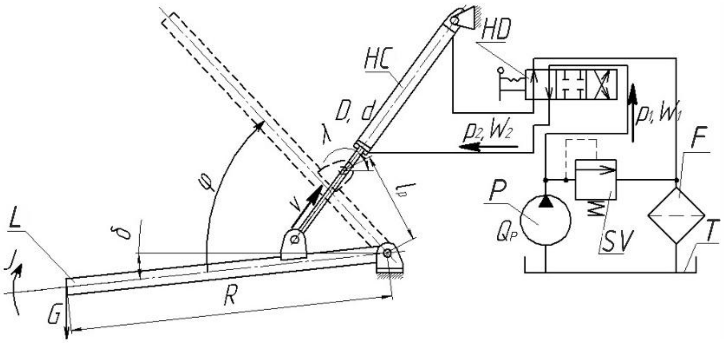

Fig. 1. Schematic diagram of the linearized mathematical model of the hydraulic drive for the manipulator arm rotation mechanism of a garbage truck

Fig. 1 also includes the following designations: HC – hydraulic cylinder, L – lever, HD – hydraulic distributor, SV – safety valve, P – hydraulic pump, T – tank with working fluid, F – filter. The coefficient of working fluid loss due to flow from the high-pressure region to the low-pressure region, taking into account wear caused by friction pairs, can be determined using the formula [34]:

$$\sigma_l=\frac{\pi D\left(\delta_0+u\cdot10^{-6}\right)^3}{12\nu\rho l}\ \text{[m}^5\text{/(N·s)]}, \tag{4}$$

where D – hydraulic cylinder piston diameter, m; δ_0 – nominal clearance, m; u – wear on the manipulator hinge, μm; ν – kinematic viscosity of the working fluid, m^2/s; ρ – density of the working fluid, kg/m^3; l – length of the annular gap, m.

Results

Substituting formula (4) into expressions (1)–(3), we obtain the relationships for the quality indicators of the transient processes in the hydraulic drive of the garbage truck manipulator's arm rotation, taking into account the wear of the friction pairs:

$$\sigma = \left[\sin\left(\frac{\pi Q_P}{4 l_p^2 S_{C1}^2} \sqrt{\frac{KW_{12} J}{2\sin\lambda_{av}}} + \frac{\pi}{4} \right) + \frac{Q_p}{2GR\cos\delta} \sqrt{\frac{J\sin\lambda_{av}}{KW_{12}}} e^{-\frac{\pi^2 D\left(\delta_0 + u\cdot 10^{-6}\right)^3}{48 l_p S_{C1}\nu\rho l}\sqrt{\frac{J}{2KW_{12}\sin\lambda_{av}}}} - 1 \right] 100\%; \quad (5)$$

$$N = \frac{12 l_p S_{C1}\nu\rho l}{\pi^2 D\left(\delta_0 + u\cdot 10^{-6}\right)^3} \sqrt{\frac{2KW_{12}\sin\lambda_{av}}{J}} \ln\left\langle \left\{ 1.05 - \sin\left[\frac{\pi Q_P}{4 l_p^2 S_{C1}^2} \times \right.\right.\right.$$
$$\left.\left.\left. \times \sqrt{\frac{KW_{12} J}{2\sin\lambda_{av}}} + \frac{\pi}{4} \right] \right\} \frac{2GR\cos\delta}{Q_P} \sqrt{\frac{KW_{12}}{J\sin\lambda_{av}}} \right\rangle^{-1} + 0.75; \quad (6)$$

$$t_{set} = \frac{24 KW_{12}\nu\rho l}{\pi D\left(\delta_0 + u\cdot 10^{-6}\right)^3} \ln\left\langle \left\{ 1.05 - \sin\left[\frac{\pi Q_P}{4 l_p^2 S_{C1}^2} \sqrt{\frac{KW_{12} J}{2\sin\lambda_{av}}} + \frac{\pi}{4} \right] \right\} \frac{2GR\cos\delta}{Q_P} \sqrt{\frac{KW_{12}}{J\sin\lambda_{av}}} \right\rangle^{-1}. \quad (7)$$

The proposed analytical dependencies (5)–(7) for the quality indicators of transient processes in the hydraulic drive of the manipulator arm rotation mechanism of a garbage truck, taking into account the wear of friction pairs, can be used to develop an improved method for the design calculation of the parameters of the manipulator arm rotation mechanism during the loading of municipal solid waste, which will significantly reduce design time and avoid unnecessary costs associated with labor-intensive experimental and theoretical studies.

Using expressions (5)–(7), graphical dependencies of the quality indicators of transient processes in the hydraulic cylinder of the garbage truck manipulator's arm rotation mechanism as a function of friction pair wear were obtained, as shown in Figs. 2–4, based on the following initial data, which correspond to the parameters of a real production model of the KO 436 garbage truck manufactured by Turbivskyi Machine-Building Plant LLC (Ukraine): $K = 10^{-9}$ Pa^{-1}; $W_{12} = 1.98\cdot 10^{-3}$ m^3; $S_{C1} = 4.222\cdot 10^{-3}$ m^2; $D = 80$ mm; $Q_P = 55$ l/min; $GR = 4627$ Nm; $\delta = 6°$; $l_p = 450$ mm; $\lambda_{av} = 54°$; $J = 1151$ kg·m^2; $\delta_0 = 0{,}136$ mm; $\nu = 1.83\cdot 10^{-5}$ m^2/s; $\rho = 890$ kg/m^3; $l = 35$ mm.

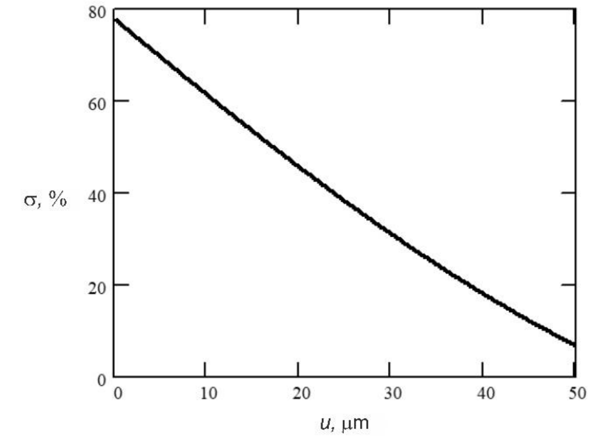

Fig. 2. Dependence of the relative overshoot of the working fluid pressure in the rod chamber of the hydraulic cylinder of the garbage truck manipulator's arm rotation mechanism on the wear of the friction pairs

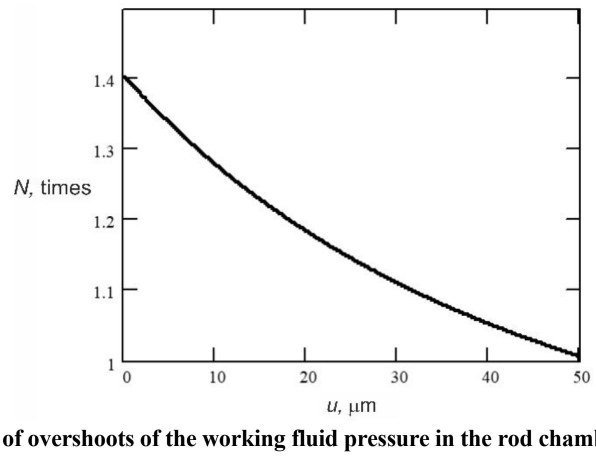

Fig. 3. Change in the number of overshoots of the working fluid pressure in the rod chamber of the hydraulic cylinder of the garbage truck's manipulator arm mechanism during the during the settling time due to wear of the friction pairs

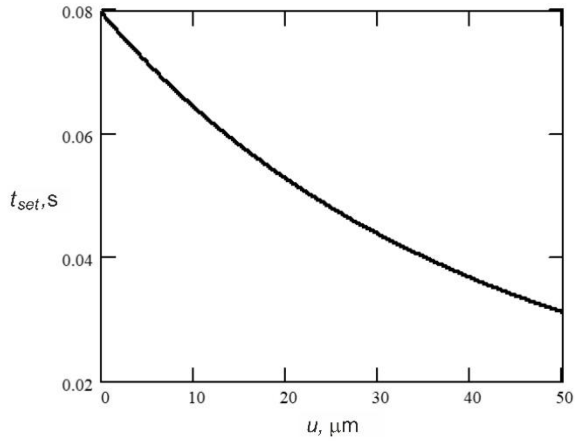

Fig. 4. Dependence of the settling time of the working fluid pressure in the rod chamber of the hydraulic cylinder of the garbage truck manipulator's arm rotation mechanism on the wear of the friction pairs

Figs. 2–4 show that accounting for wear on friction pairs significantly affects the quality indicators of the transient processes in the hydraulic drive of the garbage truck manipulator's arm rotation mechanism. It has been established that an increase in the wear of the friction pairs in the garbage truck manipulator arm rotation mechanism leads to a decrease in the quality indicators of the transient processes of its hydraulic drive.

The development of an improved method for the design calculation of the parameters of the manipulator arm rotation mechanism during the loading of municipal solid waste into a garbage truck, taking into account friction pair wear, requires further research.

Conclusions

Analytical dependencies of the quality indicators for the transient processes of the hydraulic drive of the manipulator arm rotation mechanism on a garbage truck, taking into account the wear of friction pairs, have been proposed. They can be used to develop an improved method for the design calculation of the parameters of the manipulator arm rotation mechanism during the loading of municipal solid waste, which will significantly reduce design time and avoid unnecessary costs associated with labor-intensive experimental and theoretical studies. For a garbage truck with the actual parameters of the KO 436 production model manufactured by Turbivskyi Machine-Building Plant LLC (Ukraine), graphical dependencies of the quality indicators of transient processes in the hydraulic drive of the manipulator arm rotation mechanism were established. The obtained dependencies revealed a significant influence of wear on the quality of transient processes in the hydraulic drive of the garbage truck's manipulator arm rotation mechanism. It was found that the development of an improved method for the design calculation of the parameters of the manipulator arm rotation mechanism for loading municipal solid waste into a garbage truck, taking into account the wear of friction pairs, requires further research.

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Березюк О.В., Харжевський В.О., Ivanov S.Cv., Яворський В.С. Залежність показників якості перехідних процесів гідроприводу повороту важеля маніпулятора сміттєвоза від зносу пар тертя

Стаття присвячена визначенню аналітичних залежностей показників якості перехідних процесів гідроприводу механізму повороту важеля маніпулятора сміттєвоза із урахування зносу пар тертя, які можуть бути використані для розробки удосконаленої методики проєктного розрахунку параметрів механізму повороту важеля маніпулятора під час завантаження твердих побутових відходів. Привод робочих органів механізму повороту важеля маніпулятора сміттєвоза – гідравлічний з живленням від насосної станції сміттєвоза. Під час роботи даного приводу неминуче виникають перехідні процеси, пов'язані з роботою органу управління, включенням гідронасоса об'ємного типу, зміною навантаження виконавчого органу тощо. Побудовано графічні залежності показників якості перехідних процесів в гідроциліндрі механізму повороту важеля маніпулятора сміттєвоза від зносу пар тертя, на основі вихідних даних, що відповідають параметрам реальної серійної моделі сміттєвоза КО-436 виробництва ТОВ "Турбівський машинобудівний завод" (Україна), які показали, що врахування зносу пар тертя суттєво вливає на значення показників якості перехідних процесів гідроприводу механізму повороту важеля маніпулятора сміттєвоза. Встановлено, що збільшення величини зносу пар тертя механізму повороту важеля маніпулятора сміттєвоза призводить до зниження значень показників якості перехідних процесів його гідроприводу. Виявлено, що розробка удосконаленої методики проєктного розрахунку параметрів механізму повороту важеля маніпулятора під час завантаження твердих побутових відходів у сміттєвоз із урахуванням зносу пар тертя вимагає проведення подальших досліджень.

Ключові слова: перехідні процеси, показники якості, урахування зносу, гідропривод, знос, вузли тертя, механізм повороту важеля, маніпулятор, сміттєвоз, тверді побутові відходи