Application of hard surfacing for repairing of agricultural parts

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Abstract

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The contribution deals with the analysis of claddings quality realised by shielded metal arc welding with covered electrodes. For cladding, covered basic electrodes marked as E Z Fe 8 EN 14700 and E Z Fe 15 EN 14700 were used. The third type of electrode was experimentally made basic electrode with operating name EW11 (wolfram content 11%). New share made of C50R EN10083/1-98 was used as reference material. Quality of repairing deposits was evaluated by micro hardness measuring and by metallographic analysis of claddings and base material. Wear resistance of claddings was determined by weight loss during abrasive wear test by wading in following loose abrasive agents – Al_2O_3 (corundum), crushed rock and arable soil.

Keywords: repairing; cladding; share; abrasive wear

Frequent reasons of mechanical parts and structures failure are tribological processes, performed on functional surfaces. Interaction of functional surfaces during their relative movement causes undesirable changes in surface layers conducing to wear. External display of the process is cutting or removal particles of the functional surface material (Blaškovitš et al. 2001; Chotěborský et al. 2009a). Functional parts repairing by cladding technology seems to be a suitable way to renew parts used in the agricultural production. One group of intensive worn part is ploughshare. The share wear occurs in consequence of abrasive wear by the arable soil moving. The wear depends on the kind of soil, its grain size, structure, humidity and cationic composition of sorption soil completion (Kotus et al. 2011).

Larger thickness of share cutting edge markedly enlarges force needed to drag plough together with the fuel consumption whereas work intensity and ploughing depth decrease. It is possible to increase the share-operating life also by chemical-heat treatment of the material surface. Nitridation enables to increase material hardness into a depth of 0.5 mm (Marônek et al. 2009).

The aim of the presented experimental works is to evaluate the quality of claddings made on functional share surfaces, verify abrasion resistance of

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Table 1. Chemical composition of material C50R EN10083/1-98 (% wt)

C	Mn	Si	Cr	Mo	Ni	P	S	Fe
0.51	0.80	0.32	0.30	0.06	0.2	0.03	0.03	Balance

Table 2. Mechanical properties of material C50R EN10083/1-98

Yield strength (MPa)	Tensile strength (MPa)	Ductility (%)	Reduction (%)	Hardness HV30
500	700–850	15	35	173–214

the claddings made of three types of additional materials, and, based on the obtained results to determine cladding conditions at share repairing.

MATERIAL AND METHODS

Examined shares are made out of the material marked as C50R EN10083/1-98 by forging. Chemical analysis and mechanical properties of the material presented by share producer are shown in Tables 1 and 2.

For reparation of worn functional parts of the share, the technology of MMAW – Manual metal-arc welding (method 111 – EN 24063) was chosen. Choice of the cladding method also depends on the number of parts, which are necessary to renew. With a low number of reparations needed, MMAW method seems to be economically the most suitable for this purpose. Repairing of more series requires application of automated cladding methods (methods 131, 136 –EN 24063) GMAW Gas metal-arc welding.

Cleaning and pre-treatment of worn share surfaces before cladding was realised by abrasive blast cleaning (pneumatic blasting equipment TJVP 320 (Škoda, Pilsen, Czech Republic), air pressure 0.5 MPa). The abrasive used for blast cleaning: chilled steel grit marked G_B8 (ISO 11124-3), grain size 0.71 mm, distance between jet and the blasted part 150 mm, blasting angle 45°.

Next there was applied cladding on the cleaned and pre-treated share (see Fig. 1) by MMAW method with help of three types of additional materials: basic electrodes marked E Z Fe 8 EN 14700 (sample A), E Z Fe 15 EN 14700 (sample B). In the frame of so-called "technological innovation" (Spišáková 2008a), also experimentally-made basic electrodes EW11 (sample C) were included in the experiment besides the commercially used electrodes.

Table 3. Characteristics of used electrodes

Sample	Electrode	Electrode diameter (mm)	Chemical composition (% wt)						Hardness HV30	Preheating temperature (°C)
			C	Cr	Mn	Si	W	V		
A	E Z Fe 8 EN 14700	3.2	0.2	13	0.6	0.3	–	–	520	200
B	E Z Fe 15 EN 14700	4.0	3.5	29	0.8	0.8	–	–	670	400
C	EW 11	4.0	1.3	4.5	0.4	0.5	11.5	4.0	720	400

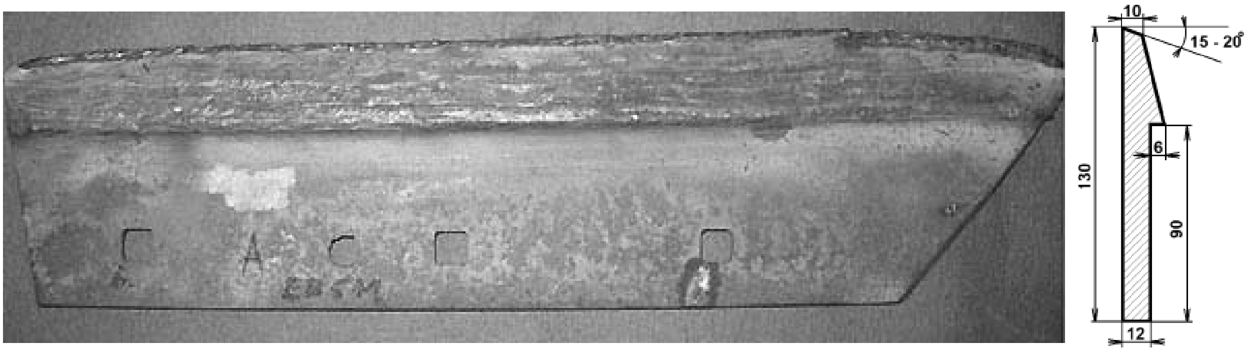

Fig. 1. Share with two-layer cladding produced with electrode E Z Fe 8 EN 14700 before machining on required dimensions

Fig. 2. Disk head with clamped samples

Characteristics of the used electrodes are listed in Table 3. Cladding was realised by the pulse welding rectifier CLOOS MC 303 (Carl Cloos Schweisstechnik GmbH, Haiger, Germany) at the welding position PA – ISO 6947. The share was preheated in an induction furnace. After cladding share cooling down in insulating pack followed. Table 3 shows used welding parameters. Quality of the cladding was evaluated by determination of the share samples weight loss after wading in loose abrading agent in laboratory test equipment marked Di-1.

The test equipment is based on relative movement of samples in loose abrading agent. The disk head enables to clamp 6 test samples at once on the pitch diameter D = 270 mm (Fig. 2). Slewing samples enable to adjust abrasive contact angle from 0° to 90°. Depth of the samples immersion into the abrading agent was 60 mm. Samples were prepared from the share by cutting operations without thermal affection. Sample dimensions were 30 × 90 mm. Contact angle between abrading agent – sample: 65°, sample speed 1.74 m/s. In the experiment were used the following types of abrasive agents:

(1) corundum, grain size 0.9 mm, worn corundum was exchanged after every each 5.10^3 m,

(2) crushed rock – calcite, fraction 5–12mm, EN 721512,

(3) arable topsoil from Agrofarm Viničky, district of Trebišov, Slovakia. This is a sandy-loamy spongy soil (www.pedologia.sk).

Abrasive agents mentioned above for 10 h wore samples, what responds to the path of length 62,000 m. The influence of abrasive agent to the one-layer and two-layer claddings was evaluated.

Metallographic analysis of claddings was realised according to the EN 1321 on cross sections of the examined samples. The structure evaluation as well as photo documentation were carried out with help of the light microscope.

Considering Cr content in examined materials there was used specific etching solution to visualise microstructure of materials. Composition of the etching solution was as follows: 95 ml methanol, 5 ml HCl, 1 g $C_6H_3N_3O_7$. Etching time was 15 s (samples A and B, Table 3) and for sample C 30 s.

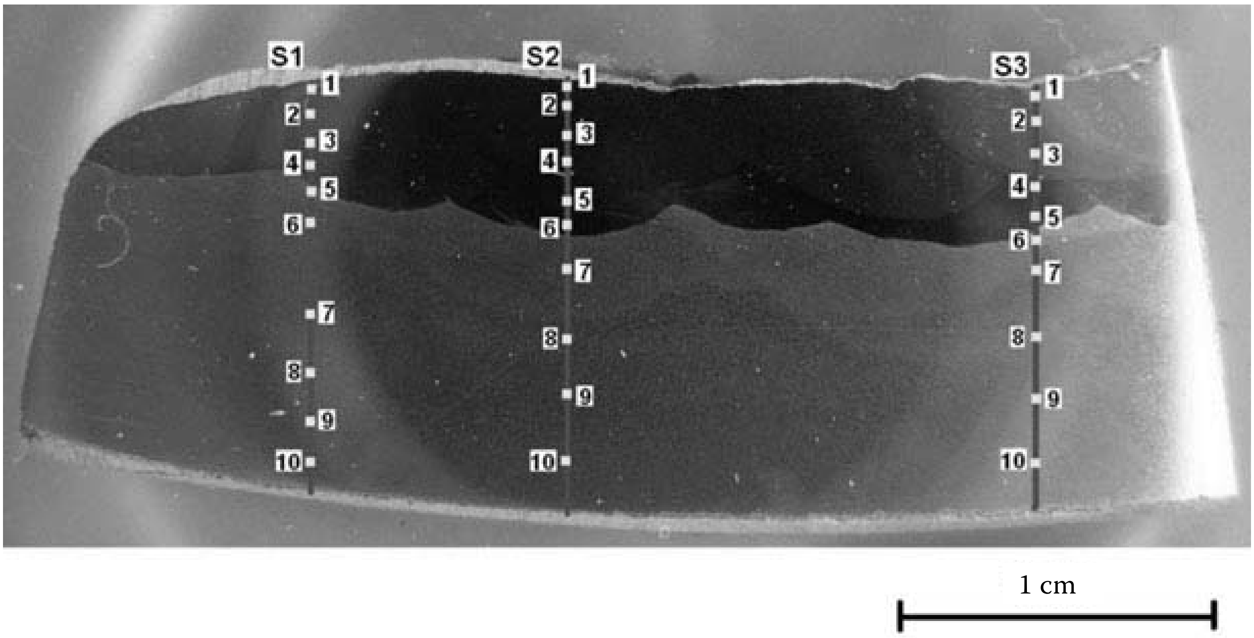

Fig. 3. Macrostructure of the share with two-layer cladding of C type with marked lines of micro hardness measurement

RESULTS AND DISCUSSION

Micro hardness was measured on metallographic cross-sections (Fig. 3). On the three spots there were realised 10 measurements, which records hardness course from the thermally untouched base material up to the cover layer with respect to the standard requirement.

Fig. 4 shows micro hardness course in the particular cladding layer up to thermally untouched base material. There was also observed shuffle of cladding layers with the base material. In one-layer cladding at observance of welding parameters didn't come to shuffle of cladding and base material in whole material volume, which was proved by micro hardness values in transition zone between base material – cladding. The highest hardness values were foun out on the cover layer of claddings made out by electrode C – 798.3 $HV_{0.2}$. Samples with cladding made out by the electrode A show maximum hardness value 632.8 $HV_{0.2}$ and the cladding made out by electrode B 726.3 $HV_{0.2}$. All micro hardness values agree with values declared by producers of hard facing electrodes. Micro hardness corresponds to the chemical composition of claddings (influenced mainly by content of C, Cr, W, V) and the structure of claddings.

The most intensive abrasive effect on evaluated materials showed corundum and crushed rock, which corresponds to the abrasive hardness. Least abrasive effect showed the arable soil. Weight loss of samples after wading in arable soil was multiple lower than weight loss of samples abraded by corundum or crushed rock.

Figs 5 and 6 show course of particular claddings wear expressed by weight loss.

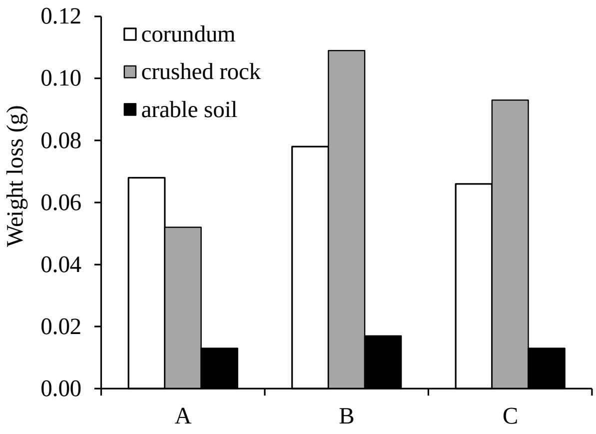

Fig. 5. Weight loss of one-layer claddings (electrodes A, B and C, Table 3)

The highest weight loss (0.12 g) was found in sample with two-layer cladding made by the electrode B after wearing in crushed rock. The least weight loss was found in samples with one-layer (0.066 g) and two-layer (0.093 g) cladding made by the electrode C after wear in corundum. Visual check of claddings surface after wearing showed due to the abrasive agent (corundum) removing of oxide layers and slag remained on the cladding surface. Samples after wading in crushed calcite rock was contaminated by the colloid calcite particles. The crushed rock as abrasive agent had not so negative effect on repaired surfaces as corundum, what corresponds to the weight loss values with the exception of two-layer cladding made by B electrode. Results of these experimental tests will be compared with results achieved by operating tests of repaired parts carried out in the agricultural cooperative Viničky, Slovakia.

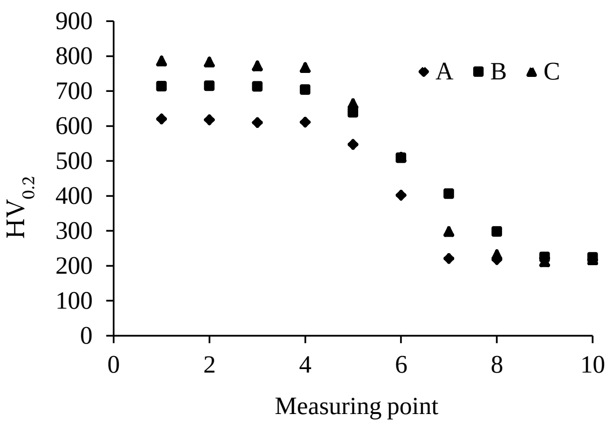

Fig. 4. Course of micro hardness $HV_{0.2}$ in two-layer claddings (electrodes A, B and C, Table 3)

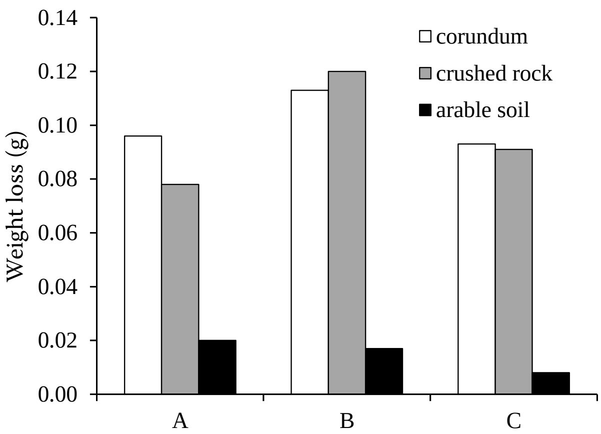

Fig. 6. Weight loss of two-layer claddings (electrodes A, B and C, Table 3)

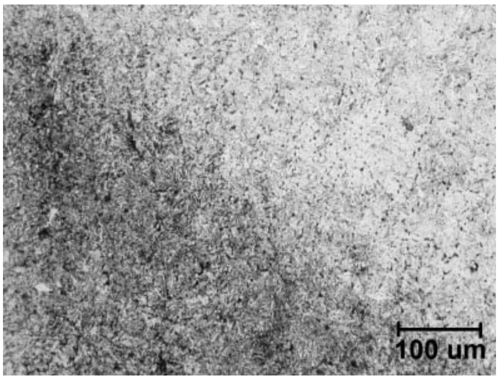

Fig. 7. Microstructure of HAZ C50R EN10083/1-98

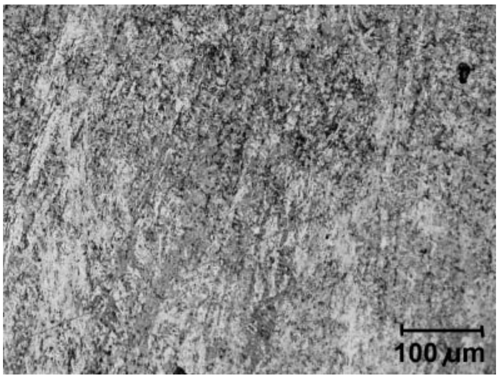

Fig. 8. Microstructure of the cladding sample A

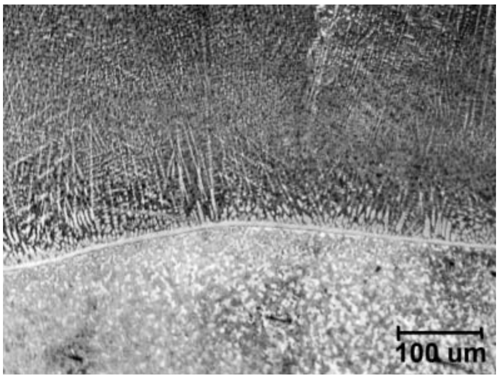

Fig. 9. Microstructure of the base material and cladding transition zone

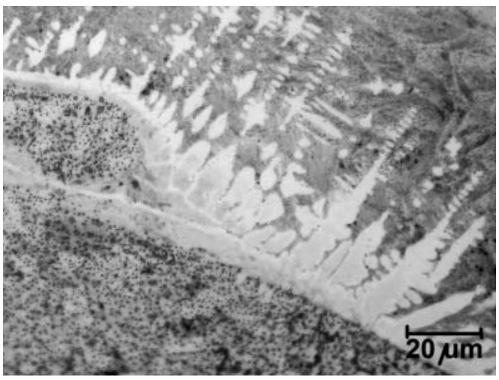

Fig. 10. Microstructure of HAZ and cladding transition zone

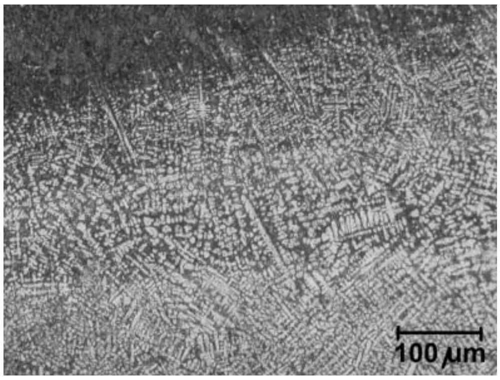

Fig. 11. Structure of austenite and eutecticum

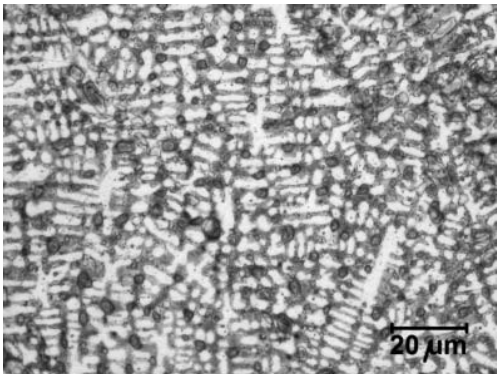

Fig. 12. Detail of eutecticum dendrites

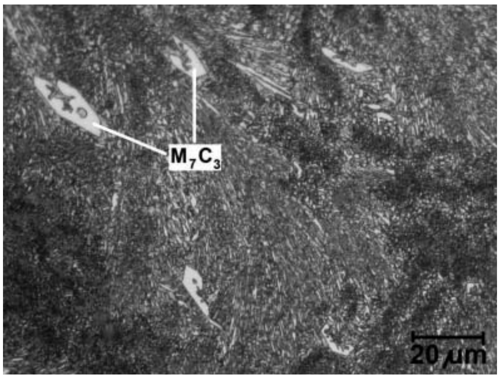

Fig. 13. Carbides precipitated in cladding layer made by electrode B

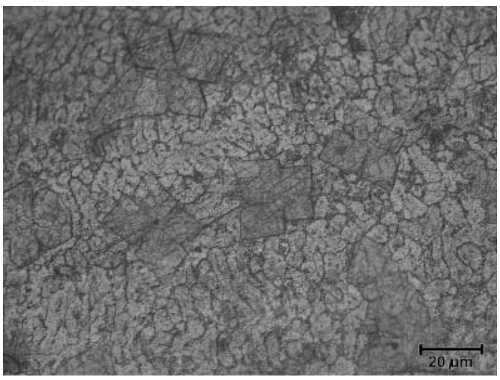

Fig. 14. Microstructure of the cladding layer made by electrode C

Structure prediction in claddings of Fe-Cr-C type

It is possible to determine eutectic carbon concentration C_{eu} with help of Jackson diagram (Chotěborský et al. 2009b) by following equation:

$$C_{eu} = 4.25 - 0.162\frac{Cr}{C} + 0.0023\left(\frac{Cr}{C}\right)^2 \quad (1)$$

where:

Cr – weight of chromium concentration (%)

C – weight of carbon concentration (%)

If carbon concentration is $C > C_{eu}$, cladding structure will be hypereutectic with content of the primary carbides. If the carbon concentration is $C < C_{eu}$, cladding structure will be hypoeutectic with content of primary austenite transformable to the martensite.

After substitution to equation (1) it is possible to state, that structure of the cladding made by the electrode A and C will be hypoeutectic with primary austenite content. The structure of the cladding made by electrode B will be hypereutectic with primary carbide content.

Metallographic analysis

Metallographic analysis was carried out only on two-layer claddings to eliminate influence of the shuffle of cladding layers with the base material.

Fig. 7 shows transition of HAZ (heat affected zone) into cladding layer made by the electrode A. The transition zone is close without marked shuffle with the base material.

Microstructure of the cover layer in Fig. 8 is martensite-ferrite. Structure mainly consists of the lath martensite and $\alpha M_{23}C_6$ ($Cr_{23}C_6$) carbides.

Fig. 9 shows microstructure of HAZ and the cladding B transition zone. The transition between the base material and the cladding is relatively sharp without markedly shuffle of both metal. In HAZ expansion of pearlitic-sorbitic grains occurred in consequence of heat. Structure of the claddings consists of approximately austenite 35% and carbidic eutecticum 65%.

At the cladding microstructure in Fig. 10 it is possible to observe dendrite solidification with epitaxial growth of grains. Relatively high Si content (0.8%) decreases chromium content in austenite and thereby also corrosion resistance of the cladding and at the same time it influences dimensions of primary carbide particles in cladding (Atamert, Bhadeshia 1990). The cladding structure is shown in Figs 11 and 12.

In the cover cladding metal (Fig. 13), dispersed primary carbides mainly of M_7C_3 were used. Microstructure of the cover cladding metal made by the electrode C is shown in Fig. 14. The figure shows minimal shuffle of the cladding and base material. A lot of dispersed carbides MC, M_7C_3 were found in martensitic matrix of cladding. Considering high content of alloying elements W and V, the structure contains also less volume of WC, VC, V_4C_3, V_6C_5 carbides, which is proved by EDX (Energy Dispersive X-Ray) analysis and micro hardness values.

Volume of W and V carbides is not proportional to their content in melting, because they tend to form complex carbides M_7C_3 in which they substitute chromium.

CONCLUSION

Besides the problems in companies, the current financial crisis brings also "opportunities" to streamline business activity (Spišáková 2008b). The aim of medium-sized and small companies is to introduce increasingly innovative solutions to the restoration of damaged parts, and thus prolong their lifespan, as was presented in this paper solved in cooperation with agricultural farm Viničky.

On the ground of the achieved results it is possible to recommend using electrodes EW11, or E Z Fe 8 EN 14700 for reparation of functional surfaces stressed by abrasive wear. It is possible to effectively increase abrasive resistance of the share cutting edge by claddings application. Microstructure suitable for abrasively stressed parts seems to be martensitic structure with carbides. Chromium is used as carburizing element. Just carbides parallelly oriented with functional surface cause high metal hardness (Chotěborský et al. 2007). In claddings made by electrode A and B predominantly carbide $Cr_{23}C_6$ with hardness about 1,600 HV and carbide M_7C_3 were present in the cover layer. From the economic point of view cladding is the most advantageous repairing technique. Maximal hardness value of cladding made by the electrode B is 726.3 $HV_{0.2}$, its structure, so-called cast-iron structure, consists of austenite and carbidic eutecticum.

The experimental electrode C with the highest content of alloying elements supporting carbide formation, which highly affects its price, showed the highest abrasion resistance in the arable soil. The highest abrasion resistance is a result of martensitic matrix of the cladding with high content of carbides Cr_7C_3 and $C_{23}C_6$, together with presence of dispersed WC carbides with hardness of 2,400 HV, and VC, V_4C_3, V_6C_5 carbides with hardness about of 2660 HV (Mohyla 2002; Yang, Lei 2006; Mohyla et al. 2009).

Considering the application of repaired parts for functional agricultural soil treating, based on the obtained abrasive test results and simultaneously taking into account the price of particular electrodes, it is possible to recommend parts made of material C50R EN10083/1-98 to use for repairing two-layer cladding made by electrode E Z Fe 8 EN 14700.

By hard surfacing it is possible to restore the shape of the functional parts of the ploughshares and thus prolong their lifespan. Economic efficiency of the renovation is given by the ratio of costs for renovated and new ploughshare, which is about 50%. Due to the experimental results of claddings abrasive wear it is possible to recommend 2-layer cladding with welding electrode C and A for ploughshare renovation. From an economic point of view it is preferable to apply the cladding made by electrode A, because the electrode C is more expensive (by about 20%) compared to the electrodes A and B, as it has the high content of alloying elements (W, V).

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