WEAR OF PLOUGH CHISEL DURING PROCESSING OF PODZOLIC SOIL

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Abstract. Possibility to predict wear of the plough chisel during tillage of podzolic soil is evaluated. Calculation methodology for determination of load on chisels is developed. Experimental studies had been performed by tilling podzolic gleyish soils in Ozolnieku region, Latvia. Chisel wear was evaluated in dependence of the distance run and the particle elasticity coefficient *k* value was calculated. The chisel wear change in relevance of its hardness and composition of soil was calculated. It was also determined, how the amount of clay in soil affects chisel wear. It was concluded that intensity of plough chisel wear is closely related to the run, chisel material physical and mechanical properties and composition of podzolic soil, as well as the wear depends on chisel hardness and resistance to wear, and is closely related to the soil composition. The more clay contains the soil, the faster the chisel wears, and the more sand it contains, the chisel wear is slower.

Keywords: chisel, wear, podzolic gleyish soil.

Introduction

Rational use of material resources is one of mankind's most important problems. Equipment that is used in agricultural production contains parts that come in direct contact with the soil, moves in relation to it and is wearing out. Most actively employed part in the plough is the ploughshare chisel, which, consequently, wears out the fastest and has to be replaced. Intensity of chisel wear depends on many factors, including the tribological properties of the material, resistance to wear and hardness, physical and mechanical properties of the soil in processing, and other factors. The problem is to predict when a chisel has to be changed, how many chisels are needed for tillage of a particular plot of soil, or the possibility of a broken or worn chisel to be plowed into the soil, with unpredictable consequences, such as spoiled technique during the sowing season.

In this paper, possibility to predict chisel wear during tillage of podzolic gleyish soil is being analysed. Such soil is very popular in Europe and also in the middle part of Latvia – in fields and pastures near Cēsis, Aizkraukle, Ogre, Riga and Jelgava [1]. Exchange reaction for podzolic gleyish soils is acid to depth of 50 cm (pH 4.4). Podzolic gleyish soils are formed on low carbonate, containing light loam, clayed sand, or fluvioglacial sand rocks on moraines. Grading composition of mother rock, content of primary minerals and heavy minerals vary in a wide range among individual regions.

Materials and methods

Podzolic soils generally consist of sand and clay. If the soil is composed of sand, abrasive wear is formed. Presence of clay in the soil causes adhesive wear. During treatment of loam soils both abrasive and adhesive wears are observed. Abrasive wear size is calculated according to equation (1) [2; 3]:

$$W = k \cdot P \cdot L / 3H, \tag{1}$$

where W – wear;
k – particle coefficient of elasticity;
P – amount of applied load;
L – length of run;
H – hardness of decrescent material.

The size of wear can be measured either by loss of mass, or by changes in dimensions. If applied load, run, hardness of material and changes in mass or in dimensions are known, the particle coefficient of elasticity k, which depends on many various conditions and can be between 0.1 and 0.00000001, can be calculated. By knowing the value of the coefficient k and the load, the wear of instrument or part during the working process can be predicted.

Load, which acts on the chisel during tillage, P, according to previous research [4], depends on frontal resistance P_f, weight of reversible soil P_g, and adhesive power P_a. Changes in the plowing speed within real boundaries do not significantly affect the intensity of wear [5]. Frontal resistance is determined using the data [4] by equation (2). Specific soil resistance is expressed as N·cm^{-2}.

$$P_f = k_p \cdot d_0 \cdot i \cdot b, \tag{2}$$

where k_p – coefficient, which depends on the surface orientation towards axis of coordinates,
d_0 – characteristic of specific soil resistance on 1 cm^2, N·cm^2,
i – width of the chisel, cm,
b – length of the chisel's working part, cm.

Coefficient k_p is calculated by taking into account the alignment of the chisel towards z and y axes, by formula (3):

$$k_p = \sin xz \cdot \sin xy, \tag{3}$$

Specific soil resistance depends on the composition of soil and its moisture content. According to literature [4], for soils with the clay content between 5 % and 40 % and moisture between 10 % and 15 %, the specific soil resistance is in range of 1…9 N·cm^{-2}.

Force of reversible soil P_g is expressed as (4):

$$P_g = g \cdot i \cdot b \cdot h, \tag{4}$$

where g – density of the soil, N·m^{-3};
h – depth of plowing, cm.

According to the data [6], the density of the soil, g, can be within range of 12000 to 18000 N·m^{-3}.

Adhesive power P_a is determined by relevance (5):

$$P_a = p_a \cdot i \cdot b, \tag{5}$$

where p_a – specific soil adhesive power, N·cm^{-2}.

Total load, which is applied to the chisel, is calculated by summing all applied forces (6):

$$P = P_f + P_g + P_a. \tag{6}$$

Results and discussion

To determine the chisel wear during plowing podzolic soil and the coefficient k value, an experiment was performed. The farm "Mauriņi" fields, which are located in Ozolnieku region, were selected. According to the research performed by the Department of Agricultural Chemistry Unit of Soils agricultural studies (not published), fields, in which the experiment was performed, are sod podzolated gley soil and sod gleyic soil. Grading composition of the soil consists of sand and clayed sand. Soil reaction is from neutral (pH 6.0..7.6) to acid (pH 4.8).

Chisel wear is measured by changes in the distance from fastening the bolt to the spike of the chisel, L_1, and changes in chisel thickness. Shape and dimensions of the chisel are shown in Figure 1.

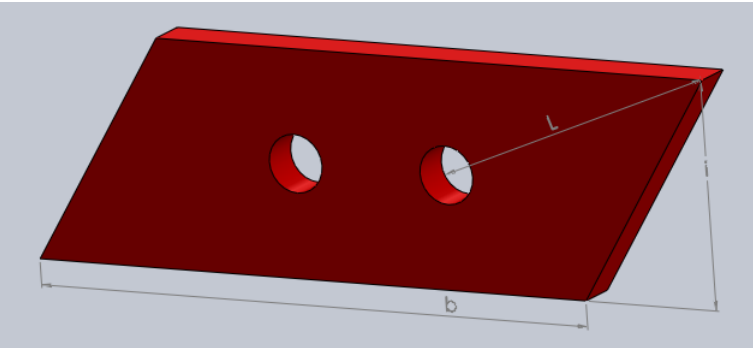

Fig. 1. **Shape and dimensions of the chisel:** L_1 – distance measurement

The size of a new ploughshare L_1 is 110 mm. The chisel is worn and needs to be turned, when this size has decreased to 85 mm, so protecting the supporting parts of the plough from wear. When the chisel is removed, its geometrical dimensions and mass can be measured.

Before the experimental study, hardness of the chisel was measured with the Brinell method. It was determined that the hardness of new chisels is *HB* 500±20 or 5000 MPa. Chisel hardness did not significantly change when worn out.

The alignment of the chisel towards axis is measured. It was determined, that with moving towards x axis, the chisel was aligned to z axis by 30 ° and to y axis – by 80 ° angle. The coefficient k_p value was calculated from equation (3): $k_p = \sin 30° \cdot \sin 80° = 0.5 \cdot 0.98 = 0.49$

It is assumed that the soil contains 20 % clay, the moisture level is 12 %. By using a diagram from the previous research [4] it was assessed that specific resistance for such loam soil is d_0=3 N/cm^2. The chisel width is 6.5 cm, length of the chisel's moving part is 24.0 cm. Frontal resistance is calculated by equation (2): $P_f = 0.49 \cdot 3 \cdot 6.5 \cdot 24.0 = 229.3$ N.

To estimate the weight of reversible soil, P_g, equation (4) is used, where the density g for soil with 12 % moisture content was measured in the experiments, and it was 1350 kg·m^{-3}.

$P_g = 1350 \cdot 0.065 \cdot 0.24 \cdot 0.22 = 4.63$ kgf = 46.3 N.

To determine the adhesive power, the specific coefficient of adhesion p_a has to be known. According to the data [6], for soils with the clay content 20 % and moisture level 12%, the coefficient p_a is 2 kPa. The calculation results in: $P_a = 2000 \cdot 0.065 \cdot 0.24 = 28.6$ N.

Using equation (6), the cumulative load on a chisel is calculated: $P = 229.3 + 46.3 = 275.6$ N. In this case, the adhesive power is not taken into account, because the calculation of the frontal resistance and specific resistance of soil for loam already includes the adhesive power.

To determine the value of the coefficient k during processing of podzolic soil, experimental studies were carried out. Tractor Valtra 8950 with mounting with 4 ploughs of semi-helicoidal body KVU-40000 manufactured for the PGP plow group, equipped with the company "Riginal FRAM" 053090 chisels, was used.

The tillage width – 50 cm. Tillage depth – 22 cm. Speed of tillage – 2.5 m·m^{-1} (or 9 km·h^{-1}). Moisture content in the soil – 12 %. Soil hardness – 2 MPa. The ploughs were equipped with new chisels, the mass of which, hardness and geometric size, including size L_1, were measured. At the beginning of tilling, the tractor odometer reading was registered as well. After tilling 20 000 meters, the size L_1 was measured with caliper, with accuracy ±0.1 mm. Such measures were taken every 20 000 meters, up till 100 000 m, incl. The results were summarized and the intensity of chisel wear in dependence of the run was assessed. The experiment results are shown in Table 1.

Table 1

Chisel wear according to the run

Run, m	0	20000	40000	60000	80000	100000
Size L_1, mm	110.0	105.6	101.4	97.5	93.8	89.9
Wear W, mm	0	4.4	8.6	12.5	16.2	20.1

Eventually it was determined that chisel wear for this type of chisels in the above described soil is apr. 20 mm on 100 km, or the specific wear is on average 200 mkm·km^{-1}. This result allows calculating the average value of the coefficient k from formula (1):

$$k = W \cdot 3H/P \cdot L = 20.1 \cdot 3 \cdot 5000/275.6 \cdot 100000 = 0.01094$$

When the coefficient k is known, it is possible to calculate how the wear of chisels would change in podzolic soils depending on the changes in various factors.

It is possible to evaluate how wear is influenced by chisel hardness HB, if the load on the chisel is P = 275.6 N and the run is L = 100 000 m (see Table 2 for the results).

Table 2

Chisel wear according to its hardness

Chisel hardness, *HB*, N·mm^{-2}	3000	4000	5000	6000
Wear, mm	33.50	25.12	20.10	16.75

The results show that chisel hardness significantly influences the wear. By increasing the hardness of the chisel, the wear is proportionally decreased. To evaluate how chisel wear is influenced by the composition of arable soil, percentage of clay in soil is evaluated by the amount of particles, which are smaller than 0.01 mm in the soil. It is assumed that moisture of the soil is 12 %. Clay content is selected 0, 20, 40, 60, 80 and 100 %. Chisel hardness is *HB* 5000 N·mm^{-2}, run – 100 000 m. To calculate the load *P*, specific resistance of various soils with different clay proportion d_0 should be known, as well as sand and clay specific weights taken into account. Values of the coefficient of soil specific resistance, at clay percentage 0, 20 and 40 %, are read from the diagram [4]. Data for soil with 100 % clay are given in [6]. Load values for soils with 60 and 80 % clay are calculated and shown in the diagram in Figure 2.

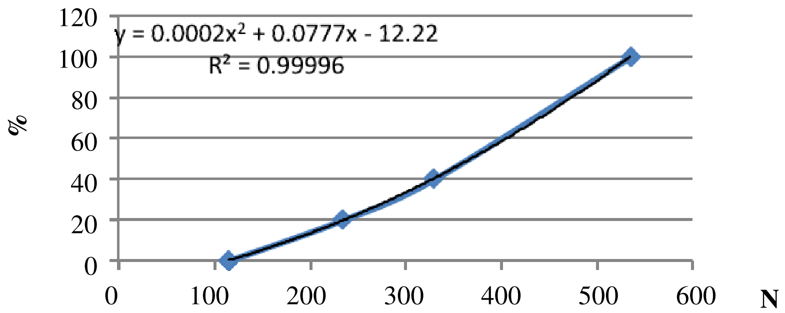

Fig. 2. **Relationship between coefficient of soil specific resistance (*X* axis) and clay proportion in the soil (*Y* axis)**

Load is calculated by equation (7):

$$P = P_{sm} \cdot c_{sm} + P_m \cdot c_m + P_g, \tag{7}$$

where P_{sm} – resistance of sand soil, N,
c_{sm} – special weight of sand in the soil, %,
P_m – resistance of clay soil, N,
c_m – special weight of clay in the soil, %.

Density of the soil varies between 1200 and 1800 kg·m^{-3} in calculations proportionally to the clay specific weight, kg·m^{-1}. If the load to the chisel size is known, chisel wear can be calculated. The results are summarized in Table 3: if the soil contains no clay, but is pure sand, load is the lowest and wear – minimal, on the other hand, if soil contains no sand, only clay, load is the biggest and so is the wear.

Table 3

Chisel wear according to soil composition

Proportion of clay, %	0	20	40	60	80	100
Soil type	sand	loam	loam	clayed sand	clayed sand	clay
Load, N	116	275	330	405	470	531
Wear, mm	8.46	20.00	24.00	29.50	34.30	38.70

The calculations revealed that chisel wear is largely dependent on the chisel hardness and composition of podzolic soil. Increasing the amount of clay in the soil, wear is increasing.

Changes in the tillage speed within real limits did not significantly affect the chisel wear.

The hardness of the chisel surface at the beginning of the experiment and also after wear did not differ significantly and was in range between HB 5000 ± 200 N·mm^{-2}.

Value of the elasticity coefficient *k* for podzolic soil is 0.01 ± 0.002.

Conclusions

1. Intensity of plough chisel wear is closely related to the run, chisel material physical and mechanical properties and composition of podzolic soil.
2. Chisel wear depends on its hardness and resistance to wear.
3. Wear increases in proportion to the increase of clay percentage in the soil composition.
4. Value of the elasticity coefficient, *k*, of soil particles in podzolic soil is 0.01 ± 0.002.

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