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Dynamics of wear and tear of garbage trucks in Khmelnytskyi region

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Abstract

The article is dedicated to determining the regularity that describes the dynamics of wear and tear of garbage trucks at the regional level, using the example of the Khmelnytskyi region. During 2015-2020, wear and tear of the fleet of garbage trucks of municipal enterprises of Khmelnytskyi region decreased from 63% to 59%. Using the method of regression analysis, an adequate power law was determined that describes the dynamics of wear and tear of garbage trucks in the region in 2015-2020. To perform the study, the method of regression analysis of the results of one-factor experiments and other paired laws was used by choosing a more adequate type of function from the 16 most common options according to the criterion maximum correlation coefficient. The regression was carried out on the basis of linearizing transformations, which allow reducing the non-linear regularity to a linear one. A graphical dependence describing the dynamics of wear and tear of garbage trucks was constructed, and the sufficient convergence of the obtained regularity was confirmed. According to forecasts the wear and tear of garbage trucks in the Khmelnytskyi region by 2030, at the current rate of decline, will decrease to 51.9%. The expediency of conducting further studies to determine the influence of factors on the dynamics of wear and tear of garbage trucks has been revealed.

Key words: dynamics, garbage truck, wear and tear, municipal solid waste, regression analysis.

Introduction

Among the important tasks of utility engineering, increasing the wear resistance and reliability of parts and machines in general are mentioned in the following works [1, 2]. For the collection and transportation of municipal solid waste (MSW) to landfills and incineration sites in Ukraine, body-mounted garbage trucks in the amount of more than 4,100 units are used, which are capable of compacting solid waste, reducing transportation costs and the required area of landfills. The decrease in the rate of growth of land plots for solid waste disposal is facilitated by their primary treatment during loading into the garbage truck by compaction, dehydration and grinding. At the same time, during technological operations, the surfaces of the working bodies of garbage trucks are subjected to intensive wear. This is caused by the presence of small metal products, glass, ceramics, stones, bones, dust, polymer materials in the waste that have abrasive properties. In addition, the moisture present in MSW, which is an average of 39-92% by mass, creates an aggressive corrosive environment. Despite the taken measures, wear and tear of the fleet of garbage trucks of municipal enterprises of the Khmelnytskyi region during 2015-2020 almost did not change; it decreased only from 63% to 59% [3, 4]. According to Cabinet Resolution No. 265 [5], it is important to ensure the use of modern highly efficient garbage trucks in the country's communal economy, as the main link in the structure of machines for collection and primary processing of solid waste. This allows not only to solve a number of environmental problems, but also to increase the reliability of the work of utility companies. The planning of renewal, maintenance and repair of garbage trucks is facilitated by the determination of the regression law, which describes the dynamics of wear and tear of garbage trucks at regional levels, in particular, using the example of Khmelnytskyi region. An urgent task is to combine the solution of the problem of wear and tear with the improvement of the drives of the working bodies of machines for handling municipal solid waste.

Analysis of recent research and publications

The article [6] proposed a mathematical model for calculating the rate of wear of triboelements in the tribosystem under conditions of corrosive-abrasive wear. At the same time, the following factors were considered by the authors: active acidity, abrasiveness, roughness, load and sliding speed. The degree of influence of the above factors on the rate of wear has been determined theoretically. It was established that abrasiveness is the most important factor, followed by the level of active acidity and load in descending order of influence.

When the authors of the work [7] evaluated the data of observations of garbage trucks, it was found that the largest number of failures occurs due to wear and corrosion of the working surfaces of the working equipment parts. Failures of hydraulic cylinders due to wear of the working surfaces of couplings, deformation of the rod and cylinder during operation make up 32% of all failures of hydraulic drive elements, which is associated with uneven loading of the body and abrasive wear of the working surfaces in difficult working conditions of the garbage truck. During the investigation of the causes of failures, it was found that the predominant cause is the wear of the working surfaces of the main parts in the structure of the hydraulic drive, namely spools and housings of hydraulic distributors, hydraulic cylinder rods, etc. The main cause of wear was hydroabrasive damage due to untimely replacement of the working hydraulic fluid and the use of poor-quality or worn sealing parts (for example, seals of hydraulic cylinders), which causes dust particles and wear products to enter the sliding zone, which accelerate the process of wear of the working surfaces of the parts. One of the promising ways of restoring worn parts is chrome plating in a cold self-regulating electrolyte, which makes it possible to obtain high-performance chrome coatings with high deposit quality.

The analysis [8] of developments in the field of municipal engineering showed that in most garbage trucks, technological operations are carried out with the help of a hydraulic drive of working bodies. According to studies [9], the hydraulic system has the shortest durability (mileage to failure) among the main components of garbage trucks with a side-loading method of solid waste, which makes the most significant contribution to increasing the wear and tear of garbage trucks. According to the results of observations [10], the structure and most frequent causes of failures of the hydraulic equipment of garbage trucks were determined: hydraulic cylinders - 34.92% (wear of cuffs, seals, rod; rupture of the nut attaching the piston to the rod; bending of the rod; mechanical damage), hydraulic pump - 16.40% (casing failure, wear of gears, extrusion of oil seals, cracks in the casing), pipelines, hoses - 15.34% (breakage of hoses, wear of pipelines), hydraulic distributor - 13.23%, (wear of seals, spools; cracks in the casing). Significant loads on drive elements caused by transients during start-up are the most dangerous. Taking into account the considerable mass of solid waste containers (up to 0.5 tons), dynamic overloads can reach significant values. This poses a particular danger for the hydraulic cylinder-lever, hydraulic cylinder-body connection units, as well as for high-pressure flexible pipelines that supply the working fluid to the hydraulic cylinder. Such pressure jumps in the mode of transient processes can cause the rupture of high-pressure pipelines, the exit of the equipment from the operating state. Therefore, the stability of the operation of the hydraulic drive and the quality of transient processes during start-up and acquisition were investigated depending on such indicators of the quality of transient processes as regulation time and relative overregulation, from the main parameters of the working bodies of garbage trucks during loading and unloading of solid waste [8], respectively, which began to be calculated rational parameters of the working bodies of garbage trucks, which ensure high-quality transient processes during the start-up of hydraulic drives, and, therefore, a decrease in the intensity of their wear.

In the work [11], it was established that electronic telemetric navigation and control systems of the machine during operation on the route allow automatic control of the machine and ensure a smoother movement of the levers, reduce their jerks and vibrations during the unloading of solid waste containers. These jerks and vibrations have a negative effect on the car. As a result of reducing the negative impact, the service life of the body and chassis increases, and their wear and tear decreases.

A system analysis showed that a complex of machines is needed to solve the problems of MSW [12], a promising way to minimize the amount and harmfulness of solid waste is their dehydration and subsequent vibration compaction with a press plate with a hydraulic drive and vibration excitation using a pressure pulse generator. On the basis of the studied interaction of the working body – MSW with the executive bodies of the machines, the structure of machines for collecting and primary processing of solid waste was formed [13]. It was established that the design of the garbage truck should take into account the strategy of handling solid waste and the technology of their collection. Thus, for the collection of mixed solid waste with subsequent burial at a landfill or pyrolysis waste incineration, garbage trucks with maximum dehydration and compaction of waste should be used, and in the case of a dual system of collection of "dry" and "wet" waste or their separate (fractional) collection with further processing and repeated using secondary resources, container garbage trucks should be used. Therefore, the production of new constructions of garbage trucks with enhanced functionality will also contribute to reducing the rate of wear and tear of the fleet of garbage trucks of municipal enterprises.

In the article [14], it was established that the tires of cars for collecting and transporting solid waste, which are installed on the front axle, have less wear than on the rear axle. This is due to the fact that in the process of transporting solid waste, the load on the rear axle is greater than on the front. Accordingly, it is possible to compare the actual mileage of the tires with the standards of the enterprise.

The works [3, 4] provide statistical data on wear and tear of garbage trucks in the Khmelnytskyi region in 2015-2020. However, as a result of the analysis of known publications, the authors did not find specific mathematical regularities that describe the dynamics of wear and tear of garbage trucks and can be used for planning the infrastructure of communal enterprises.

The aim of the article

Determining the regularity that describes the dynamics of wear and tear of garbage trucks at the regional level (on the example of Khmelnytskyi region) to solve the problem of forecasting and planning the infrastructure of communal enterprises (warehouse and renewal of garbage trucks, production base for maintenance and repair).

Methods

The determination of the paired regularity describing the dynamics of wear and tear of garbage trucks in the Khmelnytskyi region was carried out by the method of regression analysis [15]. Regressions were determined on the basis of linearizing transformations, which allow reducing the non-linear regularity to a linear one. The coefficients of the regression equations were determined by the method of least squares using the developed computer program "RegAnalyz", which is protected by a certificate of copyright registration for the work.

Results

In the table 1 the statistical data on the dynamics of wear and tear of garbage trucks in the Khmelnytskyi region in 2015-2020 is shown [3, 4].

Table 1

Statistical data for 2015-2020 on the dynamics of wear and tear of garbage trucks in the Khmelnytskyi region [3, 4]

Year	2015	2017	2018	2019	2020
Wear and tear of garbage trucks in the Khmelnytskyi region, %	63	61,52	60,29	60,2	59

Based on the data in the table 1, it was planned to obtain a mathematical model in the form of a pairwise regression regularity of wear and tear of garbage trucks in the Khmelnytskyi region. Since the argument of the regression regularity is the year, the order of values of which is three orders of magnitude greater than the order of the width of the range of its change, in order to increase the accuracy of the regression regularity, it is proposed to take the year preceding the beginning of the studied range ($x = t - 2014$) as the origin of the coordinates.

The results of the regression analysis are shown in the table 2 where the cells with the type of regression with the maximum value of the correlation coefficient R are marked in gray.

Table 2

The results of the regression analysis of the dynamics of wear and tear of garbage trucks in the Khmelnytskyi region

№	Type of regression	Correlation coefficient R	№	Type of regression	Correlation coefficient R
1	$y = a + bx$	0,98609	9	$y = ax^b$	0,95645
2	$y = 1 / (a + bx)$	0,98541	10	$y = a + b \cdot \lg x$	0,95914
3	$y = a + b / x$	0,89699	11	$y = a + b \cdot \ln x$	0,95914
4	$y = x / (a + bx)$	0,97975	12	$y = a / (b + x)$	0,98541
5	$y = ab^x$	0,98581	13	$y = ax / (b + x)$	0,88818
6	$y = ae^{bx}$	0,98581	14	$y = ae^{b / x}$	0,89263
7	$y = a \cdot 10^{bx}$	0,98581	15	$y = a \cdot 10^{b / x}$	0,89263
8	$y = 1 / (a + be^{-x})$	0,85706	16	$y = a + bx^n$	0,98620

So, according to the results of the regression analysis based on the data in the table 1, the following regression model was finally accepted as the most adequate

$$W_{GKhm} = 63,89 - 0,8874\left(t - 2014\right)^{0,9396} \text{ [\%]},$$

where W_{GKhm} – wear and tear of garbage trucks in the Khmelnytskyi region, %; t – year.

Fig. 1 shows a graphical dependence describing the dynamics of wear and tear of garbage trucks in the Khmelnytskyi region, it was built using the regression equation (1), which confirms the previously determined sufficient convergence of the obtained theoretical dependence compared to the data given in the works [3, 4].

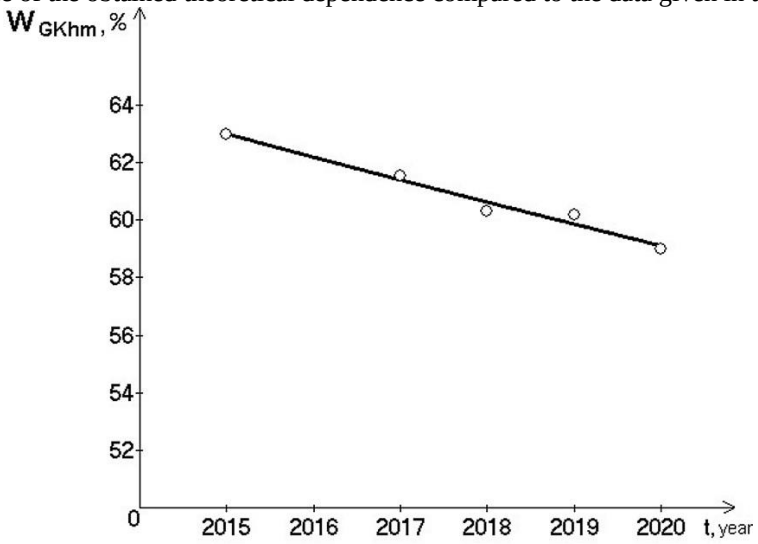

Fig. 1. The dependence describing the actual (○) and theoretical (—) dynamics of wear and tear of garbage trucks in the Khmelnytskyi region in 2015-2020.

The analysis of the graphic dependence in fig. 1 showed that the wear and tear of garbage trucks in the Khmelnytskyi region in 2015-2020 decreased exponentially.

Using pattern (1), it is possible to forecast that by 2030, the wear and tear of garbage trucks in the Khmelnytskyi region will decrease to 51.9% at the current rate of decline.

Determining the influence of factors on the dynamics of wear and tear of garbage trucks in the Khmelnytskyi region requires further research.

Conclusions

A regression regularity has been determined that describes the dynamics of the wear and tear of garbage trucks in the Khmelnytskyi region and allows it to be forecasted and planned for the infrastructure of municipal enterprises (warehouse and renewal of garbage trucks, production base for maintenance and repair), which is necessary to solve the problem of municipal solid waste management. A graphical dependence was built that describes the dynamics of wear and tear of garbage trucks in the Khmelnytskyi region and allows to visually illustrate this dynamic, to show a sufficient convergence of theoretical and actual results. It was established that the wear and tear of garbage trucks in the Khmelnytskyi region in 2015-2020 decreased according to a power law. It is foreseen that by 2030, the wear and tear of garbage trucks in the Khmelnytskyi region will decrease to 51.9% at the current rate of decline. Therefore, determining the influence of factors on the dynamics of wear and tear of garbage trucks in Khmelnytskyi region requires further research.

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Березюк О.В., Савуляк В.І., Харжевський В.О. Динаміка зношеності сміттєвозів у Хмельницькій області.

Стаття присвячена визначенню закономірності, що описує динаміку зношеності сміттєвозів на регіональному рівні за прикладом Хмельницької області. Зношеність автопарку сміттєвозів комунальних підприємств Хмельниччини протягом 2015-2020 років зменшилась з 63 % до 59 %. За допомогою використання методу регресійного аналізу визначено адекватну степеневу закономірність, що описує динаміку зношеності сміттєвозів у регіоні в 2015-2020 рр. Для виконання дослідження використано метод регресійного аналізу результатів однофакторних експериментів та інших парних закономірностей шляхом вибору більш адекватного виду функції із 16 найпоширеніших варіантів за критерієм максимального коефіцієнта кореляції. Регресія проводилась на основі лінеаризувальних перетворень, які дозволяють звести нелінійну закономірність до лінійної. Побудовано графічну залежність, що описує динаміку зношеності сміттєвозів, підтверджено достатню збіжність отриманої закономірності. Зроблено прогноз, що до 2030 року зношеність сміттєвозів у Хмельницькій області, за існуючих темпів спадання, зменшиться до 51,9 %. Виявлено доцільність проведення подальших досліджень з визначення впливу факторів на динаміку зношеності сміттєвозів.

Ключові слова: динаміка, сміттєвоз, зношеність, тверді побутові відходи, регресійний аналіз.