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RESISTANCE OF MODIFIED MATERIAL SURFACES FOR AGRICULTURAL TILLAGE TOOLS TO WEAR BY SOIL PARTICLES

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Preliminary Note – Prethodno priopćenje

Agricultural tillage tools are exposed to various forms of wear during operation. Abrasive wear by soil particles is the most important wear form, and the most exposed to it are representatives of tools whose working parts are in direct contact with the soil during work - plows, subsoilers, disc harrows, harrows, cultivators, etc. The factors of wear process can be divided into three categories - abrasive soil conditions, tillage tool properties and operational factors. The paper presents a research of the abrasive wear of modified material surfaces (quenched, cladded and boronized) during motion in the mass of soil particles at different speeds and a comparison of their abrasion resistance.

Keywords: abrasive wear, soil particles, tillage tools, modified material surface, motion speed

INTRODUCTION

Soil cultivation (tillage) occupies one of the most important places in agricultural production. All agricultural machines used during tillage are exposed to various forms of wear, mainly caused by the motion of their working parts (plows, subsoilers, disk harrows, harrows, cultivators, etc.) through the mass of the cultivate soil. Such tribological system is very complex [1, 2] and the interaction between tillage equipment and soil is a complicated tribological problem [1, 3]. According many authors, the most significant part of the overall wear forms in this process is the abrasive wear due to the presence of hard abrasive particles in the soil [1, 2, 4, 5]. The main abrasive elements in the most soils are stones and gravel [2-5].

Apart to abrasion, the wear process include impact, fretting and chemical action [6]. This wear process is influenced by various factors which may be divided into three categories, i.e., depends upon the soil condition (soil type, soil texture, bulk density and moisture content, etc.) [1, 3, 4], operational factors (motion speed, cultivation depth, impact angle between soil and the tool surface, etc.) [1, 4] and design parameters of the tillage tool (material, shape and dimensions, etc.) [1, 2, 4]. The wear resistance of tillage tools depends mainly on surface hardness, and in order to increasing this resistance as the most appropriate method is indicated the surface treatment. In the surface treatment of such tools, various processes can be applicated, like heat treatment and termo-chemical processes [5-8] or hardfacing and coating processes [5, 6, 9, 10].

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Given the importance of agricultural production and the wide application of various tillage tools, they have been numerous researches conducted in the field and laboratory conditions, which dealt with the protection of work surfaces of these tools from abrasive wear by soil particles. The aim of presented research is to establish the resistance of steel samples with modified surfaces to abrasive wear during motion through the mass of soil particles at different speeds.

EXPERIMENTAL PROCEDURE

Wear test samples

The test was carried out on samples made of medium carbon steel C45E (EN) with maximum surface hardness of 207 HB. The declared chemical composition of samples material was: C = 0,42 – 0,50 %; Si $\leq$ 0,40 %; Mn = 0,50 – 0,80 %; P $\leq$ 0,035 %; S $\leq$ 0,035 %; Cr $\leq$ 0,040 %; Mo $\leq$ 0,10 %; Ni $\leq$ 0,40.

The samples were made in shape of a cylinder with dimensions $\varnothing$ 20 × 40 mm. The microstructure of samples was analyzed by inverted metallographic microscope Olympus GX51F-5 with integrated digital camera DP25 and corresponding software for image analysis. Surface hardness and sample cross-section hardness is measured by Shimadzu Microhardness Tester Type M.

Quenched samples

The microstructure of the quenched samples is shown in Figure 1.

The quenching process was carried out without a protective atmosphere, by heating the specimens in an electric furnace to 850 °C, and then by quenching in the water at room temperature. This process achieved

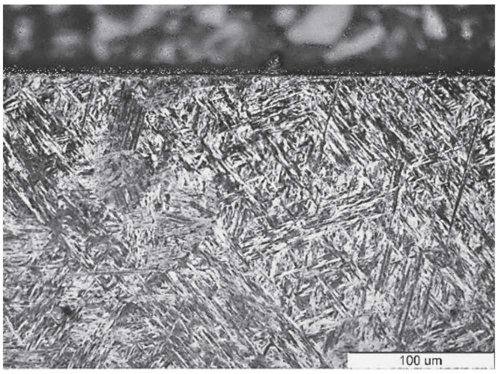

Figure 1 Microstructure of quenched sample

of the martensitic structure with hardness 60-62 HRC shown in Figure 1.

Cladded samples

The cladding process was carried out by the technology of high-frequency induction and deposition of additive powder material with the composition of Ni-Cr-Si-B-Fe (UTP HA-6, Böhler Welding) at a temperature of 1 150 °C. A cladded layer of about 1 mm thick and hardness of about 750 HV 0,1 was formed. The microstructure of the cladded layer is shown in Figure 2.

Boronized samples

Figure 3. shows the microstructure of boride layer.

The boronizing process was carried out in the granulate „EKABOR 3“. The samples were boronized for 4 hours at 1 000 °C and cooled on air in a box. This process resulted with the boride layer in a thickness of 120 – 180 μm and hardness of 1 900 – 1 950 HV 0,1.

Abrasive in Wear test

As the abrasive in wear test was used soil with textural marks „sandy clay loam“. A soil was taken from the plow layer (up the 30 cm depth) and prepared for wear test by drying, manual crushing and sieving through the sieve of 2 mm. Soil moisture was measured before, during and after carrying the experiment and was in the range of 1,2 to ,.6 %. Considering the fact that 65 % of the soil sample was sand, the microhardness of the sand grains was measured and it was determined that most grains have microhardness in range 950 – 1 600 HV 0,1. A smaller amount of grains had a microhardness in range 60 – 80 HV 0,1.

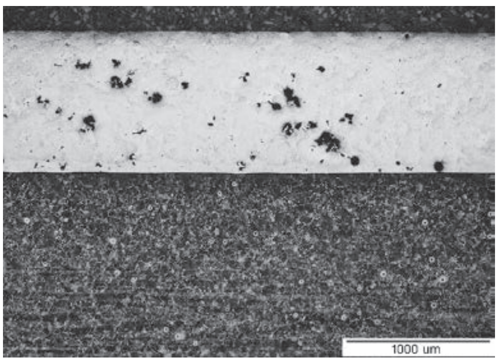

Figure 2 Microstructure of cladded layer

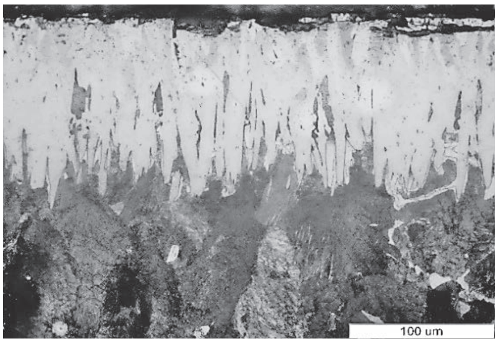

Figure 3 Microstructure of boride layer

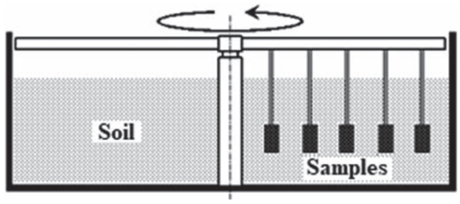

Figure 4 Sketch of wear testing device

Wear testing device

Wear testing was carried out at the device shown with sketch in Figure 4.

For the wear test were selected speeds of samples motion which are within usual limits of the speeds of the tools for basic tillage under exploitation conditions (3,0 – 10,0 km/h), ie. in the interval from 1,0 to 3,0 m/s.

Wear path of samples was determined according to the assumption on the abrasiveness of the soil mass in which the test was carried out and the exploitation indicators of the tillage tools wear, and amounted to 50 000 m.

Masses of samples before and after wear testing are measured by analytical scale Mettler B5C 1000 with precision of 10^{-4} g. Differences in measured masses of samples are the loss mass because of wear. Before each measurement, the samples were thoroughly washed under water jet, cleaned from pasted fine particles of soil and dried with hot air.

RESULTS AND DISCUSSION

Wear experiment was conducted in three replicates for each experiments condition and on the basis of measured weight of samples were calculated the mass loss values, shown in Table 1.

The obtained results were statistically processed by using the software SAS Enterprise Guide 7.1.

Distributions of mass losses data, according to the research parameters – material condition and motion speed, are shown in Figures 5 and 6.

It can be seen in Figure 5 that the distribution of mass loss according to material condition is largest in

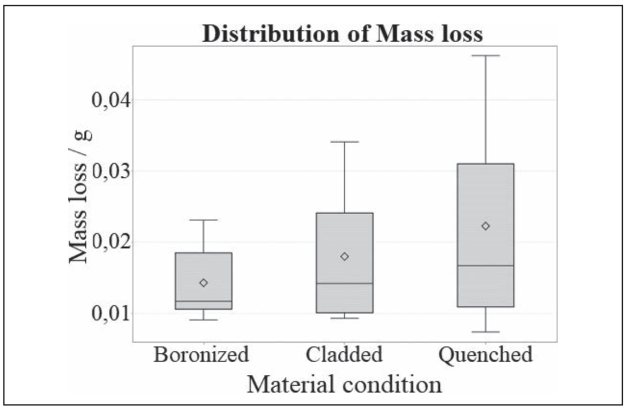

Figure 5 Distribution of mass loss according to material condition

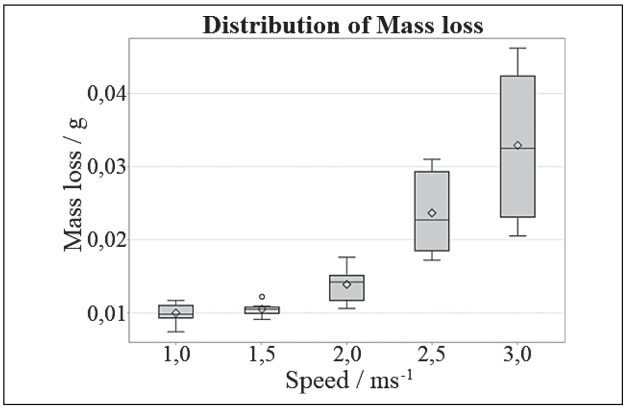

Figure 6 Distribution of mass loss according to motion speed

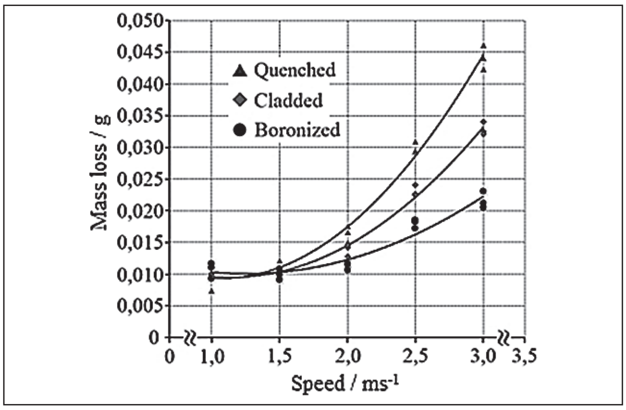

Figure 7 Wear of tested materials

quenched samples and decreases with increasing of surface hardness, so it is smallest in boronized samples.

The distribution of mass loss according to motion speed is small at low speeds and increases with increasing of speed, so it is largest at 3 m/s, as seen in the Figure 6.

The influence of testing factors was determined by analysis of variance (ANOVA), shown in Table 2, which shows that both factors (material condition and motion speed) also their interaction are significant for the wear process.

The results of the wear experiments were processed by regression analysis, which determined the dependence of the mass loss of the tested materials on the change in the motion speed of the samples, as shown in the diagram in Figure 7.

Table 1 **Mass losses of tested samples**

Speed / m/s	Mass loss /g		
	Δm_1	Δm_2	Δm_3
Quenched samples			
1,0	0,0074	0,0114	0,0098
1,5	0,0122	0,0104	0,0109
2,0	0,0151	0,0167	0,0176
2,5	0,0293	0,0310	0,0295
3,0	0,0462	0,0424	0,0441
Cladded samples			
1,0	0,0093	0,0098	0,0101
1,5	0,0105	0,0099	0,0107
2,0	0,0128	0,0142	0,0146
2,5	0,0241	0,0224	0,0227
3,0	0,0341	0,0325	0,0321
Boronized samples			
1,0	0,0093	0,0110	0,0117
1,5	0,0108	0,0099	0,0091
2,0	0,0116	0,0117	0,0106
2,5	0,0172	0,0182	0,0185
3,0	0,0205	0,0231	0,0212

Table 2 **ANOVA for testing factors**

Source	Sum of Sqares		Mean Square
Material condition	0,00047767		0,00023883
Speed	0,00352733		0,00088183
Mat condi * Speed	0,00055169		0,00006896
Error	0,00003814		0,00000127
Corected Total	0,00459483		
Source	DF	Pr > F	F value
Material condition	2	< 0,0001	187,86
Speed	4	< 0,0001	693,63
Mat condi * Speed	8	< 0,0001	54,24
Error	30		
Corected Total	44		

Wear dependences on motion speeds were interpreted as regression equations:

- Quenched samples:

$$y = 0{,}0096x^2 - 0{,}0207x + + 0{,}0205;\ R^2 = 0{,}9883 \quad (1)$$

- Cladded samples:

$$y = 0{,}0069x^2 - 0{,}0157x + + 0{,}0185;\ R^2 = 0{,}9911 \quad (2)$$

- Boronized samples:

$$y = 0{,}0040x^2 - 0{,}0101x + + 0{,}0164;\ R^2 = 0{,}9299 \quad (3)$$

The high value of the coefficient of determination R^2 for each material indicates a strong dependence of mass loss on changing of motion speed.

CONCLUSION

Based on the conducted experiment and statistical analysis, it was found as followed:

- The wear by soil particles at all tested materials increases with increasing of motion speed. The dependence of wear intensity on motion speed for each material can be described by equation in the form of a square polynomial.
- The wear of quenched samples was more highly than samples with cladded and boride layers, es-

pecially at higher motion speeds. This can be attributed to the significantly lower surface hardness of quenched samples compared to the samples with specified layers.

- The cladded layers showed less wear resistance compared to the boride layers, which can also be attributed to the lower surface hardness than the boride layers.

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Note: Responsible translator: Prof. Martina Šuto, University of Osijek