Verification of the working life of a ploughshare renovated by surfacing and remelting in the operation

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Abstract

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The most common way of renovation of the working parts of agricultural machinery is surfacing by hardfacing coated electrodes and piped hardfacing wires. Another way to prolong the working life of the machinery is the chemical heat treatment of the material surface by nitriding. By nitriding, high hardness is obtained of the surface affected by a suitable environment and by raised temperature. This paper deals with the possibilities of increasing the lifetime of the functional area of a ploughshare by the surfacing piped wire and hardfacing electrodes and reshaping the surface layer in an argon and nitrogen environment by using a welding rectifier and the Tungsten Inert GAS method, and by validation of these methods of renovation in operating conditions.

Keywords: equipment wear; renovation; weld deposit; saturation; soil processing tool

The wear of the cutting edges of tillage machinery in operating conditions significantly affects the quality of work and energy demands of land cultivation. With a greater thickness of the ploughshare cutting edge, the traction force and fuel consumption significantly increase while the working intensity and depth of tillage decrease. Also, the quality of tillage greatly decreases with a greater thickness of the ploughshare cutting edge. Therefore, the renovation of individual tools is performed so that the cutting edge is resistant against wear and the self-sharpening effect is created. This can be achieved through the thickness of the layer applied and the hardness of the additional and basic material (Žitňanský, Žarnovský 2005; Mikuš et al. 2006).

The size and intensity of wear can be measured by using quantitative methods, monitoring the weight loss and linear dimensions of a unit circuit in laboratory and operating conditions (Daňko et al. 2011; Kotus et al. 2011).

The user's sphere looks for different ways of prolonging the technical life of these tools. One of the potential possibilities is the application of a surfaced layer of hard material on the working part of the tool. The most common way of the renovation of the working parts of agricultural tools is surfacing by hardfacing coated electrodes and piped hardfacing wires. However, the metal inert gas (MIG) and metal active gas (MAG) technologies have recently been put in use for surfacing with piped hardfacing wires, mainly due to a higher labour productivity, the increase of surfacing performance, and the economy and quality of the weld deposit. High wear resistance and significant savings are achieved

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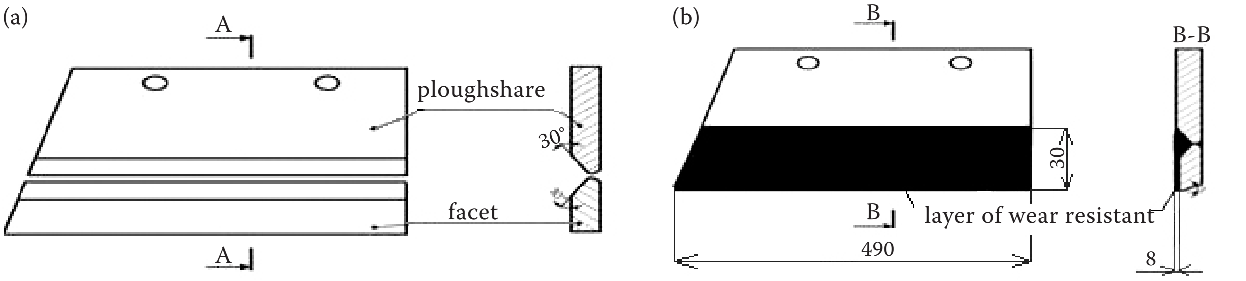

Fig. 1. Modification of the ploughshare (a) preparation of the facet and ploughshare, (b) weld deposit and creating the edge

by these procedures as evidenced by the works of authors Chotěborský et al. (2009a,b), Čičo and Bujna (2011), Kotus and Čičo 2011, and Kovaříková et al. (2011).

The structure of the weld deposit very significantly changes the characteristics of the weld deposit, weight losses, and relative wear resistance (Tolnai, Čičo 2001; Chotěborský et al. 2009a,b).

Another option to increase the resistance of the functional areas is the heat and chemical heat treatments, for example boriding and nitriding. The required hardness for nitriding is achieved already during the saturation of the surface by nitrogen, i.e. without further heat treatment. The essence of the higher hardness is the formation of very hard chemical compounds of nitrogen with iron and some ingredient elements. Hard layers with a thickness of up to 0.5 mm are formed by nitriding. Nitriding is conditioned by the presence of atomic nitrogen on the metal surface. Atomic nitrogen is able to penetrate through the surface absorption layer of nitride at an increased temperature of the basic metal lattice, and further to diffuse into the steel (Pulc et al. 2004).

In conditions of arc remelting in the gaseous atmosphere, a dissociate environment is created, which allows to create a stable structure with better mechanical properties and mainly with a higher wear resistance.

By this contribution we would like to highlight the possibilities of improving the lifetime of agricultural machinery working tools, especially by increasing the abrasion resistance of the surface layer due to nitrogen diffusion applied on the surface by remelting the material – the facet from the material class according to standard STN 41 5230 (1977), and by surfacing the facet from the material class according to standard STN 41 2050 (1976), followed by comparing these technologies in operating conditions. Surfacing was done by hand arc surfacing (MMAW) with hardfacing electrode and by using the MAG method (FCAW) of hardfacing wire electrode.

MATERIAL AND METHODS

A six-furrow plough Lemken EuroDiamant (Lemken GmbH & Co., Alps, Germany) was used for conducting the operating test. Ten worn-out ploughshares were renovated; the cutting blades of worn-out ploughshares were cut off with the laser and in their place a belt (facet) from the material of size 490 × 30 × 8 mm was welded on so that all ploughshares were of the same size (Fig. 1). Two ploughshares were used as etalons, one with the facet from the material according to STN 41 2050 (1976) without a weld deposit, and one from the material according to STN 41 5230 (1977) without remelting. The welding of the facet was done by using the welding semi-automatic machine Uni MIG 450p (Billik s.r.o., Nitra, Slovakia). The facet for hard-welds was produced from steel according to STN 41 2050 (1976). The facet for nitriding was made from steel according to STN 41 5230 (1977), the composition and properties of which contributed at the best to meeting our desired final quality parameters. The piped welding wire (referred to in the text as No. 1; Table 1) was used as an additional material for three ploughshares, and the hardfacing coated electrode (referred to in the text as No. 2; Table 1) was used for the remaining two ploughshares.

The welding parameters with the coated electrode No. 1: Ø d =1.6 mm, U = 25.5 V, welding speed v_n = 0.35 m/min, wire passing speed v_d = 0.3 m/min. Wire electrode No. 2: Ø d = 2.5 mm, current I = 75 A, voltage U = 28V. The protective atmosphere Ferromix C18 in the flow amount of 16 l/min.

Table 1. Chemical composition (%) of material No. 1 – WELCOVARE 1736 and No. 2 – WELCO 1707 S

Material	Component					
	C	Mn	Si	Cr	S, P, Mo, Cu	Fe
No. 1	0.45	1.6	0.6	5.5	up to 0.5	residue
	C	Mn	Si	Cr	Mo	V	Fe
No. 2	0.4	0.3	0.8	8.0	1.0	0.6	residue

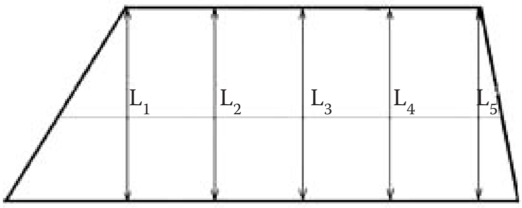

Fig. 2. Positions of the measurement of wear

Remelting using the TIG (GTAW) technology was done on five ploughshares by the application of the mixture of gases Ar + N_2 in mixing ratios 10:5, 10:6, and 10:7 l/min. It was accomplished by a welding source Invertig 360 GV (Rehm GmbH & Co., Baden-Württemberg, Germany) with the parameters I = 100 A, voltage U being regulated by the welding device. Argon performed the function of carrier gas, the flow quantity was adjusted to the value of 10 litres. Only the flow quantity of nitrogen was changed. The converter of gasses was used for blending. The output of the converter was connected to the welding torch.

RESULTS AND DISCUSSION

Operating tests were conducted at the AG H-N Nevidzany, s.r.o. (Červený Hrádok, Slovakia) company premises. The first measurement was done after treating 76 ha and the final measurement after treating 700 ha. When measuring the wear, the ploughshares were removed and evaluated based on the loss of linear dimensions which describe more reliably the extent of the wear; the ploughshare width plays an essential role in the quality of tillage, however, a weight loss was also detected (Fig. 2). The measured points of the ploughshare were marked as notches. The measurements were done on one plough.

The measurement locations on the ploughshares were strictly identified. The measured losses due to wear on the individual ploughshares and in particular areas of are shown in Table 2. The ploughshares dimensions before and after tillage as well as the linear decrease are graphically illustrated in Fig. 3.

Operating tests were continuously evaluated. The dry conditions and compacted soil layers also contribute to the increased wear (Kollárová et al. 2007). The most intensive wear occurred after processing 76 ha of soil, when the ploughshares were working in extremely dry conditions. The resistance against wear was seen on the ploughshares which had been remelted from the material of class 15 by the gas atmosphere Ar + N_2. This increase was not too great, it showed only 57.8% when compared with standards. When talking about the remelted ploughshares, the ploughshare that was the most intensively worn out was that in the measurement location L_1 on the tip, an equal wear was seen in other measured locations. The ploughshares renovated by surfacing reached several times higher resistance against wear and remelting, as well as against the standard. The ploughshares surfaced by the additional material marked as No. 2 reached the best resistance results, on average 3.6 times higher resistance compared with the standard; the ploughshare most intensively worn was that in the measurement location L_1 on the tip and the measurement decreased gradually in other measurement locations. The ploughshare surfaced by the additional material marked No. 1 reached on average 2.6 times increased resistance against the standard from the material of class 12, and we can see equal wear in the measured locations.

Čičo and Bujna (2011) say that ploughshares surfaced with electrodes labelled as Fidur 10/60 and 10/65 revealed lower wear as compared to untreated ploughshares, on average 2.2 times smaller.

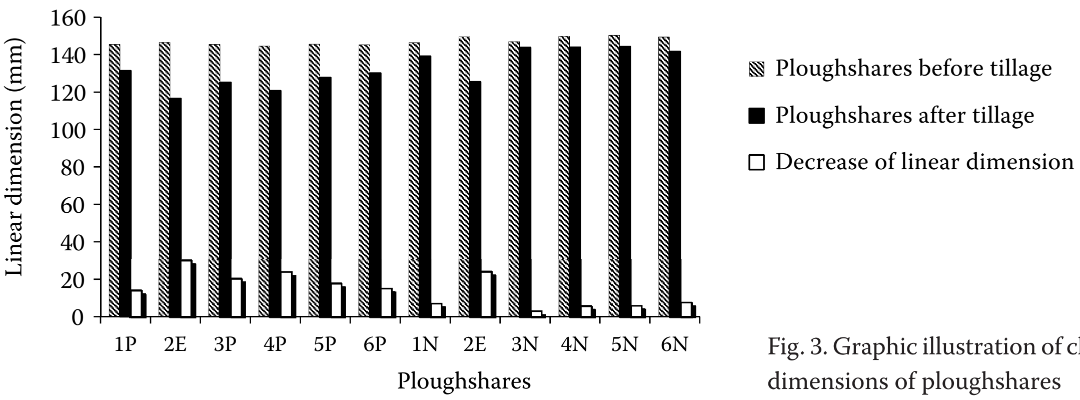

Fig. 3. Graphic illustration of changes in linear dimensions of ploughshares

Table 2. The loss of linear dimensions of ploughshares after tillage (76 ha)

Ploughshare identification	Ploughshare	ΔL_1 (mm)	ΔL_2 (mm)	ΔL_3 (mm)	ΔL_4 (mm)	ΔL_5 (mm)	ØΔL (mm)
L1	remelted 10:6	18.2	15.6	13.9	12.3	10.8	14.16
L2	etalon	26.2	28.1	29.5	31.9	34.2	29.98
L3	remelted 10:7	18.3	19.3	20.4	20.7	23.0	20.34
L4	remelted 10:7	20.2	22.0	23.6	25.4	27.9	23.82
L5	remelted 10:5	17.7	18.4	18.8	17.1	17.0	17.8
L6	remelted 10:5	14.7	15.1	15.0	15.2	16.0	15.2
	Ø remelting	21.46	18.08	18.34	18.14	18.94	–
P1	remelted MMAW	8.4	6.8	7.2	6.5	7.3	7.24
P3	remelted MMAW	4.4	4.7	3.8	1.7	1.6	3.24
	Ø surfacing MMAW	6.4	5.75	5.5	4.1	4.45	–
P2	etalon	19.6	22.9	24.9	25.8	27.0	24.04
P4	remelted FCAW	6.2	6.1	7.7	5.7	5.0	6.14
P5	remelted FCAW	5.2	6.4	6.2	6.6	6.5	6.12
P6	remelted FCAW	8.7	8.1	5.8	7.4	8.6	7.72
	Ø FCAW surfacing	6.7	6.87	6.57	6.57	6.7	6.68

MMAW – manual metal arc welding; FCAW – flux-cored arc welding; L1–L6 – left side; P1–P6 – right side

The results were favourable with the ploughshares which we tested. This also depends on the choice of the additional materials.

Ploughshares – etalons demonstrated the highest loss of wear, the best results having been achieved with the ploughshare with the welded facet from the material of class 12. The content of the alloying elements significantly affects the structural composition of the weld deposit and properties of the structures, perhaps even phases (Tolnai, Čičo 2001). In our case, the weld deposit with carbides freely distributed in matrix (Fig. 4) showed greater resistance than the weld deposit with carbides which had a needle-shaped structure (Fig. 5).

The structure of the remelted area is made by upper bainite, martensite, and ferrite (Fig. 6). In it, a grainy texture is observable. The grains are composed of dark heterogeneous phase which is a mixture of bainite and martensite. The white phase excluded on the edges of the grains is ferrite in the form of netting. The presence of bainite and martensite in steel structure 15 230 after remelting was shown by relatively increased hardness.

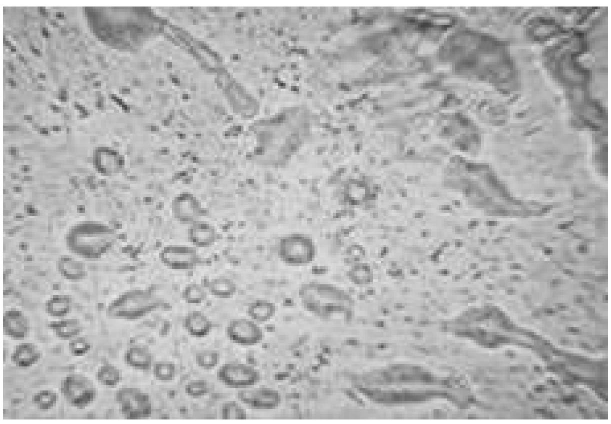

Fig. 4. Detail structure of the weld deposit of material No. 2, carbides freely distributed in basic matrix (etching by nital)

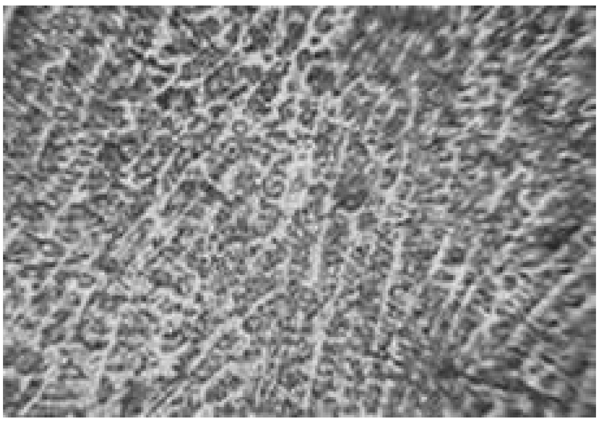

Fig. 5 . Detail structure of the weld deposit of material No. 1, acicular structure of chromium carbides with the typical elongated shape (etching by nital)

Table 3. Weights of ploughshares before and after the test and the loss of weight of ploughshares after tillage (76 ha)

Ploughshare identification	Ratio of immixture of gases Ar and N_2 (l/min)	Weight of ploughshare before test (g)	Weight of ploughshare after test (g)	Loss of weight Δm (g)	Average loss of weight (g)
5P (remelted)	10:5	3,912	3,462	450	406.5
6P	10:5	3,418	3,055	363	
1P	10:6	3,920	3,540	380	380
3P	10:7	3,830	3,300	530	567.5
4P	10:7	3,830	3,225	605	
2E (etalon)	etalon 15 230	3,850	3,120	730	730
Surfacing material					
1N (surfacing)	1707 S	4,272	4,100	172	156
3N	1707 S	4,170	4,030	140	
4N	1736	4,170	4,056	114	
5N	1736	4,268	4,175	93	99.3
6N	1736	4,362	4,271	91	
2E (etalon)	etalon 12 050	4,015	3,596	419	419

The presence of nitrides and carbonitrides in the said structures was not proven at the given magnification. The fact that in the given structure nitrides and carbonitrides are probably not present is also confirmed by a small increase in hardness (Table 3).

The weight losses that are indicated in this paper correspond (Fig. 7) with the linear losses. Operating test results confirmed that, despite the higher wear of the remelted ploughshares, this technology allows to extend the technical life, is very simple, and it must also be realised that without the welding of the facets and the follow up renovation the worn ploughshares would go to the scrap. The utilisation of the results obtained must be preceded by farmer's interest. Irrespective of that, the operating tests continued later on under optimal soil conditions. The wear gradually grew while the ploughshares processed 700 ha of soil.

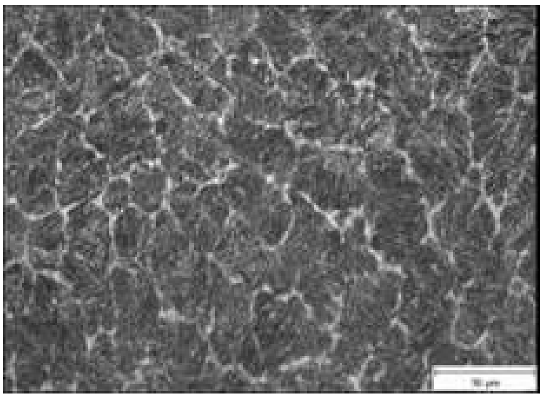

Fig. 6. The microstructure of the remelted layer of steel 15 230 in the mixture of 10 l Ar and 5 l N_2 is represented by upper bainite, martensite, and ferrite

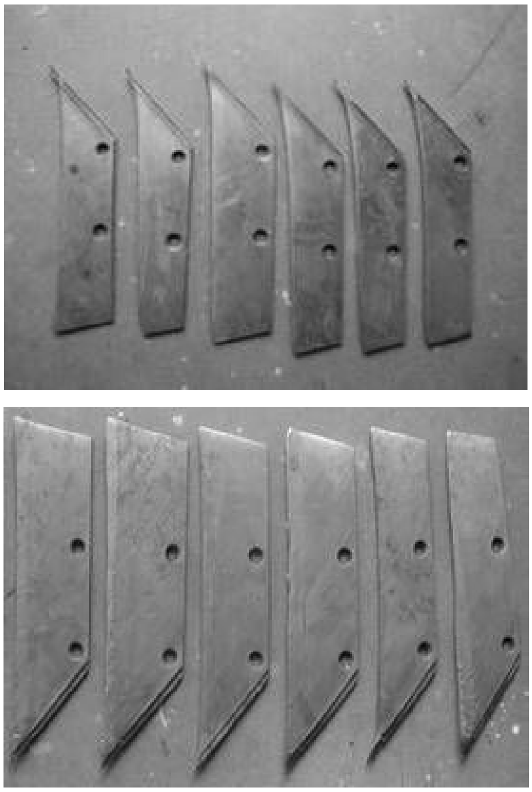

Fig. 7. Wear of ploughshares after operating test

CONCLUSION

Ploughing is one of the most demanding operations in agricultural production in terms of tillage machinery wear; therefore the ways of increasing the working life of this machinery must be sought. One means is the renovation of the worn ploughshares. The most used is the renovation by surfacing as preventive weld deposit, which proved in this case to be the optimal one but it can also be used as renovation described in this paper.

The effect of the surfacing renovation prolonged in our case the technical life 2.6–3.6 times. When alloying by gas mixture Ar + N_2 remelting using the TIG technology, the technical life was prolonged by 56% over the standard, and by renovation the technical life was given back to the ploughshare. The achieved results are only partial results; it is necessary to conduct further operating tests using these technologies. In this paper, we intended to point out other possibilities of renovation in operating conditions.

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