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EFFECT OF REFRACTORY ELEMENTS ON WEAR INTENSITY OF THE SURFACE LAYERS IN THE ABRASIVE SOIL MASS

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Abstract: *The paper presents the results of researches on tthe influence of vanadium and niobium on wear intensity of the surface layers in soil mass. The investigations were conducted in the laboratory conditions on a wearing machine MZWM -1. The study adopted two types of surface layers obtained by welding with additon of niobium and vanadium. The resulting layers were tested in three kinds of soil masses: loamy sand, ligh clay and ordinary clay. Significant differences in the wear between the layers, depending on the type of soil were observed.*

Keywords: *weld overlay layer, vanadium, niobium, soil abrasive mass, the wear process.*

1. INTRODUCTION

Wear in abrasive soil mass is a natural process of destruction which intensity depends on kind of soil [2,5]. Significant here is the occurrence of various phenomena of wear, depending on the random changes in the soil, the working process parameters and material properties used in the working elements. The choice of material for elements work in soil with optimal properties for specific environmental conditions should be preceded by an analysis of the nature and type of wear on the surface and the surface layer [1,4]. The criterion for the selection of the material is chosen primarily on the basis of well-defined heterogeneous phase composition of the layer structure. It has been found that the abrasive wear resistance is the sum of the individual resistances [3].

In the case of iron alloys it is just a matter of carbide phase. Selection of carbide must take into account the specific characteristics of the interaction between Fe-Cr-C and carbide formers elements. Some of them are refractory elements such as vanadium and niobium. These elements melting at very high temperatures are quite difficult to obtain in the pure state. In chemical terms are relatively unreactive, and their reactivity decreases with increasing atomic number. Most of the niobium is used in the form of ferrosilicon, and may be used in the form of NbC carbides. Only about 6% of the total production of niobium is intended for Nb alloys production. Niobium has a relatively low solubility in iron- a (alpha), and *iron-γ* (gamma). Niobium is added to the surface layer in an amount up to 10%. The addition of niobium to the steel and heat resistance alloys gives the effect of precipitation hardening by intermetallic compounds or by NbC. Pure vanadium has good plasticity, it is easily workable and have a good welding properties under argon atmosphere. It is resistant to corrosion and influence of alkali. The vanadium in the steel forms a very hard VC carbides in combination with the resistance to tempering heat makes it is used in engineering constructions.

Aim of this study is to analyze the wear process in the soil mass in the context of the construction of the abrasive surface layers containing refractory elements V and Nb.

2. METHODS

The laboratory researches have been conducted on a wear machine "spinning mass" type. The sample was a rectangular prism with dimensions 30x25x10 mm, cut from the weld overlay padding (with additional materials) on steel

38GSA. The chemical composition, determined by methods of classical chemistry, is as follows: C - 0.38%, Mn - 1.07%, Si - 1.17%, P - 0.028%, S - 0.02%, Cr - 0 , 18% Cu - 0.16% Al - 0.022%. The microstructure of the steel: martensite with bainite and troostyt. At the same time two samples of one of each type were placed in the machine. The chemical composition of the surface layers are shown in Table 1.

Table 1. Chemical composition of layers tested

Root		Chemical composition [%]	
		Nb	V
C	Coal	5.2	5
Si	Silicon	2.2	1.5
Cr	Chrome	29	23
Nb	Niobium	6.8	-
V	Vanadium	-	10
Other	-	3.5	-
Fe	Iron	rest	rest

Each sample underwent a total of 20 000 meters with speed of about 1.7 m/s. Measurement of the mass of the sample was performed at each 2 000 meters with use of laboratory scale with accuracy of 0.0001 g, after the cleaning in an ultrasonic cleaner. At that time the mass of soil were exchanged with a new one. Samples had oscillating movement.

The study was conducted in three types of abrasive soil mass (according to USDA) in loamy sand, light clay and ordinary clay. Characteristics are shown in Table 2. Granulometric evaluation was performed using a laser particle size meter + Hydro Mastersizer 2000. Humidity of the soil was determined by measuring the weight of the dried solid at a temperature of 105 °C. The study was conducted on humid mass.

Table 2. Characteristics of soil pulp

Group grain size	Fraction [%]			Humidity weight %
	2,0-0,05 mm diameter sand	0,05-0,002 mm diameter dust	Clay below 0.002 mm in diameter	
Loamy sand	77, 48	20.83	1.69	9-11
Light clay	56.48	30.83	12.69	12-13
Ordinary clay	26.86	48.62	24.52	13-15

Microscopic examination was performed by light microscopy methods - Neophot 52 microscope coupled with a digital camera Visitron Systems. Scanning microscope JEOL JSM - 5800 LV coupled with X-ray microanalyser Oxford ISIS LINK - 300 were used for scanning electron microscopy and chemical composition microanalysis. Samples were digested with 3% HNO3 (Mi1Fe) and electro-chromic acid.

Hardness measurements of the surface layer were determined by Vickers method in accordance with DIN EN ISO 6507-1:1999. Measurements were carried out with load of 1 kg (9.807 N) acting during the 15s. To quantify the wear it was assumed unit weight wear related to 1cm2 abraded surfaces and road friction. Figure 1 presents wear machine "spinning mass" type which was used during experiment.

Figure 1. Photo of wear machine "spinning mass" type

3. RESULTS

Figures 2 and 3 shows macroscopic images of the construction of the layer containing Nb and V.

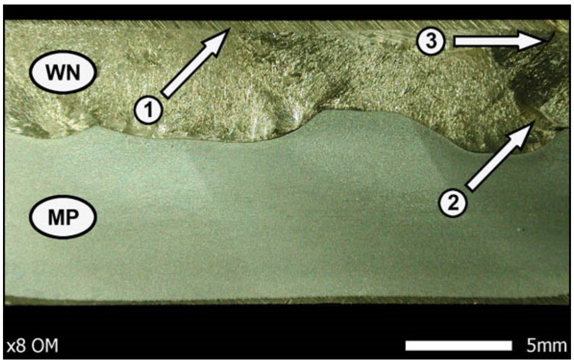

Figure 2. Macroscopic picture of the construction of the layers with Nb content. Visible traces of grinding (1). In the right part of the layer - macro cracks (2) and (3). WN – weld overlay, MP - pad material.

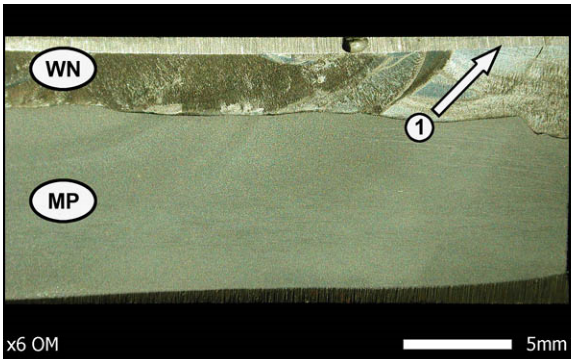

Figure 3. Macroscopic picture of the construction of the layers with V content. Visible traces of grinding (1). No evidences of macro cracks .
WN – weld overlay, MP - pad material.

Figures 4 and 5 show microscopic structure of Niobium-containing layer. In addition to the narrow strip of ferritic alloy, weld overlay has homogeneous structure. Large initial separation of chromium carbides and niobium carbide are visible on background of ledeburite (Fig. 11).

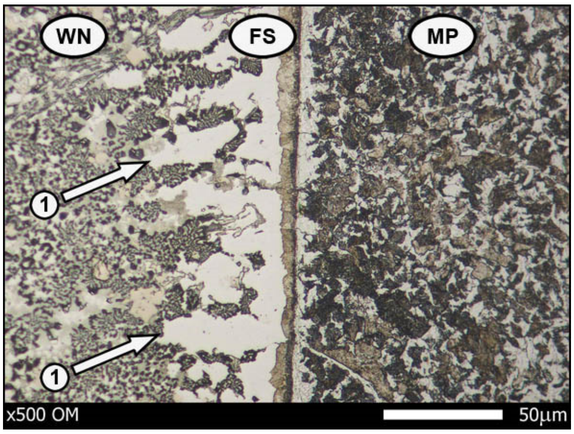

Figure 4. Microscopic image of material "Nb" fusion zone. At the junction of the weld metal pad material visible "bar" of ferrite alloy from which crystallized dendritic deposit separating the phases (1). In the material "pad" the microstructure of ferrite grains with bright dark areas of perlite. WN - layer of the deposit, FS - ferrite alloy, MP - pad material.

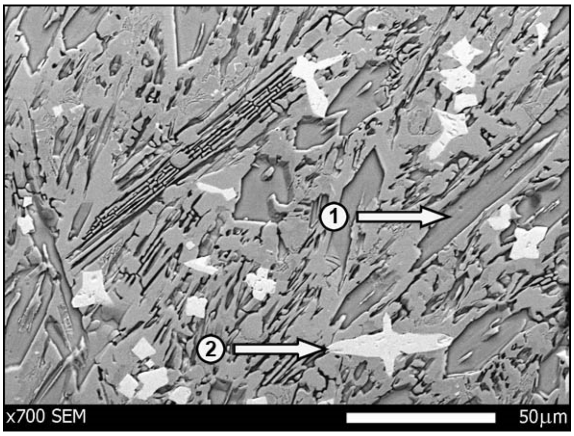

Figure 5. The microstructure of the weld layer material "Nb" of chromium carbide precipitates (1) and niobium (2).

Figures 6 and 7 show the characteristics of the surface layer containing vanadium. Outside the fusion zone, layer has a microstructure consisting of ledeburite, primary carbides of chromium and vanadium carbides.

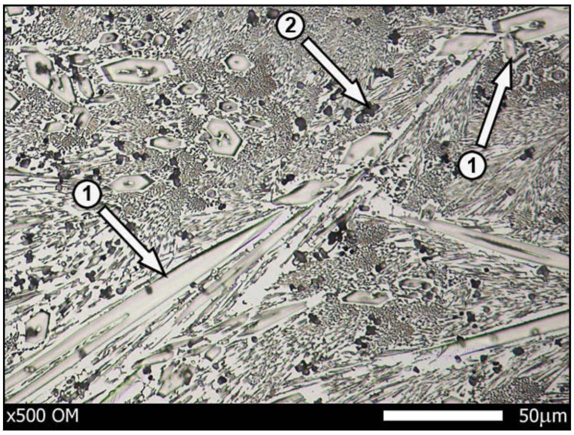

Figure 6. Microscopic images of the surface layer material "V". Ferrite tungsten alloy (mixture of construction ledeburitic) with unevenly spaced primary chromium carbide precipitates (1) and fine carbides of vanadium (2).

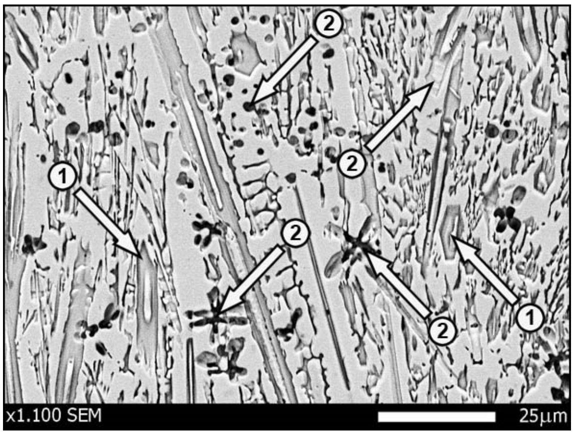

Figure 7. Microscopic image of the plastic layer "V". Ledeburitic mixture of ferrite alloy and chromium carbides M7C3 type (1) and vanadium carbides (2).

Table 2. Distribution of layers hardness

Type of layer		Material "Nb"	Material "V"
Hardness		HV 10	HV 10
The distance from the surface [mm]	0.5	694	783
	1.0	676	777
	1.5	643	733
	2.0	638	722
	2.5	612	692
	3.0	593	654
	3.5	5 of 85	639
	4.0	540	641
	4.5	541	266
	5.0	550	256
	5.5	286	-

As is clear from the measurements of hardness (table 2) test layers have diverse hardness on the cross section. The layer of vanadium content is harder for almost 90 units of the layer containing niobium. It should be noted that for both layers gradual decrease in cross-sectional hardness was observed. Figure 8-11 presents the results of wear in different abrasive masses.

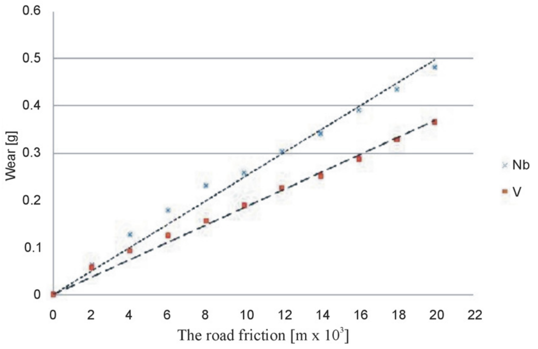

Figure 8. The course of wear layers in loamy sand.

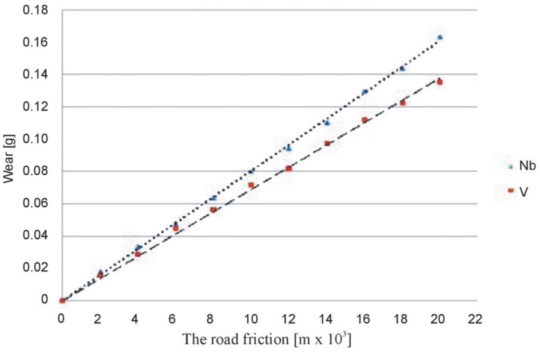

Figure 9. Mileage wear light layers in clay.

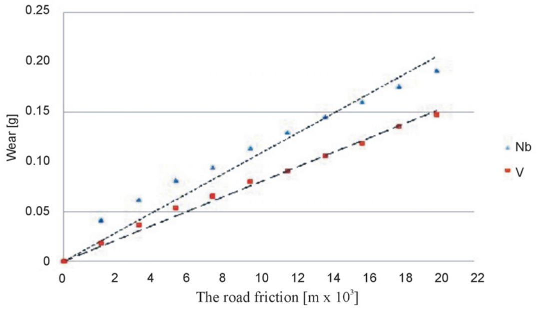

Figure 10. Light clay wear layers in the clay normal

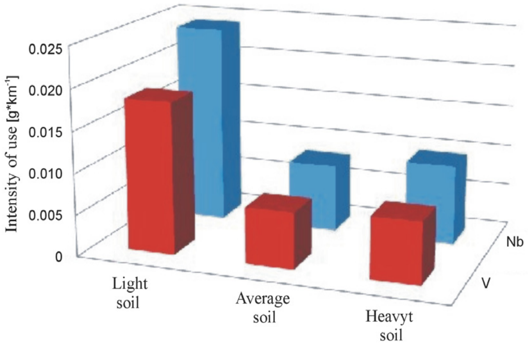

Figure 11. Comparison of intensity of layers depending on the type of mass

4. CONCLUSION

The results of the research carried out in three different soil masses showed the complexity of process of the abrasive wear in tribological discrete nodes. The highest wear was recorded in layers of sandy soil and it was higher by more than 2.5 times higher than in clay soils. Wear of layer with vanadium content was about 30% smaller than the layer containing niobium. Causes of dependence should be sought in the mechanism of wear. In the event of wear in the abrasive mass containing large amounts of silica, there was the greatest contact with the abraded area. A different analysis is required for results obtained during friction in clay soil masses. The friction in these soils had a different course than the sandy soil. Clay soil tends to form aggregates of soil, hence there are many air pores, and thus much more discontinuities friction surface than in the case of sandy soil. In addition, the impact of the clay and dust on the process of wear is negligible, but in combination with other factions can be multiplied. Greater wear in clay hard was observed due to the fact that the weight of the formed soil aggregates was greater than a light loam. The intensity of wear for layers of light and ordinary clay remained at the same level values wherein layer containing vanadium wear less intense than the layer containing niobium.

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