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THE EFFECT OF THE SURFACE LAYER OF A PLOWSHARE CHISEL ON PLOWSHARE WEAR IN MEDIUM LOAM*

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Key words: surface layer, wear, plowshare chisel, medium loam, niobium carbide.

Abstract

The effect of the surface layer of a plowshare chisel on plowshare wear in medium loam was studied under laboratory conditions. The hardness, percentage composition of chemical elements, including transition metals, and microstructure characteristics of the surface layer were determined. The obtained results suggest that niobium and chromium content and the microstructure of the surface layer significantly affect the intensity of plowshare wear.

WPŁYW RODZAJU WARSTWY WIERZCHNIEJ DŁUTA LEMIESZA PŁUŻNEGO NA ZUŻYCIE W GLINIE ŚREDNIEJ

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Słowa kluczowe: warstwa wierzchnia, proces zużycia, dłuto lemiesza, glina średnia, węglik niobu.

Abstrakt

Przedstawiono wyniki badań nad wpływem warstwy wierzchniej dłuta lemiesza płużnego na przebieg zużywania w glinie średniej w warunkach laboratoryjnych. Warstwy wierzchnie scharakteryzowano twardością, procentowym udziałem poszczególnych pierwiastków, w tym metali przejściowych, oraz charakterystyką mikrostruktury. Na podstawie przeprowadzonych badań stwierdzono istotny wpływ zawartości niobu, chromu oraz mikrostruktury warstwy wierzchniej na intensywność zużywania.

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Introduction

The properties of working elements are one of the three principal factors affecting the wear intensity of soil engaging implements. Resistance to wear in the soil is determined by the hardness, plasticity, microstructure, microstructure stability and crystalline anisotropy of the surface layer. The above properties are optimized through the selection of the appropriate chemical composition, including the size, shape and distribution of carbide grains (RUTKOWSKI, STOBIERSKI 2007). NAPIÓRKOWSKI (2005) demonstrated that the presence of selected elements which make up the working element intensifies hydrogen absorption (e.g. sulfur), while other elements inhibit the process (e.g. manganese, silicon, carbon). The cited author noted that materials with a high content of C+Cr (45%) and boron (2.7%) were characterized by the highest resistance to wear. The crumbling of hard carbide particles out of the matrix can be inhibited through the use of compounds with a higher content of transition metals and amphoteric elements.

The highest wear intensity is noted in working elements of plowing implements, in particular plowshares, leading to interruptions in tillage operations and increasing process costs. The above problem prompts tool suppliers to search for new structural solutions (e.g. plowshares with chisels) and materials with increased resistance to wear.

Pad welding is one of the methods applied to increase the resistance of working elements. JANKAUSKAS et al. (2008) compared the wear of original and pad welded plowshares in a sugar beet harvester. The authors investigated pad welds with a low carbon and chromium content, pad welds with a high carbon and chromium content, pad welds with a high carbon, chromium, silicon and boron content as well as pad welds with a high carbon, chromium, niobium, molybdenum, tungsten and boron content. The results of their experiment indicate that the wear intensity of standard plowshare material was six-fold higher than that of pad welds containing Fe-C-Cr-Nb-Mo-W-B. It should be noted, however, that the grain size distribution of the processed soil and the chemical composition of the plowshare were not given in the cited study.

The aim of this study is to compare the wear intensity of surfaces faced with iron-based pad welds with a high content of C + Cr and transition metals and plowshare chisels coated with boron steel.

Materials and Methods

The experimental material comprised the surface layers of Kverneland plowshare chisels and chisel surfaces pad welded with materials that increase tilling equipment's resistance to wear (Tab. 1). The investigated plowshare chisels were made of fine-grained boron steel treated with heat induction. Detailed information concerning the chemical composition of boron steel applied in Kverneland chisels could not been obtained, therefore, it was assumed that its composition is similar to that of boron steel used by other chisel suppliers in the world (Tab. 2).

Table 1

Chemical composition of padded welds [%]

Element	Abradur 64	EStelMn60	EStelMoNb60
C	7.0	4.40	5.11
Mn	1.73	4.82	1.02
Si	0.38	1.68	1.46
Cr	24.20	29.60	21.90
Mo	0.11	0.04	7.00
Ni	0.12	0.30	0.06
Al.	0.04	0.03	0.05
Cu	0.08	0.09	0.09
P	0.03	0.05	0.02
S	0.01	0.01	0.02
B	–	0.03	–
W	–	0.05	2.00
V	0.06	–	1.10
Ti	–	–	0.03
Nb	7.00	–	7.00

Table 2

Characteristics of boron steel used in working elements of soil engaging implements

Steel type	Chemical composition [%]							
	C	Si	Mn	P	S	Cr	Ti	B
ThyssenKrupp Tbl Plus	0.35	0.25	1.30	0.04	0.03	0.14	0.03	0.003
Ovako 27MnB4	0.27	0.30	1.20	0.03	0.03	0.20	–	0.004
Rautaruukki B27	0.27	0.25	1.20	0.03	0.02	0.30	–	0.002

The hardness of the investigated surface layers was measured with the HMu 10 hardness tester in accordance with standard PN-EN ISO 6507. Microscopic evaluations were carried out using the Neophot 52 microscope with standard and reversed lenses under 50x to 2000x magnification. Surface layers were observed under the TESLA BS340 scanning electron microscope coupled with the TESLA NL-2001A microanalyzer.

A total of 20 samples were prepared, including five samples of every material type. The samples were overlaid using the following low-hydrogen, heavy coated electrodes:

– Abradur 64,
– EStelMn60,
– EStelMoNb60.

Prior to pad welding, traces of corrosion, paint and impurities were removed from the chisels. Additional materials were overlaid in accordance with the manufacturer's requirements at the Laboratory of the Department of Vehicle and Machine Design and Operation. Layers with the thickness of 2.5 mm – 3.0 mm were placed on a rectangular prism cut out from a Kverneland chisel, measuring 30 × 25 × 10 mm. After pad welding, the samples were ground.

The samples were tested in a wear testing machine with the involvement of a "rotating pan method" (Fig. 1). The abrasive substance was natural soil whose grain size distribution was determined as medium silty loam by Bouyoucose-Casagrande's aerometric method modified by Prószyński in accordance with standard BN-78/9180-11 (Tab. 3). Soil moisture was kept constant at approximately 11%. Soil pH(KCl) was 6.19 (slightly acidic).

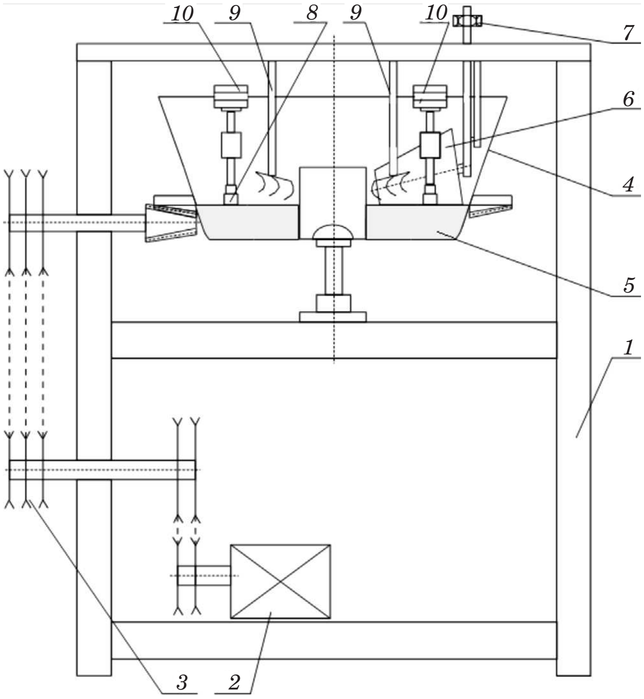

Fig. 1. Test stand for testing wear resistance in soil: *1* – frame, *2* – engine, *3* – belt transmission, *4* – pan, *5* – soil, *6* – crushing rollers, *7* – roller clamp, *8* – sample holder, *9* – loosening forks, *10* – sample weights

Table 3

Grain size distribution in soil

Grain size groups	Sand			Silt		Clay		
Fraction diameter [mm]	1.0–0.5	0.5–0.25	0.25–0.1	0.1–0.05	0.05–0.02	0.02–0.005	0.005–0.002	<0.002
Fraction content [%]	5	8	21	8	20	16	11	11
	34			28		38		
Classification as per BN-78/9180-11	medium silty loam							

Results and Discussion

The surface layer padded with the Abradur 64 electrode (Table 4) was characterized by the highest hardness and the lowest hardness range, indicating relatively even distribution of chromium and niobium carbides throughout the surface layer (Fig. 2). According to RUTKOWSKI and STOBIERSKI (2009), when a small quantity of chromium carbide is added, microstructures with a niobium and chromium carbide matrix may be single-phase structures containing only solid chromium carbide solution in the matrix carbide, or two-phase structures containing $Cr_{23}C_6$ as well as Cr_7C_3.

Table 4

Results of hardness measurements

Series	Average hardness HV10	Standard deviation HV10	Confidence interval boundaries $\alpha = 0.05$ HV10	Range HV10
Kverneland steel	597.56	14.54	586.59 ÷ 608.52	48
EStelMoNb60	723.89	61.00	677.88 ÷ 769.90	161
Abradur 64	760.56	28.50	739.06 ÷ 769.90	77
EStelMn60	678.67	44.69	644.96 ÷ 712.37	130

The second highest hardness value was reported for the EStelMoNb60 padded weld which was characterized by highly irregular distribution of numerous Mo_2C, VC and TiC carbides (Fig. 3). The microstructure of the EstelMn60 weld (Fig. 4) comprised primary carbides with diverse thickness and length and [α + (Fe, Cr)$_7$ C$_3$] eutectic. The lowest hardness range was observed in respect of boron steel. The reference microstructure of boron steel is presented in Figure 5.

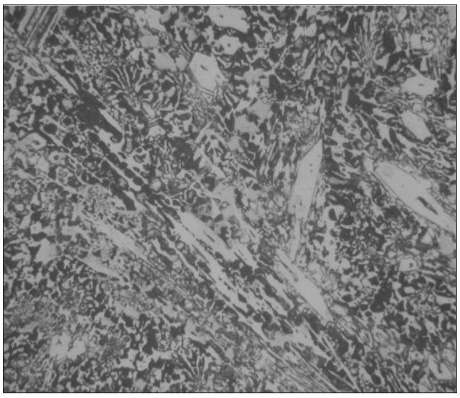

Fig. 2. Microstructure of Abradur 64 padded weld

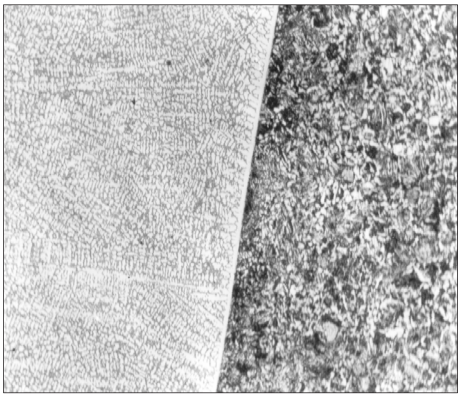

Fig. 3. Microstructure of EStelMoNb60 padded weld

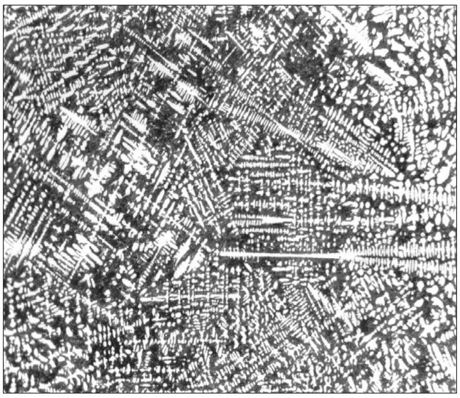

Fig. 4. Microstructureof EStelMn60 padded weld

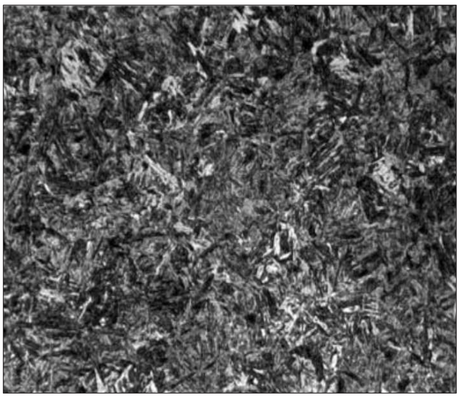

Fig. 5. Microstructure of boron steel
Source: ŁABĘCKI et al. (2007)

In the studied group of structural materials, surface layers containing niobium, transition metal of group VB in the periodic table, were characterized by the highest resistance to wear (Fig. 6). Niobium carbides were marked by significant structural variation, thus supporting the production of ceramic matrix composites (CMC). Structural variations in niobium carbides NbC (hardness of 1800 HV) limits the solubility of chromium carbides in the network carbide, thus supporting the synthesis of $NbC_{0.95}$–$Cr_{23}C_6$ composites (RUTKOWSKI, STOBIERSKI 2009). The resulting structure significantly reinforces the surface layer whose resistance to wear increases with its C and Cr content.

The wear intensity of pad welded surface layers was more than 21.3- (Abradur 64) to 3.5-fold (EStelMn 60) lower than that of Kverneland boron steel (Fig. 7).

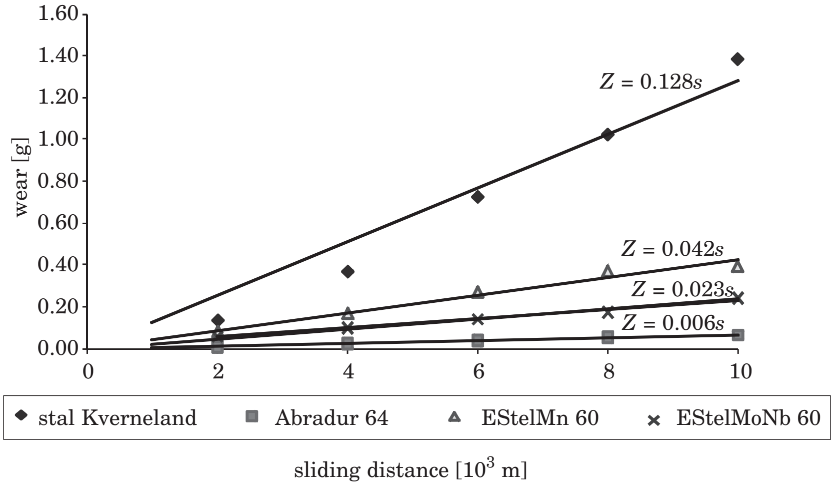

Fig. 6. Wear of padding welds as a function of sliding distance

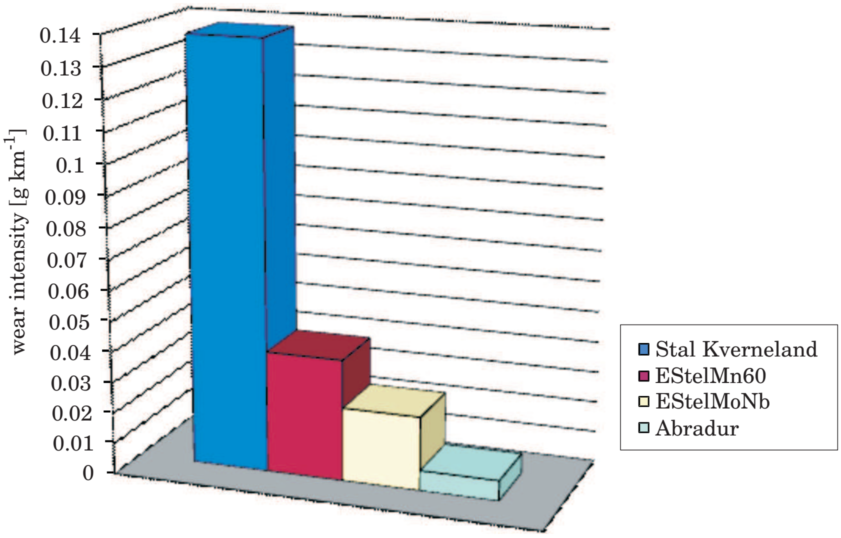

Fig. 7. Wear intensity of padded welds in medium silty loam

Conclusions

The pad welding technology supports the selection of surface layer properties that best match working process requirements. In comparison with boron steel, iron-based welds are characterized by significantly higher resistance to wear in the soil environment. The highest resistance to wear in medium silty loam was reported for surfaces padded with the Abradur 64 electrode with weld hardness of 760 HV10. The average wear of Kverneland boron steel was more than 20-fold higher in comparison with Abradur 64 welds. Wear intensity in medium silty loam decreases with a rise in the niobium and chromium content of welds, thus contributing to the formation of surface layers that are highly resistant to wear. The wear intensity of a surface layer is determined by its structural homogeneity and the range of surface hardness.

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