Innovative: International Multi-disciplinary Journal of Applied Technology
(ISSN 2995-486X) VOLUME 03 ISSUE 12, 2025

Analysis Of Primary Tillage Plate Harrows

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Abstract:

Considering that the world's primary tillage area is 4.2 billion hectares, the development of high-quality, energy-efficient and resource-efficient soil tillage machines and tools is one of the important tasks. This article analyzes mechanical vibrations, their use in primary tillage, active and passive oscillating working bodies, soil tillage technical means with oscillating working bodies, and the impact of oscillating plate tines on the traction resistance of the plow and the quality of work.

Keywords: soil, plowing, plowshare, harrow, body, soil blade, aggregate, plate, plow, working body, drag resistance, soil compaction level, fuel, energy.

1. Introduction

Digitisation That the world's main cultivated area is 4.2 billion hectares , the development of high-quality, energy- and resource-efficient soil cultivation machines and tools is one of the important tasks. Soil cultivation is a prerequisite for growing agricultural crops and obtaining high yields from them. The development and use of energy-saving and highly productive soil cultivation machines while maintaining productivity occupies a leading position.

Vibration is a process that characterizes a change in state, that is, a change in the quantities that determine the state over time. Vibration represents the process of mechanical vibrations and determines relatively small deviations of some points of the body. Mechanical vibrations are a process of change in a mechanical quantity that determines the state of a material body or its point, in which this quantity, characterizing the rate of its change, sometimes increases and sometimes decreases over time. Depending on the method of excitation, vibrations are divided into: free, forced, and coupled vibrations.

Mechanical vibrations have three main parameters: the amplitude of the body's vibrations A (the largest deviation of the body from its equilibrium position), the period of oscillations T (the time it takes to complete one full oscillation), and the frequency of oscillations υ (the inverse of the period).

2. Materials and Methods

Various Objectives: This study aims to systematically analyse, evaluate and compare the application of mechanical vibrations in primary soil tillage, with an emphasis on vibrating plate type and plate tine harrow working bodies. The research is based on a wide-ranging review and synthesis of the scientific literature, laboratory experiments, and patent information on active and passive vibrating tillage tools. Theoretical principles of mechanical vibration are then explored — including amplitude, frequency and oscillation modes — in order to provide a mechanical basis for their interaction with the soil during tillage processes. Then, based on fast-forward experimental data, the author judges the impact of vibration parameters on the degree of soil deformation, loosening, crumbling, and traction resistance at various speeds and soils. This enables a comparative analysis that delineates the differentiating aspects of active (vibratory systems driven by hydraulic, electric or power take off mechanisms) vibration characteristics, structural complexity and energy consumption, and passive (self oscillating systems driven by variable soil resistance) characteristics together with their performance. Special attention is focused on plate type vibrating working bodies of which induced oscillations of the soil and elastic elements reduce draft force and improve the quality of soil processing. The methodology also includes conformation to reported field and laboratory validation tests involving traction resistance reduction, vibration amplitudes, and frequency ranges, operational speed limits, and soil sticking behavior. Using this combined analytical framework, the paper parses out technical merits, operational impediments, and some operational efficiency trends associated with vibrating plate harrows, thus coherently informing conclusions about their suitability and optimal use in contemporary energy efficient primary tillage systems.

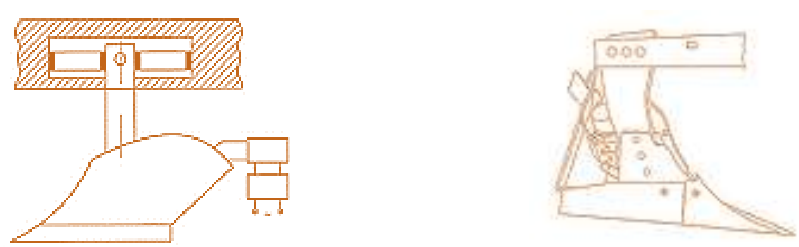
3. Results

The When cultivating the soil, it is necessary to introduce vibration as an additional effect on the working bodies. Therefore, in the early 1930s, vibration began to be used in Russia to combat soil sticking to the working bodies. For example, when a plow is working, the bodies vibrate with a small amplitude but with a high frequency. The blade moving along the surface of the plowshare receives a large number of impulse impacts directly along the contact surface with the plow body. In this case , the soil layer is in a suspended state , its pressure on the body decreases, as a result of which the friction force also decreases [1].

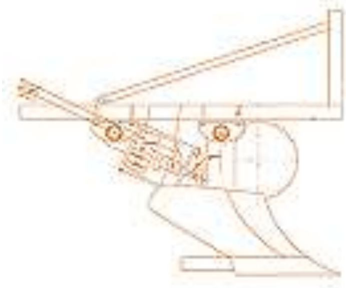
A number of scientific studies have been conducted on the effect of vibration on soil loosening , crumbling, and the traction resistance of the plow [2]. Many scientific studies on the development of vibrating plows were conducted by AA Dubrovsky [3].

previously conducted theoretical and experimental studies , it is possible to impart active and passive oscillatory motion to the working bodies that cultivate the soil .

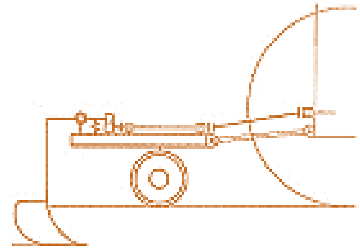
The vibration energy is supplied to the active vibrating working bodies without additional drive (Figure 1).



a) *b*)



c)



d)

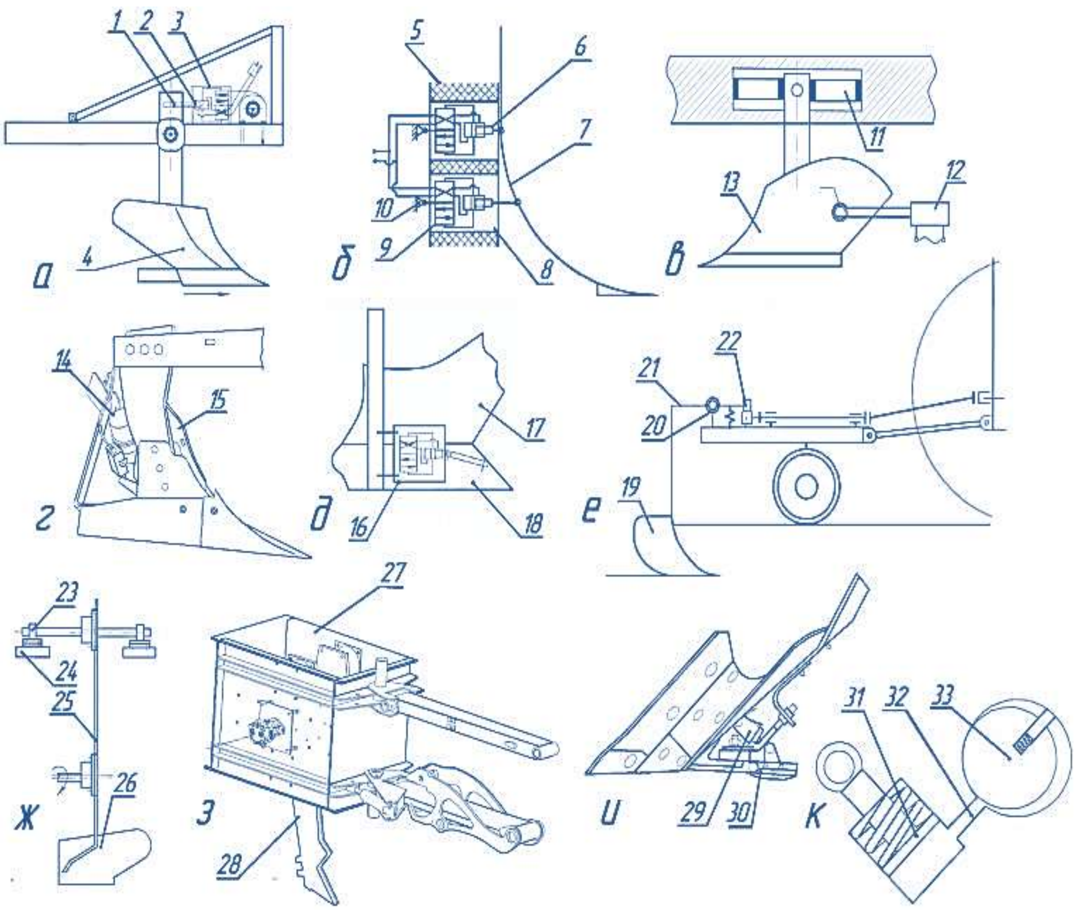
a - according to patent RU 2304371 *b* - according to patent RU 2635931 ; *v* - under patent UA 63591 ; *g* - under patent UA 117287

Figure 1. Plows with active oscillating working bodies construction

With increasing speed, the power consumed by the vibratory drive becomes greater than the power obtained with its decrease, since, according to the studies of AADubrovsky, the effect of vibration is observed only up to a speed of 0.6-1.0 m/s. The vibration effect is provided by an eccentric rotary mechanism, which is driven by the tractor's power take-off shaft and provides a reduction in traction resistance.

According to the studies of ASKushnarev and VPBazarov on the analysis of soil resistance, it was concluded that the process of soil processing of the working body in steady motion consists of three phases [4][5]. During the first phase, the working body sinks into the soil, in the second phase, deformation and a continuous increase in internal stresses occur. When the internal stresses exceed the strength limit of the soil, the third phase occurs, in which fracture occurs [6][7].

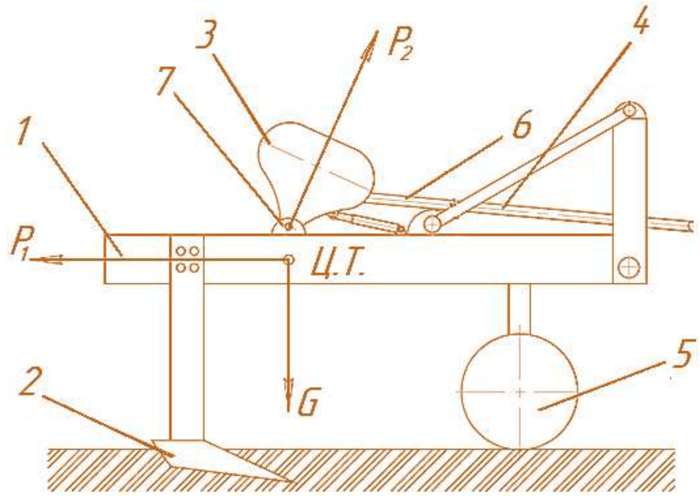
active oscillating working bodies (Fig. 2), the working bodies (Fig. 2, a, b, d, z, i) that are given vibration from the hydraulic drive work by transferring oil under pressure to the pistons 2, 6, 33. The pistons 2, 6, 33 move back and forth, giving the turner (Fig. 2, b, d, i) or the entire working body (Fig. 2, a, z) an oscillatory motion. In the electric drive (Fig. 2, c, g), the vibrations are given either from a magnetic pulse device 12, or from an electric motor 14 that periodically strikes the rear of the turner with a cam on the shaft. In some designs , the vibrations come from the tractor's power take-off shaft (Fig. 2 , e, j).



a - under patent UA 106663 ; *b* - under patent UA 18775 ; *c* - under patent RU 2369057 ; d - under patent RU 2635931 ; *d* - under patent UA 19528 ; *e* - under patent UA 117287 ; *j* - under patent UA 117495 ; *z* - under patent UC 7546883 ; *i* - under patent UA 31573 .
1, 29, 31 - rod; 2, 6, 33 - piston; 3, 8, 14, 16, 27 - vibrator; 4, 13, 15, 19, 26 - plow body; 5 - rubber shock absorber; 7, 17 - overturner; 9 - tine; 10, 24, 25 - column; 11 - hydraulic shock absorber; 12 - magnetic impulse device; 18 - plowshare; 20, 23 - bearing; 21 - traction; 22 - roller; 28 - working body; 30 - field board; 32 - pressure main.

Figure 2. Actively vibrating working bodies of the plow

V. S. Loveykin and L. A. Dyachenko, hydro-hydraulics allowed to reduce the traction resistance of the PLN-2-25 double-body plow by up to 54% . [8]. A vibrating oscillating plough was developed by the Saratov Agricultural Institute, and tests showed that it reduced draft resistance by 17% [9].
S.N.Drozdov developed a pendulum-type soil tillage machine (Figure 3). It was possible to reduce the traction resistance of soil tillage machines by up to 26% [10].
N.M.Belyaev used vibrating soil compactors in his research to reduce the traction resistance of the plow [11]. It was observed that the traction resistance of one soil compactor was reduced by up to 30% when the aggregate speed was 5.0 km/h.



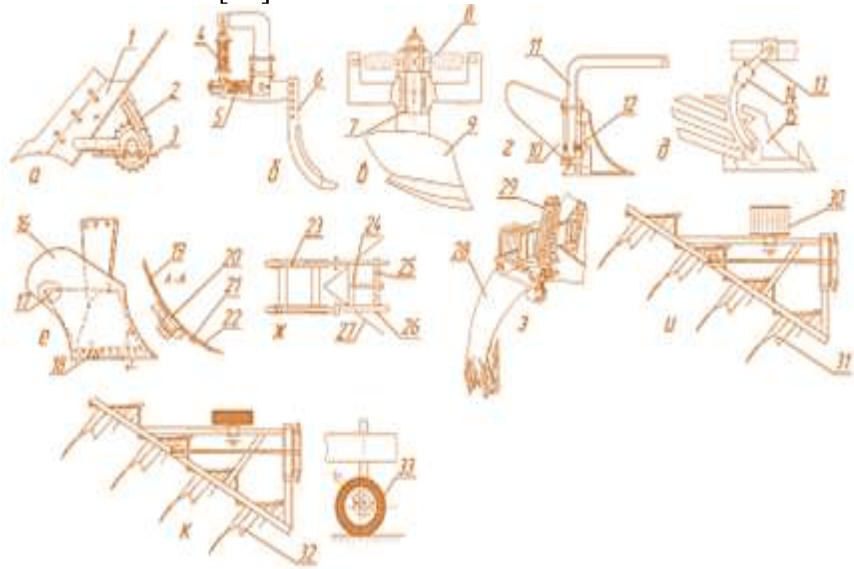
1-frame; 2 - working body; 3-pendulum vibrator; 4-cardan transmission;
5-base wheel; 6-hinge; 7- jointed arrow
3. Soil tillage machine

S.G. Shukin developed an experimental vibration damper driven by the tractor's power take-off shaft (Fig. 4). It was found that when the speed of the unit was 9.0 km/h, its traction resistance decreased from 25.5 kN to 24.4 kN (by 14.38%). In this case , a decrease in the vibration effect was observed with increasing speed [12].

1-softener; 2- brat
Figure 4. Experimental vibrating softener

According to the analysis of technical literature, passive vibrating working bodies have the following advantages over active vibrating working bodies: simplicity of structure, low cost, low energy and metal consumption. The simplest of passive working bodies is a spring-loaded working body that absorbs the variable resistance of the soil. In passive vibrating working bodies, the spring element can be located in the handle of the working body (Fig. 5, b, c, d, j, z) or behind the surface of the tine-turning harrow (Fig. 5, a, g, e). In both cases, the variable pressure of the soil creates vibrations that reduce the resistance to traction. There are also designs in which vibrations are transmitted to the entire machine from a support wheel made in the form of a right-angled pulley (Figure 5, i) and a wheel with eccentricity relative to the machine frame (Figure 5, k) [13].
According to IYFedorenko, self-oscillations produce large amplitudes, so their use is preferable.

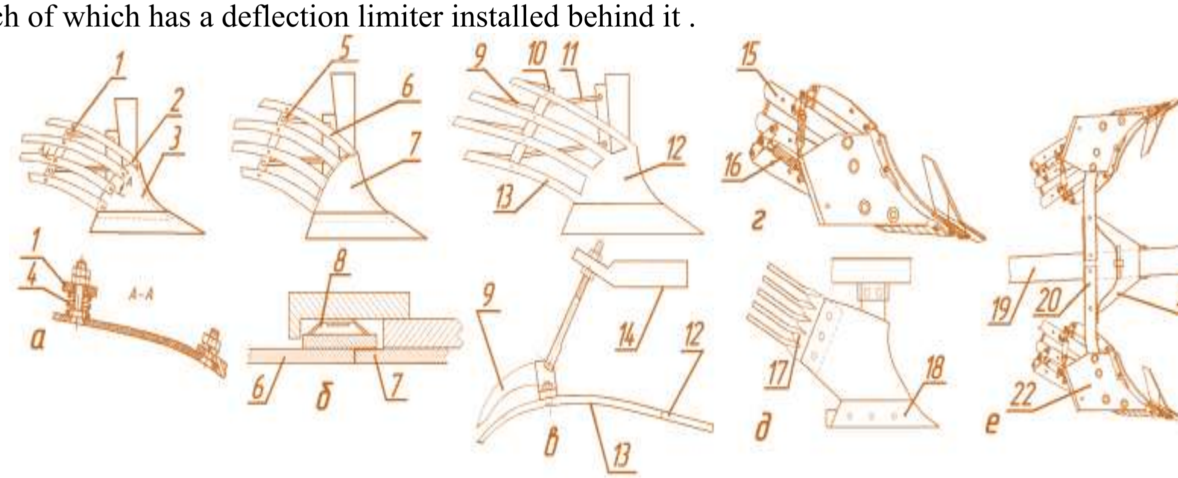
Structurally simple, with low energy and metal consumption, this is a self-oscillation process, the oscillation of which occurs due to the variable resistance of the soil. The direction of vibration should not coincide with the direction of movement of the aggregate. It is preferable that the vibration occurs in the lateral or vertical directions [14].



a - according to patent RU 173221 ; *b* - according to patent CN 108353540 ; *v* - under patent RU 2667768 ; *g* - under patent RU 2380874 ;
d - under patent RU 144741 ; *e* - under patent RU 2115278 ; *j* - under patent RU 2327324 ; *z* - according to patent US 3960220 ; *i* - under patent RU 2478270 ; *k* - under patent UA 108167 .
1, 6, 9, 10, 15, 16, 27, 28, 31, 32-working body; 2, 4, 5, 8, 12, 14, 17, 23, 25, 26, 29-elastic element; 3-field board; 7, 11, 13, 24-handle; 18-comb; 19-turning device; 20-nut; 21-rivet nail; 22-share; 30, 33-base wheel

Figure 5. Passive vibrating working bodies

Figure 6 shows the designs of passive vibrating working bodies with plate (pin) rollers. The designs of passive vibrating rollers (Figure 6, a, b) were revised and an improved design was achieved (Figure 6 , c). The next design of the vibrating plate roller (Figure 1, d, e) is a strip made of 65G spring steel , each of which has a deflection limiter installed behind it .

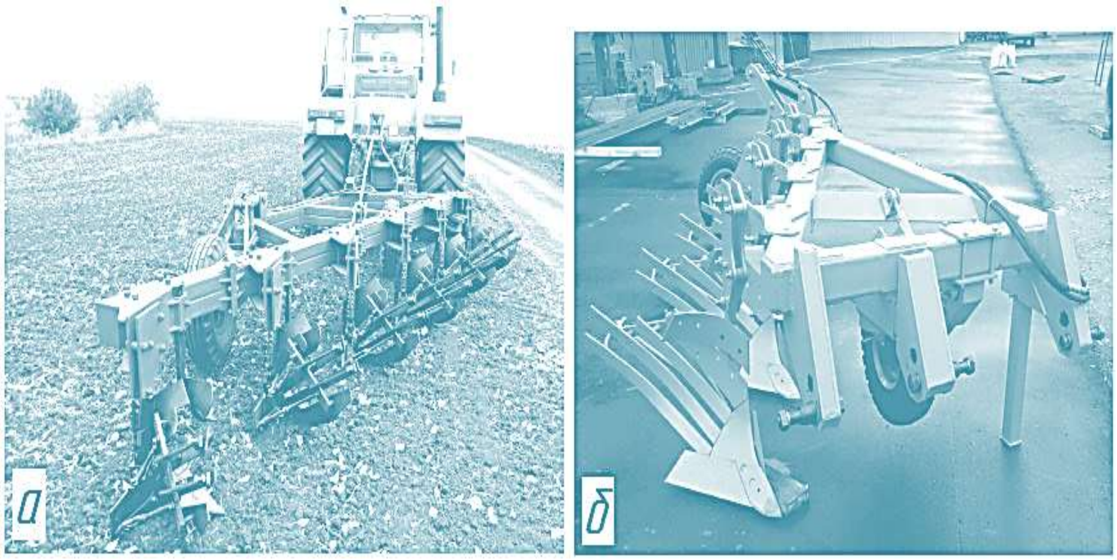


a -according to patent BY 18090 b -*according* to patent RU 2426290 ;
v - according to patent RU 2008102690 ; *g* - according to patent RU 97234 ;
d - according to patent RU 2435342 ; *e* - according to patent RU 2010115813 ;
1, 5, 10-next support; 2, 6, 13, 15 - thrust plate plates ; 3, 7, 12-thrust collar ; 4, 8, 16-elastic element; 9-bend limiter; 11-pillar; 14, 20- handle ; 17-spring guard; 18- plowshare ; 19-frame; 21-bracket; 22-

plate-shaped body

Figure 6. Passive vibrating plate-type working bodies

When the plug body is working, the variable resistance of the soil pushes the plates against the limiter, which causes vibration along the entire length of the plates and helps to reduce the resistance to traction. Experimental samples of this design have also been developed (Fig 7 , a ,b).



a - six-body suspension plow with a coverage width of 2.7 mb o ' ;
b - a four - body semi-mounted plow with a working width of 1.8 m.

Figure 7. Vibrating plate (with grooves) plows with a furrow

Vibrator In tests conducted on plate-body plugs, the vibration amplitude was 2 - 5 mm and the vibration frequency was 8 - 10 G s. When they are, their tensile strength decreases to 14.5% [15].

In addition, in passive vibrating plate hoppers , it is proposed to install vibration supports in the form of a disc -shaped spring under the front ends of the plates, at the point of contact with the hopper's chest . In this case , when plowing wet soils, the traction resistance is reduced due to the soil not sticking to the nose of the harrow. Also , the housings with elastic elements (compression springs) reduce the traction force and ensure improved soil processing quality [16].

Based on the analysis of scientific, technical and patent literature, the following conclusions can be drawn:

1. When using forced vibration in soil tillage machines with a speed of movement of the aggregate exceeding 6-7 km/h, it is necessary to maintain a large amplitude and frequency of vibrations, which creates technical difficulties.
2. It is advisable to use forced vibrations in slow-moving soil-tillage machines where the speed of the aggregate does not exceed 3-4 km/h.
3. Self-oscillating working bodies perform large vibration amplitudes, so their use is preferable.

4. Conclusion.

Based on scientific, experimental and patent evidence, the mechanical vibration used in the primary tillage of the soil, especially the vibrating plate and plate tine harrow working bodies, has technical and energy benefits that can be quantified. These results verify that vibration alleviates traction resistance from reduced soil surface contact pressure, decreased adhesion of soil particles and activated soil loosening and crumb-forming processes, which consequently leads to less fuel consumption and enhanced tillage quality. Passive systems (attached to the vibrating bottom to mimic passive vibration isolation) have the potential for much larger reductions in net draft force, but their performance is limited by speed of operation, along with higher power consumption, and structure complexity as compared to in-vivo systems. On the other hand, passive and self-oscillating working bodies have some essential practical advantages: simplicity of structure, reduction of metal and energy costs, and stable operation within a wider range of soil conditions, which makes them more promising for agricultural use. These results have important implications in the construction of energy-saving and resource-conserving tillage machinery, especially on the background of the large scale of cultivated land and the increase in energy prices. Passive vibrating plate harrows, when integrated into contemporary tillage systems, supported by high operational efficiency with preserved soil quality and productivity. Whereas, the geometric numbers, elastic element parameters, and direction of vibration concerning the direction of machine movement need to be optimized, so the investigations of geometric parameters, elastic element characteristics, and direction of vibration should be performed with field experimentation at various soil and weather conditions over a longer duration. Other studies should also focus on durability, wear performance, and cost effectiveness to help mass-market adoption and technological standardization of vibration tillage objects.

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