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Development of Recommendations on the Design of the Grader Based on the Use of Multivariate Parametric Analysis

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Abstract. *The principle of operation, purpose and scope of the grader are considered. The main brands and manufacturers of equipment operated on the territory of the Republic of Kazakhstan are described. Parametric information is collected and systematized. A factor analysis was carried out to determine the relationship of indicators. Cluster analysis was performed to determine homogeneous groups. The structure of the technical level coefficient has been formed. To estimate the coefficient of the technical level, a program for processing statistical data StatGraphicsCenturion was used. A graphical explanation of the results obtained is presented and promising indicators of the machine are determined, which must be taken into account when designing.*

Keywords: *grader, knife, working body, central trend, measure of variability, traction calculation.*

Introduction

Road machines perform both basic work (excavation, improvement of lightweight and transitional road surfaces, construction of asphalt concrete roads, laying cement concrete pavements) and auxiliary (preparatory), and are also used in the maintenance and repair of roads.

Today's equipment market has a fairly wide range of such machines, in this regard, the contractor is faced with the need to choose a greater variety of them.

Not the last place in the construction of highways is occupied by cars called a grader. A grader is a machine equipped with a main blade and additional equipment such as a bulldozer blade, a pickaxe, a snowplow.

Graders are needed for moving, leveling soils and other materials. The design features of these machines allow them to perfectly level the surface in a small number of passes. The classification of graders is carried out depending on the volume of construction work (light, medium and heavy).

With the help of the grader blade, the alignment and planning of the slopes of the roadway is carried out, along with this, the grader uses additional equipment, such as a pickaxe for preliminary loosening, and snow-clearing equipment for cleaning roads in winter, the general view of the grader is shown in Figure 1.

Taking into account the importance of developing grader designs, it is necessary to carry out an expert assessment of the proposed technical solutions. The existing methods of expert evaluation do not give a complete answer to the question of the need to replace a particular node, and also do not provide information about the technical level of products that must be provided for a better solution to the task. In this regard, it is necessary to conduct a more detailed multifactorial analysis of the machine design.

The purpose of the study is to develop recommendations on the design of the grader based on the obtained coefficient of technical level.

The scientific novelty of the work consists in determining the coefficient of the technical level on the basis of a multivariate analysis of parametric data.

Literary review

In the work of the authors [1], the principles of developing the design of security systems based on the use of new automated control technologies are presented. The authors propose the use of modern control systems based on artificial intelligence. In the work of the authors [2], an assessment is given of the use of intelligent control systems for the operation of a hydraulically driven grader. The effectiveness of the use of such systems is presented. The article [3] describes the principle of operation and develops the design of an electrohydraulic control system for the operation of the machine. In a number of other studies [4, 5, 6, 7, 8, 9, 10], much attention is paid to the design of earthmoving machines. This allows us to judge the high importance of conducting research on the development of recommendations for the construction of the machine.

Materials and methods of research

In order to develop recommendations on the design of the grader, the use of StatGraphicsCen-

turion software is proposed. Multivariate analysis of parametric data was carried out in the software environment.

Research results

The indicator of the coefficient of technical level characterizes the trends and prospects for the development of technology, the ability to accurately assess the indicator of technical level allows you to create more competitively capable models of machines, justify the failure or continuation of production, machines, modernization or improvement of the design of working equipment.

Table 1 presents statistical data on the indicators

a b

a) grader; b) grader with snow-clearing equipment

Figure 1 – Grader

Table 1 – Statistical data on the indicators of earthmoving machines (graders)

№	Brand of the earthmoving machines	Weight of the machinery, t	Power of the main unit, kW	Speed of movement equipment, km/h	Width of working mechanism, m	Height of working mechanism, m
1	Volvo G960	17,55	175,5	45,8	3,66	0,63
2	Komatsu GD8	26,5	209,5	44,7	4,88	0,899
3	Komatsu GD675	15,7	149,2	42,1	3,67	0,712
4	Bell 772d	21,2	172,2	41,5	4,28	0,611
5	770 dolaroj	17,8	171,5	41,6	4,26	0,62
6	Mitsuba GR215	17,1	162,2	38,1	4,28	0,61
7	Bell 672d	20,4	138,8	40,2	4,27	0,611
8	GR-180	15,5	128,2	38,1	3,9	0,61
9	XCMG GR165	15,1	125,2	38,8	3,9	0,61
10	GR-165	15,1	114,1	38,1	3,9	0,61
11	Volvo G930	15,89	145,2	45,78	3,6	0,64
12	CAT 24M	61,97	373,3	37,8	7,33	1,07
13	Raŭpo 160	14,61	147,1	40,8	4,28	0,69
14	Volvo G940	16,5	160,4	43,5	3,66	0,73
15	Komatsu GD705A	17,7	149,2	43,2	3,67	0,667
16	Volvo G946	17,2	175,2	43,4	3,66	0,73
17	CAT 20M	11,32	104,2	42,5	3,67	0,62
18	Bell 872d	19,1	194,1	41,1	4,31	0,69
19	GS-18.05	16,35	128,2	40,1	3,67	0,64
20	DZ-98	20,61	173,1	41,2	4,11	0,71
21	BELL 670d	17,15	148,5	41,4	4,28	0,61
22	CMG 618	8,12	95,1	27,5	3,0	0,48

of earthmoving machines (graders) for carrying out work to determine the main links.

To obtain more accurate data, in order to form an equation for determining the technical level of products, we apply the values obtained as a result of processing in the software.

As a result of checking the statistical data on the parameters of the grader, the following was revealed:

- the mass of equipment directly depends on the indicator of the working power of the engine, the coefficient is 0.95;

- the parameter power generated by the engine has a very strong correlation with the height of the main working body of the machine (blade), and the coefficient is 0.88;

- the parameter power generated by the engine also has a very strong relationship with the width of the blade of the machine, and the coefficient is 0.95.

The analysis well describes the relationship of these machine parameters, which is explained by the fact that in order to increase the mass of the machine, the height and width of the blade, it will be necessary to increase the power generated by the internal combustion engine.

Cluster analysis revealed classificationally homogeneous groups of machines. This will allow us to draw conclusions with confidence from the histograms of the distribution. The histogram of the distribution of grader indicators is shown in Figure 3, and the characteristics of the modal intervals of grader indicators are shown in Table 4.

After making calculations and forming indicators, an analysis was formed that provides information about a selection of objects. The values obtained in this case provide us with the opportunity to build histograms of the distribution of indicators. Information on the distribution histogram is shown in Figure 3, and the values of the indicators from the sample

Table 2 – Multivariate analysis on the indicators of earthmoving machines (graders)

	Weight of the grader	Motor grader power	Grader speed	Blade height	Blade width
Quantity	19.0	19.0	19.0	19.0	19.0
Average	19,5995	165,1	41,4	0,67	4,18
Standard deviation	10,7188	56,71	2,6	0,11	0,83
Coefficient of variation	54,6%	34,3%	6,3%	17,5%	19,8%
Minimum	11,358	104,0	37,7	0,6	3,6
Maximum	61,970	373,0	45,7	1,06	7,3
Range	50,592	269,0	8,0	0,4	3,6
Asymmetry	6,70	5,10	0,02	4,2	5,7
Excess	13,60	9,40	-0,90	5,4	10,8

Table 3 – Checking multicollinearity of indicators of earthmoving machines (grader)

	Weight of the grader	Motor grader power	Grader speed	Blade height	Blade width
Weight of the grader		0,95	-0,25	0,85	0,95
		(19)	(19)	(19)	(19)
		0	0,29	0	0,
Motor grader power	0,9537		-0,10	0,88	0,89
	(19)		(19)	(19)	(19)
	0		0,68	0	0
Grader speed	-0,25	-0,1		0,03	-0,40
	(19)	(19)		(19)	(19)
	0,29	0,6834		0,89	0,08
Blade height	0,85	0,8806	0,03		0,78
	(19)	(19)	(19)		
	0	0	0,89		
Blade width	0,95	0,89	-0,4	0,78	
	(19)	(19)	(19)	(19)	
	0	0	0,08	0	

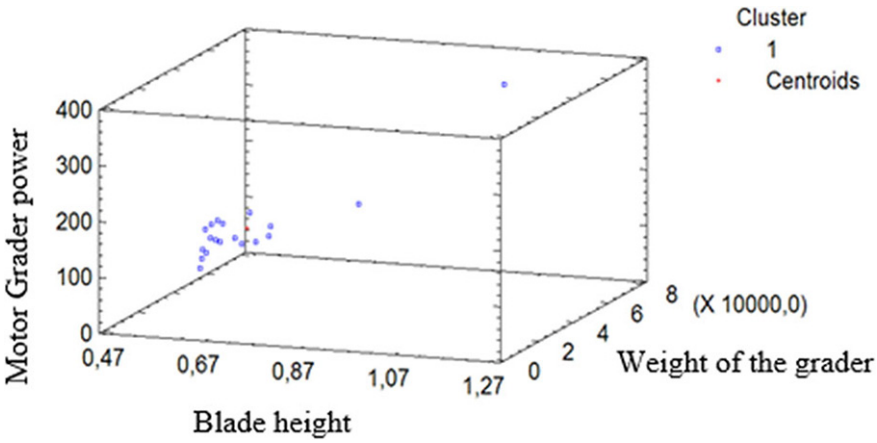
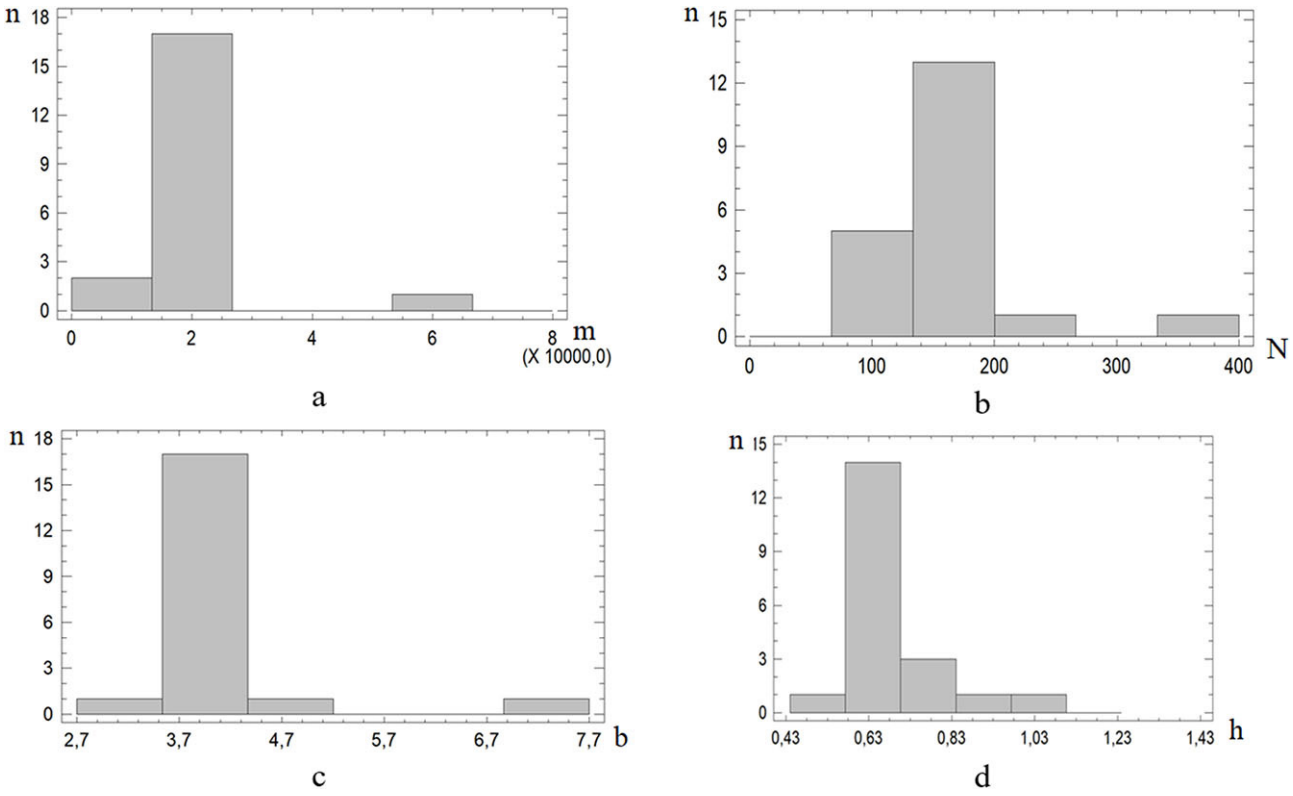


Figure 2 – Cluster analysis of graders



a) the mass of the grader, tons; b) the power developed by the grader kW;
c) the width of the grader blade, m; d) the height of the grader blade, m

Figure 3 – Histogram of the distribution of grader indicators

Table 4 – Characteristics of modal intervals of motor grader indicators

The name of the indicator	Characteristics of the interval with the highest frequency			The number of cars in the interval
	restrictions left	restrictions center	restrictions right	
Weight of the grader, tons	13,3	20	26,6	13
Power, kW	133,3	166,6	200	13
Blade width, m	3,53	3,95	4,36	17
Blade height, m	0,57	0,64	0,76	14

are presented in Table 4. To determine the K_{TLA} (coefficient of the technical level of the autograder), we will use the known equations.

$$K_{TL} = \gamma_b \frac{b_i}{b_{bi}} + \gamma_N \frac{N_i}{N_{bi}} + \gamma_h \frac{h_i}{h_{bi}} + \gamma_m \frac{m_i}{m_{bi}}, \quad (1)$$

where γ_b, γ_N, γ_h, γ_m – accordingly, the weighting coefficients of the indicators are the width of the blade, power, height of the blade, mass;

b_{bi}, N_{bi}, h_{bi}, m_{bi} – accordingly, the basic values of the indicators are blade width, power, blade height, mass. The values of the basic indicators, criteria of significance and the weighting coefficient of the grader are presented in Table 5, and the calculated values are presented in Table 6.

Conclusion and discussion of the results obtained

As a result of the conducted research, statistical data characterizing the relationship between the parameters of the machine were obtained. Based on cluster analysis, statistically homogeneous groups of the machine are determined. Based on the histograms of the distribution, modal intervals are obtained. As a result, the coefficient of the technical level was calculated and promising values of the technical parameters of the machine were obtained.

For motor graders, promising models with a high KTLA index include the following models:

1. CBC MG618;
2. Caterpillar 160M;
3. Bell 872D.

Promising indicators of the motor grader are the following:

- the engine power should be 95 kW with an overall weight of 8.1 tons, a blade width of a meter and a blade height of 0.475 meters;
- the engine power should be 147 kW with the

Table 5 – The value of the basic indicators of the grader

№	Indicator	Basic value	Significance criterion	Weighting factor
1	Weight, tons	20	0,95	0,264
2	Power, kW	166,6	0,75	0,208
3	Blade width, m	3,95	0,95	0,264
4	Height, tons	0,64	0,95	0,264

Table 6 – Calculated values of the motor grader's K_{TLA} indicator

Brand	K_{TLA} (m)	K_{TLA} (N)	K_{TLA} (b)	K_{TLA} (h)	K_{TLA} (gen)
CBC MG618	0,65	0,118	0,200	0,195	1,166
Caterpillar 160M	0,36	0,183	0,285	0,282	1,113
Bell 872D	0,27	0,242	0,287	0,282	1,088
Caterpillar 20M	0,46	0,129	0,244	0,251	1,093
Volvo G940	0,32	0,199	0,244	0,304	1,0702
Volvo G946	0,305	0,218	0,244	0,304	1,072
Bell 670D	0,308	0,184	0,285	0,251	1,030
Volvo G960	0,3008	0,218	0,244	0,261	1,0257
Komatsu GD675A	0,338	0,186	0,245	0,293	1,062
Komatsu GD705A	0,3	0,186	0,244	0,272	1,002
ДЗ-98	0,25	0,215	0,274	0,288	1,035
Volvo G930	0,33	0,181	0,244	0,261	1,021
XCMG GR165	0,35	0,156	0,265	0,251	1,024
Mitsuber GR-165	0,35	0,142	0,265	0,247	1,006
Mitsuber GR-180	0,342	0,159	0,265	0,247	1,015
Mitsuber GR-215	0,31	0,202	0,285	0,247	1,045
Bell 770D	0,29	0,213	0,285	0,251	1,048
Bell 772D	0,25	0,214	0,285	0,251	1,001
ГС-18.05	0,323	0,159	0,244	0,259	0,988
Bell 672D	0,25	0,173	0,285	0,251	0,968

overall dimensions of the mass of 14.6 tons, the blade width of 4.27 meters and the blade height of 0.686 meters;

- the engine power should be 194 kW with an overall weight of 19.4 tons, a blade width of 4.3 meters and a blade height of 0.686 meters.

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Көп факторлы параметрлік талдауды қолдану негізінде автогрейдер дизайны бойынша ұсыныстар әзірлеу

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Аңдатпа. *Автогрейдердің жұмыс принципі, мақсаты және қолдану саласы қарастырылады. Қазақстан Республикасының аумағында пайдаланылатын техниканың негізгі маркалары мен өндірушілері қаралды. Параметрлік ақпарат жиналды және жүйеленді. Көрсеткіштердің өзара байланысын анықтау үшін факторлық талдау жүргізілді. Біртекті топтарды анықтау үшін кластерлік талдау жасалды. Техникалық деңгей коэффициентінің құрылымы қалыптасты. Техникалық деңгей коэффициентін бағалау үшін StatGraphicsCenturion статистикалық деректерін өңдеуге арналған бағдарлама пайдаланылды. Алынған нәтижелерге графикалық түсініктеме берілген және жобалау кезінде ескеру қажет машинаның перспективалық көрсеткіштері анықталған.*

Кілт сөздер: *автогрейдер, пышақ, жұмыс органы, орталық тенденция, өзгергіштік өлшемі, тарту есебі.*

Разработка рекомендаций по конструкции автогрейдера на основе применения многофакторного параметрического анализа

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Аннотация. *Рассмотрены принцип работы, назначение и область применения автогрейдера. Описаны основные марки и производители техники, эксплуатируемой на территории Республики Казахстан. Собрана и систематизирована параметрическая информация. Проведен факторный анализ для определения взаимосвязи показателей. Выполнен кластерный анализ для определения однородных групп. Сформирована структура коэффициента технического уровня. Для оценки коэффициента технического уровня использована программа для обработки статистических данных StatGraphicsCenturion. Представлено графическое пояснение к полученным результатам и определены перспективные показатели машины, которые необходимо учитывать*

при проектировании.

Ключевые слова: *автогрейдер, нож, рабочий орган, центральная тенденция, мера изменчивости, тяговый расчет.*

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