Identifying reasons for failure of soil processing units of working bodies

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Abstract. The causes of wear of the working bodies of soil cultivating units are analyzed. The main culling parameters are presented, due to which the working bodies lose their performance. The analysis of factors affecting the degree of wear of working bodies is carried out. Theoretical recommendations are proposed for the creation of an equal-strength tillage unit, the working bodies of which wear out with equal intensity.

1. Introduction

A working body moving in the soil acts on it normally and tangentially with directed efforts. Under their action, soil compaction first occurs with subsequent cleavage of the soil, and then the resulting lumps move along the working surface of the paw. The reactions that arise from the soil are called the pressure exerted on the working body. The magnitude of this pressure depends on the geometric parameters and the speed of movement of the paws, as well as the mechanical properties and composition of the soil. The process of wear of the working bodies of soil cultivating aggregates proceeds during their continuous interaction with the soil mass. The abrasive particles that make up the soil slide over the metal surface, causing a gradual change in the shape and size of the part and ultimately its destruction. The speed and nature of wear of the working bodies depend on the nature and properties of abrasive particles, as well as on the conditions of their interaction with the material of the part. Consequently, the intensity of wear of the working bodies of tillage aggregates on different soils is not the same. The average resource of, for example, paws of cultivators is 40...100 h [1].

More than 60% of the working bodies lose their performance due to the extreme wear of the cultivator paw toe and wings in width. Culling parameters also include a reduction in grip width, liner wear and wing breakage.

The toe of the paw experiences the greatest, of all its design elements, mechanical load created by the cultivated soil, and, therefore, wears out with increased intensity. At the same time, its length and thickness are reduced. As a result, its strength decreases, and the paw toe is deformed and, in some cases, is destroyed [2]. The maximum wear of the toe of the paws is 30 mm. The wear rate of the cutting edge decreases as it moves away from the toe [3].

The sharpness of the blade of the working bodies of cultivators determines their self-sharpening. At a normal and increased level of self-sharpening, the cutting edge is determined by the thickness of the reinforcing layer, and the radius of its rounding is equal to half the thickness of this layer [1, 3]. In the absence of self-sharpening with extreme wear, the edges of the blade take a radius of more than 0.5 mm. The maximum wear of the wing along the width of the lancet paw is 15 mm.
The change of the shape of the two-layer cutting part of the lancet paw during operation is possible according to three options (Fig. 1). The profile shape of the double-layer blade \(a_1b_1c_1\) (Figure 1, a) indicates its normal self-sharpening during operation, that is, the resulting contour is optimal in the sense of performing the given functions. The resulting section of the blade \(a_1b_1\) wide (occipital chamfer) is a relatively small area, therefore, the buoyancy force from the soil side will be small and the movement of the working body at a given depth is stable. If the wear rate of the upper layer of the \(b_2c_2\) blade is much higher than the lower one, a cantilever protrusion is formed (Figure 1, b). This relatively thin cantilevered protrusion (reinforcing layer) consists of a hard and fairly brittle material, which will lead to its partial chips during operation. And this means an increase in the amount of wear and the formation of a saw tooth-shaped cutting edge. In the case when the wear rate of the lower layer of the blade \((a_2b_2)\) exceeds the same parameter for the upper layer of the blade \((b_2c_2)\), the width of the occipital bevel increases noticeably (Figure 1, c), which negatively affects the stability of the working body in depth and contributes to an increase in traction resistance.

One of the factors affecting the degree of wear of the working bodies of cultivators is soil moisture. The amount of moisture in the same soil over time is not the same. With increasing humidity, the soil becomes loose. So, at a moisture content of 22 - 28%, the wear rate of the paws decreases, but with a greater increase in humidity (over 30%), soil sticks to the blades of the working bodies. The greatest wear is observed on sandy soils with a moisture content of 20%.

Another factor affecting the degree of wear of the working bodies is the hardness of the soil. With high hardness of the soil, the intensity of wear at the upper edge of the blade increases. This process is especially pronounced in the working bodies installed in the front row and along the axis of movement of the wheels of the cultivator and tractor [3]. As a result, an occipital chamfer is formed on the back of the blade, located at a negative angle to the bottom of the furrow. The size of the occipital chamfer mainly affects the magnitude of the traction resistance of the working body and the buoyancy force acting on it [3].

As a result of the analysis, we can conclude that the intensity of wear of the working bodies of cultivators depends on the hardness and composition of the soil. Along with the fertile component, the soil contains the following solid particles: fine earth - particles with a diameter of less than one millimeter, for example, quartz and corundum (from 0.01 to 1 mm) and stony inclusions (from 1 mm). These particles abrade and deform the paws, which makes them inoperable. Ultimately, there are three main factors that affect the wear of working bodies [4, 5, 6]:

– granulometric composition of the soil, determining its abrasive aggressiveness and cohesion;
– soil hardness, which determines the pressure on the blade of the soil mass and the intensity of wear of its cutting part;
– physico-mechanical properties of the material of the part.

It should also be noted that tractor propulsion and support wheels of the soil cultivating unit have a negative effect on the soil, as a result of which its hardness increases, and thermal and water-air
conditions are also violated. This effect extends inland from the surface. This happens because in the process of performing tillage operations, the propellers and wheels of the machine-tractor unit create stresses in the soil that cause its deformation.

2. The object and method of research

To assess the degree of impact of the movers of the machine-tractor unit on the soil GOST 26955-86 «Mobile agricultural machinery. Norms of influence of movers on the soil» has been developed. In accordance with the requirements of the standard, the pressure on the soil of the wheels at a moisture content of 0.7 HB should not exceed 100 kPa in the spring, and 120 kPa in the summer-autumn [7]. But energy-saturated tractors have an impact above regulatory levels. To determine this effect, the small-sized potentiometric sensors DMP-1A, DMP-2A, and DMP-3A were used with measurement limits of 0-100 kPa, 0-200 kPa, and 0-300 kPa, respectively [5, 8, 9]. Sensing elements, which are a rubber bulb, Figure 2, were attached to the sensors through a tube with a fitting. The formed cavity was filled with liquid and connected through the tube to the working cavity of the potentiometric sensor. Moving the sensor membrane leads to a change in the state of the potentiometer, this was recorded on the strain gauge MIC-018. The sensors were laid in advance in the soil along the intended route of movement of the machine and tractor unit to different depths from 0 to 100 cm with an interval of 10 cm. During the studies, the pressure at the spot of contact of the mover with the soil was determined for various tractors and wheels of tillage units.

3. Results

As a result of studies, it was found that the tractor mover VT-100 has the least effect on the soil, creating pressure in the contact spot from 50 to 75 kPa, which causes the formation of a trace with a depth of 5-6 cm and an increase in soil hardness to 1.0 MPa (table 1). The wheels of heavy tractors K-701, K-744R1, T-150K, as well as wheels of tillage units have the greatest impact on the soil. Moreover, despite the small mass of tillage machines due to the installed wheels with a small width and diameter, they have a small bearing area, and as a result create high contact pressure, leading to an increase in the depth of the track and the density of the soil along their tracks. The pressure in the soil during the movement of the wheels of the tractor or tillage unit extends to great depths. Sufficiently high stresses are also created by tillage machines. Thus, the stresses after the cultivator’s passage are on average 23.9% higher compared to the voltage created by the VT-100 tractor propulsion and 67.3% less compared to the
voltage created by the K-701 tractor wheel. A similar situation can be observed with the action of the seeder wheels on the soil.

**Table 1.** Parameters of the impact of tractor propulsion on the soil

| Tractor brand      | Mover pressure on the soil, kPa | Soil hardness, MPa | Depth of the track, cm |
|--------------------|---------------------------------|--------------------|------------------------|
| MTZ-80             | 180–210                         | 1.52–1.72          | 6–8                    |
| K-701, K-744R1     | 225–240                         | 1.8–2.12           | 7–9                    |
| VT-100             | 95–105                          | 0.91–1.14          | 5–6                    |
| MTZ-1221           | 175–200                         | 1.46–1.68          | 6–7                    |
| MTZ-1522           | 170–210                         | 1.63–1.79          | 6–8                    |
| LTZ-155, RT-M-160  | 190–220                         | 1.70–1.84          | 7–8                    |
| T-150K             | 220–260                         | 1.87–2.7           | 8–10                   |
| Tillage cultivator | 180–230                         | 1.68–2.11          | 6–9                    |
| Seeding machine    | 205–250                         | 1.72–2.24          | 7–9                    |

It should be noted that the wheels of tillage machines move along the track left after the tractor passed, thereby exerting an additional effect on the soil due to the multiplicity of exposure. At the same time, the secondary passage of the wheels along one track leads to an increase in the effect on the soil by an average of 12.4%.

**Figure 3.** Lancet cultivating paws after processing 26 ha of loamy soil: a - located in the first row outside the traces of the tractor mover; b - located in the front row along the trail of the tractor propulsion; c - located in the second row along the track of the support wheel of the unit; d - located in the second row outside the traces of the tractor propulsion and the support wheel of the unit.

As a result of the negative impact of MTA movers on the field surface, traces of various widths up to 0.8 m and depths up to 0.15 m remain. Soil hardness in the tracks reaches 2.12–2.7 MPa, table 1.
increase in soil hardness leads to the decrease in cereal crops [10, 11]. Ultimately, this circumstance results in a subsequent increase in energy costs for performing tillage operations and increase in wear of the working bodies of tillage machines. The nature and amount of wear of the cultivator paws, with the same operating time, depend on its location on the cultivator frame (Fig. 3) [1, 7, 8].

Compared to the paws of the first row (12...15%), the paws installed in the second row wear out less intensively (Figure 3). This is due to a decrease in the density and hardness of the soil due to its partial loosening by the paws of the first row [1, 7, 8]. So, the paws moving along the traces left by the wheels of the cultivator and the tractor propeller wear out 1.5 ... 2 times more intensively than the neighboring and occipital chamfer is more clearly identified (Fig. 4) [1, 7, 8].

![Figure 4. Changing the shape of a monometallic blade cultivating paws during operation: $S_{oc}$ – occipital facet, mm; $r_{ed}$ – the radius of the cutting edge, mm; $e_{oc}$ – the angle of inclination of the occipital bevel.](image)

4. **Conclusion**

After conducting the research and analysis of the wear of the working bodies of cultivators, we can conclude that the toe and the blade of the paws are subjected to the greatest wear, and this affects the efficiency of the cultivator as a whole. It follows that when restoring lancet paws, it is necessary to increase the hardness and wear resistance of the toe and blade, which ultimately will increase the resource of the restored part. In addition, the uneven wear of the working bodies, depending on the location on the unit should be taken into account. The lancet paws, standing in the front row and located along the axis of movement of the wheels of the cultivator and tractor should have increased strength and wear resistance compared to the rest. Consequently, the task of creating an equal-strength soil-cultivating unit, the working bodies of which undergo uniform wear, regardless of their location on the machine, becomes promising. This will ultimately increase the durability of tillage machines as a whole and reduce downtime for repair work.

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