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# THE ANALYSIS OF THE STEPPING MACHINES CONSTRUCTIVE FEATURES INFLUENCE ON THE INTERACTION OF THE SKIS SUPPORTING SURFACE WITH GROUND

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***Summary**: The stepping machines constructive features influence on the interaction of the skis supporting surface with ground is analyzed. The comparison is justified with the known stepping mover's constructive features. It is determined that the necessity of the supporting elements using increases the adhesion strength of the stepping machine with ground greatly. The experimental research of the change in the adhesion strength at the stepping mover cycle beginning has confirmed that the "chevron" supporting element of the skis has more adhesion with ground than those with straight supporting elements. The experimental research results concerning the stepping mover power characteristic dependence on the supporting element of the skis height, the pressure of the skis on the ground and the displacement force allow us to determine the optimal skis construction of the stepping motor.*

***Key words**: stepping mover, analysis, the stand of the skis adhesion with ground experimental research, supporting surface of the skis, supporting elements of the skis.*

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**Statement of the problem.** Stepping machines can move on different soils. Stepping machines require less energy when moving on wet and soft soils in comparison with tracked and wheeled vehicles. Therefore, the research of the interaction between the skis supporting surface and the stepping motor with the soil is relevant.

**The Objective of the work.** The analysis of the stepping movers construction.

**Statement of the task.** In this paper, the known constructional characteristics are used to analyze the construction of stepping machines. The using of the supporting elements on the stepping motors skis is determined as necessary.

**Analysis of the stepping machines.** The first stepping machine was invented by P. Chebyshev. He called his invention "a stopping machine" (Fig. 1) [1 – 5].

The machine was based on the lambda mechanism of Chebyshev. The body of the machine moves horizontally forward, leaning against a ground with the help of a shoe. The shoe moves along a curve in the air when it separates from the ground. This curve resembles the trajectory of the pedestrian foot.

This is the first stepping mechanism in the world that received general approval at the World Exhibition in Paris in 1878 [1]. Nowadays, the scientific works of P. Chebyshev are relevant, since most of the stepping machines are based on Chebyshev's lambda mechanism.

The company "Monighan Machine Company" used the first stepping mechanism in the construction of dragline in 1913. In Ukraine, the first stepping machine which was developed and constructed at the Novokramatorsk machine-building plant (NKMZ) appeared in 1948. This is a stepping excavator ES-1 (Fig. 2) which was the first domestic construction of the machine. He had a bucket capacity of 3.4 m and an arrow in length 37.5 m. The drive mechanisms were carried through alternating current [6 – 11].

Due to the hard impact of the AC motors mechanical characteristics on the excavator parts, large dynamic loads were created, for this reason, the ES-1 excavator was not reliable in operation.

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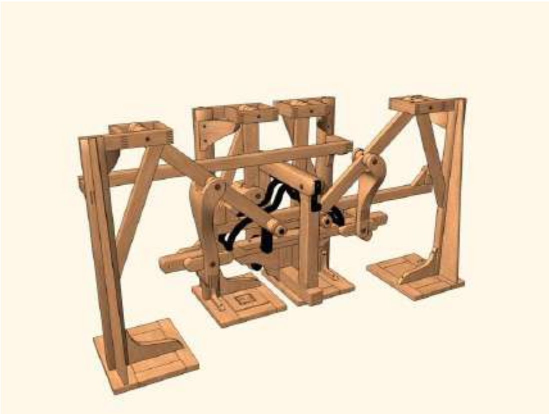


**Figure 1.** Stepping machine

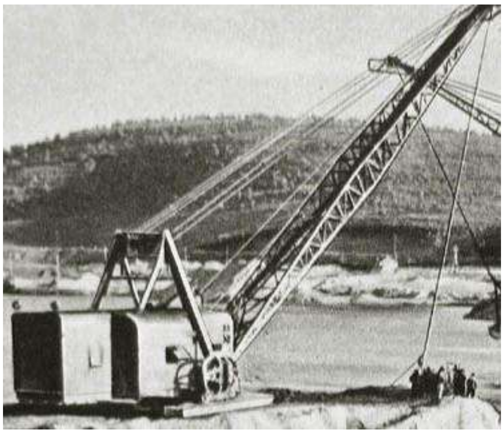


**Figure 2.** Walking Excavator ES-1

The walking excavators, draglines ES-1, were used on Volgodonbud in 1949 – 1952 for the first time. They were used on those sections of the navigable canal and the Donskoy main canal, where the excavation of the soil prevailed over the transport-transport scheme [7].

The construction of a four-hinged stepping motor was invented on the NKMZ in 2002 (Fig 3) [10 – l4] unlike the well-known three-hinged stepping mover, he has two pairs of supporting shoes, internal and external, driven by two pairs of eccentrics. In the process of movement in such a mechanism, the lifting and lowering of the trolley is at the expense of the pairwise raising and lowering internal and external supporting boots. When working on the excavator, the weight of the machine is evenly distributed over all four supporting boots.

In this step, in comparison with the tracked vehicles movement, each of the tracks is replaced by a pair of supporting shoes.

**Figure 3.** Stepping four-hinged motor

**Figure 4.** Stepping machine "Vosmynih"

There are drive shafts with two eccentrics on each side on the lower frame side. In this case, the drive shafts of the eccentric, located on each side of the frame, have independent drives. Each of the drive shafts has two eccentrics, displaced one relative to one by 180°. The eccentrics turned inside the frame are connected by means of cylindrical hinges with the ends of the inner skis, and the external eccentrics, turned from the frame, in the same way with the ends of the outer skis [14].

Significant influence on the development of stepping machines has the Volgograd State Technical University, namely prof. E. Briskin and Prof. V. Zhoga [15 – 16]. They invented machines with so-called cyclic stepping mechanisms and machines with original orthogonal drives. An example of such developments can be the stepping machine "Vosmynih" (Fig. 4) [15].

A stepping mechanism is based on the idea of Chebyshev's lambda mechanisms in this development, so the step of the cycle is actually produced by a mechanical device of the leg. Perhaps this is somewhat restrictive of the adaptability of the machine, but its undoubted advantage is the considerable simplicity of the control system and the very high permeability of the machine. The machine is capable of moving and working on very weak soils [16].

Stepping movers are also used on the koper units of such companies as HAIZHOU (China); Przedsiębiorstwo Innowacyjno-Wdrożeniowe Wamet Sp. z o.o. (Poland); LLC "MERIMAKS" (Russia). Stepping kopers (Fig. 5) are constructed to perform pile works. The most effective applying area of the stepping koper pushing technology is the immersion of reinforcing concrete piles and plywood in conditions of dense building, in historical centres of cities, near the old and emergency buildings, in landslides and other places where it is forbidden to immerse piles by shock method and vibro-immersion due to the inadmissibility of dynamic, vibrational and noise effects [17 – 18].

**Figure 5.** Stepping koper

**Figure 6.** Walking dump maker

The stepping type movement mechanism with a hydraulic drive ensures good manoeuvrability and high productivity [18].

The Chasov-Yarskoye ore management with the participation of NKMZ designed and manufactured on the basis of ES-4/40 a dump formulation OSH-1 with a productivity of 750 m3/h and the departure of the console 80 m in 1955 for the first time in the world [19].

The firm "STROMMASHINA" (Belarus) has used a stepping dump maker for a dump forming unit since 2006 (Fig. 6). When working, the stepping dump maker is leaning on the base, and the skis of the stepping mechanism are raised above the ground [20 – 21].

Structurally constructed in the form of a belt conveyor skis, consisting of a mooring and receiving console, pivotally attached to the platform rotating and using a cable (ropes), are kept in a certain position. When working, OSH is leaning on the base, and the skis of the stepping mechanism are raised above the ground. When turning on the stepping mechanism, with the help of a lever and an eccentric, the legs with the skis lower downwards, lean on the ground, raise the base above the ground, and move forward by a step equal to 1,8 m, that is, in one turn the eccentric OSH moves one step [21].

A new model of stepping dump maker with higher technical characteristics compared to previously made (supply voltage of 0.4 kV instead of 6.0 kV is supplied with a system of software control based on controllers) was manufactured in 2008 [20].

The analysis of the existing construction allows us to find out that improving the stepping mover ski construction will significantly increase the possibility of stepping machines.

It should be noted that theoretical and practical research was carried out.

The laboratory stand for the research (Fig. 7, 8), consisting of a ground channel 1, a ski 2 which is installed on the ground and supporting elements 3 attached to it, was made.

**Figure 7.** The experimental stand for the interaction research of the skis supporting surface and the stepping motor with the ground

A force measuring sensor 5 is attached to the skis with the help of bolt connections 4. Using the rope 6, a force is transmitted through the winch 7 to the ski, which produces a simulation of the load from the stepping mechanism through the leg sphere to the ski [22 – 24].

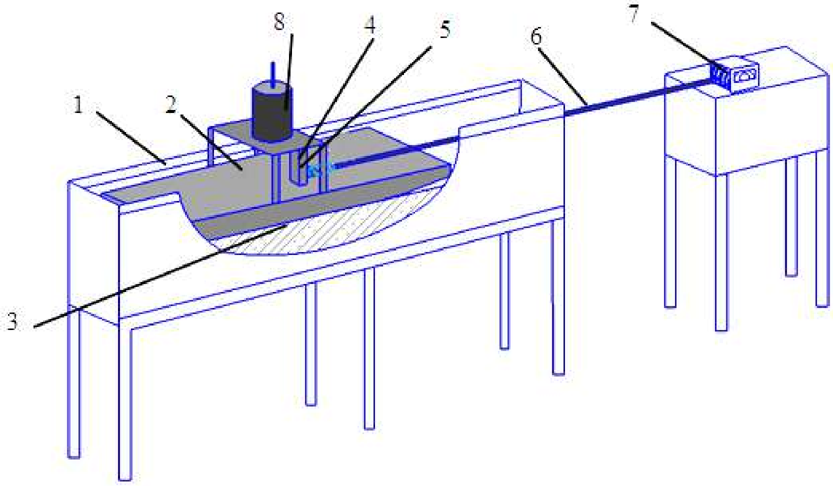



**Figure 8.** Principal scheme of the experimental stand for the interaction research of the skis supporting surface and the stepping motor with the ground

When the drum is rowing rope winches transmit an effort that reaches the excess of the engagement force increasingly, which leads to the skis movement. The data from the sensor 5 are read, using an analogue-to-digital converter, displaying the result on the laptop screen. In this way, a force equal to frictional force is measured. Normal force is produced by means of loads 8.

The experiment was conducted with the use of the stepping mover ski various supporting elements and the supporting elements location changes. (Fig. 9)


а) б)


в) г)

д)

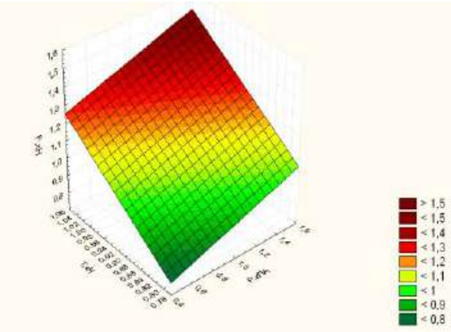
**Figure 9.** The ski main elements location. a) the ski without supporting elements; b) the ski with straight supporting elements; c) the ski with supporting elements of "chevron" shape in a forward direction; g) the ski with supporting elements of "chevron" shape in the opposite direction; e) the ski with supporting elements of "chevron" shape in the direction to each other

**The results of the research.** This way of experiments results processing provides a mathematical model of sight, providing a satisfactory convergence of calculated and experimental data in a wide range of variables: the pressure of the ski on the ground ( $P_l$ ), the displacement force of the skis on the ground ( $T_{cl}$ ), the height of the stepping koper ski supporting element on the ground ( $h_{se}$ ) [24].

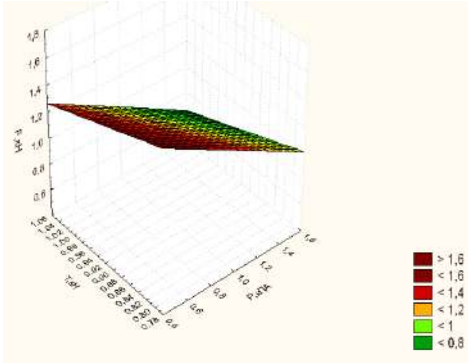
Statistical analysis showed that the resulting regression equations are adequate to experimental data on Fisher criterion. Given the insignificant negative coefficient according to Student's t test, the model of ski supporting elements power characteristic adhesion with ground has the form:

$$y(x_{1,}x_2, x_3) = 1{,}05 + 1{,}2x_1 - 0{,}2x_2 - 1{,}6x_3 - 0{,}63x_1x_2 - 0{,}23x_1x_3 + 0{,}35x_2x_3 + 0{,}35x_1x_2x_3. \qquad (1)$$

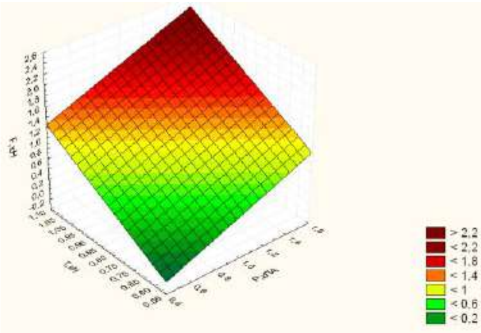
Using the STATISTICA 8.0 program, f dependencies were constructed from $P_l$ , $T_{cl}$ and $h_{se}$ .




$h_{oe}. = 0{,}008 м$




$h_{oe}. = 0{,}012 м$




$h_{oe}. = 0{,}016 м$

**Figure 10.** The experimental research results concerning the dependence of on $P_l$, $T_{cl}$ i $h_{se}$ for "loam"

The response surface analysis in Fig. 10 showed that the pressure of the stepping mover skis on the ground and the displacement force have a significant impact on the adhesion between the skis and the soil strength change. However, the height of the skis supporting elements has a greater effect than the individually varying pressure of the stepping mover ski on the ground and the displacement force.

With the increase in the supporting element height, when the pressure parameter of the stepper motor is varied on the ground and the displacement force, the stepping mover adhesion force value increases.

**Conclusions.** The analysis of the stepping machines construction makes it possible to assert that the stepping machines are a promising kind of vehicles, and that researches in the field of interaction between the stepping mover ski supporting surface and the ground are necessary for this type of machinery improvement.

The analysis of the regression equations showed that the mathematical model adequately describes the experimental research carried out with a probability of 5 %. The adhesion change expexperimental research at the beginning of the cycle has confirmed that the construction of the skis supporting elements "chevron" has more adhesion with the ground than those with straight supporting elements.

The obtained experimental research nontrivial results concerning the dependence of the stepping mover strength characteristics on the skis supporting element height, the pressure of skis on the ground and the force of displacement allow us to determine the optimal construction of the stepping mover skis; confirm the main functional dependences and conclusions obtained in theoretical research of the constructional scheme of the mechanism.

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# АНАЛІЗ ВПЛИВУ КОНСТРУКТИВНИХ ОСОБЛИВОСТЕЙ КРОКУЮЧИХ МАШИН НА ВЗАЄМОДІЮ ОПОРНОЇ ПОВЕРХНІ ЛИЖ З ҐРУНТОМ

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***Резюме.*** *Проведено аналіз впливу конструктивних особливостей крокуючих машин на взаємодію опорної поверхні лиж з ґрунтом. Порівняння обґрунтовано відомими конструктивними характеристиками крокуючих рушіїв. Відзначено необхідність використання опорних елементів на лижі крокуючого рушія, які значною мірою збільшують силу зчеплення крокуючої машини з ґрунтом. Опрацювання результатів дозволяє отримати математичну модель прицілу, що забезпечує задовільну збіжність розрахункових і експериментальних даних у широкому діапазоні зміни величин: тиску лижі на ґрунт, сили зсуву лижі по ґрунту, висоти опорного елемента лижі крокуючого рушія на ґрунт. Статистичний аналіз показав, що отримані рівняння регресії є адекватними експериментальними даними за критерієм Фішера. Аналіз рівнянь регресії показав, що математична модель адекватно описує проведені експериментальні дослідження з імовірністю 5%. Експериментальне дослідження зміни сили зчеплення на початку циклу переміщення підтвердили, що конструкція «шевронних» опорних елементів лижі має більше зчеплення з ґрунтом, порівняно з лижами крокуючих рушіїв без застосування опорних елементів та з рівними опорними елементами. Отримані нетривіальні результати експериментального дослідження залежності коефіцієнта зчеплення крокуючого рушія з ґрунтом від висоти опорного елемента лиж, тиску лиж на ґрунт та сили зсуву дозволяють визначити оптимальні параметри конструкції лижі крокуючого рушія. Результати експериментального дослідження підтверджують основні функціональні залежності й висновки, отримані при теоретичному дослідженні процесу взаємодії опорної поверхні лижі крокуючого рушія з ґрунтом.*

***Ключові слова:*** *крокуючий рушій ,аналіз, стенд дослідження зчеплення лиж з ґрунтом, опорна поверхня лиж, опорні елементи лиж.*

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