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4.3.1. Технологии, машины и оборудование для агропромышленного комплекса

ИСПОЛЬЗОВАНИЕ ЯЗЫКА ПРОГРАММИРОВАНИЯ PYTHON ДЛЯ РАЗРАБОТКИ ПРОГРАММЫ ВЫПОЛНЕНИЯ ПЕРВОГО ЭТАПА СТАТИСТИЧЕСКОЙ ОБРАБОТКИ ИЗНОСА ДЕТАЛЕЙ ШЛИЦЕВОГО СОЕДИНЕНИЯ – СОСТАВЛЕНИЯ СТАТИСТИЧЕСКОГО РЯДА

Псюкало Сергей Петрович
кандидат технических наук, доцент
РИНЦ: SPIN-код: 8928-4869
sergei_psyukalo44@mail.ru
Азово-Черноморский инженерный институт ФГБОУ ВО Донской ГАУ в г. Зернограде, г. Зерноград, Ростовская область, Россия

Статья посвящена разработке компьютерной программы, которая на базе информации об износах, позволяет реализовывать методы компьютерного статистического моделирования. Для изучения процесса износа, на примере сопрягаемых поверхностей конического редуктора механизма привода масляного насоса КПП трактора «Кировец», был составлен алгоритм, первая часть которого служит для статистической обработки полученных в результате эксперимента данных. Данный алгоритм позволяет строить статистический ряд с разбиением его на интервалы, определением середины интервалов, опытной частоты m_i, опытной вероятности p_i и накопленной опытной вероятности Σp_i.. По представленному алгоритму разработана программа на языке программирования Python. Алгоритм и компьютерная программа позволят в дальнейшем правильно устанавливать и выдерживать оптимальные сроки службы трактора и его составных частей, а это значит обеспечивать низкую себестоимость продукции, при этом будет улучшена экономичность использования сельскохозяйственной техники в хозяйствах и обеспечен быстрый темп технического прогресса в сельском хозяйстве

Ключевые слова: ШЛИЦЕВОЕ СОЕДИНЕНИЕ, КОНИЧЕСКИЙ РЕДУКТОР, ТРАКТОР, ИЗНОС, СТАТИСТИЧЕСКАЯ ОБРАБОТКА, РАСЧЕТ, АЛГОРИТМ, ПРОГРАММНОЕ ОБЕСПЕЧЕНИЕ, ЯЗЫК ПРОГРАММИРОВАНИЯ PYTHON

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4.3.1. Technologies, machinery and equipment for the agro-industrial complex

USING THE PYTHON PROGRAMMING LANGUAGE TO DEVELOP A PROGRAM TO PERFORM THE FIRST STAGE OF STATISTICAL PROCESSING OF THE WEAR OF SPLINED CONNECTION PARTS – COMPILING A STATISTICAL SERIES

Psyukalo Sergey Petrovich
Candidate of Technical Sciences, Associate Professor
RSCI SPIN-code: 8928-4869
sergei_psyukalo44@mail.ru
Azov-Black Sea Engineering Institute of the Federal State Budgetary Educational Institution of Higher Education Donskoy State Agrarian University in Zernograd, Zernograd, Rostov Oblast, Russia

This article is devoted to the development of a computer program that, using wear data, enables the implementation of computer statistical modeling methods. To study the wear process using the mating surfaces of a bevel gearbox of a Kirovets tractor's oil pump drive mechanism as an example, an algorithm was developed. The first part of this algorithm is used for statistical processing of the experimental data. This algorithm allows for the construction of a statistical series, dividing it into intervals and determining the interval midpoint, the experimental frequency mi, the experimental probability pi, and the cumulative experimental probability Σpi. A program in the Python programming language was developed based on the presented algorithm. The algorithm and computer program will enable the correct establishment and maintenance of optimal service life for the tractor and its components, thereby ensuring low production costs, improving the efficiency of agricultural machinery use on farms, and ensuring the rapid pace of technological progress in agriculture

Keywords: SPLINED CONNECTION, BEVEL GEAR, TRACTOR, WEAR, STATISTICAL PROCESSING, CALCULATION, ALGORITHM, SOFTWARE, PYTHON PROGRAMMING LANGUAGE

Introduction. Most research on the durability and wear resistance of machine parts, as far as we know, is narrow, sometimes even speculative. It's not particularly dynamic, in the sense that it's almost completely unrelated to the practical methods of designing, manufacturing, and testing machines. Designers and engineers who create tractors and agricultural machinery pay little attention to the results of such research. Only this can explain the lack of proposals for producing simple, convenient, and durable agricultural machines to replace machines with poor reliability and durability characteristics, as well as inconvenient and unsuitable maintenance and repair requirements.

Increasing the wear resistance of machine parts is a critical issue for both machine builders and users. Wear is considered to be the result of interactions between mating parts, with the workpiece (for working elements), and with the environment in general. Typically, during wear, external and internal changes in the part are observed. External changes include geometric changes (size, shape), color changes (gloss, surface color, etc.), as well as microgeometry and other changes. Internal changes include changes in the elastic and plastic properties of the material's surface layers, structural transformations, and so on. Research into the wear resistance of parts is also schematically reduced to these two areas. In the first case, based on practical needs and reproducing, to some extent, the operating conditions of the part, researchers have obtained valuable data and recommendations for selecting materials for rapidly wearing pairs. The influence of mechanical and thermal treatments, as well as surface hardening and lubrication conditions, on the service life of working pairs has been established. In this case, wear is characterized by external changes: the dimensions of the part, the clearances of mating pairs, the yield of wear debris, etc. This type of research provides a very definitive answer in each specific case regarding the resistance of the part to wear without explaining the nature of the phenomena. Work in the second category concerns studies of the internal changes of the part, partially or fully accounting for external changes, and aims to understand the physical nature of friction and wear phenomena. The goal here was to obtain fundamental data for the development of a theory for calculating the wear resistance of metals. Naturally, both approaches, mutually complementing and correlating each other, together contributed to the development of a general theory for calculating the wear resistance of machines.

Their downside is the recognition of the impossibility of mastering the phenomenon of wear to the point where long-term wear resistance calculations can be made, relying as a first approximation solely on empirical data. On the other hand, numerous researchers point to patterns in the wear process. This tacitly acknowledges both the possibility and necessity of establishing general principles, with a certain abstraction of the process, that allow for the predicted service life of machine parts.

When a researcher understands, navigates, and applies the theoretical relationships developed by this theory, they are able to solve many theoretical and applied problems facing today's science. These problems may have completely different focuses, but they are closely related to the reliability of machinery and equipment. Furthermore, solving problems related to the durability of technical objects is straightforward, requiring minimal mathematical analysis and scientific effort, and achieving maximum benefit for companies developing methods and techniques for increasing the durability of equipment [1-7]. This theory is closely linked to probability theory, so its results are applicable to a wide range of practical probabilistic problems.

Among other things, it's essential to be familiar with the basic tasks of technical diagnostics, which are designed to maintain agricultural machinery in good working order [1-7]. Diagnosing possible or probable technical conditions of a tractor is essential to predicting its service life, ensuring timely commissioning, and ensuring trouble-free operation. Therefore, it's essential and important to have specialized staff knowledgeable in the basic methods of ensuring equipment maintainability, as using "intuitive" methods to diagnose the technical condition of complex tractor models is ineffective and even unsuitable.

Purpose of the study. Using the PYTHON programming language and based on an algorithm, develop a program for performing the first stage of statistical processing of wear of splined connection parts – compiling a statistical series.

Materials and methods. The following research methods were used: micrometric analysis of parts, variation analysis and statistical processing.

Micrometric measurements of the components were taken using a ЩЦЦ-I-150-0.01 caliper, brand "GRIFF" (GOST 166-89), after its adjustment and calibration using the KMD No. 1 end gauge block set, accuracy class Kl-1 (GOST 9038-90). Prior to micrometric measurements, the splined parts of the components were cleaned by immersing them in an ultrasonic cleaning bath with a Labomid detergent solution for 5-10 minutes, wiping them, and drying them with acetone.

Preliminary statistical data processing, construction, and visualization of the variation series were performed using Microsoft Office Excel 2003 software. The Microsoft Visual Studio development environment, Python Tools extension, Community version 3.11.3, were used to write and debug the Python code.

Python programming language was chosen due to its openness, availability of libraries for statistics, and ease of integration.

We examined the wear of all splines on eight pairs of mating components from tractors operated during the 2024-2025 season and received for repair at ZAO RTP Zernogradskoye. A total of 48 splines were examined for width micrometric measurements. We also ensured that the shafts exhibited wear within the tolerances for mating with both previously used and new components (see technical charts, maintenance and repair manuals, and defect cards supplied with the Kirovets tractor).

Figures 1 and 2 show the mating worn surfaces of the bevel gearbox of the oil pump drive mechanism of the Kirovets tractor gearbox.

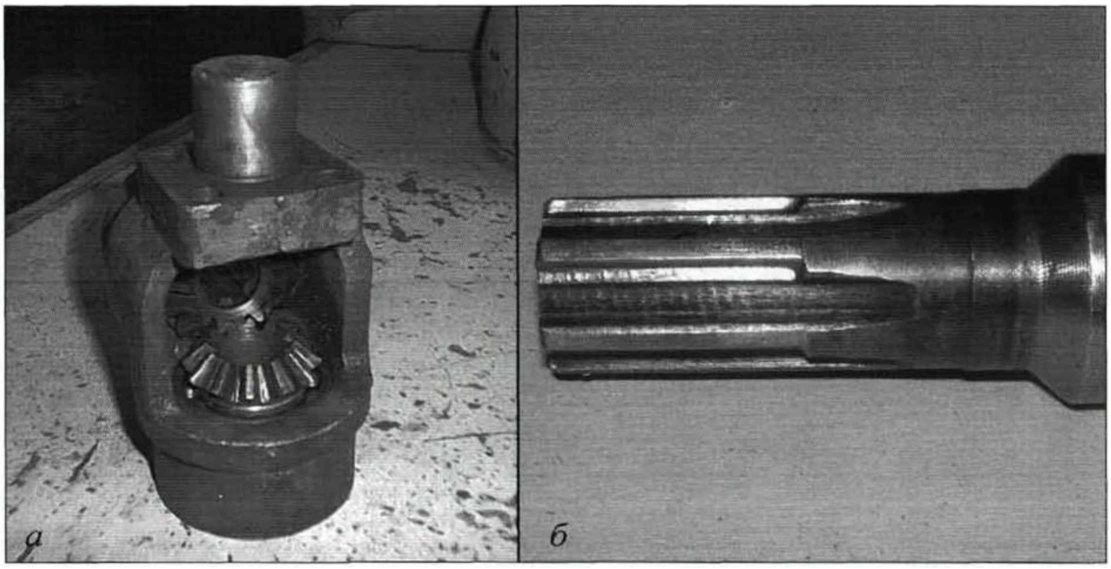
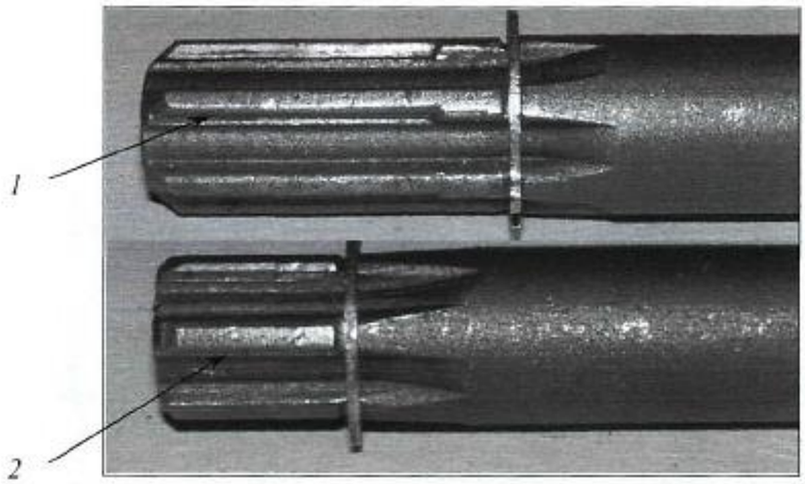


Figure 1 – Bevel gear of the oil pump drive mechanism assembly 700A.17.01.290 (a) and splined section of the pump drive shaft 700A.17.01.191 (b)

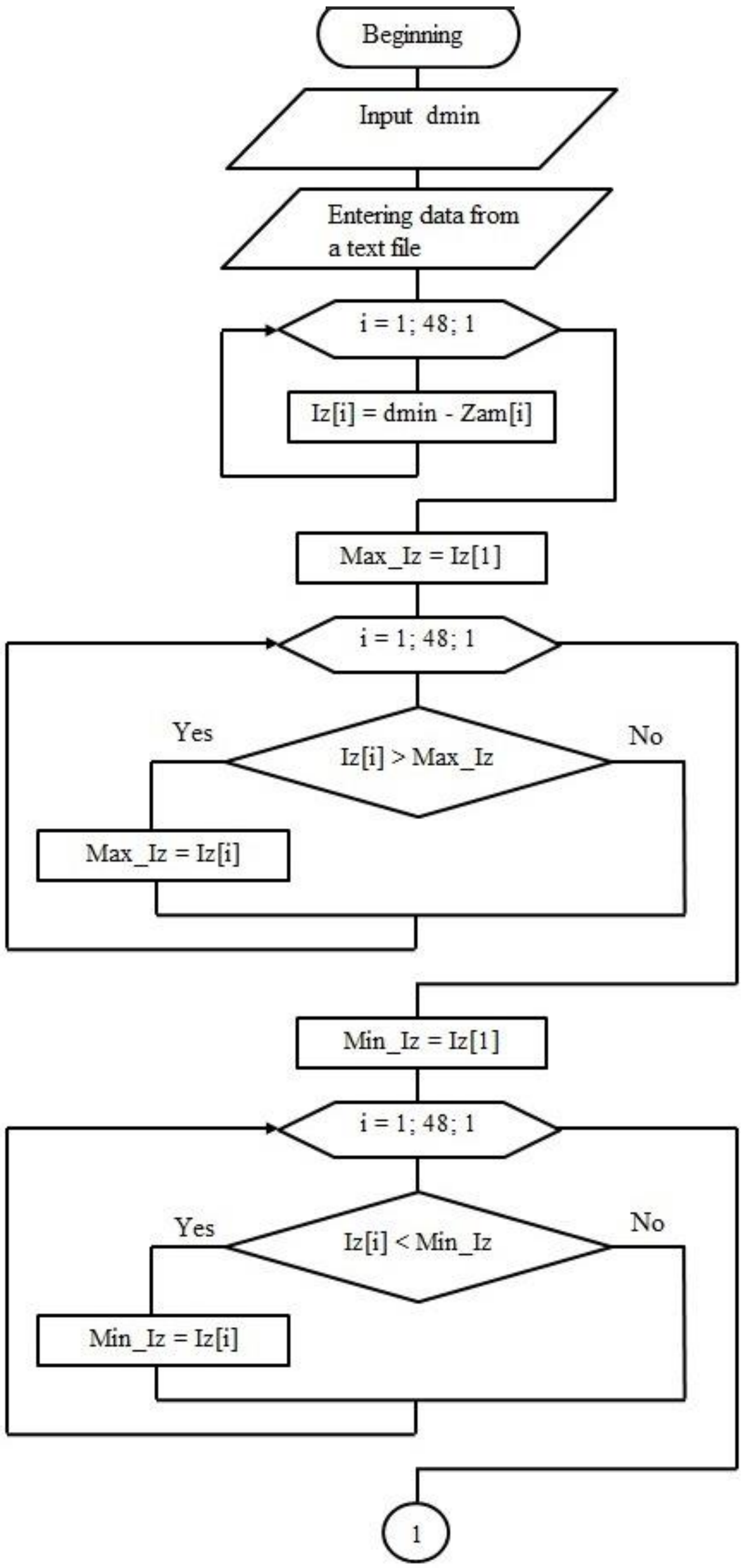


1 – splined part of the shaft, connected to the gear of the bevel gear;

2 – splined part of the shaft, connected to the pump drive sleeve

Figure 2 – Worn surfaces of the splines of the roller 700A.17.00.038-3

To study the wear process of roller splines, an algorithm was developed, the first part of which serves for statistical processing of the data obtained as a result of the experiment (Figure 3).


Beginning
Input dmin
Entering data from a text file
i = 1; 48; 1
Iz[i] = dmin - Zam[i]
Max_Iz = Iz[1]
i = 1; 48; 1
Yes
Iz[i] > Max_Iz
No
Max_Iz = Iz[i]
Min_Iz = Iz[1]
i = 1; 48; 1
Yes
Iz[i] < Min_Iz
No
Min_Iz = Iz[i]
1

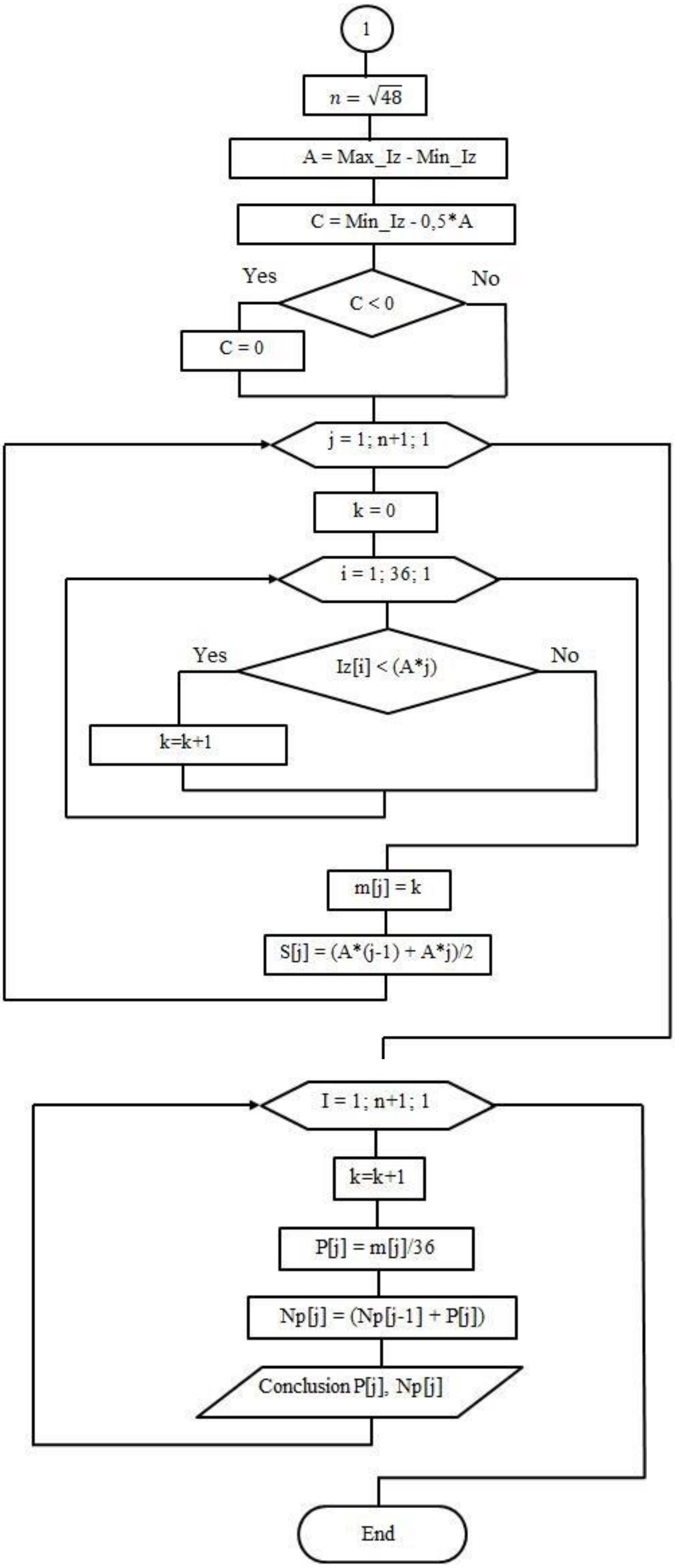


Figure 3 – Wear of the splines of the roller 700A.17.00.038-3

Results and discussion. After preliminary statistical processing of the micrometric results, it was discovered that the data on spline wear by thickness obey one of the probability laws: normal distribution (ND); Weibull, etc. [9].

For a more detailed study of the wear process of roller splines, an algorithm was developed, the first part of which is used for statistical processing of data on the measured thickness of one spline in several places (n.m. 3..5); the second - determines the range of data in the experimental sample and constructs an interval variation series; the third - calculates the experimental frequencies and probabilities of the occurrence of quantities in the intervals of the series; and, finally, the fourth - calculates the cumulative probabilities, which makes it possible to restore the differential and integral distribution function for the constructed series. The block diagram of the algorithm is shown in Fig. 3. This algorithm makes it possible to construct a statistical series by dividing it into intervals, determining the midpoint of the intervals, the experimental frequency mi, the experimental probability pi and the cumulative experimental probability Σpi.

Modeling of technical and technological wear processes can be accomplished using a variety of mathematical packages and application programs [9]. A program in the Python programming language was developed using the algorithm presented above. To test the functionality of the developed program, measurements of 48 splines on eight rollers operating in conjunction with a bevel gear were used (Table 1).

The program performs statistical data processing: a variation series is obtained, providing a preliminary statistical analysis of the experimental data. This variation series will subsequently allow for the construction of a frequency histogram and an accumulation curve, as well as the determination of the data distribution law. The program displays a normalized variation series (from 0 to 1) on the PC screen, providing a preliminary understanding of the probabilistic data distribution law. The program interface, with an informational message about the parameters of the obtained variation series, is shown in Figure 4.

Table 1 – Results of spline wear measurements (fragment)

roller	Slot Item No.	Average spline thickness, mm	Amount of wear, mm
1	1	3.08	0.442
	2	3.07	0.458
	3	3.00	0.525
	4	3.03	0.500
	5	3.03	0.492
	6	3.03	0.500
2	1	3.11	0.417
	2	3.12	0.408
	3	3.13	0.392
	4	3.18	0.350
	5	3.20	0.325
	6	3.17	0.358
…			
8	1	2.09	1.433
	2	2.13	1.400
	3	2.13	1.400
	4	2.14	1.383
	5	2.13	1.400
	6	2.13	1.392

Table - Statistical series

	Intervals	The middle of the interval, si	Experimental frequency, mi	Experimental probability, Pi	Accumulated experience probability, Npi
1	0-0,15	0.075	2	0.04	0.04
2	0,15-0,30	0.225	3	0.06	0.1
3	0,30-0,45	0.375	4	0.08	0.18
4	0,45-0,60	0.525	14	0.28	0.46
5	0,60-0,75	0.675	19	0.38	0.84
6	0,75-0,90	0.825	6	0.12	0.96
7	0,90-1,05	0.975	2	0.04	1

Figure 4 – Results of the Python program

The algorithm and computer program we developed will enable us to correctly establish and maintain optimal service life for tractors and their components, ensuring low production costs, improving the economics of agricultural machinery use on farms, and ensuring rapid technological progress in agriculture. The same applies to maintenance and repair intervals. Until farm managers and all agricultural specialists develop the right attitude toward machine maintenance and repair, and until parts and components are replaced within optimal timeframes, significant progress in reducing the cost of mechanized agricultural work will be impossible.

Conclusions. As follows from the data presented in Table 1, the observed values of linear wear of the roller splines by thickness (taking into account the standardized tolerances for the dimensions of new and/or used parts) are located within the range from 0.325 to 1.433, i.e., they can differ by a factor of 4.4. Nevertheless, after statistical processing and construction of an interval variation series, it turned out that 66% of the observed experimental wear values are located in the middle of this series, i.e., the distribution of this parameter in the studied sample was close to the law of normal distribution.

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