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The Significance of Vibration Motion in Reducing the Traction Resistance of Technical Means for Soil Processing

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Abstract: This study examines the significance of vibrational motion in reducing the traction resistance and energy consumption of technical means used for soil processing. A comprehensive review of scientific literature, patent resources, and existing vibration-based tillage technologies was conducted to evaluate the effectiveness of forced vibration in improving soil cultivation performance. The study analyzes the influence of vibration parameters, including direction, frequency, and amplitude, on the interaction between tillage tools and soil. The findings indicate that the application of controlled vibrational motion decreases soil adhesion and draft resistance, enhances soil fragmentation, improves moisture retention, and reduces the wear of working components. Experimental evidence reported in previous studies demonstrates that vibration-assisted tillage can reduce traction resistance by up to 35–60%, depending on soil conditions and machine design. The results also highlight that the optimal selection of vibration parameters and oscillation-generating mechanisms contributes to improved energy efficiency, increased operational productivity, and sustainable agricultural practices. The study concludes that the implementation of forced vibration technology is particularly suitable for the soil and climatic conditions of Uzbekistan, where it can significantly enhance the efficiency of tillage operations while reducing fuel consumption and overall operating costs.

Keywords: Soil, processing, productivity, vibrational motion, forced vibration, vibration direction, frequency, amplitude, traction, resistance, strength, energy.

Introduction: Currently, food products for the needs of the population and raw materials necessary for economic sectors are grown on more than 3.2 million hectares of irrigated arable land in our republic. In particular, more than 860.0 thousand hectares of sown areas are currently used for growing cotton, and about 911.0 thousand hectares for grain. Large-scale irrigation and land reclamation measures are being implemented within the framework of state programs to increase the productivity of irrigated areas, improve their reclamation status, and improve water supply [1,2].

In agricultural production, primary and pre-sowing soil cultivation is the most energy-intensive process. These processes account for 40–50 percent of the total energy consumed for growing cotton, grain, and other agricultural products. The issue of achieving a reduction in energy and resource consumption during soil cultivation is one of the most pressing issues today: saving tons of fuel and lubricants, increasing the productivity of units, the durability of machines and units, and reducing the amount of metal and labor and material costs for preparing these units for production; providing agriculture with energy- and resource-saving machinery.

The purpose of soil cultivation is not only to create favorable conditions for the growth and development of crops, but also to ensure a proper water and air regime, which is one of the most important factors.

Research Method: During the cultivation and harvesting of agricultural crops, the repeated passage of tractors and agricultural machinery through the field leads to the compaction of the arable and sub-arable layers, an increase in their hardness and the number of erosive particles, and a deterioration of their physical, mechanical, and agrophysical properties. This leads to a decrease in soil fertility and agrotechnical indicators during mechanical cultivation due to violations of water and air regimes, as well as an increase in the energy consumption of these machines [3].

The absorption, runoff, and evaporation of water in the soil layer treated according to agrotechnical requirements lead to an increase in crop yields [4].

Experiments conducted by scientists in the field provide three main methods for reducing soil density: reducing the degree of compaction, exerting more mechanical impact on the soil, and preventing soil compaction.

At the current stage of scientific and technological development, the most common method for reducing soil density is loosening according to agrotechnical requirements through mechanical impact.

For this purpose, traditional and resource-saving methods of soil cultivation are used. The method used is selected in accordance with the soil condition and local conditions.

There are primary (deep) and additional (shallow) tillage systems. Basic tillage is carried out in two ways: by plowing with and without tillage of the soil layer (Fig. 1). Additional cultivation is divided into pre-sowing and post-sowing types. Recently, the need for rational energy use and resource-saving methods in soil cultivation worldwide has been increasing day by day.

Three-bottomed plow

Disc plow

Deep ripper | Suspended chisel cultivator

Deep Softener (Spring) | Combined chisel cultivator

Figure 1. Soil cultivation units.

Theoretical research has shown its advantages in the development and implementation of vibration-generating mechanisms in agriculture. Experimental studies have proven the feasibility of using vibration-generating mechanisms to reduce the traction resistance of soil-cultivating machines by up to 60% and to reduce the wear of the working parts [5,6,7,8,9,10,11].

Along with forward displacement, the working elements of soil vibration units move with a specific oscillation at a specific amplitude and frequency (Fig. 2). The mechanisms generating oscillations in these units can be linear or arc oscillatory. The oscillation can occur horizontally in a plane, vertically, or at any angle in three-dimensional space [12].

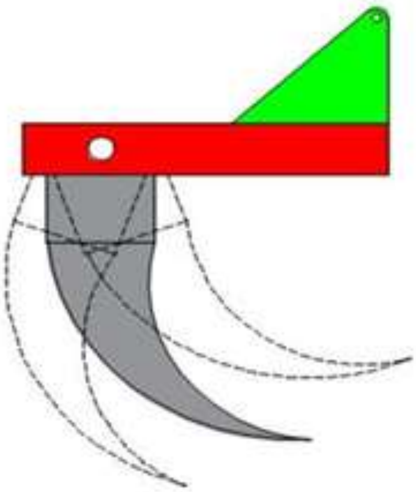


Figure 2. Vibratory soil cultivation unit

Research results and discussion. One of the main issues in soil vibration treatment is the impact of the working tool on the soil through oscillatory motion. Various springs or elastic supports are used to vibrate the working element (Fig. 3).

In such working bodies, solids vibrate under the influence of soil resistance, along with safe self-regulation under the influence of rocks and roots. As a result, the breakdown of soil layers is observed. However, the vibration frequency and amplitude of the working element in this process are variable and not at the optimal level. To ensure the optimal level of soil crumbling, it is necessary to ensure that the working element vibrates at a specific frequency and amplitude.

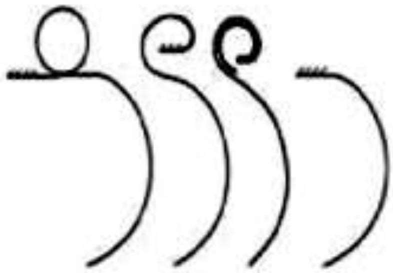
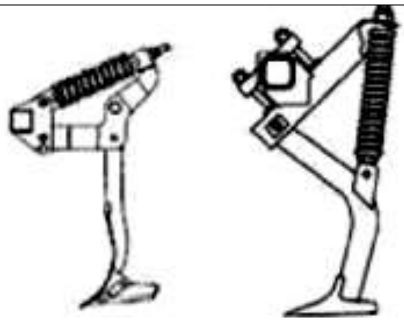
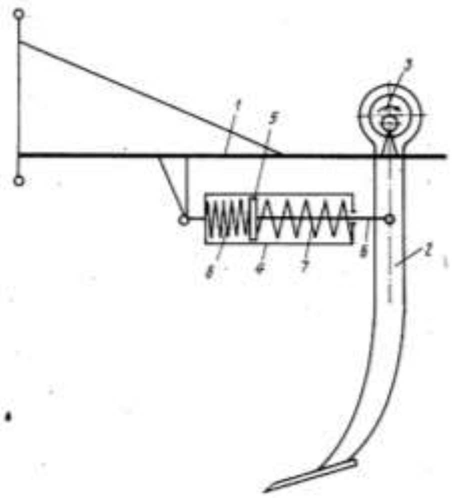
	S and S-shaped supports
	Spring self-adjusting S-shaped supports
	Spring self-adjusting supports

Figure 3. Main types of elastic supports.

In the 1980s, V.P. Ostrovsky proposed a subsoiler with a working element that oscillates along a circular trajectory [13]. This subsoiler (Fig. 4) consists of a frame, a column, a subsoiler, an eccentric vibration device, and a spring, which reduces draft resistance. The disadvantage of this machine is that it is not equipped with support wheels to adjust the machining depth.



1 – frame; 2 – column; 3 - eccentric; 4 – cylinder; 5 – disc; 6 – rod; 7, 8 - spring;

Figure 4. Design scheme of a subsoiler equipped with a vibration eccentric, proposed by V.P. Ostrovsky

N.I. Buchukuri proposed a design for a deep-soiling machine equipped with a vibration-generating device [14]. This machine (Fig. 5) consists of a frame 1, a column 2, a chisel 3, a hinge 4, a moving part 5, an oscillating knife 6, an oscillator 7, a bracket 8, a lever 9, a nut 10, a spring 11, 12, a slot 13, and a finger 14. Energy consumption is low when cultivating the soil using this machine. The main disadvantages of the machine are its extremely complex design, large overall dimensions, and high metal consumption.

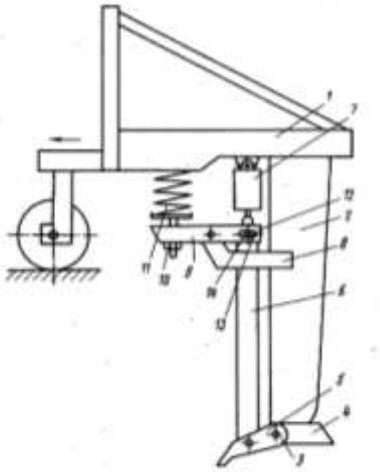
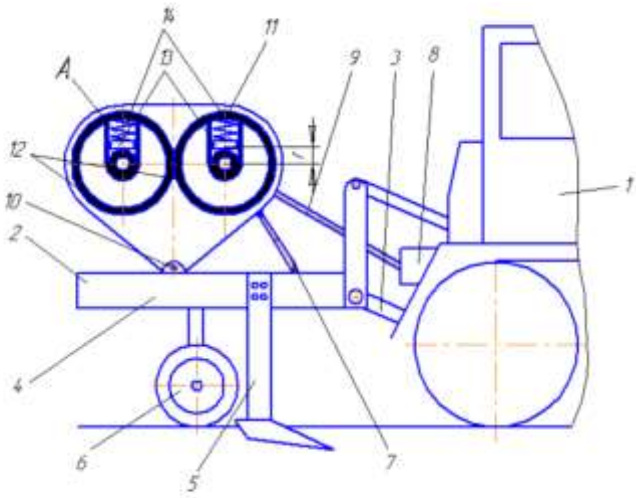


Figure 5. Structural diagram of the vibratory subsoiler proposed by N.I. Buchukuri

I.V. Trofimov proposed a chisel cultivator design equipped with a pendulum oscillating device [15]. During the operation of this machine (Fig. 6), motion is transmitted from the tractor's main control unit 1 to the pendulum 11 using a cardan drive 9. The machine vibrates the entire unit because the vibrating device is mounted on the unit frame. The main disadvantage of the oscillating device for oscillating such a large mass is its high energy consumption and overall dimensions, as well as its complex design.



1 – tractor; 2, 4 – frame; 3 – suspension device; 5 – working element; 6 – support wheel; 7 - hydraulic cylinder; 8 – power take-off shaft; 9 – cardan drive; 10 - hinge; 11 – pendulum; 12 – balance device; 13 – cargo; 14 - spring;

Figure 6. The design of the pendulum-type oscillating device proposed by I.V. Trofimov

There are contradictions regarding the overall power requirements of the vibrating unit. To cultivate the soil, it can increase, decrease, or remain the same.

In dry soils, a decrease in tractive resistance was observed, as the working element forces the soil to vibrate, causing it to decompose and reducing its viscosity. In high-humidity soils, the opposite is observed [16].

Vibratory tillage reduces the tractive effort of the unit by 35% compared to non-vibratory tillage [17,18]. Several experiments confirmed that the traction resistance decreased, but the power requirement for the working parts of the vibration-generating mechanism increased [19]. A series of field trials conducted on sandy soils showed that vibration treatment reduces draft resistance compared to non-vibration treatment [20].

Conclusion. Based on the conducted research, it can be concluded that effective results are achieved when soil is treated through forced vibration. The effective operation of the tillage unit is influenced by the design, parameters, and vibration direction of the unit's working parts. As a result of the forced vibration of the working element on the soil, its fragmentation, reduction of adhesion, and density are improved. When using a forced vibration unit, the moisture retention capacity of the soil also increases.

Thus, based on the aridity of Uzbekistan's climatic conditions and the physical and mechanical properties of the soil, it is advisable to use forced vibration equipment on agricultural lands, as it increases the efficiency of soil cultivation.

Consequently, the creation of energy- and resource-saving structures, the correct selection of a mechanism for generating oscillatory motion taking into account the physical and mechanical properties of the soil, the direction, frequency, and amplitude of oscillatory motion, as well as the transmission of oscillatory motion through the links to the working element, require research to resolve such issues

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