Akaki Tsereteli State University
Faculty of Agrarian

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Ioseb Abuladze

Increasing Operational Reliability of Adjara-based Agricultural Equipment and Resource Saving Technology Processing to Restore Depreciable Parts

Speciality 0415 – Agro Engineering

Abstract

Of the Dissertation Submitted to Obtain Academic Degree of the Doctor of Agronomy

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The present dissertation paper has been performed at the Agro Engineering Department of the Faculty Agrarian of Akaki Tsereteli State University and Agrarian University of Georgia

Research Director:
Jemal Katsitadze – Professor of Agrarian University of Georgia, Doctor of Technical Sciences, Academician of the Academy of Agricultural Sciences of Georgia.

The Head of the Doctoral Program in Agro Engineering
Rani Chabukiani - Doctor of Technical Sciences, Emeritus, Academician of the Academy of Environmental Sciences.

Reviewers:
Revaz Makharoblidze - Professor of Agrarian University of Georgia, Doctor of Technical Sciences, Academician of Georgian Academy of Agricultural Sciences, Laureate of State Prize.

Dimitri Natroshvili - Professor of Agrarian University of Georgia, Doctor of Technical Sciences, Chief Scientific Officer at K. Amirejibi Engineering Institute

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Professor V. Kobalia /V. Kobalia/

General Description of the Thesis

Topicality of the issue: Adjara is one of the distinguished regions of Georgia with its diverse natural conditions, relief and soil and climatic peculiarities. There are mountainous terrain, angled, steep sloping lands and small contour plots, which are characterized by sharply expressed curves. In addition, high density and sun radiation is observed in most parts of the region.

The above mentioned factors are obviously negatively affecting the reliability of mobile and small mechanized machinery, imported from abroad, causing reduction of their technical resources and employability. The productivity and capacity is also reduced, the cost of fuel and lubricants increases, technical management and sustainability becomes more difficult, loads while stopping or releasing the vehicle are increased and according to the final calculations, resources of aggregates, nodes and parts of the machinery are reduced.

The use of mobile techniques in the highlands is characterized by low profitability, as the frequent maneuvering in turnings causes fuel consumption and increases operational time, as well as the downtime of the equipment.

One of the unresolved problems in the region is the lack of staff, serving the equipment. According to the official data of the Ministry of Agriculture of Georgia, by 2013, more than 72% of the excellent specialists of the technical service industrial unit of the agrarian sector left the field, in order to be involved in other spheres of business. There are no technical service centers in the

municipalities of Adjara Region, except fot the Meqanizatori LTD. Due to the lack of specialists and the low qualifications of the existing specialists, the owners have to serve their own private machinery. Therefore, the quality of service is low and the cost of performed work is high. Thus, the performance of the machinery is poor, when its readiness coefficient amounts to 40-45%. The mentioned fact leads to a violation of agro-terms of agricultural labourious works and a non-profitability of the whole agricultural works.

It is necessary to develop an agricultural service centers in Adjara, which will fulfill all functions of technical services, which will take into account the production-technical services in crop production, in breeding and processing industry, together with the marketing, technical exploitation, repair works, management, quality assurance, organization of transportation, trainings and retrainings of staff, technical supervision, etc.

We believe that it is necessary to develop and implement the rational forms of agricultural technologies at a country, region and rural level, which will enable us to utilize the foreign agricultural machinery effectively and significantly increase agricultural production. It is also necessary to develop a type of device and resource saving innovative technology to restore depreciated parts and give them the "second life".

Based on the above mentioned, determination of quantitative indicators of operational reliability of agricultural machinery operating in Adjara, resource saving innovative technology development for restoration of the depreciated parts and establishment of rational forms of technical services appears to be a very important scientific problem, having a practical character.

The goal of the thesis. The goal of the thesis is to develop technological and organizational measures for increasing the reliability and resources of small mechanization agricultural machinery in Adjara, substantiation of a new technological process and equipment to restore the depreciated parts, optimization of modes, calculation of technical and economic indicators and development of rational forms of technical service for Adjara Region.

The following tasks have been set up to accomplish the goal of the thesis:

1. Influence of mountainous conditions of Adjara on reliability and resource of small mechanization agricultural machinery.
2. Analysis of existing studies, substantiation of a principally new, resource and energy saving technology for restoration of depreciated parts.
3. Analysis of constructive peculiarities of mini-techniques and determining the units and complex indicators of their operational reliability with respect to the work in Adjara region.
4. Probabilistic statistical modeling of depreciation of the parts of engine blocks, determination of the most common (modal) depreciation and substantiation of the method of restoration with the help of the electrosparking alloying.
5. Processing, preparation, testing of equipment needed for restoration of depreciated parts with the help of the electrosparking alloying.

6. Research and optimisation of the strength, structure, wear resistance and hardness of restored surface by means of electrosparking alloying and processing the rational technological process of recovery.
7. Technical and economical assessment of the process of recovery of depreciated parts of agricultural machinery by means of electrosparking alloying.
8. Organization of technical services for small mechanical machinery in Adjara Region.

Object of the research. The object of the research is small mechanization agricultural machinery, working in Adjara, for studying the rate of their performance reliability and the device, processed by us, for restoring the depreciated parts by means of electrosparking alloying.

Scientific innovation of the research. General and private methods are processed to calculate the unit of reliability of agricultural machinery and calculate complex indicators, which have been implemented with the help of the example of small mechanization machinery, operating in Adjara Region, adequate probabilistic statistical mathematical models of the mentioned indicators have been obtained, principally innovative equipment to restore the depreciated parts by means of electrosparking alloying and increase their resources, have been designed, produced and researched, physical and mechanical properties, hardness, tightness, wear resistance of metal surface have been researched using planning and similarity theories of experiments, they have been optimized by the Box-Wilson experimental design method and optimal modes of recovery and resource saving technology have been received, for the first time in Adjara, organization of machinery services have been studied and their rational forms are substantiated.

Approbation of the work. The main issues and research outcomes of the dissertation thesis were presented to the enlarged sitting of Agro Engineering Department of the Faculty of Agrarian of Akaki Tsereteli State University (2018); Sixth International Scientific-Practical Internet Conference, Akaki Tsereteli State University, 2016; IV International Scientific Congress "AGRI-CULTURAL MACHINERY 2016", Varna, Bulgaria, 2016; V International Scientific Congress "Maintenance and repair of agricultural machines", Varna, Bulgaria, 2017.

Publication. 6 scientific papers on the topic of the dissertation have been published in Georgian and foreign top-rated periodicals.

Scope and Structure of the thesis. The dissertation work is presented in 174 printed pages and consists of 5 chapters, general conclusions and 47 references. It includes 46 tables, 22 drawings and 20 pictures.

Contents of the Thesis

Chapter One – "Conditions and Research Tasks" discusses the natural and climatic conditions of Adjara Region, stationing of lands according to individual municipalities, soils and mechanization capabilities, the use of small mechanization machinery. Adjara region is one of the distinguished regions of Georgia with diverse natural conditions, relief and soil-climatic

peculiarities. There are mountainous terrain, angled, steep sloping lands and small contour plots, which are characterized by sharply expressed curves. In addition, high density and sun radiation is observed in most parts of the region.

The above mentioned factors are obviously negatively affecting the reliability of mobile and small mechanized machinery, imported from abroad, causing reduction of their technical resources and employability.

The abrasive particles of the environment and cultivating agricultural crops, as well as the alternating dynamic loads, which are caused by the curved terrain and small contour plots, have a negative impact on an operational efficiency of the equipment.

Specific conditions characteristic to Adjara Region have a significant effect on the efficiency of agricultural machinery. The productivity and capacity is reduced, the cost of fuel and lubricants increases, technical management and sustainability becomes more difficult, loads while stopping or releasing the vehicle are increased and according to the final calculations, resources of aggregates, nodes and parts of the machinery are reduced.

On the basis of the research analysis, which have been carried out, as well as the existing scientific and research works, carried out to improve the reliability indicators of small mechanization machinery, the present paper substantiates the type of foreign agricultural equipment that would be the most efficient for Georgian conditions and which would enable us to take measures to increase the reliability and predictability as well.

Analysis of modern methods of restoration of the parts of agricultural machinery and the characteristics of their use for small mechanization machinery have been conducted.

Chapter two - "Methods of Theoretical and Experimental Work", substantiates quantity of the research objects. The object of the research was modern agricultural machinery of private farms in Adjara Region, imported from abroad, operational reliability indicators of which have not been studied yet in terms of working in local conditions.

The objects of our research were mainly agricultural tractors and technical means of small mechanization, as well as agricultural machinery and tools, plates, milling cutters, cultivators and seeders.

We have used the methods, developed by V. Mikhlin and J. Katsitadze to select and justify the quantity of the machinery.

Based on the above mentioned method, the mean arithmetic value of the research object, the average square deviation of the indicator and variation coefficient have been determined. For the purpose of obtaining statistical data, a special log of agricultural machinery data was developed together with J. Katsitadze. The log reflected all the data of the machinery, to be studied: work on malfunction, type and reason of malfunction and time, required to eliminate the malfunction, less reliable nodes and other data.

The statistical information about the reliability of small mechanization machinery was collected and the plan to examine the reliability was selected. The statistical array of small mechanization malfunctions is presented below. The following plans were used by us in collecting statistical indicators of exploitation reliability of agricultural machinery, existing in Adjara:

The plan of reliability test was selected according to the standard, which envisages five plans: NUN, NUT, NUr, NRT and NRr. In the given plans, the Latin notions are defined as follows:

N - Number of machinery, tested for reliability;

T - Time for testing reliability;

r - Number of malfunctions during the test on reliability;

U - Replacement of the failed machinery.

The correctness of filling out the log had been periodically examined. Later, collected statistical material was processed using special methods, according to the probabilistic statistical modeling. The statistical analysis has given the following statistical array.

200; 201; 204; 210; 230; 200; 300; 210; 310; 400; 300; 290; 220; 224; 210; 330; 400; 350; 360; 380; 400; 384; 390; 350; 360; 420; 500; 480; 470; 200; 300; 290; 240; 290; 240; 380; 400; 430; 460; 880; 480; 470; 480; 500; 550; 500; 580; 520; 600; 800; 890; 300; 280; 282; 288; 200; 440; 460; 580; 600; 504; 720; 600; 570; 700; 800; 710; 200; 370; 450; 500; 300; 480; 660; 700; 680; 690; 700; 900; 300; 400; 330; 360; 400; 340; 500; 480; 488; 500; 600; 570; 600; 650; 700; 650; 700; 720; 800; 790; 800; 900; 600.

A variation array of malfunction is compiled for the mathematical processing and probabilistic statistical modeling, which differs from the statistical one by its escalating order:

22; 22; 22; 22; 22; 22,1; 22,4; 23; 23; 23; 23; 24; 24,4; 25; 26; 26; 30; 30,2; 30,8; 31; 31; 31; 32; 32; 32; 32; 32; 33; 35; 35; 37; 37; 38; 38; 38; 39; 40; 40; 40,4; 41; 42; 42; 42; 42; 42; 42; 42; 45; 46; 47;

48; 48; 49; 49; 50; 50; 50; 50; 50; 50,8; 52; 52; 52; 52; 52; 52,4; 54; 57; 58; 59; 59; 59; 60; 62; 62; 62; 62; 62; 62; 67; 67; 68; 70; 71; 72; 72; 72; 72; 72; 73; 74; 74; 81; 82; 82; 82; 82; 90; 90; 92; .

After compiling a variation array, we can define the empirical frequency of the malfunction work m_i and the relative frequency, i.e. empirical probability by the following formula:

$$W_i = \frac{m_i}{N}$$

Where N is the number of malfunctions, which equals to $N = 100$.

Table 1 presents calculation results.

Empirical and relative frequencies of malfunction works of small mechanization machinery

Table 1

The interval of the work on malfunction $a...b$	Interval average x_i	Empirical frequency m_i	Relative frequency W_i
22...32	27	27	0.27
32...42	37	20	0.20
42...52	47	18	0.18
52...62	57	14	0.14
62...72	67	10	0.10
72..82	77	8	0.08
82...92	87	3	0.03
	Total	100	1.00

Determining the general characteristics of distribution of malfunction work:

_ Arithmetic average:

$$\overline{H} = \sum_{i=1}^{k} W_i h_i = 27 \cdot 0.27 + 37 \cdot 0.20 + 47 \cdot 0.18 + 57 \cdot 0.14 +$$

$$+67. \cdot 0.10 + 77 \cdot 0.08 + 87 \cdot 0.03 = 7{,}29 + 7{,}4 + 8{,}46 + 7{,}98 + 6{,}7 + 6{,}16 + 2{,}6 = 47$$

H.

_ Dispersion:

$$D = \sum_{i=1}^{k} (H_i - \overline{H})^2 W_i = (27-47)^2 0.27 + (37-47)^2 0.20 +$$

$$+ (47-47)^2 0.18 + (57-47)^2 0.14 + (67-47)^2 0.10 +$$

$$(77-47)^2 0.08 + (87-47)^2 0.03 = 108 + 20 + 14 + 40 + 72 + 48 = 302$$

_ Average square deviation:

$$\sigma = \sqrt{D} = \sqrt{302} = 17{,}4 \text{ H.}$$

_ Variation coefficient:

$$V = \frac{\sigma}{\overline{H}} = \frac{17.4}{47} = 0.4$$

Then, the intensity of malfunctions of engine blocks will be:

$$\lambda = \frac{1}{\overline{H}} = \frac{1}{47} = 2{,}10^{-2} \text{ H}^{-1}.$$

The density of distribution of probabe malfunctions i.e. differential function of distribution according to the exponential law will be:

$$\varphi(\overline{H}) = \lambda e^{-\lambda H_i} = 2 \cdot 10^{-2} e^{-2{,}10^{-2} \cdot H_i}$$

Integral distribution function:

$$F(H) = 1 - e^{-2 \cdot 10^{-2} H_i}$$

And the probability of work without malfunction will equal to:

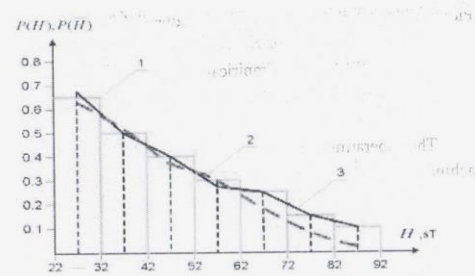
$$P(H) = 1 - F(H) = e^{-2\cdot10^{-2}H_i}$$

The mentioned formulas were used to calculate the reliability of engine blocks.

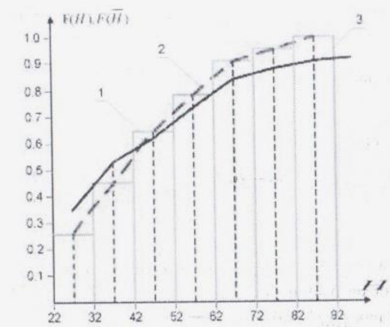
Values of differential function of distribution of engine blocks reliability

Table 2

The interval of the work on malfunction $a_i...b_i$	Interval average H_i	Empirical frequency m_i	Relative frequency W_i	Distribution density $\varphi(\bar{X})X10^{-2}$ (Empirical)	Distribution density $\varphi(X)X10^{-2}$
22...32	27	27	0.27	1.72	1.82
32...42	37	20	0.20	1.30	1.4
42...52	47	18	0.18	1.02	1.06
52...62	57	14	0.14	0.66	0.78
62...72	67	10	0.10	0.52	0.59
72..82	77	8	0.08	0.44	0.48
82...92	87	3	0.03	0.32	0.34



Pic. 1. Probability of engine blocks work without malfunction
1. Histogram, 2. Empirical curve, 3. Theoretical curve



Pic. 2. Graphs of integral function of engine block malfunction distribution

1. Histogram 2. Empirical curve of distributio
3. Theoretical curve of distribution.

The operating reliability unit of small mechanization machinery, working in mountainous conditions and the theoretical basics and methodology for the study of complex indicators have been processed.

Chapter three - Research of operational reliability indicators of small mechanization agricultural machinery working in Adjara. The malfunctions of first, second and third difficulties, quantity of malfunctions and time spent on a malfunction were registered in the logs. On the basis of statistical material, the number of intervals was determined by the Sturges formula:

$$K = 1 + 3{,}2l(\quad = 1 + 3{,}2l(\;\; 50 = 7$$

Width of interval

$$h = \frac{x_m \quad - x_m}{K} = \frac{900 - 200}{7} = 100H$$

Where, x_m =900H - the maximum work of motorized cultivator on malfunction, H; and x_m = 200H - the minimum work of motorized cultivator on malfunction, H;

The statistical array of the outcomes of the collected material about the malfunctions of the motorized cultivators was

compiled. After compiling variational series, we can determine the empirical frequency of the work of cultivator on malfunction (m)

$$W_i = \frac{m}{N}$$

Where, N is the quantity of malfunctions, which equals to $N = 100$

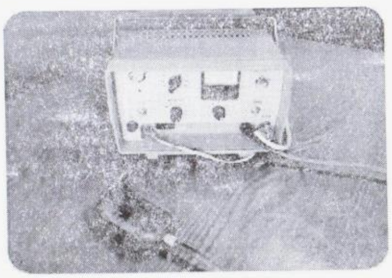
Table 3 presents calculation results

Empirical and relative frequencies of work of small mechanization machinery on malfunction

Table 3

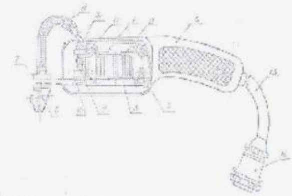
Depreciation interval a-b	Interval average X_i	Empirical frequency m_i	Relative frequency W_i
200-300	150	26	0,26
300-400	250	20	0,20
400-500	350	18	0,18
500-600	450	14	0,14
600-700	550	10	0,10
700-800	650	8	0,08
800-900	750	4	0,04
	Total	100	1,0

Chapter 4. Development of innovative resource saving technology for restoration of the depreciated parts of small mechanization machinery. Electrosparking method of restoration of depreciable parts. Sparking discharging belongs to the non-standard form of discharging, during which the anode material breaks down and is taken to the cathode. This is explained by the fact that the flow of electrons suddenly heats the surface to high temperature (10^{4}°C) while shooting the spark, as it reaches the anode with the highest speed. At this time, the metal melts down and moves into a liquid and gas form. The metal steam, which is rapidly expanding, removes the surface of the anode from the melted metal, which quickly penetrates into the atmosphere or spreads over the cathode, so that it almost does not suffer from corrosion. Each sparking impulse leads to the local erosion of the surface of the part, which is used as anode, the surface of the cathode (tool) also suffers from erosion, but with a lower degree. Picture 2 shows the device for restoration of parts with electrosparking alloying.



Pic. 2. Device for restoration of parts with electrosparking alloying

Picture 3 represents the general view of the vibrator of the device.



Pic. 3. General view of the vibrator

The mentioned device is different from the similar device Elitron-20 by almost four time more productivity and also, increased coverage thickness.

If earlier, the coverage thickness of the device Elitron-20 amounted to 0.05 mm, our device will allow the coverage of the depreciated part, which amounts to 0.15 mm.

The device consists of two nodes - impulse generator and working body. The purpose of the vibrator is to cover the part with a vibrating electrode. At the same time the part represents the negative pole (cathode) and the part attached to the top of the vibrator - anod.

Standard TK and BK type sintered-hard alloys are used as anodic material. In order to detect the degree of electrosparking alloying and restored layer, the test samples were examined with

65G, from which mainly the engine block cutter hands are made and also, the depreciated natural cutter hands are restored. The samples were brushed in advance, according to the relevant level of cleanliness, fats are dissolved from them with acetone or gasoline. This operation is necessary to ensure that the coated layer is reliably attached to the main part, which is to be restored.

Examinations for optimal recovery modes were performed by starting from the "clean" mode (by electronic power 0,8....15 a) to "gross" mode (by electronic power 15......20 a), by varying the mentioned modes.

We have conducted the metallographic analysis in order to study the main metal, having thickness of the coated metal cover and the transit zone of its cover and to research the mechanical characteristics of the alloying surface.

Determination of the thickness of the alloying layer and the structure of the transition zone was conducted by МИМ - 8 microscope.

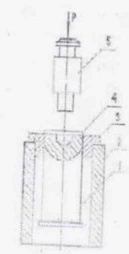
The samples were poisoned in 3 and 5% alcoholic solution of nitric acid in order them to reveal the coated layer structure.

Determination of the hardness of the restored parts was carried out by Vickers machine at the first stage. However, later, we have used the micro hardness measuring device ПМТ- 3 with a load 50 P on the identifier in order to obtain more accurate results.

Gripping strength of metal coating represents one of the most important parameters of reliability of the restored parts and high resource. Exactly for this reason, this research represents one of the important parts of our theoretical and experimental study.

Olard Method was used for researching the gripping strength of metal coating obtained by electrosparking alloying,

which was confirmed by Professor J. Katsitadze. Picture 4 represents the examination scheme of gripping strength.



Pic. 4

Examination scheme of gripping strength of metal coating obtained by means of electrosparking alloying

In various technological modes, the test samples (1) were restored by electrosparking alloying, which were placed in (2) bush and (3) half bush.

The metal cover was broken off by means of (5) punch of hydraulic pressure and gripping strength was calculated by the following formula:

$$\sigma = \frac{4P}{\pi(D^2 - d^2)}$$

Where σ is a gripping strength, mpa.

P - power of peeling off

D = 28 mm - diameter of the test sample

d = 12 mm - perforating diameter.

The results received were registered in special logs. The results were processed by means of modern mathematical methods for processing the experimental outcomes.

Examination of the depreciation durability of the restored parts were conducted in operational conditions by their periodical mitrometer and mathematical processing of the results obtained.

Parts, having the form of rotational bodies, will be restored and strengthened by the lathe-turning workshop. At this time, vibrator is reinforced to the carriage of the workshop together with the electrode. Between the part of the crack and electrode, it is regulated by the transverse supply of carriage. The initial insert restoration in ball and roller bearing and other parts is conducted while coverage of the surface. Table 4 provides electrosparking processing modes.

Electrosparking processing modes

Table 4

№	Mode	Power in the discharge contour, A	Voltage at the beginning of the electrode rupture, V	Condenser capacity, mf	Cavity depth, km	Surface downiness (level)
1	Rough	10	100	100	100	1...2
2	Averag	1-10	50-100	10-100	10-	2...4
	e				100	
3	Light	<1	<50	<10	<10	<5...50

Based on the analysis of the mentioned method, we can conclude that the electrosparking processing can be considered as a rational method for restoration of the agricultural machinery parts, slightly depreciated. For this purpose, principally new construction, easy-to-use equipment shall be manufactured and optimize the restoration process of the parts using it.

4.1 Examination of the hardness of the metal surface restored by means of electrosparking alloying using the similarity and dimensional methods

We have tried to use the similarity and dimensional methods to examine the hardness of alloyed metal cover to achieve its maximum value.

The theoretical advantage of this theory is that it allows studying simultaneous impact of several factors on optimization parameters (in our case, hardness). For this purpose, we have analyzed the factors affecting the hardness of the alloyed layer. The outcomes of the analysis is provided in the table 4.1.

Factors affecting the hardeness of the alloyed metal layer

Table 5

#	Name of the factor	Indicator	Dimension in the system	Dimension depicted by the symbols of magnitude
1	Speed of electrosparking alloying	V	m/wm	LT^{-1}
2	Time of restoration	T	wm	T
3	Amplitude of voltage impulses on the condenser	γ	a	$ML^{2}\Im^{-1}T^{-3}$
4	Welding coefficient	K	kg/a.wm	$ML^{-1}T^{-1}$
5	Short circuit power	$\Im$	a	$\Im$
6	Thickness of the cover	h	mm	L
7	Size of the part to be restored	D	m	L
8	Density of anodic material	ρ	kg/m³	$ML^{-1}T^{-1}$

The functional connection between the micro hardness of the alloyed metal cover and its factors has the following form:

$$H_{\mu} - f(D, \Im, \rho, V, K, h, \gamma, T)$$

According to the similarity and dimensional methods [34], this connection may be replaced by the connection between the similarity criteria, which characterize the restoration process. The quantity of the mentioned criteria is determined by using the theorem according to which:

$$r = N - n$$

N _ The number of values;

n _ The number of key factors.

The latter shall be selected so that the determinant of the value dimensions does not equal to zero. Based on these requirements, we choose $D, \Im, \rho$ and V as key factors.

The dimentions of the mentioned factors have the following form:

$$[\Im] = M^0 L^0 \Im T^0$$

$$[\rho] = ML^{-3} \Im^0 T^0$$

$$[V] = M^0 L \Im^0 T^{-1}$$

Determinant of the dimentions equals to:

$$D = \begin{vmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 1 & -3 & 0 & 0 \\ 1 & 1 & 0 & -1 \end{vmatrix} = 1 \neq 0$$

i.e. key factors are correctly chosen, the number of similarity criteria, characteristic to the electrosparking alloying equals to:

$$N = 9 - 4 = 5$$

The above criteria can be presented as follows:

$$\pi = H_{\mu} D^{\alpha} \Im^{\beta} \rho^{\gamma} V^{\delta}$$
$$\pi_1 = K D^{\alpha_1} \Im^{\beta_1} \rho^{\gamma_1} V^{\delta_1}$$
$$\pi_2 = h D^{\alpha_2} \Im^{\beta_2} \rho^{\gamma} V^{\delta_2}$$
$$\pi_3 = \gamma D^{\alpha_3} \Im^{\beta_3} \rho^{\gamma_3} V^{\delta_3}$$
$$\pi_4 = T D^{\alpha_4} \Im^{\beta_4} \rho^{\gamma} V^{\delta_4}$$

Where $\alpha_i, \beta_i, \gamma_i$ and δ_i are the quality indicators that are unknown.

In order the members to become indicators of quality without dimensions, they shall be such that by changing them,

the combinations $[V] = M, L, \Im, T$ it shall equal to zero in obtained expressions, i.e.:

$$\pi = H_{\mu} D^{\alpha} \Im^{\beta} \rho^{\gamma} V^{\delta} = M L^{-1} T^{-2} L^{\alpha} \Im^{\beta} M^{\gamma} L^{-3\gamma} L^{\delta} T^{-\delta} = M^{0} L^{0} \Im^{0} T^{0} = 1$$

$$1 + \gamma = 0$$
$$-1 + \alpha - 3\gamma + \delta = 0$$
$$-2 - \delta = 0$$
$$\beta = 0$$

From which:

$$\gamma = 1,\ \beta = 0,\ \delta = -2,\ \alpha = 0.$$

By inserting degree indicators in π, we obtain the similarity criterion to be determined:

$$\pi = \frac{H_{\mu}}{\rho V^{2}}$$

The criteria for determining similarity equal to:

$$\pi_1 = K D^{\alpha} \Im^{\beta_1} \rho^{\alpha} V^{\delta_1} = M L^{-1} L^{\alpha_1} \Im^{\beta} M^{\gamma} L^{-3\gamma_1} L^{\delta_1} T^{-\delta} = M^{0} L^{0} \Im^{0} T^{0} = 1$$

$$1 + \gamma_1 = 0$$
$$-1 + \beta_1 = 0$$

$$-1-\delta_{.}=0$$
$$\gamma_1-3\alpha_1+\delta_1=0$$

We obtain the following:

$$\gamma_1=-1,\quad \beta_1=1,\quad \delta_{.}=-1,\quad \alpha_1=-2$$

i.e. $\pi_1=\dfrac{K\mathfrak{Z}}{\rho VD^2}$;

By similar calculations, we obtain the following:

$$\pi_2-\frac{h}{D};\quad \pi_3-\frac{\mathfrak{Z}\gamma}{\rho D^2V^2};\quad \pi_4-\frac{TV}{D}.$$

The functional connection between the determining criteria and criteria to be determined have the following form:

$$\pi=\varphi(\pi_1,\pi_2,\pi_3,\pi_4)$$

Or:

$$\frac{H_\mu}{\rho V^2}=\varphi\left(\frac{K\mathfrak{Z}}{\rho V\gamma^2},\frac{h}{D},\frac{\gamma}{KV^2},\frac{TV}{D}\right)$$

The connection between them may be as follows:

$$\frac{H_\mu}{\rho V^2}-C\left(\frac{K\mathfrak{Z}}{\rho VD^2}\right)^{x}$$
$$\frac{H_\mu}{\rho V^2}=C_1\left(\frac{h}{D}\right)^{x}$$
$$\frac{H_\mu}{\rho V^2}-C_2\left(\frac{\alpha}{KV^2}\right)^{x}$$
$$\frac{H_\mu}{\rho V^2}-C_3\left(\frac{TV}{D}\right)^{x_3}$$

By converting to logarithms and addition of the mentioned expressions we obtain the following:

$$\lambda g\frac{H_\mu}{\rho V^2}=\lambda gC+\lambda gC_1+\lambda gC_2+\lambda gC_3+X\lambda g\frac{K\mathfrak{Z}}{\rho V\gamma^2}+$$
$$+X_1\lambda g\frac{h}{D}+X_2\lambda g\frac{\alpha}{KV^2}+X_3\lambda g\frac{TV}{D}$$

After taking antilogarithms:

$$\frac{H_\mu}{\rho V^2}-A\left(\frac{K\mathfrak{Z}}{\rho VD^2}\right)^{a}\left(\frac{h}{D}\right)^{b}\left(\frac{\alpha}{KV^2}\right)^{c}\left(\frac{TV}{D}\right)^{d}$$

Where $A=\sqrt[4]{C\cdot C_1\cdot C_2\cdot C_3}$;

$$a = \frac{X}{4};\quad b = \frac{X_1}{4};\quad c = \frac{X_2}{4};\quad d = \frac{X_3}{4}.$$

The general form of the obtained criterial equation is the theoretical basis for carrying out the deliberate experiments, in order to establish those optimal factors, which provide obtaining the alloyed metal cover, having a maximal hardness.

For obtaining the analysis of the criterial equation, experiments were conducted using the electrosparking alloying device. Restoration of the depreciated parts in various modes. Hard alloy T15K6 was used as anode, micro hardness of the obtained metal cover was measured by PMT_3 device. The obtained results were processed by the least squares method. The tables 4.2, 4.3, 4.4 and 4.5 provide results of our experimental work.

Table 6

Attitude between $\lambda g\pi$ and $\lambda g\pi_1$

H_M	$\pi \cdot 10^{9}$	$\lambda g\pi$	З	$\pi \cdot 10^{11}$	$\lambda g\pi_1$
1700	8.02	19.9042	10	0.14	10.1461
1600	7.55	19.8780	20	0.28	10.4472
1400	6.60	19.8195	30	0.42	10.6233
1300	6.14	19.7882	40	0.57	10.7539
11500	5.43	19.7848	50	0.70	10.8451
11000	5.19	19.7152	60	0.85	10.9294

Table 7

Attitude between $\lambda g\pi$ and $\lambda g\pi_2$

#	H_M	$\pi \cdot 10^{10}$	$\lambda g\pi$	$h \cdot 10^{3}$	$\pi_2 \cdot 10^{-1}$	$\lambda g\pi_2$
1	15000	7.10	19.8513	0.04	0.08	-5.031
2	15500	7.31	19.8639	0.06	0.12	- 5.10792
3	16000	7.55	19.8779	0.08	0.16	-5.1204
4	16500	7.78	19.8910	0.10	0.20	-5.1301
5	16200	7.64	19.8831	0.12	0.24	-5.1380
6	16100	7.59	19.8802	0.14	0.28	-5.1447

Table 8

Attitude between $\lambda g\pi$ and $\lambda g\pi_3$

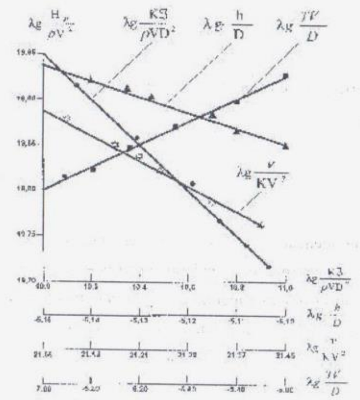
#	H_M	$\pi \cdot 10^{19}$	$\lambda g\pi$	v	$\pi_3 \cdot 10^{21}$	$\lambda g\pi_3$
1	16300	7.69	19.8831	30	1.11	21.0453
2	16600	7.55	19.8780	40	1.48	21.1703
3	15600	7.36	11.8669	50	1.85	21.2672
4	15000	7.10	10.8513	60	2.22	21.3464
5	14500	6.84	10.8325	70	2.60	21.4150
6	14000	6.60	10.8195	80	2.96	21.4713

Table 9

Attitude between $\lambda g\pi$ and $\lambda g\pi_4$

#	H_M	$\pi \cdot 10^{19}$	$\lg\pi$	T	$\pi_4 \cdot 10^{18}$	$\lg\pi_4$
1	16500	7.7877	19.8914	3	18	-6.2552
2	16550	7.8066	19.8925	6	36	-6.5363
3	17000	8.0188	19.9011	9	54	-6.7324
4	16200	7.6415	19.8832	12	72	-6.8573
5	14300	6.7453	19.8295	15	90	-6.9542
6	14000	6.6037	19.8198	18	108	-5.0334

The mentioned results are presented in graphical form on Pic. 5.



Pic. 5 Attitude between $\lambda g\pi$ -and $\lambda g\pi_1$, $\lambda g\pi_2$, $\lambda g\pi_3$ and $\lambda g\pi_4$

As a result of mathematical processing of experimental results we received:

$$C = 9.1 \cdot 10^{19}$$

$$C_1 = 9.08 \cdot 10^{19}$$

$$C_2 = 8.8 \cdot 10^{19}$$

$$C_3 = 6.3 \cdot 10^{19}$$

$$X = 1.2;\quad X_1 = -0.36;\quad X_2 = -0.56;\quad X_3 = 0.84$$

After inserting these values in the criterial equation, we obtain the following:

$$\frac{H_p}{\rho V^2} = 6.9\cdot 10^{-1}\left(\frac{K3}{\rho VD^2}\right)^{0.3}\cdot\left(\frac{h}{D}\right)^{0.09}\cdot\left(\frac{\gamma}{KV^2}\right)^{0.14}\cdot\left(\frac{TV}{D}\right)^{0.21}$$

The adequate examination of the obtained mathematical model has shown that the calculation error does not exceed 3,5%.

Analysis of experimental data and obtained formula shows that the most substantial influence on the hardness of the metal surface obtained through the electrosparking alloying is the strength of the current of a short circuit and the time of restoration. Increasing the strength of the current up to 20 A increases the hardness, then decreases. Also, covering time effects on the hardness.

As the experiments have demonstrated, an intensive transfer of anodic material on the cathode takes in the first minute and therefore hardness increases. The maximum mimcro hardness of the obtained metal surface $H_M = 17000$ Pa have been obtained while having the following values of similarity criteria:

$$\pi_1 = 0.14\cdot 10^{-1}$$

$$\pi_2 = 0.2\cdot 10^{-3}$$

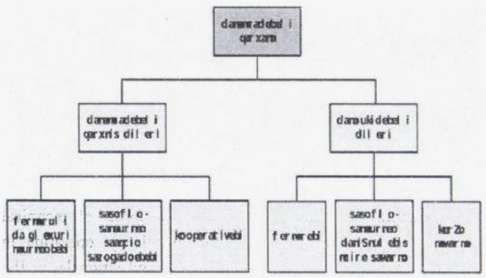
$$\pi_3 = 1.11\cdot 10^{-1}$$

$$\pi_4 = 5.4\cdot 10^{-6}$$

Chapter 5. Procession of rational forms of technical services for the small mechanization machinery, operating in Adjara. Technical services form, acceptable and rationale for the Adjara Region is discussed, based on the world best practices analysis, in this Chapter.

In the nearest transition period, it is necessary to introduce a system of dealer service in Adjara, in which firm technical service system will operate simultaneously. Having 80% of the technical services and repairs of tractors in the developed countries, particularly in the US, are carried out by independent dealers, it is desirable that 90% of the mentioned works were implemented by the dealers' patronage in the first period in Georgia. In the future, these works will be gradually distributed among independent dealers. The specialized repairing workshops can be used as factory-producers and the service centers, general purpose workshops, etc. - as independent dealers.

The organizational structure of the dealer service for Adjara conditions should be selected based on the rational use of existing repairment-service industries. Developed countries offer us a dealer service organization scheme in the agrarian field, which is shown on Picture 6.



Pic. 6 The structural scheme of dealer service in agro-industrial field

Small mechanization machinery service is one of the most important problems for Adjara Region, as there is still no repair workshop, which would provide technical services and repair work of the equipment. An important problem is the determination of the optimal deployment of the mentioned enterprise.

To address this problem, the experience of developed countries, also, the scientific understanding of the problem for selecting the location of the service center, minimum expenditures on agricultural equipment as service facility and other factors, examined by A. Sterzhes, I. Levitski, A. Achkurin and J. Katsitadze, should be taken into consideration. We use J. Katsitadze's method in our study, which takes the mountainous relief of Adjara, soil and climatic conditions and concentration degree of the equipment and constructional peculiarities in separate regions into consideration.

For the implementation of these methods, Adjara regions - Kobuleti, Khelvachauri, Keda, Shuakhevi and Khulo were selected as trial sited, as well as the agricultural machinery existing in the mentioned regions. The necessary material were taken using the geograohical map of the region, as well as the data, provided by the Ministry of Agriculture of Adjara and State Department of Statistics. In particular, the total number of the agricultural machinery of small mechanization in the region, according to their brands, their total weight, distance between the objects, also the coordinates were determined.

In order to find the optimal location for the service centers of the agricultural equipment on the basis of the example of the Adjara Region, first of all, we developed a scheme, showing the location of the service centers and distance between them and only after that we determined the work necessary to perform the transportation works of agricultural objects.

According to the scheme, we determined the following:

$$A_1 = P_2 \cdot S_1 + P_3 \cdot S_2 + P_4 \cdot S_3 + P_5 \cdot S_4 = 391{,}2.30 -$$
$$+ 372{,}6.65 + 537{,}6.95 + 616{,}2.65 = 772{,}8 \text{ MJ.}$$

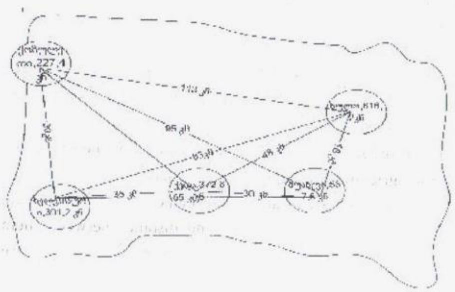
$$A_2 = P_1 \cdot S_1 - P_3 \cdot S_5 + P_4 \cdot S_6 + P_5 \cdot S_7 = 227{,}4.30 +$$
$$+ 372{,}6 \cdot 35 + 537{,}6.65 \cdot - 616{,}2 \cdot 83 = 106 \text{ MJ.}$$
$$A_3 = P_1 \cdot S_2 + P_2 \cdot S_x + P_4 \cdot S_8 + P_5 \cdot S_9 = 227{,}4.65 +$$
$$+ 391{,}2 \cdot 35 + 537{,}6 \cdot 30 + 616{,}2 \cdot 48 = 702 \text{ MJ.}$$
$$A_4 - P_1 \cdot S_3 + P_2 \cdot S_n + P_3 \cdot S_8 + P_5 \cdot S_{10} - 227{,}4.95 +$$
$$+ 391{,}2 \cdot 65 + 372{,}6 \cdot 30 + 616{,}2 \cdot 48 = 693 \text{ MJ.}$$
$$A_5 = P_1 \cdot S_4 + P_2 \cdot S_7 + P_3 \cdot S_9 + P_4 \cdot S_{10} = 227{,}4 \cdot 113 +$$

$$+ 391{,}2 \cdot 83 + 372{,}6 \cdot 48 + 537{,}6 \cdot 18 = 857{,}2 \text{ MJ.}$$

Where A is work spent on equipment transportation, MJ;

P - weight of equipment to be transported;

S - tranportation distance, km.



Pic. 7 Calculation scheme for substantiation of optimal deployment of small mechanization machinery maintenance industry in Adjara.

The studies have shown that Shuakhevi Region can be considered as an optimal location for the technical service and maintenance of small mechanization machinery in Adjara Region.

Conclusions and Recommendations

The following conclusions and recommendations can be made on the basis of the theoretical and experimental work, conducted in the frameworks of the dissertation thesis:

1. The present paper substantiates the peculiarities of small mechanization agricultural machinery work, operating in Adjara mountainous region and their impact on a working capacity is analyzed.

2. Constructive peculiarities of small mechanization machinery and their key defects in mountainous conditions are discussed and the most deprecated parts that have a substantial effect on operational reliability were established.

3. Theoretical basis for calculation of the reliability of mini-techniques, increasing their number and restoration of the depreciated deficit parts with the help of the innovative resource saving technologies is processed on the example of mountainous region of Adjara.

On the basis of analysis of theoretical and experimental works, it was established that the average work of engine blocks on malfunction, operating in Adjara amounts to $\overline{H}$=47H, intensity of malfunctions - $\lambda = 2X10^{?}$ H^{-1}, probability of working without malfunctions - P(H)=0,54, preparedness coefficient – $K_{prep.}$=0,8 and coefficient of technical application- $K_{t.u.}$=0,76 .

Adequate mathematical models are obtained, which allow us to predict reliability indicators.

4. Distribution of the types of malfunctions is studied according to the separate regions of Adjara. It was detected that they are:

- Constructive - 30%;

- Production - 26%;
- Exploitation - 44%.

The biggest share is exploitation malfunctions - 44 %, which can be explained by the peculiarities of working of equipment and low qualification of mechanical engineers.

5. Regularities of parts depreciation of small mechanization machineries, operating in mountainous conditions in Adjara are studied. Differential and integral functions of distribution of parts depreciation of agricultural equipment are determined. Adequate probabilistic statistical models are obtained and the most common (modal) value of part depreciation is determined Mo=0,064 mm, according to which, a rational method for restoration of depreciated parts - electrosparking alloying is substantiated, the relevant device is designed, manufactured and tested and the mentioned device is compact and convenient for farmers.

6. Methodological grounds and separate original methods for studying and optimization of important physical and mechanical characteristics of the obtained metal cover, such as gripping strength, hardness and wear resistance, are processed. Based on the theoretical and experimental examinations, the optimal modes of recovery are obtained.

7. Optimization of the recovery process is carried out by the steep moving (Box-Wilson) method. Optimal modes are the following:

Power	I=18 A
Voltage	V=60 V
Time of electrosparking alloying	T= 4 min.

8. The parts, restored by means of electrosparking alloying, were examined in operation in the mountainous regions of Adjara

(Khulo, Shuakhevi) and it is substantiated that the wear resistance of the parts, restored by means of the mentioned method, increases by 1,5 ... 2,0, comparing with the new parts.

9. Calculation of technical and economic efficiency for the restoration of the depreciated power shield of the engine block by the electrosparking alloying, offered by us, is conducted and it is substantiated that its usage in the case of N=500 part, provides E_{annual} = GEL 6350 annual economic effect.

10. The forecast of small mechanization machinery is calculated for the Adjara Region for the next 10 years by means of the least-squares method.

11. The optimal location for the service centers for the small mechanization machinery in Adjara Region and rational forms of services are substantiated.

12. A business plan is designed, by means of which, the farmers would significantly increase the productivity of agricultural products and earn profits.

13. We recommend technical service centers for the small mechanization machinery to be established in Shuakhevi Region.

The issues, provided in the present dissertation thesis, are published in the following publications:

The following shall be indicated: Surname and title letter of the author (authors), name of the article, name of the journal, year of publication, number (volume), initial and last pages of the paper.

1. Theoretical grounds for calculation and enhancement of the reliability of modern agricultural equipment by means of resource saving technologies for restoration of the depreciated parts. Georgian Academy of Agricultural Sciences "Moambe" #1(35) pp. 148-153. Tbilisi - 2016
2. Automatic device restoring the depreciated parts of agricultural equipment to increase their reliability, Sixth International Scientific-Practical Internet Conference, Collection of works, Kutaisi, 2016, pp. 34...38
3. WEAR RESISTANCE OF THE PLOWSHARES OF THE AGRICULT URAL PLOWS WORKING UNDER MOUNTAINOUS CONDITIONS AND THE INCREASE OF THEIR RESOURCE. IV INTERNATIONAL SCIENTIFIC CONGRESS "AGRICULTURAL MACHINERY 2016" IV, Volume III, issue (18)204, p.12..14, VARNA, BULGRIA, 2016
4. Automatic device restoring the depreciated parts of agricultural equipment to increase their reliability. Sixth International Scientific-Practical Internet Conference, Collection of works, pp. 34...38, Kutaisi, 2016.
5. The number of small mechanization machinery in Adjara and their prediction by the least squares method. Georgian Academy of Agricultural Sciences "Moambe" #2(36) pp. 85-88, თბილისი - 2016

6. Probabilistic statistical modeling of power shield of the engine block. Periodical scientific journal AgroNEWS # 3, pp. 157-163, Kutaisi - 2017'

7. IMPROVING THE RELIABILITY OF AGRICULTURAL MACHINERY, USING THE METHOD OF RESTORATION OF PARTS UNDER SUBMERGED ARC WELDING, AND ITS TECHNICAL AND ECONOMIC EVALUATION. **International journal for science, technics and innovations for the industry** Machines technologies material Scientific technical union of mechanical engineering "INDUSTRY4.0', p. 307 31, Sofia, BULGARIA - 2017.

8. Planning a repair workshop for farming for technical services and maintenance of agricultural machinery. Agrarian-Economic Science and Technologies, 2017 Tbilisi, pp.13-19

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