International Journal of Psychosocial Rehabilitation, Vol.24, Issue 09, 2020
ISSN: 1475-7192

Substantiation of Rational Values of the Basic Parameters of a Bulldozer Blade for Leveling Municipal Solid Waste

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Abstract: *Solid waste management is an acute and widespread problem in both urban and rural areas of many developed and developing countries. The collection and disposal, as well as the disposal of municipal solid waste (MSW), is today one of the main environmental problems. Any solution for processing solid waste should be financially sustainable, technically feasible, socially and legally acceptable, as well as environmentally friendly.*

This article is devoted to an urgent problem, the development of a criterion dependence of the leveling process of a solid bulldozer blade with a solid waste dump, which in turn will serve as a link between a theoretical analysis and an experimental study of this process. Based on the established analytical dependencies and restrictions arising from the properties of the waste, as well as on the basis of the accuracy of the measuring instruments, a linear scale is determined. The experimental studies carried out on physical models allowed a simple multiplication of the linear scale by the values of the parameters obtained experimentally from the blade, and rational values of the main parameters of a real bulldozer will be obtained.

Keywords: *municipal solid waste, semblance, criterion, analytical dependence, linear scale, bulldozer, landfill, mathematical model, mathematical theory of experimental design.*

I. INTRODUCTION

The increase in population, rapid urbanization, rapid growth of the economy and improving living standards in developing countries have significantly accelerated the pace, quantity and quality of solid waste generation (MSW) [1, p. 1275-1276; 2, p27-28;].

Solid waste includes waste generated in residential and public buildings, trade, sports and industrial enterprises, fallen leaves, bulky waste [3, p. 6-9; 4, p. 11-12; 5, p. 16-17; 6, p. 76-77].

Recently, there has been a decrease in the density of solid waste due to the increased content of paper and plastic in them (mainly due to packaging materials). The composition of MSW in different countries is not fundamentally different, and therefore the problems of their storage, disposal, disposal or processing are largely identical.

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Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019

However, this does not mean that in solving these issues it is possible to use some universal method of MSW management, since each country and each region has its own specifics [7, p 1-2]. In our opinion, this specificity is as follows:

- system for the collection and transportation of solid waste (separate or mixed);
- climatic zone (northern, temperate, southern);
- the level and lifestyle of people (average annual income per capita).

But, one of the fundamental is a separate type of waste collection and transportation system, to which, most EU countries have switched [8, p. 41-42; 8]. Separate waste collection has a number of undeniable advantages. With a separate collection and transportation method, the components of solid waste are pre-sorted, which eliminates the need for preparatory waste sorting. In addition, with a separate method of collecting and transporting the waste components retain their original form, which favorably affects the quality of secondary raw materials. In the case of mixed collection and transportation, the components of the waste mixed with food waste become unusable and thereby increase the negative impact of the waste on the environment. Recognizing the versatile benefits of separate collection and transportation of waste, Uzbekistan is also taking practical steps to move from mixed to separate collection, in particular, the President of the Republic of Uzbekistan adopted April 17, 2019, PP-4291 “On approval of the Strategy for the management of municipal solid waste in the Republic of Uzbekistan”, Uzbekistan for the period 2019-2028” [9, p. 19-20], which clearly indicates the terms for a staged increase in the percentage of solid waste processing in the Republic, as well as the timing of the transition to separate collection. Unfortunately, despite the adopted resolution at this stage, it is rather difficult to organize separate waste collection everywhere. The reason for this is not only the unpreparedness of the population, but also the lack of appropriate living conditions and technical support, in particular, for a separate way of collecting and transporting solid waste, a certain number of garbage trucks are needed, adapted for separate transportation of waste.

An analysis of the literature on the problem of processing solid waste on a global scale showed that the main type of waste processing in developing countries is their disposal at landfills. The main parameters of bulldozers and compactors used for landfill disposal at landfills are designed for soil development, therefore, when leveling solid waste, the traction forces of the above machines are underutilized. The basis for the creation of efficient and economical (energy-efficient) road cars is the solution to the issue of reducing the specific energy consumption of the process of digging and leveling solid waste. So, for a bulldozer, this issue is closely related to the characteristics of the dumping tool, since the resistance to digging and movement of the MSW prism depends on the shape of the transverse profile of the blade. In this case, of particular interest are issues of improving the working equipment, the selection of rational parameters of the dumping organs, that is, the geometric parameters of the dozer blade at which the lowest specific energy consumption of the working process is achieved. In this regard, the question of determining the basic parameters of dozer dumps is an urgent task.

The wide variation of the properties of solid waste components, as well as their significant heterogeneity, does not allow the development of a clear mathematical model that describes the process of leveling waste at landfills. Conducting research in natural objects of technology is very laborious and has large material costs. Therefore, to establish the regularities of the digging process, as well as the dependencies between the parameters in the form of criterial dependencies, it is necessary to use methods of physical modeling. In addition, methods of physical modeling will significantly reduce the cost of experiments, including those aimed at testing analytical solutions.

II. MATERIALS AND METHODS

Literature review. Researchers such as V.I. Balovnev, G.V. Kustarev, N.D.Seliverstov [10, p. 75-80], T.I. Askarkhodzhaev [11, p. 83-86], K. Wiemer [12], T.K. Khankelov, A.K. Honkelov [13, p. 1-5], L.E. Sorokin [14, p. 1-

5], N. D. Sergeev, N. I. Tokar, S. L. Guzenok [15, p. 1-8], V.P. Lozhechko, V.I. Okunev, R.D. Okulov [16] and others.

The design, calculation, optimization of the parameters and operating modes of the bulldozer cannot be considered without the connection of the machine and working equipment with the external environment and other factors determining the conditions of their operation. It is necessary to take into account the random nature of the factors of influence. Obviously, it follows from the above that the physicomechanical and strength characteristics of MSW should be considered as the main quantities that determine operating conditions and have a stochastic nature [17, p. 45–46]. Obviously, the physical and mechanical properties of the waste include their morphological and fractional compositions, as well as their morphological composition depending on the size of the fractions. In addition, we need data on their strength properties.

In accordance with the task of creating a rational construction of the bulldozer blade, checking the theoretical conclusions and substantiating the main parameters and operating modes of the bulldozer, the following questions are included in the experimental research program:

1. The study of the physical and mechanical properties of solid waste arising in the city of Tashkent, in particular: determination of the morphological composition of the waste; determination of fractional composition of waste; determination of the morphological composition of the waste, depending on the size of the fractions.
2. Development of similarity criteria for the leveling of solid waste by the dimensional analysis method.
3. The justification of the linear scale of the physical model and the definition of the transition formulas from model to nature.
4. Development of a physical model of the blade and experimental studies on a physical model.
5. The transition from the values obtained on the model to natural values.

To study the morphological and fractional composition of solid waste, as well as the morphological composition, depending on the size of the fractions, 10 waste collection points were selected in the city of Tashkent (Republic of Uzbekistan):

- The city of Tashkent, the otchopar-1 makhalla;
- Tashkent city, “Kizil Dekhkon” makhalla;
- Tashkent city, Yunusabad district, 11th quarter;
- Tashkent city; Yunusabad district, 11th quarter;
- Tashkent city, Yunusabad district, 13th quarter;
- Tashkent city, Yunusabad district, 13th quarter;
- Tashkent city Yunusobod district, 15th quarter;
- Tashkent city Yunusobod district, 15th quarter;
- Tashkent city Yunusobod district, 19th quarter;
- Tashkent city Yunusobod district, 19th quarter;

The studies were carried out for three years, according to the seasons, i.e.: in winter, spring, summer, autumn. The average percentage of the total mass of waste was calculated for all ten objects and the average annual value was determined. The determination of the morphological composition was carried out in raw waste, i.e. in waste in their natural state. The weight of each sample was 30 kg. The methodology for determining the morphological composition of household waste was as follows: the waste was leveled on a tarpaulin with dimensions (2000 2000 mm), after leveling, the tarpaulin area was divided into four parts, waste from ¾ was thrown away, and ¼ part of the waste was used for analysis (quarting method) [18] .

After that, the analyzed part of the waste was leveled on a tarpaulin and each component of the waste was separated from each other. The percentage of constituent wastes was determined by the formula [19, p. 15-17].

, (1)

Where the percentage of constituent waste, %; mass of constituent waste, kg; total mass of waste, kg.

The value of the constituent components of MSW — the fractional composition was determined by successive sieving of samples weighing 30 kg on sieves with mesh sizes 250 250; 150 150; 100 100; 50 50; 15 15 mm.

The repetition of experiments with each option was taken three times. To conduct a series of experiments, 10 medium samples weighing 30 kg each were also prepared. The results of the experiment to determine the morphological composition of solid waste occurring in the city of Tashkent are presented in Table

Table 1-Morphological composition of municipal solid waste arising in the city of Tashkent

Waste composition	2017					2018					2019				
	Winter	Spring	Summer	Autumn	Wed for a year	Winter	Spring	Summer	Autumn	Wed for a year	Winter	Spring	Summer	Autumn	Wed for a year
Paper, cardboard	28,7	28,0	25,0	25,2	26,7	29,0	29,8	28,0	26,1	28,2	30,1	30,3	29,8	30,5	30,2
Food waste	30,4	30,2	33,7	34,5	32,2	32,3	31,5	33,5	37,2	33,6	33,2	32,5	35,1	35,0	34,0
Tree, leaves	4,7	5,7	5,8	6,0	5,6	3,2	4,2	3,7	3,5	3,7	3,5	4,2	2,8	2,0	3,1
Black metal	3,5	3,6	3,2	3,0	3,2	3,0	2,1	3,0	2,5	2,7	1,5	1,7	1,5	1,5	1,5
Non-ferrous metal	0,5	0,2	-	0,2	0,2	-	0,3	0,2	-	0,13	-	0,2	-	0,2	0,1
Bones	3,4	3,0	2,6	3,0	3,0	3,0	2,5	2,8	3,5		2,5	2,7	2,3	2,3	2,5
Leather, rubber	1,5	2,0	2,1	2,2	2,0	1,5	2,5	2,2	2,0	2,1	1,5	1,2	1,5	1,7	1,5
Textile	4,0	3,5	3,0	3,0	3,4	3,5	3,0	3,5	3,0	3,3	2,8	3,0	2,5	3,0	2,8
Glass	3,8	4,2	4,5	4,2	4,2	3,2	3,0	3,7	2,5	3,1	2,0	2,0	1,8	1,5	1,8
Stones, ceramics	1,8	1,5	1,4	1,5	1,6	1,5	1,5	2,0	1,8	1,7	2,0	2,1	1,5	1,5	1,8
Plastic	7,8	8,0	8,5	8,2	8,1	8,0	7,8	8,2	8,1	8,0	8,3	8,3	9,0	8,7	9,1
Screening less than 15 mm	2,0	2,5	3,0	3,0	2,6	2,2	2,7	1,8	2,2	2,2	3,6	2,2	2,0	2,1	2,5
Other	7,9	7,6	7,2	6,0	7,2	9,6	9,1	8,4	7,6	8,7	9,0	9,7	10,1	10,0	9,7
	100	100	100	100		100	100	100	100		100	100	100	100	

Analysis of table 1. shows that the content of paper and plastic in the waste increases, as well as the percentage of other waste.

The fractional composition of solid waste is determined by its constituent components, i.e. morphological composition. So, the more fractions in food waste having mainly dimension less than 50 mm, the smaller fractions in its composition. Conversely, if more packaging materials (paper, wood) having a dimension of more than 150 mm fall into the general waste stream, a significant proportion of the waste mass will fall into a large fraction. To determine the fractional composition of MSW, a sieve was created with a mesh size of 250 to 250 mm; 150x150 mm; 100x100 mm; 50x50 mm; 15x15 mm.

Fig. 1. General view of the bench for determining the fractional composition of solid waste

For the experiment, 10 samples weighing 30 kg were prepared.

The results of the experiment to determine the fractional composition of solid waste are presented in table 2.

Table 2-Fractional composition of solid waste arising in the city of Karshi.

№ p / p	The residue on the sieve mesh size, mm (%)					
	250 × 250	150 × 150	100 × 100	50 × 50	15 × 15	Screening less than 15 mm
1	4,5	5,8	21,6	24,5	40,6	3,0
2	-	7,9	22,8	22,0	45,5	2,5
3	3,5	4,2	18,0	26,5	44,8	3,0
4	-	6,4	25,0	24,8	40,8	3.0
5	-	5,9	23,6	26,9	41,0	3.0
6	2,5	4,5	25,0	28,7	36,8	2,5
7	-	6,0	27,5	25,5	39,0	2,0
8	3,0	5,5	22,5	24,0	42,5	2,5
9	-	7,5	20,5	26,5	43,7	1,8
10	-	6,0	23,5	24,8	42,9	2,8
Mean	1,35	6,0	23,0	25,4	41,7	2,6

Analysis of table 2 shows that the bulk of the waste have a dimension of less than 150 mm. But on the other hand, the fractional composition of the waste is interconnected with its morphological composition.

Table 3 shows the results of an experiment to determine the morphological composition of MSW depending on the size of the fractions (in% of the weight of the residue on individual sieves).

Table 3-The morphological composition of MSW, depending on the size of the fractions

Components	>250	150-250	100-150	50-100	15-50	<15
Paper, cardboard	17	28	26	15	4	-
Food waste	-	-	8	16	47	22
Plastic	36	20	22	20	-	
Tree, leaves, estimates	24	22	7	5	4	38
Textile	4	10	16	14		

Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019

Bones	14	8	11	24	10	-
Glass	-	2	4	-	12	
Leather, rubber	-	4	6	-	-	-
Metal	-	2	2	2	5	-
Stones, ceramics	-	-	2		10	4
Other	5	4	6	4	8	24
Dropout (<15 mm)	-	-	-	-	-	12
Total	100	100	100	100	100	100

The analysis of table 3 shows that on sieves with cells of 15 to 15 mm, the bulk of the waste is the share of food waste. More than half of the paper waste falls into fractions with a size of 100-250 mm.

To determine the similarity criteria for the process of leveling solid waste with a bulldozer blade, we use the dimensional analysis method [20, p. 30-31]. The choice of this method for determining the similarity criteria is explained by the fact that the properties of the MSW components vary widely, and their significant heterogeneity does not allow us to develop a clear mathematical model that describes the process of leveling waste at landfills.

From the studies conducted to determine the rational shape of the transverse profile of the blade of a bulldozer during the development of solid waste at landfills, it was found that a direct dump is the most suitable due to low energy intensity indicators.

Consider the system of solid waste - dozer blade (Fig. 2).

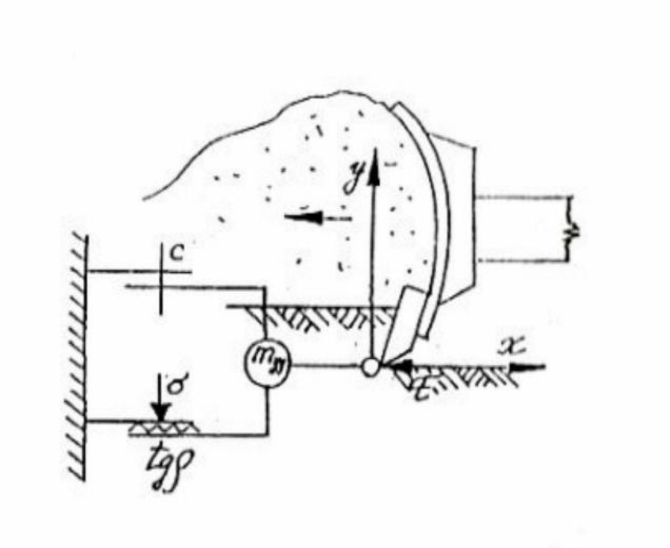

Fig. 2: Schematic diagram of the development of solid waste by a dozer blade and the rheological equivalent of the process.

For a given curvature, the blade can be determined by the following parameters: dyne B , height H , and cutting α angle. The digging mode is determined by the depth of h cut, the speed of the blade ϑ and the acceleration of g gravity. MSW is considered as a medium characterized by c adhesion, the angle of internal ρ friction and external φ friction, and bulk δ density.

The digging force in this case will be

$$P = (B, H, \alpha, c, \rho, \varphi, \delta, h, \vartheta, g) \text{, (2)}$$

The process of digging solid waste with a bulldozer blade is characterized by 11 physical quantities. We define the similarity criteria for this process, in our case. From the consideration of these quantities it follows that three of them ($\alpha, \rho, \varphi)$ in themselves, are similarity criteria. Dimensions of other physical quantities $11-3=8$ can be expressed in

Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019

three basic units of measurement - P, length L and time T.

Let us write the formula for the dimensions of these quantities:

$$[B]=[H]=[h]=L;\ [P]=P;\ [c]=PL^{-2};\quad [\delta]=PL^{-3};\ [\vartheta]=LT^{-1};\quad [g]=LT^{-2}.$$

To find an additional number of similarity criteria, one should choose for basic quantities with independent dimensions, which would include all the basic units of measurement. In our case, we take the following three quantities with independent dimensions: $\delta, B, g\ (m=3)$. Then it remains to find 8-3 = 5 similarity criteria. To find the criterion $\ddot{I}_1$, we take, for example P, the dimension of the parameter and write it in the numerator, and write in the denominator by the product of the dimensions of the quantities δ, B, g with the degrees of degrees unknown so far a_1, a_2, a_3.

$$\ddot{I}_1=\frac{(P)'}{(PL^{-3})^{a_1}(L)^{a_2}(LT^{-2})^{a_3}},\ (3)$$

The exponents are determined by equating each other with the dimensions of the numerator and denominator so that a dimensionless complex is obtained. So, with

$a_1=1$, $a_2=3$, $a_3=0$ we get

$$\ddot{I}_1=\frac{(P)'}{(PL^{-3})'(L)^3},\ (4)$$

Подставим вместо размерностей символы физических величин. Тогда, возводя эти величины в указанные степени, окончательно получим

$$\ddot{I}_1=\frac{P}{\delta B^3},\ (5)$$

In the same way we get the remaining similarity criteria. We write down all the similarity criteria:

$$\ddot{I}_1=\frac{P}{\delta B^3},\ \ddot{I}_2=\frac{\vartheta^2}{\mathrm{gB}},\ \ddot{I}_3=\frac{\mathrm{h}}{\mathrm{B}},\ \ddot{I}_4=\frac{\tilde{n}}{\delta\hat{A}},\quad \ddot{I}_5=\frac{\hat{A}}{\acute{I}},\ \ddot{I}_6=\alpha,\ \ddot{I}_7=\rho,\ \ddot{I}_8=\varphi\ (6)$$

According to the $\pi-$theorem [21, 13-14], we replace function (2) with the criterion equation. To do this, we write one of the criteria in the function of the other similarity criteria and obtain an expression in the criterial form:

$$\frac{P}{\delta B^3}=f(\frac{c}{\delta B},\frac{B}{H},\frac{h}{B},\frac{\vartheta^2}{gB},\alpha,\rho,\varphi),\ (7)$$

Now we must identify the relationship between the scales of physical quantities. We establish this connection using the formula for establishing similarity indicators. To determine the similarity indicator, you need to divide the similarity criterion for nature by the similarity criterion for the model. For example, a relationship of k_p scale to other scales will be

$$\frac{k_p}{k_\delta k_B^3}=1$$

In the same way, we determine the relationship of the remaining scales. Then we get

The next series of equations is a series of equations of communication between the scales of parameters that determine the process:

$$\frac{k_p}{k_\delta k_B^3}=1;\ \frac{k_c}{k_\delta k_B}=1;\ \frac{k_B}{k_H}=1;\ \frac{k_h}{k_B}=1;\quad \frac{k_\vartheta^2}{k_g k_B}=1;\ k_\alpha=k_\rho=k_\varphi=1,\ (8)$$

Now you should choose independent scales. They can be any of the available scales, however, based on the convenience of modeling, it is better to choose independent scales k_δ, k_h, k_g. Then the remaining scales are determined on the basis of the obtained equations

$$k_P=k_\delta k_B^3;\ k_c=k_\delta k_B;\ k_H=k_h=k_B;\ k_\vartheta=\sqrt{k_g k_B};\ k_\alpha=k_\rho=k_\varphi=1,\ (9)$$

Based on the conditions for the possibility of setting up experiments, we take $k_\delta=k_g=1$, since modeling physical quantities δ and g is very difficult. Then the experiments will be carried out under conditions of approximate physical modeling, and the scales of physical quantities will be determined by the linear scale of the model:

$$k_P = k_B^3;\ k_c = k_H = k_h = k_B;\ k_\vartheta = \sqrt{k_B};\ k_\alpha = k_\rho = k_\varphi = 1, \quad (10)$$

When determining the scale k_ϑ, it should be borne in mind that the digging speed for full-scale traditional machines is low (0.75 1.0 m / s) and therefore does not significantly affect the digging force. In these cases, the criterion $\ddot{I}_2$ cannot be met, as a result of which it is possible to conduct experiments in conditions of approximate physical modeling.

At the next stage of the study, we will decide on a linear scale.

a) the allowable volume of the medium interacting with the model of the working working body

$$\Delta V \geq 200 d^3, \quad (11)$$

where $d -$ the average linear size of the particles that make up the medium;

b) the accuracy of measuring instruments

$$k_B = \sqrt[4]{\frac{P_0 \Delta_1 \times 100}{P_{\max} k_{T.\ddot{I}}}}, \quad (12)$$

Where $P_0 -$ is the maximum force of the original, kH; $\Delta_1 -$relative measurement error when testing the original (usually up to 15%); $P_{\max} -$ maximum force for which the scale of the device is designed in kH; $k_{T.\ddot{I}} -$instrument accuracy class (usually up to 2.5%)

So, taking $P_0 = 35$ kH; $P_{\max} = 10$ Kh; $\Delta_1 = 10$; $\hat{e}_{T.\ddot{I}.} = 2.5$ get

$$\hat{e}_B = \sqrt[4]{\frac{35 \times 10 \times 100}{10 \times 2.5}} \approx 6.2, \quad (13)$$

Using dependence (12), we determine the linear scale of the model from the limiting volume of the medium interacting with the model.

The volume of solid waste in front of the dozer blade is determined depending on the length of the full blade B and its height H according to the formula.

$$V = \frac{BH^2}{2tg\rho}, \quad (14)$$

where $\rho -$ is the angle of repose of the MSW prism in front of the blade. Then substituting the value of expression (11) in terms of the model, we obtain

$$\frac{1}{2} \times \frac{B}{\hat{e}_B} \times \frac{H^2}{k_B^2 tg\rho} \geq 200 d^3$$

it follows that

$$k_B \leq \frac{1}{d} \times \sqrt[3]{\frac{BH^2}{400 tg\rho}}$$, Taking B=2,85м; H=0,9м; $\rho = 60^0$; $d = 45$ mm, we get

$$k_B \leq \frac{1}{45} \sqrt[3]{\frac{2850 \times (900)^2}{400 \times 1.74}} \leq 3.6 \quad (15)$$

From the two scales obtained (6.2 and 3.6), we select the smaller value, that is, 3.6. According to the chosen scale, a model should be built and the planned experimental studies should be carried out.

Based on the data obtained, a physical model of the blade with a linear reduction scale of 3.5 was developed. But since, when developing solid waste, the traction efforts of the bulldozer are underutilized, a decision was made to increase the efficiency of using the bulldozer to supply the bulldozer blade with side flaps. When excavating the soil, side flaps are placed perpendicular to the plane of the blade, thus they are not used in the process of excavating. When developing MSW, the side flaps are brought into working position.

Fragments of the experiment at the stand of physical modeling of the process of digging the soil and the process of digging the components of solid waste are shown in Figures 3 and 4.

Figure 3: The process of digging soil at a physical modeling bench with closed openers.

Here we consider the most general case of the digging process, i.e., combining digging with a set of drawing prisms.

Fig. 4. The process of digging the components of solid waste at the bench of physical modeling with the openers operating position.

Here we also consider a more general case of the process i.e. the process of digging the components of solid waste with the combination of a set of prism drawing.

When preparing the MSW model, it is very laborious to control the magnitude of particle adhesion on a shear device. A number of researchers have established correlation dependencies between the cohesion of the components of solid solid waste and the number of strikes of the DorNII striker. On this basis, under conditions of approximate physical modeling, the amount of adhesion can be controlled by this indicator, changing it in proportion to the scale of the model.

The transition from the model parameters to the parameters of nature is carried out according to the formulas resulting from the equality of the criteria for similarity between the model and nature. For example, to find the transition formula by the criterion $(\frac{h}{B})_H = (\frac{h}{B})_M$. Then $\frac{h_H}{B_M k_B} = \frac{h_M}{B_M}$, from here $h_H = h_M k_B$

In the same way, we learn the transition formulas from the model parameters to the original parameters

$$P_H = P_M k_B^3,\ H_H = H_M k_B,\ B_H = B_M k_B,\ h_H = h_M k_B,\ \rho_H = \rho_M,\ c_H = c_M k_B,$$

$$\alpha_H = \alpha_M,\ V_H = V_M \text{ или } V_H = V_M \sqrt{k_B} \quad (16)$$

In general, finding the form of function (7) is very difficult. It is possible to search for individual particular relationships, for example, to determine the relationship between the digging (leveling) force and the digging depth of solid waste.

$$\frac{P}{\delta B^3} = F(\frac{h}{B}), (17)$$

Assuming in a first approximation a proportional dependence, we have

$$\frac{P}{\delta B^3} = k\frac{h}{B} \Rightarrow P = k\delta hB^2, (18)$$

The value of the constant can be determined in a certain range of modes from experience. In the same way, you can find the relationship between the digging (leveling) force and the basic parameters of the blade ie, B length and H height.

$$\frac{P}{\delta B^3} = F_1(\frac{H}{B}), (19)$$

$$\frac{P}{\delta B^3} = k_1\frac{H}{B} \Rightarrow P = k_1\delta HB^2, (20)$$

The value of the constant can be determined in a certain range of modes from experience.
Finally, the dependence of the digging (leveling) of MSW is of interest.
and MSW cutting angle for some blade lengths B .

$$\frac{P}{\delta B^3} = F_2(\alpha), (21)$$

$$\frac{P}{\delta B^3} = k_2\alpha \Rightarrow P = k_2\delta\alpha B^3, (22)$$

Similarly, the value of the constant can be determined in a certain range of modes from experience.

According to the methods of mathematical planning of experiments by priori ranking based on a review and the data from one-way experiments, the main controlled factors that influence the effort of digging solid waste were established.

This dependence is generally written as

$$Y = f(h, \alpha, B), (23)$$

where $h-$ MSW digging depth, mm; $\alpha -$ MSW cutting angle, degrees; $B-$ blade length, mm; $Y-$ the value of the digging force of the components of solid waste, N.

The relationship between input and output factors is represented as a regression equation

$$y = b_0 + \sum b_i x_i + \sum b_{ij} x_{ij} + \sum b_i x_i^2, (24)$$

црукy $y-$ value of the investigated optimization parameter; $x_i -$ coded factor values ($i = 1,2,3$) $b_i -$ estimation of the regression coefficient of the corresponding $i-$ factor; b_{ij-} estimation of the coefficient of the regression equation corresponding to the interaction of factors.

The experiments were carried out according to plan B_3 [22, c 227-230], as it is the least labor intensive compared to other plans. Moreover B_3 - optimal plans provide minimum sensitivity of coefficient estimates, and also reduce the number of experimental points with varying factors at three levels. To test the reproducibility of experiments, i.e. To test the hypothesis of homogeneity of variances with the same number of repeated experiments, the Cochren criterion was used, and the significance of the coefficients of the regression equation was determined using the

Received: 10 Nov 2018 | Revised: 20 Dec 2018 | Accepted: 02 Jan 2019

Student criterion at a confidence level of 0.05.

The ability to describe the response surface well enough, i.e. The adequacy of the process model was checked using the Fisher criterion.

The model is considered adequate provided

$$F_{pac} \langle F_{\text{蜞犭}} , (25)$$

Table 4 shows the levels of factors and their intervals of variation.

Levels of factors and intervals of their variation.

Table 4

	Factors	Code Identification	Factor levels		Inter var.		Dimension
			1	+1			
	Digging depth	X1	50	75	100	5	mm
	Cutting angle	X2	45	55	65	0	hail
	Blade Length	X3	560	700	840	40	mm

III. EXPERIMENTAL RESULTS

After processing the experimental data and assessing the significance of the regression coefficients, a mathematical model of the digging force of the components of solid waste was obtained.

$$Y = 32{,}6 + 7{,}4X_1 + 3{,}4X_2 + 2{,}7X_3 - 3{,}3X_1^2 + 2{,}4X_2^2 - 1{,}8X_3^2, \quad (26)$$

Checking the adequacy of the model according to the Fisher criterion showed that with 95%
the reliability of the mathematical model is adequate

$$F_{pac} = 0{,}95, F_{\text{蜞犭}} = 2{,}36 \quad , (27)$$

In order to determine the rational values of the factors of equation (26), it was studied for an extremum, the results of which are given in table 5

Rational values of factors

Table 5

Factor values	Factors		
	X1, мм	X2, hail	X3, mm
Coded	1	-0,142	0,2

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Natural	100	52,7	778
Rounded	100	53	778

Substituting the coded values in the formula (26) we obtain the rational value of the digging effort on the model. Using the dependence (16), we obtain the values on the full dump.

$$P_H = P_M k_B^3 = 37{,}12 \times (3{,}5)^3 = 1592H\,;\ H_H = H_M k_B = 0{,}3 \times 778 \times 3{,}5 = 817\,\text{祆}\,;$$

$$B_H = B_M k_B = 778 \times 3{,}5 = 2723\,\text{祆}\,;\quad h_H = h_M k = 100 \times 3{,}5 = 350\,\text{祆}\,;\ \alpha_{\acute{\imath}} = \alpha_{\grave{\imath}} = 53^0\,;$$

$$\rho_H = \rho_M = 42^0;\ \varphi_H = \varphi_M = 27^0;\ c_H = c_M k_B = 1 \times 3{,}5 = 3{,}5\,.$$

IV. CONCLUSION

1. When using bulldozers for digging and leveling solid waste, their traction efforts are underutilized, as the main design and technological parameters of the bulldozers are designed for soil development. In this regard, studies aimed at the development and justification of rational values of the main parameters of the dozer blade are relevant.

2. A criterion dependence has been developed between the main parameters that affect the process of digging and leveling solid waste, which in turn makes it possible to conduct experiments using similarity criteria.

3. The developed methodology for conducting experimental studies allowed us to determine the morphological, fractional composition of solid waste and the morphological composition depending on the size of the fraction of the components of solid waste.

4. The results of experiments to determine the physical properties of MSW allowed us to conclude the following: the content of paper and plastic in the composition of MSW increases. The volumetric weight of waste is reduced due to an increase in the content of paper and plastic in the composition of solid waste. Therefore, it is necessary to reconsider the norms for the accumulation of solid waste in residential areas, primarily because the adopted standards relate to 2011.

5. A mathematical model of the process of digging and leveling solid waste with a bulldozer blade was developed, i.e., the dependence of the digging force (leveling) on the main process parameters.

6. The rational parameters of the bulldozer blade are established.

- dozer blade length for a natural machine:
- without postcards (when digging and leveling the ground) -2800 mm;
- with postcards (when digging and leveling solid waste) -3200 mm.
- -height of a dozer blade for a natural machine:
- without trellised peak (when digging and leveling soil) -850 mm;
- with trellised visor (when digging and leveling solid waste) -1100 mm;
- digging depth of MSW-350 mm;
- MSW cutting angle - (520-550) hail.

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