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A COMPARISON OF WEAR OF PLOUGH CHISELS MADE OF DIFFERENT MATERIALS AND AFTER PAD WELDING

PORÓWNANIE ZUŻYCIA DŁUT PŁUGA WYKONANYCH Z RÓŻNYCH MATERIAŁÓW ORAZ PO NAPAWANIU

Key words: wear, plough chisel, pad welding, field tests, soil.

Abstract The paper presents quantitative results of mass wear of plough chisels working in soil made of various steel types and subjected to pad welding. The research was carried out in real field conditions on soils with similar physical and chemical parameters during routine field work in autumn. The scope of the research included the quantitative determination of wear values depending on the type of steel used and the surface treatment carried out. The photographs also show the surface profiles of plough chisels exposed directly to the impact of abrasives.

Słowa kluczowe: zużycie, dłuto pługa, napawania, badania polowe, gleba.

Streszczenie W pracy przedstawiono wyniki ilościowe zużycia masowego dłut pługa pracujących w gruncie, wykonanych z różnych gatunków stali oraz poddanych napawaniu powierzchniowemu. Badania przeprowadzono w rzeczywistych warunkach polowych na glebach o podobnych parametrach fizycznych i chemicznych, podczas rutynowych prac polowych w okresie jesiennym. Zakres badań obejmował, ilościowe wyznaczenie wartości zużycia w zależności od zastosowanego gatunku stali i przeprowadzonej obróbki powierzchniowej. Zaprezentowano także zdjęcia ukazujące profile powierzchni dłut bezpośrednio narażonych na działanie wymuszeń ściernych.

INTRODUCTION

The dynamic development of agricultural technologies results in the continuous improvement of heavily loaded machine parts subject to abrasive wear in the soil [**L. 1**]. The quick wear of these elements increases the operating costs and adversely affects the quality parameters of work. Therefore, the elements for working in the soil require good abrasion resistance with an acceptable ratio of this resistance to their price. The problem is mainly the change in the geometric shape of the surface exposed to abrasive wear, which consequently results in the lack of adequate working capacity. In the case of agricultural ploughs, elements particularly exposed to heavy wear are the chisels of ploughshares. The plough chisel is responsible for the most important function during work, i.e. for the separation of the soil, which is closely related to the cutting angle that occurs on this element.

The paper presents the values of abrasive wear that happened in the soil with pad-welded chisels of ploughshares, the welding being aimed at increasing their resistance to abrasive wear. The wear of elements working in the soil depends on many factors, which can be divided into three groups. In the first group, there are the conditions prevailing in the abrasive material, i.e. in soil, in the second group, there are operational conditions [**L. 2, 3**]. The third group includes factors related to extortions acting on the working element. The first of the groups may include characteristics related to, inter alia, soil moisture, grain size, soil

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compactness, and soil pH. The second group includes the parameters dependent on the construction of the plough, i.e. the shape of the ploughshare body, the type of the mouldboard and plough, construction parameters of the plough, i.e. the number of bodies, the location of the body on the frame and the material and method of strengthening the surfaces most exposed to wear, and essential elements are also cutting angles and sheer angles. The third group includes the working parameters of the plough, e.g. surface pressure on soil and working speed [**L. 4**]. At present, one of the main development tendencies in agricultural technology is self-made pad welding of elements that have direct contact with the abrasive medium in order to give them adequate resistance to abrasive wear. Electrode manufacturers produce electrodes specially designed for this type of treatment, which increases its popularity. Modification of ploughshares shapes is not possible due to the type of work they do. The tests were carried out in field conditions to determine the impact of selected surface treatment parameters on the type and amount of abrasive wear under real conditions. Real working conditions were chosen, because soil has different characteristics in different parts of the field, which demands the chisel to be resistant to many specific factors depending on the type of soil.

RESEARCH METHODOLOGY

In the tests, chisels made of Raex 400 and Hardox 500 steel were used. These chisels were additionally padded in places most exposed for wear, i.e. on the blade. Two electrodes with different compositions of alloying elements and a different range of applications were used for welding. Steels used for chisels are hard-wearing steels with a high content of alloying elements such as Mn, Cr, and Ni. These additives significantly increase the resistance to abrasive wear of machine elements working in soil. **Table 1** presents the chemical compositions of steels used for the tests.

Table 1. Chemical composition of the tested elements
Tabela 1. Skład chemiczny badanych elementów

Steel type	C	Si	Mn	P	S	Cr	Ni	Mo	B	References
Raex 400	0.16	0.5	1.6	0.025	0.01	1.2	1	0.25	0.005	[5]
Hardox 500	0.27	0.5	1.6	0.025	0.01	1.2	0.25	0.25	0.005	[6]

The first electrode, which was marked in the tests with the symbol 'E1', is normally used to weld steel elements that are exposed to large impacts. The pad created as a result of welding with this electrode has a high resistance to abrasive wear caused by hard particles such as stones, coal, or sand, and it also has resistance to abrasion. The E1 electrode gives the surface hardness of 296 HV_{01}. The second electrode, denoted as 'E2', is characterised by fused tungsten carbides (FTC) and a graphite jacket, and it is intended for electric welding. It can be welded with cast steel with a carbon content of up to 0.5%. The hardness of the layer padded with this electrode is about 1000 HV_{01}. The chemical composition is presented in **Table 2**.

Table 2. Chemical composition of electrodes
Tabela 2. Skład chemiczny elektrod

Symbol	C	Cr	References
E1	0.4–0.5	6–7.5	[7]
E2	4.3–4.5	13.5–14.4	

Hardness tests were performed with a Zwick 3212 durometer. The hardness tests of native materials, i.e. Raex 400 and Hardox 500 steels, were also performed for research purposes. The test results are shown in **Table 3**. The tests were carried out on the 'chisel core' and on the chisel blade, which was covered with a padded layer. The test was aimed at checking the hardness of the materials selected for the research.

Table 3. Hardness of the tested elements
Tabela 3. Twardość badanych elementów

	Raex 400		Hardox 500	
	Core	Padding	Core	Padding
Average hardness	361.5	296.3	572	1003
Standard deviation	3.35	2.49	0.7	12.25

The tests were carried out in field conditions during autumn ploughing in sandy soil. Soil types were determined on the basis of available soil and agricultural maps of the area. The soil was characterised by the granulometric percentage of individual fractions, mechanical composition, density, and moisture. Shear stresses as well as humus content and pH of the soil were also examined. Average values of soil parameters depending on the soil class are presented in **Table 4**. In order to carry out the tests, 50 samples were taken from the field at various places.

Table 4. Soil parameters depending on the class [L. 7]
Tabela 4. Parametry gleby w zależności od klasy [**L. 7**]

Soil characteristics	Soil class
	IV
	sandy loam
Fractional composition	
Sand (1–0.1 mm) [%]	68
Fine sand (0.1–0.05 mm) [%]	10
Silt (0.05–0.02 mm) [%]	10
Floatable parts (below 0.02 mm) [%]	12
Gravel share in soil [%]	3.2
Humus content [%]	2.1

Table 5. Other soil parameters [L. 8]
Tabela 5. Pozostałe parametry gleby [**L. 8**]

Selected physical and chemical parameters	
Soil pH	6.8
Soil moisture [%]	15
Shear stress [kPa]	21

The test pieces were mounted on a four furrow agricultural plough. It has half-screw mouldboards, and the working width was set at about 50 cm, while the working depth is 25 cm (±3 cm). The tractor used for the test had a power of 150 hp. The working speed was 8–9 km/h. The speed at which the farm tractor worked is equal to the speed at which ploughing is usually performed. **Fig. 1** shows the location of the plough chisel. The mechanical parameters have been set to the value with which field treatments are performed in real conditions. This allows for the maximum reproduction of the real conditions with which agricultural ploughs are used.

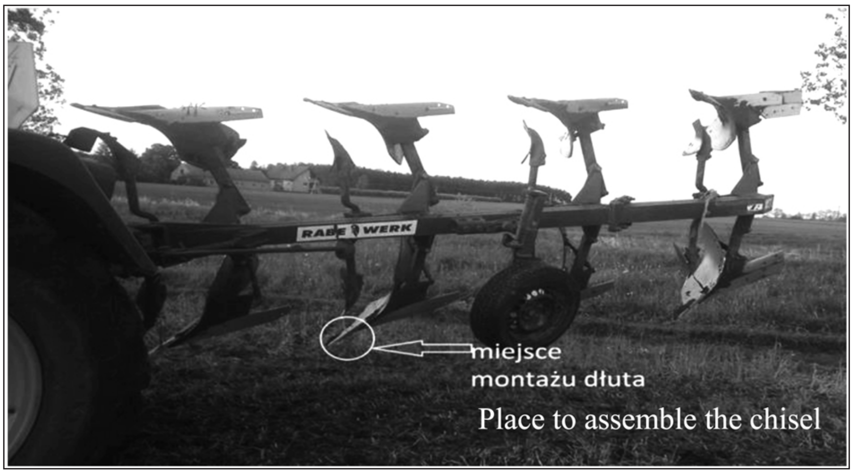

Fig. 1. Place to assemble the chisel [L. 8]
Rys. 1. Miejsce montażu dłuta [**L. 8**]

The tests were carried out over a distance of 250 km. Four chisels were made from each material and their order was changed regularly to average the impact of forces on individual chisels. The steel was padded with a layer about 1 cm thick. **Figure 2** shows the structure of Hardox 500 steel together with the padding made with the 'E2' electrode, while **Figure 3** shows the Raex 400 steel with the padding made with the 'E1' electrode.

The place of pad welding and the appearance of the element after the procedure are shown in **Fig. 4**. The pad welded surface can be easily distinguished from the surface without the treatment.

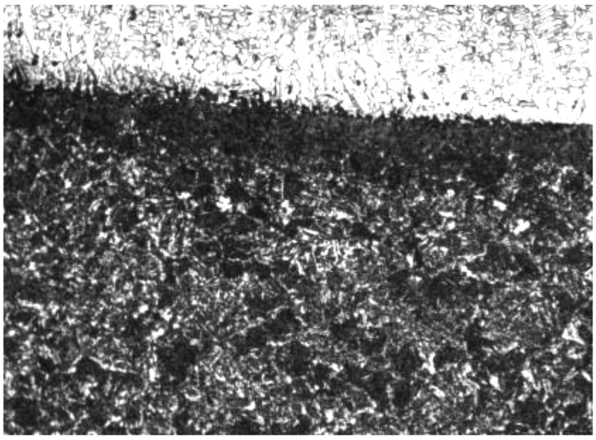

Fig. 2. Hardox steel after pad welding
Rys. 2. Stal Hardox po napawaniu

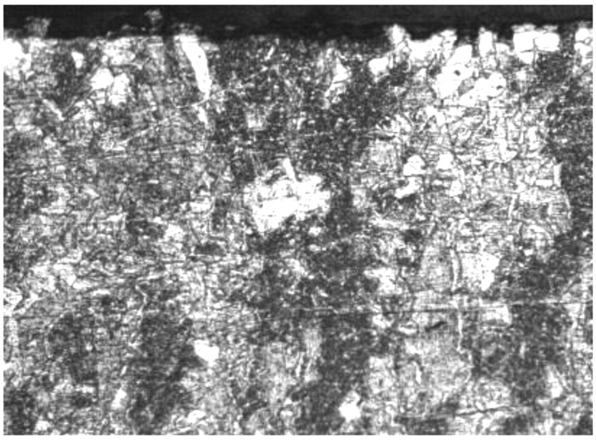

Fig. 3. Raex steel after pad welding
Rys. 3. Stal Raex po napawaniu

Fig. 4. Element after surface treatment [L. 8]
Rys. 4. Element po wykonanej obróbce powierzchniowej [**L. 8**]

In order to determine the loss of mass, the mass was determined with a weight with precision of 0.005 kg. Before the measurement, the samples were thoroughly washed in an ultrasonic cleaner and then dried in a laboratory drier. The measurement results were averaged and presented in **Table 6**.

Table 6. Results of the mass loss measurement
Tabela 6. Wyniki badania ubytku masy

Material	Sample No.	Wear values per km [g/km]			Material	Sample No.	Wear values per km [g/km]		
		100 km	200 km	250 km			100 km	200 km	250 km
Hardox 500	1H	0.175	0.27	0.542	Hardox 500 + pad welding	1HN	0.105	0.21	0.345
	2H	0.165	0.231	0.457		2HN	0.09	0.165	0.278
	2H	0.173	0.284	0.527		3HN	0.108	0.201	0.315
	4H	0.162	0.295	0.538		4HN	0.105	0.21	0.346
	Average	0.169	0.27	0.516		Average	0.102	0.197	0.321
Raex 400	1R	0.178	0.305	0.534	Raex 400 + pad welding	1RN	0.105	0.225	0.345
	2R	0.186	0.31	0.558		2RN	0.135	0.255	0.405
	3R	0.192	0.295	0.542		3RN	0.107	0.195	0.309
	4R	0.198	0.312	0.598		4RN	0.125	0.212	0.387
	Average	0.189	0.306	0.558		Average	0.118	0.222	0.362

RESULTS

The main tests were carried out during autumn ploughing. Identifiers were applied for identifying the chisels. The designation H meant a sample made of Hardox 500 steel, while the designation R stated for Raex 400 steel. The addition of the letter N meant that the chisel was also subjected to pad welding. The obtained values of the loss of mass are shown in **Table 6**.

After the tests, a significant change in the shape of the surface profiles caused by different force distributions and different methods of pad welding was also observed. **Figs. 5** and **6** show the shape changes of the element made of Hardox 500 steel, while **Fig. 7** and **8** show the obtained profiles made of steel Raex 400.

Fig. 5. The face of the Hardox 500 steel element
Rys. 5. Powierzchnia czołowa elementu ze stali Hardox 500

Fig. 6. Side surface of the Hardox steel element
Rys. 6. Powierzchnia boczna elementu ze stali Hardox

Fig. 7. The face of the Raex 400 steel element
Rys. 7. Powierzchnia czołowa elementu ze stali Raex 400

Fig. 8. The face of the Raex 400 steel element
Rys.8. Powierzchnia boczna elementu ze stali Raex 400

Analysing the surface profiles of chisels after the abrasive test, it can be concluded that the welded layers of lower hardness have been largely wiped from the sample, while the layers with higher hardness caused the native material to flow outside the padding, which resulted in the removal of the native material in a specific way (**Figures 5** and **6**). For testing purposes, a weld pad control point was placed away from the target padding site. The effect of this treatment was to check whether the single point also has an increased resistance to wear. It turned out that this point is characterised by resistance that allows one to extend the life of the element. The effect is presented in **Figure 9**.

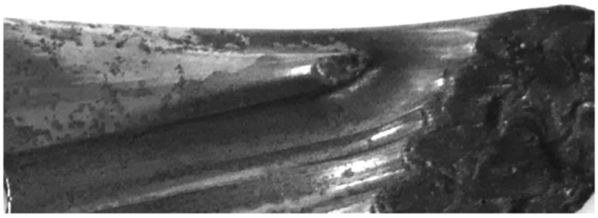

Fig. 9. Pad welding measuring point
Rys. 9. Punkt pomiarowy napoiny

CONCLUSIONS

The conducted tests allow to state that Hardox 500 steel after pad welding has a higher abrasion resistance by 62% in relation to the native material without welding. However, the wear resistance of Raex 400 steel increased by 64% compared to the original material. In addition, Hardox 500 steel showed significantly higher abrasive wear resistance than Raex 400 steel under the given operating conditions. The spot application of the pad welding significantly improves the abrasive wear resistance, especially within the padded point. The performed tests also allowed the determination of which electrode allows the extension of the service life of elements working in soil. Obtained results clearly indicate that electrodes used for welding chisels and other elements intended for work in soil significantly increase resistance to abrasive wear and the treatment can easily be performed in home workshops.

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