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HEAT TREATMENT AND THERMOCHEMICAL TREATMENT OF TOOL STEEL

Summary

The paper presents results of studies of the influence of substrate heat treatment on microstructure and microhardness of boronized tool steels. Diffusion boronizing treatment process was carried out using boronizing powder at temperature of 900ºC for 5 h. After boronizing the microstructure of surface layer was composed of needle-like iron borides. The microhardness in the boronized layer was about 1800 HV0,1. The appropriate heat treatment with diffusion boronizing process provides good properties of tool steels such as high hardness, and also good cohesion between subsurface layer and the substrate. This is very important for increasing longevity of tools and parts of machines as tools covered with a resultant boronized layer which can be successfully used in agricultural machines.
***Key words**: diffusion boronizing, microstructure, microhardness, agricultural tools*

OBRÓBKA CIEPLNA I CIEPLNO-CHEMICZNA STALI NARZĘDZIOWEJ

Streszczenie

W pracy przedstawiono wyniki obróbki cieplnej podłoża na mikrostrukturę i mikrotwardość borowanej stali narzędziowej. Proces borowania dyfuzyjnego stali narzędziowej przeprowadzono w proszku borującym w temperaturze 900ºC w czasie 5 h. Po procesie borowania mikrostruktura warstwy powierzchniowej składała się z iglastych borków żelaza. Mikrotwardość w borowanej warstwie wynosiła ok. 1800 HV0,1. Właściwa obróbka cieplna połączona z procesem dyfuzyjnego borowania prowadzi do otrzymania dobrych właściwości stali narzędziowej, takich jak duża twardość, a przy tym dobra kohezja między warstwą powierzchniową a podłożem. To jest bardzo istotne w celu zwiększenia żywotności narzędzi i części maszyn i narzędzi z wytworzoną warstwą borowaną, które mogą być z powodzeniem stosowane w maszynach rolniczych.
***Słowa kluczowe**: borowanie dyfuzyjne, mikrostruktura, mikrotwardość, części maszyn rolniczych*

1. Introduction

Materials engineering plays an important role in formation of structure and properties of materials [5, 6, 8, 16, 18]. Agriculture is one of the fields of the economy which is intensively developing. Here, a type of tool steel must be carefully selected in such a way as to avoid downtime to replace damaged tools or parts. To enhance tools performance heat treatment process can be used and diffusion boronizing is one such suitable process. Typical boronized layers are composed of two phases: FeB and Fe_2B. Iron boride FeB appears in subsurface and it can show increased brittleness and delamination from substrate. Below FeB phase the Fe_2B phase occurs, which does not exhibit these phenomena. The Fe_2B phase has a needle-like structure and is closely bound to substrate [7, 10, 15].

Diffusion boronizing process is carried out on iron alloys such as steel, cast iron or non-ferrous metals such as nickel, chromium and their alloys. Subsurface brittleness can be reduced by single-phase boride layer, which is composed of only iron borides Fe_2B [10], or by modifying with elements which are introduced by various methods [1-4, 9, 11-14].

Boronized layers are characterized by high microhardness, corrosion resistance and wear resistance, therefore, can be successfully used in agricultural machine parts or tools. In this paper, the process of production of boronized layer is presented. Cr-V tool steels belong to the most important tool materials. The tools must withstand various types of degradation processes. Therefore, the materials should have high hardness and wear resistance. On the other hand, the materials have to resist brittle fracture, e.g., impact toughness and fracture toughness. This paper deals with an overview of the heat-treatment and surface engineering techniques suitable for Cr-V steels, for example ledeburitic Vanadis 6 steel [17].

It is expected that thermo-chemical treatment suggested in the paper will produce hard surface and a relatively ductile substrate, which will affect advantageously the work of agricultural tools in the soil, as they are often exposed to various external factors.

2. Research methodology

The studies were carried out on VANADIS 6 ledeburitic steel produced by powder metallurgy of rapidly solidified particles. The chemical composition of their steel is given in Table 1. The specimens used for the study were cuboid-shaped, and had the following dimensions: length 60 mm, width 12 mm and height 4 mm.

Table 1. Chemical composition of Vanadis 6 steel [% wt]
Tab. 1. Skład chemiczny stali Vanadis 6 [%wag.]

C	Si	Mn	Cr	Mo	V	Fe
2.09	0.98	0.38	6.64	1.48	5.45	balance

Source: Own work / Źródło: opracowanie własne

The tools made from VANADIS 6 steels are used in the heat-treated state only. A proper heat treatment is recommended for the tools to ensure appropriate hardness, strength and wear resistance.

The most convenient heat treatment for this type of steels is the so-called vacuum heat treatment. The first step in heat treatment was austenitized. This is very important, because the Cr-V tool steels have a poor thermal conductivity of the materials, the heating up to the final temperature should be slow, with several ramps enabling us to minimize the thermal gradients between the surface and the core, and a subsequent too large distortion of components.

This is why the Cr-V ledeburitic steels must be heated up to a much higher temperature. During the heating from the austenitizing, part of the carbides undergoes a dissolution and the dissolution the carbon. This leads to a saturation of the matrix of carbon and other alloying elements. Tempering should follow the quenching as soon as possible. This is important as otherwise the retained austenite could not have been stabilized. For transformation of the retained austenite to martensite, as well as for tempering of the newly formed martensite, it is necessary to temper at least twice. During the tempering, the alloying elements and carbon diffuse out as from solid solutions forming precipitates, responsible for a secondary hardening effect.

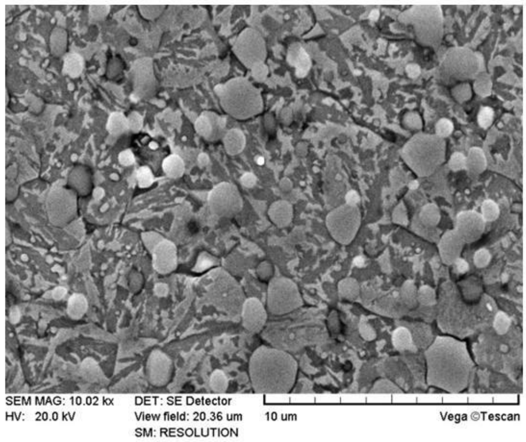
Diffusion boronizing was performed at 900°C for 5 h using powder method in the boronizing mixture. Boronized specimens were hardened and then tempered. Metallographic observations of the microstructure were conducted on polished and etched cross-sections of the specimens by using electron microscope Tescan VEGA 5135. Etching solution was a 2% HNO_3. To determine microhardness profiles a ZWICK 3212 B Vickers hardness tester was used with indentation load of 100 G (HV0,1) based on the standard PN-EN ISO 6507-1.

3. Results and discussion

The microstructure of the sample before and after heat treatment is shown in Figures 1 and 2. Figure 1 presents the microstructure in as-delivered VANADIS 6 steel. VANADIS 6 steels are normally distributed in annealed state. The main reason is to deliver the materials with low hardness suitable for machining operations. The microstructure after annealing consists of alloyed pearlite, secondary and primary carbides. The carbides are fine and uniformly distributed throughout the matrix. As shown in Figure 1, for the powder metallurgy made Vanadis 6 steel, the carbides are fine and uniformly distributed throughout the matrix. Larger secondary particles (dark gray colour) have a size between 1 μm and 2 μm. The previous X-ray analyses have shown that the carbides of a given alloy are formed by the chromium-based M_7C_3 and vanadium-based MC. Ultra-fine carbides in a pearlite substrate are M_7C_3-type, the ultra-fine having a size less than 1 μm.

Figure 2 presents the microstructure after heat treatment (hardening and tempering) consisting of alloyed martensite and carbide particles.

Figure 3 presents the microstructure of diffusion boronized layer. Total thickness of boronized layers was 50 μm and had a needle-like structure and was closely bound to the substrate. Figure 3 shows FeB phase situated closer to surface, and Fe_2B, situated below it. Under compact boronized layer a diffusion zone enriched in boron was observed. Substrate material consisted of matrix enriched with carbide particles typical to alloy ledeburitic steel.



Source: Own work / Źródło: opracowanie własne

Fig. 1. Microstructure of Vanadis 6 steel substrate before heat treatment
Rys. 1. Mikrostruktura podłoża stali Vanadis 6 przed obróbka cieplną

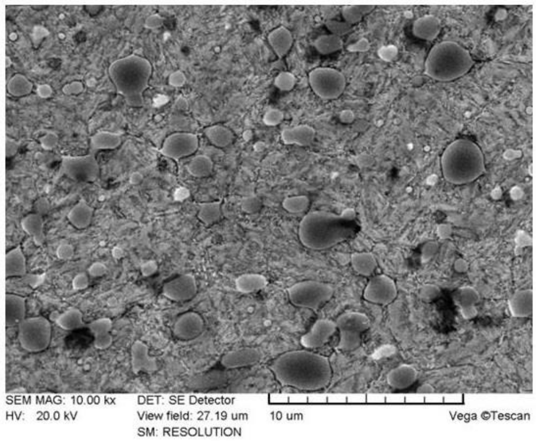


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Fig. 2. Microstructure of Vanadis 6 steel substrate after heat treatment
Rys. 2. Mikrostruktura podłoża stali Vanadis 6 po obróbce cieplnej

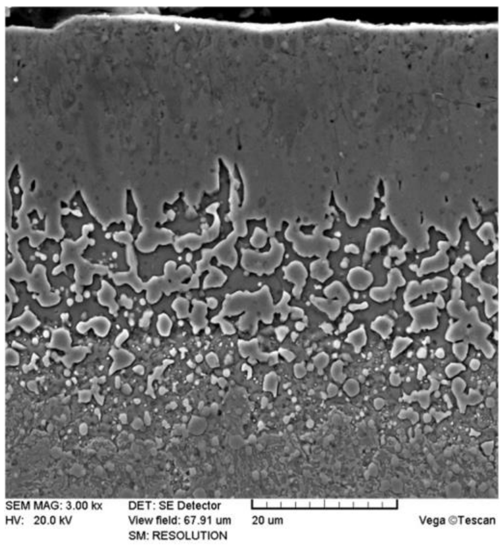

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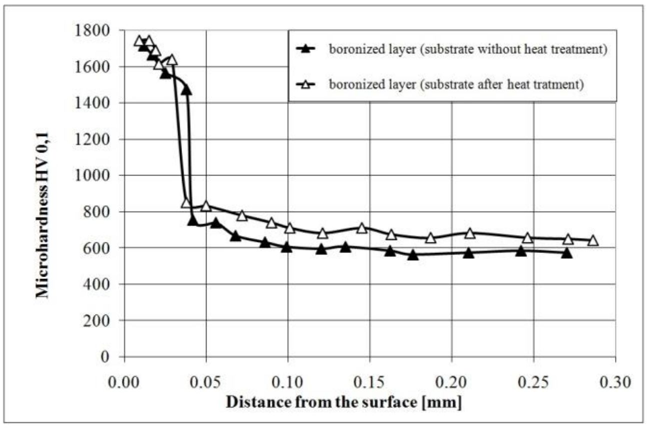
Fig. 3. Microstructure of boronized layer
Rys. 3. Mikrostruktura warstwy borowanej

Figure 4 presents the microhardness profiles of diffusion boronized layers before and after heat treatment. The diffusion boronized layer was about 1800-1400 HV0,1, and with increasing distance from the surface the microhardness of boronized layer decreased to the steel substrate. The microhardness of the steel substrate is dependent on heat treatment of substrate. In as-delivered VANADIS 6 steel the microhardness was about 600 HV0,1, but after heat treatment it was about 700 HV0,1.



Source: Own work / Źródło: opracowanie własne

Fig. 4. Microhardness profile of boronized layer on VANADIS 6 steel

Rys. 4. Profil mikrotwardości warstwy borowanej na stali VANADIS 6

4. Conclusions

- The heat treatment of substrate is very important for ledeburitic tool steels and influences microhardness of substrate.
- As a result of diffusion boronizing the needle-like microstructure of microhardness 1800 – 1400 HV0,1 was obtained.

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