

Research Article

Results of Laboratory Wear Testing of Materials of G-Shaped Freeze-Cultivator Knives

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Abstract

This article presents a comprehensive analysis of the wear behavior of G-shaped blades used in milling cultivators under controlled laboratory conditions. The study specifically focuses on evaluating how various operational factors influence the wear intensity of the blade material. Among the key parameters analyzed are the applied pressure force, the total duration of the testing process, the linear friction speed between the blade surface and the abrasive medium, as well as the rate of abrasive material consumption throughout the test cycle. The laboratory experiments were designed to simulate realistic working conditions to which the blades are typically subjected during soil cultivation operations. By systematically varying the pressure force applied to the blade samples, the researchers were able to observe and quantify the correlation between increasing load and material wear rate. Higher pressure levels generally led to a more intense abrasion effect, highlighting the critical importance of optimizing operational loads during field use. Another significant factor investigated was the testing duration. It was observed that prolonged exposure of the blade materials to abrasive interaction progressively increased the wear depth, which directly correlates with reduced blade service life. This finding underscores the necessity of selecting materials with enhanced wear resistance for longer operational cycles.

Keywords

G-Shaped Knife, Hardness, Wear, Composition, Sand, Abrasive, Pressure, Force

1. Introduction

In recent years, the use of agricultural machinery in agricultural development has been one of the main factors ensuring the high-quality performance of agricultural work in a short time based on agrotechnical requirements and increasing labor productivity. For cotton, mung beans, corn, and many melon crops, the first inter-row cultivation after irrigation begins when 75-80% of cotton seedlings emerge and the inter-rows become visible. During the first cultivation, the rotary sprocket, blades, and deep cultivators should be placed

on the cultivator in a coordinated position. Then the stars are set 3-5 cm, the middle parts 12-14 cm, and the edges 6-8 cm. Based on the above, they should thoroughly prepare for the first inter-row cultivation of cotton and implement this measure carefully. Because during this time, mung bean corn cotton seedlings and their roots are extremely delicate and fragile. Negligent first processing leads to the death of some seedlings. To prevent such situations and ensure proper implementation of measures, the following should be taken seriously: - The cul-

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tivator unit must be operated by a highly qualified mechanic, and its working parts, cultivator milling cutters, must be in good working order; - Begin the first cultivation as soon as cotton seedlings emerge and the rows become clearly visible in the fields (otherwise, the unit cannot run correctly and steadily); - Install the working parts so that they penetrate the soil more superficially (otherwise, the delicate cotton roots will move and the seedlings will die); - During the first cultivation, the tractor speed should not exceed 3-5 km/h. Further cultivation is carried out after each irrigation of cotton fields when soil moisture reaches the required level. Only then will fine and granular soil form. For the effective operation of modern agricultural machinery, each of its components, including milling cultivators, must be made of high-quality and durable materials. Materials used in the form of G-shaped knives are especially important for milling cultivators, as they are subjected to high mechanical loads during soil cultivation.

In laboratory conditions, this makes it possible to assess the degree of wear of materials and their operability, making effective decisions in their selection. In this article, the results of laboratory wear tests of G-Simon knife-shaped materials are analyzed [1].

Inter-row cultivation plays an important role in the effective use of water for the development of cotton, corn, and many other crops. When cultivating inter-rows, soil and climatic conditions, microbiological properties, air exchange and nutrient regime are improved, weeds are eliminated, soil properties, terrain relief, and water availability must be taken into account [2].

2. Experimental Procedures

The research was carried out in accordance with the sampling program for obtaining the results. According to this program, such factors as pressure force, test duration, friction speed, and abrasive material consumption were taken into account. The amount of wear was determined based on the difference in the weight and dimensions of the samples before and after testing [4].

Our goal is to determine the factors influencing the wear of materials used in the form of a G-Simon knife and, based on the test results, to select the most effective material.

In addition, the following tasks have been defined:

- 1) Laboratory testing of materials for wear.
- 2) Measuring the degree of wear using various tests.
- 3) Analyze and evaluate the differences between different materials.

The following methodology was used for laboratory tests:

- 1) Material selection: The materials used in the tests were the most common steels and alloys produced in the form of G-Simon blades.
- 2) Wear tests: Materials were subjected to wear processes under various conditions (temperature, temperature, mechanical load) over a long period. During the tests, changes, cracks, and wear on the surface of knife mate-

rials were measured.

- 3) Testing process: Each material underwent more than 30 tests, which allowed for the study of changes occurring under various conditions [5].

To determine the wear resistance of the samples, tests were conducted on an abrasive wear testing device at the Department of "Technological Machines and Equipment" of Namangan State Technical University (Figure 1).



Figure 1. Optical emission spectrometer device SPECTROLAB DFS 500.

The weight and dimensions of milling cutters and samples made from them were determined. In the study of samples of existing and hardened milling cutters, scales MH-696 and SF-400 (Figure 2), a micrometer MK 50-75, a caliper SHTS-11-160-0.5, and indicators ICH 10 of the clock type were used [3].



Figure 2. MH-696 and SF-400 scales.



Figure 3. Device for testing materials for abrasive wear.

The tests were carried out under abrasive conditions, in accordance with the requirements of the existing standard. The wear test of the samples was carried out using a roller made of elastic rubber material, in which the test sample was rubbed with abrasive particles. Quartz sand with a diameter less than 1 mm was used as an abrasive material. Weights weighing 1 kg, 2 kg, 3 kg, 4 kg, and 5 kg were used as pressing weights on the sample [1]. These loads, as pressures on the surface of the sample, were equal to 35, 70, 105, 140, and 175 N, respectively (Figure 3) [6].

One cycle of wear in an abrasive medium lasted 120 minutes. As a result of rotating a roller with a diameter of 50 mm at an angular velocity of 60 min⁻¹, the wear path in one

cycle was equal to 1130 meters [7].

3. Materials and Methods

The results of laboratory tests of the samples are presented in Table 1, and the amount of wear depending on the friction rate of the samples is given in Table 2.

From the table and graph showing the test results, it can be seen that the wear resistance of other tested samples is on average 1-3.8 times higher than that of water-hardened steel grade D.

Results of laboratory wear tests in Table 1.

Table 1. Amounts of sample wear under load.

№	Sample name	Amounts of sample wear under load, g						Total wear, g	Relative wear resistance
		HRC	35 N	70 N	105 N	140N	175N		
1	CT.D water-hardened	52.1	0,32	0,38	0,54	0,75	1,1	3,09	3,8
2	CT.D original	42.5	0,53	0,78	1,1	1,5	1,95	5,86	2
3	CT.D oil-hardened	42.1	0.66	0.94	1.3	1.74	2.26	6.9	1.7
4	CT.D unhardened	19.5	1.26	1.69	2.22	2.85	3.7	11.72	1
5	CT.50	33.5	0.86	1.19	1.59	2.1	2.7	8.44	1.4
6	CT.30	16.2	1.56	2.1	2.7	3.41	4.36	14.13	0.82

To ensure the reliability of the experiments, the same conditions were established for all samples. Quartz sand, which also served as an abrasive, was not reused [9].

The results of the experiments are presented in Table 2.

Table 2. Amount of wear depending on the speed of friction of the samples.

№	Pointer name	Friction velocity of the working part sample, m/sec				
		7	8	9	10	11
F=30N						
1	Wear amount, g	0.88	0.96	1.05	1.11	1.20
F=50N						
2	Wear amount, g	1.21	1.30	1.41	1.52	1.62

Results of the study of the dependence of wear on the speed of friction. For experimental tests, 5 different speeds were determined: $v=7$ m/sec, $v=8$ m/sec, $v=9$ m/sec, $v=10$ m/sec, and $v=11$ m/sec. In order to ensure reliability, test experiments were conducted under a pressure force $F=30$ N and

$F=50$ N.

Studies conducted to study the influence of the friction rate on the amount of wear showed that with an increase in the friction rate, the amount of wear increases in a linear relationship (Figure 4).

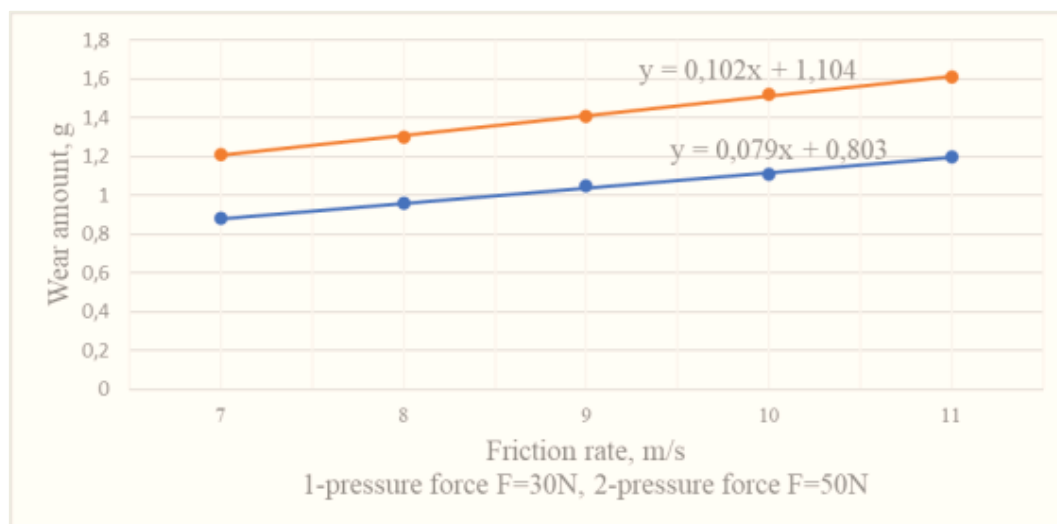


Figure 4. Dependence of wear on the rate of friction.

Based on the wear values of the samples studied under laboratory conditions, the parameters ensuring minimal wear were determined [8].

Based on the obtained results, the graphs of the change in the amount of wear of milling cutter blade samples depending on the speed of friction can be represented by the following empirical formula

a) when the applied load $F=175\text{ N}$

$$\varepsilon = -1,25989x^2 + 1,02929x + 0,541 \text{ g. } R^2 = 1$$

b) when the applied load $F=35\text{ N}$

$$\varepsilon = -1,25989x^2 + 0,87059x + 0,0209 \text{ g. } R^2 = 1$$

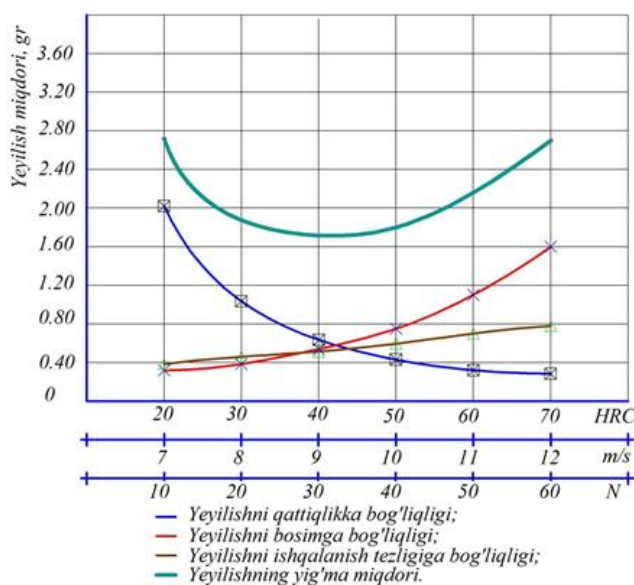


Figure 5. Dependence of wear on the rate of friction.

A generalized graph of the dependence of the material hardness, pressure force, and unit speed on the amount of wear of the cutter-cultivator blades was constructed (Figure 5).

Analysis of the graph in Figure 5 shows that as the hardness of the sample material increases, the amount of its wear decreases. At the same time, the degree of wear increases with increasing pressure and friction speed applied to the sample. In this case, the factor that has the least impact on the wear rate is the friction rate, the pressure force is moderate, and the material hardness has the greatest impact [11].

4. Results

To ensure the reliability of the research results, it is necessary to conduct statistical research. This determines the reproducibility of the research, the distribution of results, the accuracy of the experiments, and the degree of error [14].

To ensure the reliability of the research results, the expected value of mathematical statistics, standard deviation, deviation of the expected value, coefficient of variation, accuracy of the experiment, and Student's t-test were used [12].

To determine the arithmetic mean, the sum of all the values obtained in the experiment was divided by their number, i.e. [15]

$$M = \frac{x_1 + x_2 + x_3 + \dots + x_n}{n} = \frac{1}{n} \sum_{i=1}^n x_i, \quad (1)$$

where n - number of trials; $x_1, x_2, x_3, \dots, x_n$ - values of the 1st, 2nd, 3rd and n th results, respectively.

To determine the distributive nature of the obtained results, standard deviations are used, i.e.

$$\sigma = \sqrt{\sigma^2} = \sqrt{\frac{(x_1 - M)^2 + (x_2 - M)^2 + \dots + (x_n - M)^2}{n-1}}. \quad (2)$$

To get information about the extent of the distribution of values, the following expressions are used:

- deviation of the arithmetic mean

$$m = \frac{\sigma}{\sqrt{n}}. \quad (3)$$

- coefficient of variation

$$V = \frac{\sigma}{M} \cdot 100\% \quad (4)$$

- accuracy of the experiment being conducted

$$P = \frac{m}{M} \cdot 100\% \quad (5)$$

Student's t-test was used to exclude errors from the experimental results: M_2

$$t_{ishl} = \frac{x_i - M}{\sigma}, \quad (6)$$

where x_i - estimated value of expected gross error.

If the value of the experimental result criterion is greater than the value in the table by modulus t_{ishl} , the experiment is considered incorrect.

Student's t-test was also used to compare the differences in the arithmetic mean of the measurement results:

$$t_{ishl} = \frac{M_1 - M_2}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}, \quad (7)$$

where M_1 va, σ_1 and σ_2 , n_1 and n_2 - mathematical expectations, variance, and the number of compared tests, respectively.

If $t_{ishl} < t_{jad}$ the difference between the two values will be reliable. Assuming that the probability of making an erroneous decision when determining t_{jad} is 0.05 [10, 13].

5. Conclusions

To fulfill the set tasks, a work program was developed,

consisting of such stages as improving the restoration technology, conducting laboratory and production experiments, developing technological recommendations, and economic evaluation of the proposed solutions. This program allows for the effective conduct of experiments.

The necessary materials, equipment, and methods for studying the microstructure, composition, hardness, and wear resistance of the material of samples made from existing local raw materials, as well as some of them treated by hardening, were selected, which guarantees the reliable conduct of the experiments.

The developed method for conducting production tests of milling cutter-cultivator blades provides a basis for controlling the change in mass, geometric dimensions, and shape during the operation of restored and partially hardened milling cutter blades and analyzing the obtained results. The tests were carried out under abrasive conditions, in accordance with the requirements of the existing standard. The wear test of the samples was carried out using a roller made of elastic rubber material, in which the test sample was rubbed with abrasive particles. Quartz sand with a diameter less than 1 mm was used as an abrasive material. The test results indicate the need to pay special attention to the wear of materials used in the form of G-Simon blades. Steel materials are usually intended for short-term use, while alloys are long-term and highly efficient materials. In particular, the wear of materials in the form of G-shaped knives also depends on the type of soil, its moisture content, stiffness, and the operating time of the knives. At the next stages of testing, it is necessary to develop new technologies to improve the efficiency of materials, taking into account these factors. The test results showed that the assessment of the wear process of materials used in the form of a G-Simon knife under laboratory conditions is important in the selection of materials. To achieve the best results, it is necessary to select high-quality alloys and optimize production processes. These methods play an important role in increasing the efficiency of agricultural machinery and extending its service life.

Author Contributions

Karimjon Kosimov: Conceptualization, Data curation, Formal Analysis, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Kadirov Akhrorjon: Investigation, administration, Resources, Software Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



Kasimov Karimjon - Doctor of Technical Sciences, Professor, known for his great merits in the field of maintenance and repair of machine parts. He is the author of numerous articles and books, which are considered fundamental reference books in the field. His skills and deep knowledge have received recognition not only at the local level, but also at the international level. Currently, he works as a professor at the prestigious Andijan State Technical Institute, imparting his valuable knowledge to a new generation of engineers. During his honorable career, Professor Kasimov mentored many students, many of whom achieved great success in their professional fields. His dedication to the development of research, education, and technical service has made him a key figure in his field, which has a long-term impact on both academic circles and industry.



Kadirov Akhrorjon, Candidate of Technical Sciences. Currently, he is working on his doctoral research and contributing to the field through academic participation. In 2020, he graduated from the Namangan Engineering and Construction Institute, in 2022 - from the Namangan Engineering and Construction Institute with a master's degree in the field of technical maintenance of technological machines and equipment. In recent years, he has participated in several international scientific cooperation projects.

Research Field

Kasimov Karimjon: Improvement of technologies and means of increasing the resource of parts of agricultural equipment, Justify the parameters and methods of electrocontact welding of powder coatings, Introduction into production of technology for increasing the wear resistance of agricultural machinery

Kadirov Akhrorjon: Technology and equipment for fusion welding, Substantiation of the technology for increasing the resource of processing worn parts with composite materials, Technology for increasing the resource of the active working body of a milling cultivator (using the example of a Dunder cultivator)