The influence of type of abrasive soil mass on the wear intensity of multi-phase welded coating

J Napiórkowski¹, K Ligier¹, M Lemeca¹

¹Faculty of Technical Sciences, University of Warmia and Mazury in Olsztyn. M. Oczapowskiego 11, 10-719 Olsztyn, Poland.

Abstract. One of the major problems when machining soil mass is wear of working tools. The process consists of many factors related to, amongst other things, the work item, the properties of the soil and the working process parameters. Processes which occur in the surface layer material are associated with changes in its mechanical properties, physical and chemical properties. The paper analyzes the process of wear steel 38GSA and weld electrode EStelMn60, ENSW2Mo-B, EStelMoNb60. Studies were conducted in laboratory conditions by the "spinning bowl" method. During the tests carried out wear of samples depending on the road friction and soil mass. The results found that the highest wear values were observed for gravel soil for the ENSW2Mo-B welded layer and it is 2.5 times higher than in the heavy soil. The lowest wear value was characteristic of the EStelMn60 welded layer, which in the chemical composition contains carbide elements. In heavy soil, the highest wear was observed for ENSW2Mo-B the smaller for EStelMoNb60.

1. Introduction
One phenomenon accompanying the operation of working elements in the soil is their intense wear, which is a process of physicochemical qualitative and quantitative changes occurring on the friction surface [1, 2].

It is generally accepted that the wear of operating parts processing an abrasive soil mass results from abrasive wear. The basic forms of the wear include scratching, ridging, microcutting, and local fatigue. These processes are associated with the mechanical impact of abrasive material grains on the surface layer of the material. Depending on the type of an operating part, including the impact of the pressure exerted by the abrasive material, chemical processes associated with the impact of soil environment can occur as well [3-5]. The soil is a complex, animate creation of nature, in which continuous processes of decomposition and synthesis occur for both mineral and organic compounds, along with their displacement [6].

Due to the multiplicity of factors affecting the course of wear for working elements in soil mass, so far there has been no formalized theory of mutual interactions between the soil and the working element. Most papers indicate that the wearing properties of soil result from its grain sizes, cohesiveness, and humidity [7].

The course and intensity of wear in the soil mass depend on properties of the soil processed (moisture content, compactness, pH and grain size distribution), type of the impact of the working element on the soil, design and technological solutions concerning the working element.

Users of working elements expect the manufacturers to provide design solutions that offer high durability. Therefore, the materials of the working elements of tools for treating soil abrasive mass should demonstrate high abrasive wear, as well as impact performance.
The process of the rational selection of the construction and technological forms of working elements, and of planning the course of operation, is possible when their wear process is known. The identification and description of wear in soil come down to a comprehensive description of the process of friction involving: the soil - the working element - the parameters of work [8].

One of the commonly applied ways to form the chemical composition as well as to change hardness and microstructure of the outer layer of the parts interacting within an abrasive environment is the formation of abrasion resistant layers using pad welding [9, 10]. This solution offers one of the methods to increase the durability of machine parts exposed to the effect of the abrasive environment. Abrasive wear resistance can be increased by the application of welding methods, making it possible to modify the chemical composition of the base material by introducing additional components increasing the resistance to abrasive wear as well as the change in hardness and microstructure of the material.

When selecting the material for operating parts to be used within an abrasive soil mass, it is necessary to carry out an analysis of the wear processes occurring at the interface between the soil and the operating part and to determine the environmental forces, including the properties of the abrasive mass. Wear resistance is determined inter alia by the element content, resilience, the micro-structure character and the matrix hardness [11].

2. Research materials

The study was subjected to 38 GSA steel. The tests involved samples 30 x 20 x 10 mm. This is martensitic steel which contains bainite and troostite. The chemical composition was 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%. Additional materials containing carbides were applied to the steel surface by arc welding with electrodes EStelMn60, ENSW2Mo-B, EStelMoNb60 (table 1).

| Ingredients content. % | Materials       | EStelMn60 | ENSW2Mo-B | EStelMoNb60 |
|------------------------|----------------|-----------|-----------|-------------|
| C                      |                | 3.40      | 0.94      | 5.31        |
| Mn                     |                | 4.32      | 1.63      | 1.28        |
| Si                     |                | 1.68      | 1.06      | 1.46        |
| Cr                     |                | 31.60     | 5.41      | 21.90       |
| Mo                     |                | 0.04      | 6.83      | 7.66        |
| Ni                     |                | 0.30      | 0.17      | 0.06        |
| Al                     |                | 0.03      | 0.01      | 0.05        |
| Cu                     |                | 0.09      | 0.12      | 0.09        |
| P                      |                | 0.05      | 0.01      | 0.02        |
| S                      |                | 0.01      | 0.05      | 0.02        |
| B                      |                | 0.03      | -         | -           |
| W                      |                | 0.05      | -         | 2.00        |
| V                      |                | -         | -         | 1.70        |
| Ti                     |                | -         | -         | 0.03        |
| Nb                     |                | -         | -         | 7.00        |

3. Research methodology

The study was conducted under laboratory conditions using a “rotating bowl” method wear testing machine (figure 1).
Figure 1. A stand for examination of wear in abrasive soil pulp: 1 - frame, 2 - motor, 3 – belt transmission, 4 - bowl, 5 - soil, 6 – pressing rollers, 7 – roller pressing, 8 – grip with the sample, 9- scarifying fork, 10- sample weight.

Research samples are mounted on two independent sections fixed on a detached wishbone suspension. The stem of the rocker is equipped with a special stem enabling the use of weights to add extra load to the sample.

Friction tests were conducted at a load of 53 kPa, a cutting speed of 2 ms⁻¹. Measuring sections of 2, 4, 6, 8 and 10 km were used.

The tests were carried out in two types of abrasive masses. A moisture content of the soil was determined to be equal to 5%, and the soil pH to be equal to 7.

The grain size distribution, determined with Mastersizer 2000 the laser particle size analyser, was as follows (PTG 2008 classification):

- Gravel soil: gravel: 56.6%; sand: 25.4%; dust: 9.4%; silt: 8.6%
- Clay soil: sand: 9.0%; dust: 23.6%; silt: 67.4%

Mass wear was determined based on the following formula:

$$Z_m = m_p - m_k \text{[g]}, \quad (1)$$

where: $Z_m$ – mass wear [g], $m_p$ – sample mass before testing [g], $m_k$ – sample mass after testing [g]

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

Examinations by means of scanning electron microscopy 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. Analysis of the obtained results

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

- 38 GSA stell - martensite, bainite and a small content of troostyt;
- EStelMn 60 – Varied structure on the thickness and length. Fusion zone: alloy ferrite with numerous carbides (Fe, Cr)3 C. Padding weld: primary carbides eutectic mixture [$\alpha + (\text{Fe, Cr})7 \text{C3}$], mainly with plate-like structure + residual austenite. Hardness 620÷726 HV10;
- ENSW2Mo-B – Varied dendritic structure. Fusion zone: alloy ferrite with carbides located on grain borders. Padding weld: alloy ferrite with small molybdenum carbides on grain borders and inside them. Hardness 720÷762 HV10;
- EStelMoNb 60 – Dendritic structure. Fusion zone: alloy ferrite. Padding weld: alloy ferrite with numerous carbides of the Mo2C, VC, TiC type. And with eutectics \([\alpha + (\text{Fe}, \text{Cr})_7 \text{C}_3]\).

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 figures 6 and 7.

As a result of the tests, a significant influence of the type of abrasive mass on the intensity of wear of the tested materials was found.

The highest wear values were observed for gravel soil (figure 6) for the ENSW2Mo-B welded layer and it is 2.5 times higher than in the heavy soil. The lowest wear value was characteristic of the EStelMn60 welded layer, which in the chemical composition contains carbide elements.

This is mainly the result of the interaction of high hard content and at the same time an irregular shape of the sand fraction. The soil is dominated by mechanical wear processes through microplowing and microfacture.

In heavy soil (figure 7), the highest wear was observed for ENSW2Mo-B and it was 0.086 g, the smaller for EStelMoNb60, which was over 3.5 times lower.
5. Summary
The description of the use of weld layers in soil mass is very difficult. It is caused by a multitude of factors affecting the process of material destruction. Many of them result from soil properties (grain size, compactness, humidity), other from material properties. The conducted research has shown over three times greater the wear of weld layers in diversified soil conditions: gravel and clay soil.

It can be concluded that the intensity of wear of weld layers in soil depends primarily on the share and distribution of primary carbides and eutectics on their cross-section.

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