Modernization of ripping equipment of bulldozer-ripper

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Abstract. The invention proposes a variant of modernization of mounted ripping equipment of bulldozer-ripper by installation of vibration exciter on ripping tooth. A vibrator was selected and a 3D model of a new design was developed. As a result of a numerical study, a decrease in resistance forces arising during soil development was established due to tooth vibration for strong categories of developed soil. This confirms the prospect of using vibration rippers for the development of strong soils.

Keywords: loosening equipment, bulldozer-loosener, vibration exciter, loosening tooth, vibrator, development of strong soil.

Introduction

Modern methods of developing strong soils during the construction of various facilities, often, are produced using bulldozers-rippers. Depending on the category of developed soil, the class of equipment is chosen, the energy saturation of which is sufficient to overcome the resistance forces arising during loosening [1, 2]. However, when carrying out work with heavy-grade equipment, a number of shortcomings arise, which are ultimately displayed on the cost of one hour of operation of the equipment [3]. To reduce the cost of work, it is necessary to resort to bulldozers-rippers of a smaller class, whose operating costs are lower, in comparison with similar heavy-class machines.

One promising way to solve this problem is to install a vibration exciter on the working element of the ripping equipment, which converts part of the energy of the base machine into the vibration energy of the working element. Thus, the structure of the developed soil is decompressed, and due to this, resistance forces arising during loosening are reduced [4].

Purpose of the study

The aim of the forthcoming study is to upgrade the loosening equipment of the middle-class bulldozer by installing a vibration exciter on it for the development of strong soils. It is also necessary to carry out preliminary calculations to reduce the resistance force in order to find out the qualitative picture of this effect and to develop a new vibrator design for installation on the tooth of a bulldozer-ripper.

Materials and methods

To select an analogue of the design, a patent and information search was conducted, during which two patents and one study were considered, which proposed designs of dynamic tillers for the development of strong soils (Figure 1).

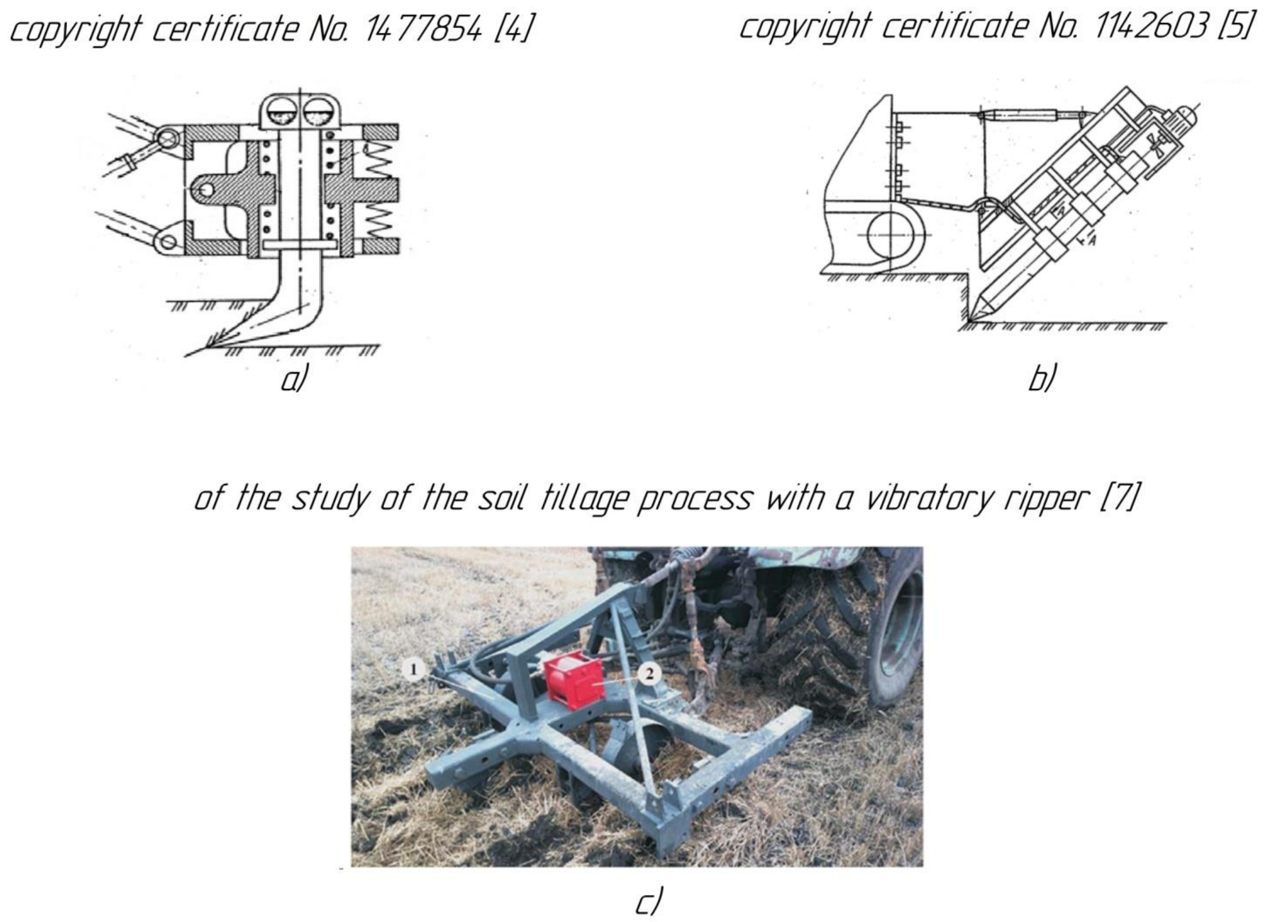

Figure 1 - Patent and information search: a) copyright certificate No. 1477854 [4]; b) copyright certificate No. 1142603[5]; c) photo of the study of the soil tillage process with a vibratory ripper [6]

The author's certificate No. 1477854 proposes the development of strong soils due to the parametric resonance of the working element [4]. The proposed design is interesting in that due to vibration energy and resonance energy of the working element there is an increase in the volume of the developed soil, however, many movable elements affect the reliability of the structure.

In the author's certificate No. 1142603, the vibration of the working element occurs due to the magnetostrictive effect [5]. The disadvantage of this dynamic ripper is the complexity of the design, the consumption of a large amount of electric energy and the generation of heat, which must be removed by an additional cooling system.

Applying the designs of copyright certificates No. 1477854 and No. 1142603, when modernizing existing structures of hinged rippers, a large amount of money will be required, but this investment will not be justified due to low reliability.

Let us turn to the study "Study of the soil treatment process with vibratory rippling agent" [6]. During this study, the vibration exciter was installed on the soil ripper using the necessary technical solutions that reduce the transfer of vibration energy to the base machine. It was found that due to vibration and pulses of the working elements of the ripper, the traction resistance of tillage machines is reduced, the maximum value of which was 14.38% [6].

Given that the soil ripper is also a soil ripper, the use of this structure on bulldozer rippers can be interesting and promising. In this regard, it is proposed to upgrade the ripping equipment of bulldozer-ripper B-11 by installing a vibration exciter on the ripping tooth.

Results and discussion

For comparative analysis traction calculation of bulldozer-ripper B-11 was performed, on which parallelogram single-tooth ripper of H type is installed [7]. Under operating conditions under known soil properties, traction calculation was carried out in order to determine soil loosening modes.

Determination of total resistance forces arising during loosening was according to formula [1]:

$$\sum W = W_f + W_{\text{p}}, \text{H} \qquad (1)$$

where W_f – resistance to movement of the ripper, H; W_{p} – soil loosening resistance, H.

Based on the obtained study data [6], the value of resistance force reduction was selected in the amount of 10%. The calculated values are shown in Table 1.

Table 1 - Values of resistance forces arising during soil tillage

Soil category	W_f, H	W_{p}, H	$\sum W$, H	$\sum W_{vibr.}$, H
3	32653,57	16900	49553,57	44598,21
4	32653,57	23400	56053,57	50448,21
5	32653,57	29900	62553,57	56298,21
6	32653,57	54600	87253,57	78528,21
7	32653,57	106600	139253,57	125328,21

The main condition when choosing the technique during soil development is the traction force of the base machine. The total force of resistance to movement should not be more than the traction force developed by the bulldozer-ripper. Calculation of traction force T_N at sufficient engine power, for tracked tractors, was made according to formula [1]:

$$T_N = \varphi_c * G_{tw}, \text{H} \quad (2)$$

where φ_c – traction coefficient of propulsor with soil; G_{tw} – traction weight of the tractor, H.

Results of calculation of developed soil category are given in Table 2.

Table 2 - Results of calculation of resistance force difference and bulldozer traction force

Soil category	$\sum W$, H	$\sum W_{vibr.}$	T_N, H	T_N -$\sum$ W, H	T_N - $\sum W_{vibr.}$, H
3	49553,57	44598,21	83118,17	33564,60	38519,96
4	56053,57	50448,21	83118,17	27064,60	32669,96
5	62553,57	56298,21	83118,17	20564,60	26819,96
6	87253,57	78528,21	83118,17	-4135,40	4589,96
7	139253,57	125328,21	83118,17	-56135,40	-42210,04

To clearly explain the modernization of hinged ripping equipment, a 3D model was developed that demonstrates one of the possible designs of a vibration ripper (Figure 2).

a) b)

Figure 2 - Hinged vibration ripper of bulldozer-ripper B-11:

a) bulldozer-ripper B-11 [8]; b) hinged vibration ripper

Conclusion

As a result of the calculation, a decrease in resistance forces arising during tillage of the soil was established due to vibration of working elements for high categories of developed soil. Thus, it can be seen from Table 2 that the use of a vibrator raises the category of soil under development from 5 to 6. This confirms a qualitative picture of the effect of reducing the resistance force.

In order to obtain more accurate data, it is necessary to conduct field tests and it is possible to increase the excitation force.

Based on the calculated data, the relevance of the use of vibration rippers in the development of strong soils is confirmed. Of particular interest for further numerical research is the strength of the ripping tooth of the bulldozer B-11, the design of which should be optimized for safety factor under given operating conditions.

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