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Wear analysis of welded layers containing node carbide, in the abrasive soil mass

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Abstract. The paper presents the research of the wear intensity of welded layers in natural soil abrasive mass. The samples made of 38GSA steel with the welded surface layers contains carbide forming elements. In case of the test abrasive mass, XHD 6715 material showed the wear 2.5 times lower than El-Hard 61 and twice smaller than El-Hard 65. The analysis of the wear indicates that the welding layer containing vanadium and chromium carbides, molybdenum and niobium carbides has proven to be the most resistant to wear in the test abrasive mass.

1. Introduction

The issue of the wear of parts operating within abrasive soil mass is very complex due to the multiplicity of factors affecting the wear process [1-3]. For compact abrasive soil masses, the abrasive particles may have an influence as fixed grains resulting in losses in the material due to processes typical for abrasive wear (scratching, microcutting, and ridging). In the soil masses with low compactness, the wear is caused by the impact of loose abrasive particles on the surface of the material being subjected to abrasion, which results in the wear through decohesion (more frequently) and fatigue.

The properties of the surface layer have a decisive influence on the service life of the parts used in machinery and tools. The outer layer, properly selected considering operating conditions, should be characterized by appropriate tribological features arising from the physicochemical properties. In order to ensure that an operating part has appropriate features contributing to its resistance to the wear processes, various methods of padding are applied involving the uniform application of an alloy onto the material surface [4, 5].

One of the main components determining the tribological properties of a padding layer is the chemical composition of an alloy being applied [6]. The formation of the outer layer microstructure is largely determined by the carbide-forming elements including inter alia vanadium, niobium, tungsten, molybdenum, and chromium [7-10].

The carried out studies on the effect of carbides forming elements on the abrasive wear resistance were mainly related to tool steels. In [11] it was shown that the increase of vanadium contents in a high-speed steel increases its resistance to the abrasive wear tested by the "pin on disc" method. The paper [12] indicates the influence of the matrix properties on abrasion resistance. The best wear resistance was obtained for vanadium carbides embedded in a martensitic matrix.

Taking into account the carried out analysis, it can be assumed that the content of elements favorable for the formation of carbides in the weld should improve the resistance of the surface layer of the tool to the wear in natural abrasive soil masses.



The aim of the work is to analyze the wear of surface layers with varied content of niobium tungsten and vanadium in a soil abrasive mass.

2. Research materials

Hardfacing materials were applied to hardened 38GSA steel. The substrate material was characterized by the structure of martensite with bainite and troostite. The hardness of the substrate material amounted to 414 HV10. The chemical composition of the steel was as follows: C – 0.38%, Mn – 1.07%, Si – 1.17%, P – 0.028%, Cr – 0.18%, Cu – 0.16%, Al – 0.02%.

The additional materials containing C + Cr + Mo + W + V + Nb were applied on the steel surface by arc welding with El-Hard 61, El-Hard 65, XHD 6715 electrodes (table 1).

Table 1. The chemical composition of welded layers.

material	Chemical composition %					
	C	Cr	Mo	W	V	Nb
El-Hard 61	5,2	29,0	0,71	-	-	7,0
El-Hard 65	4,5	34,0	6,0	2,0	1,0	6,0
XHD 6715	5,0	21,0	8,50	6,0	1,9	7,0

3. Research methodology

The wear intensity was examined in a laboratory by the “rotating bowl” method [2] (figure 1). 30 x 25 x 10 mm cuboidal shape samples were tested. The testing machine was filled with natural soil abrasive mass equivalent to dry soil with the granulometric composition as per PN- EN ISO 14668-2(2004):

- light soil: silt: 1.69%; dust: 20,83%; sand: 77.48%.

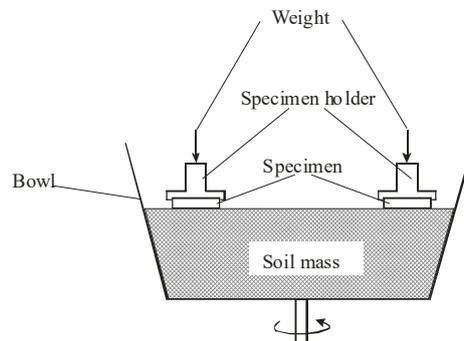


Figure 1. The diagram of a “rotating bowl” experimental test-stand.

The following friction parameters were taken into account: velocity 1.4 m/s, friction distance 10,000 m, weight 49 N (5 kg weight mass). The test-stand was equipped with elements to mix and compact the abrasive mass. Test runs were repeated six times for each tested material. The soil moisture was maintained at 10%. The pH of the abrasive soil mass was in the range from 6.3 to 6.9.

The measurements of the wear were taken every 2000 m. The unit wear was calculated from the following formula:

$$Z_j = \frac{Z_w}{s \cdot P} \text{ [g/km} \cdot \text{cm}^2\text{]}, \quad (1)$$

where: Z_w – mass wear [g], s – friction path [km], P – the surface area of the examined sample [cm²]

The hardness of the materials was measured by means of a type HV-10D Vickers hardness tester, in accordance with the PN-EN ISO 6507-1:1999; quality standard, an indenter load of 98 N was used, lasting for 10 s. The light microscopy examinations were conducted using a Neophot 52 microscope coupled with a Visitron Systems digital camera.

The scanning electron microscopy examinations and the microanalysis of the chemical composition were conducted using a JEOL JSM – 5800 LV scanning microscope, coupled with an Oxford LINK ISIS – 300 X-ray microanalyzer.

4. Test results

On the basis of the conducted research, the following structures of the examined layers were identified:

- 38GSA steel – martensite, bainite and small contents of troostyt (figure 2).
- El-Hard 61 – alloy ferrite, which passes in the structure of the layer consisting of ferrite and carbides (ledeburitic structure) (figure 3). In the microstructure of the padded layer, the separation of chromium and niobium carbides was identified.
- El-Hard 65 – in the alloy ferrite there are visible of large primary chromium carbides (type M7C3), and other fine carbides (figure 4) and niobium carbides.
- XHD 6715 – in the alloy ferrite matrix there are large secretions of primary chromium carbides (Figure 5) and other types of carbides (Mo, Nb, W). Small areas of ledeburite are also visible.

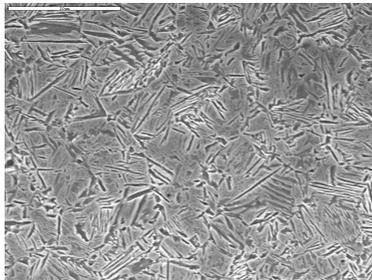


Figure 2. 38GSA Steel – microstructure of martensite, bainite and a small content of troostyt. SEM microscopy.

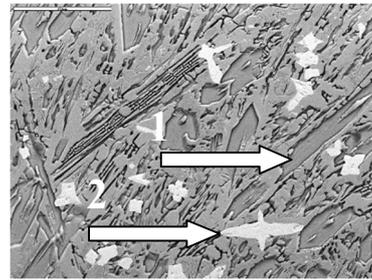


Figure 3. The microstructure of El-Hard 61 welded layer, chromium carbide (1-grey) and niobium chromium (2-white) exuded. SEM microscopy.

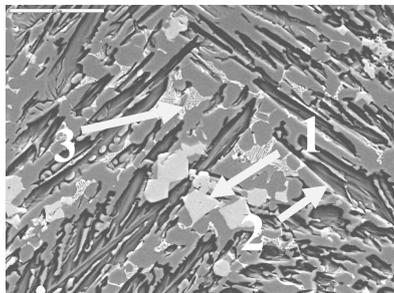


Figure 4. XHD 6715 welded layer microstructure, large primary chromium carbides (2), in ferrite groundwork and niobium carbides (1). Visible small areas of ledeburite (3), SEM microscopy.

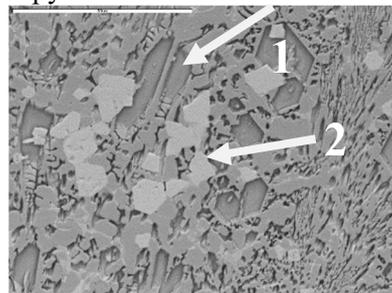


Figure 5. El-Hard 65 welded layer microstructure, mixture of ferrite and M7C3 – [Fe,Cr7C3] carbides (1) and niobium carbides (2), SEM microscopy.

The highest hardness of the surface layer was found respectively for XHD 6715 (820 HV10), then EL-Hard 65 (682 HV10) and EL-Hard 61 (632 HV10).

The results of the study of the value of the weight loss of the tested materials as a function of the friction distance are presented in figure 6.

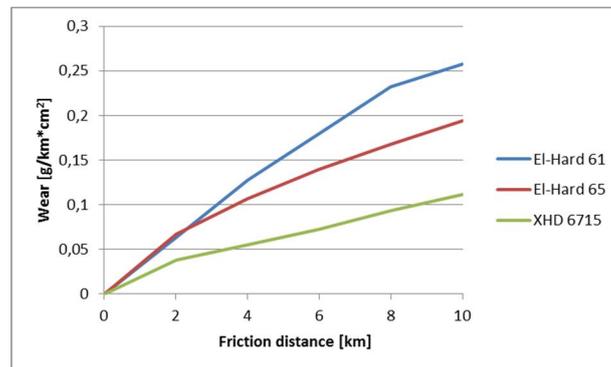


Figure 6. Change of wear value in light soil.

The highest wear values were observed for the El-Hard 61 padding (figure 6). The light soil abrasive mass is characterized by a high content of hard, irregular shaped abrasive grains. In this kind of soil furrowing and drawing are dominating in by mechanical wear processes (figure 7). For this type of abrasive mass, XHD 6715 material showed wear 2.5 times lower than El-Hard 61 and twice smaller than El-Hard 65. The El-Hard 61 welded layer contains only niobium. The other two layers, in addition to niobium, also contain vanadium and tungsten, while the XHD6715 material contains the largest amount of the mentioned elements.

The scratches created on the surface of the tested materials are the largest in the case of the material El-Hard 61 (figure 7a). On this surface, there are also visible traces of the removed carbides.

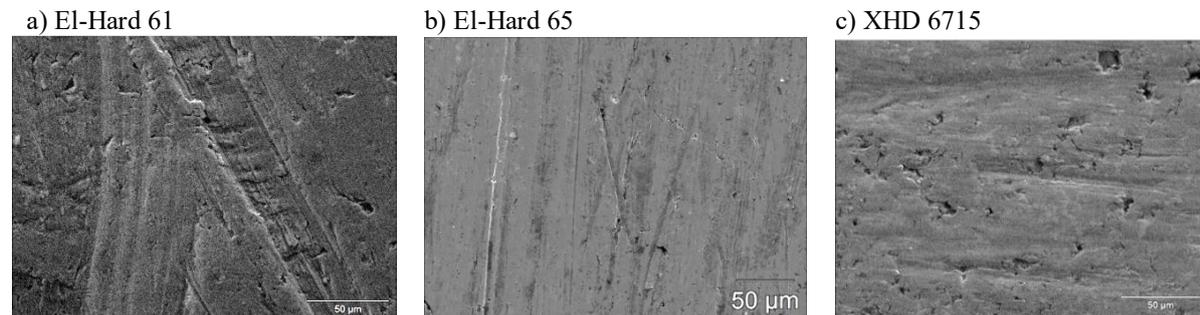


Figure 7. Welded layers surface following wear test in light soil

5. Summary

Given that the process of the pad welding was carried out at a relatively low temperature (high carbon and chromium contents), no structures of the metallic matrix comprising austenite were obtained. The metallic matrix of the obtained layers comprises alloy ferrite and, for the XHD6715 layer, ledeburite as well. As for the padding weld with significant tungsten (6%) and vanadium (1.9%) contents, the increased amount of carbides was obtained, with a significantly smaller size as compared to other layers, within the metallic matrix of alloy ferrite and small-sized ledeburite. This was due to the decrease of the carbon content of the metallic matrix, at the expense of the formation of a greater amount of carbides. Such a structure ensures the greatest hardness of the outer layer and resistance to wear within the soil mass.

The use of niobium alone in the outer layers of Fe-Cr-C does not ensure high resistance to the wear due to the chipping of hard niobium carbides from the relatively soft metallic matrix. In order to increase this layer resistance to the wear, cooling the obtained padding weld with water in order to obtain an austenitic matrix should be considered.

6. Reference

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