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DIFFUSION AND LASER BORIDING OF HARDOX 450 STEEL

Summary

The effect of diffusion and laser boriding on the microstructure, microhardness and wear resistance of Hardox 450 steel compared to initial state is the subject of this article. After the boron modification process of Hardox 450 steel microhardness and wear resistance increased. After the diffusion boriding a needle-like microstructure of microhardness about 1800-1500 HV0.1 was obtained. As a result of laser boronizing the microstructure consisted of a remelted zone (MZ), heat-affected zone (HAZ) and core. In the remelted zone enriched of boron microhardness was about 1500-1600 HV0.1 The wear resistance tests showed the higher wear resistance of the diffusion borided layers, whereas the lower were in initial state but the lowest was for laser borided layer.
Key words: *diffusion boriding, laser boriding, microstructure, microhardness, wear resistance*

BOROWANIE DYFUZYJNE I LASEROWE STALI HARDOX 450

Streszczenie

W pracy przedstawiono wpływ borowania dyfuzyjnego i laserowego na mikrostrukturę, mikrotwardość oraz odporność na zużycie przez tarcie stali Hardox 450 w porównaniu do stali w stanie wyjściowym. Po procesie modyfikacji stali Hardox 450 borem uzyskano zwiększenie mikrotwardości i odporności na zużycie przez tarcie. W wyniku procesu borowania dyfuzyjnego warstwa miała iglastą strukturę o mikrotwardości ok. 1800-1500 HV0,1. Natomiast w wyniku borowania laserowego uzyskano budowę strefową składającą się ze strefy przetopionej, strefy wpływu ciepła oraz rdzenia. W strefie przetopionej wzbogaconej w bor mikrotwardość wynosiła ok. 1500-1600 HV0,1. Badania odporności na zużycie przez tarcie wykazały, że najlepszą odporność posiada warstwa borowana dyfuzyjnie, natomiast mniejszą stal w stanie wyjściowym a najmniejszą warstwa borowana laserowo.
Słowa kluczowe: *borowanie dyfuzyjne, borowanie laserowe; mikrostruktura, mikrotwardość, odporność na zużycie przez tarcie*

1. Introduction

There are many methods to improve the mechanical properties of the materials. Diffusion boriding is one of them. The borided layers can be produced on different materials eg. iron alloys and non-ferrous metals eg. titanium, nickel. Typical layer formed on the steel have a characteristic needle-like structure and was composed of iron borides FeB and Fe_2B which is closely associated with the core. The microhardness of layer is about 2000 HV0,1. This type of treatment increases wear resistance, heat resistance and corrosion resistance [1, 2, 4-6]. The disadvantage of these layers is the fragility so it could be applied the laser boriding. Laser boriding of steel consists of laser-melted surface layer material with the alloying material added by various methods, in this paper, the method of melting the surface layer material alloyed with a stopping paste containing boron amorphous [3]. In this paper, the method of melting the surface layer material of steel and alloyed with a paste containing boron amorphous. A laser alloying allows you to perform local processing of selected parts and tools, and eliminates the need for specialized equipment using gas, making the technology more eco-friendly [7].

The aim of this study is to investigate the effect of diffusion boriding and laser boronizing on the chosen properties of Hardox 450 steel.

2. Research methodology

The Hardox 450 steel was investigated material and its chemical composition is given in Table 1.

Diffusion boronizing was performed at 950°C for 4 h. The boronizing mixture used in the process contained: amorphous boron, KBF_4as activator and black carbon as filler. After diffusion boronizing specimens were hardened in oil from 850°C and then tempered at 560°C for 1h.

Laser heat treatment (LHT) was carried out using TRUMPF TLF 2600 Turbo CO_2 laser of nominal power of 2.6 kW. The parameters used in the experiment were: laser beam power P = 0.91 kW, laser beam radiation density q = 28.98 $kW \cdot cm^{-2}$, scanning laser beam velocity v = 3.84 $m \cdot min^{-1}$, distance between axes of adjacent tracks f = 0.50 mm and laser beam diameter d = 2 mm.

Table 1. Chemical composition of Hardox 450 steel
Tab. 1. Skład chemiczny stali Hardox 450

% C	% Mn	% Si	% P	% S	% Cr	% Mo	% B	% Ti
0.258	1.047	0.241	0.014	0.001	0.260	0.152	0.002	0.003

Source: own study / Źródło: badania własne

Microstructure observations were carried out using Metaval Carl Zeiss optical microscope equipped with a camera Moticam 2300 3.0 MP and Live Motic Images Plus 2.0 Resolution software.

To determine microhardness profiles a ZWICK 3212B Vickers hardness tester was used. Indention load of 50 G and loading time 15 seconds were used in this study, based on the standard PN-EN ISO 6507-1.

Wear resistance test were carried out with tribometer MBT-01 type Amsler. A ring as specimen and sintered carbide plate S20S as counterspecimen was used to examine wear resistance. Wear resistance test were carried out under the load F = 147 N and at specimen rotatio speed of n = 250 rev⊙min^{-1}, in dry friction conditions. Wear resistance was evaluated by specimen mass loss (Δm [mg]) per friction surface (S [cm^2]) in a time unit (t [h]). Wear intensity coefficient (Iz) was determined from the equation: $Iz = \Delta m/(S \cdot t)$ [mg⊙cm^{-2}⊙h^{-1}].

3. Results and discussion

Microstructure of Hardox 450 steel in the initial state is composed of tempered martensite (Fig. 1), while the diffusion boriding and hardening and tempering boronized layer had a needle-like structure and was closely related to a martensite substrate. It was composed of iron borides FeB and Fe_2B (Fig. 2).

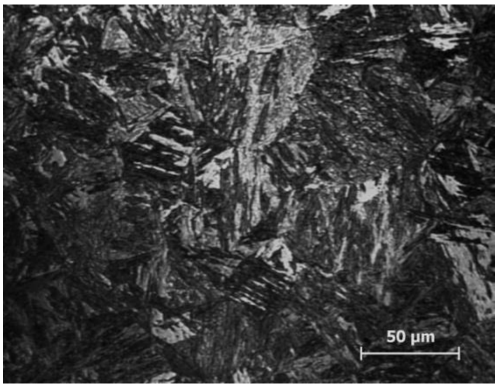

Fig. 1. Microstructure of Hardox 450 steel [8]
Rys. 1. Mikrostruktura stali Hardox 450 [8]

The thickness of the produced boronized layers was about 100 µm. Microhardness of Hardox 450 steel was about 500 HV0.1, while after diffusion boriding was about 1800 – 1500 HV0.1 on the surface (Fig. 4). With increasing distance from the surface, microhardness of boronized layer gradually decreased towards the substrate. Figure 3 shows the microstructure after laser boronizing. The resulting microstructure consisted of a remelted zone (MZ), heat-affected zone (HAZ) and core (Fig. 3). The remelted zone was about 90 µm. In remelted zone there were borides-martensite eutectic, of microhardness lower than iron borides (Fig. 4). Figure 4 shows the microhardness of Hardox 450 steel after laser boronizing. In the remelted zone microhardness was about 1500-1600 HV0.1 and decreased to 600 HV0.1 in heat-affected zone until the sorbite core of microhardness about 400HV0.1.

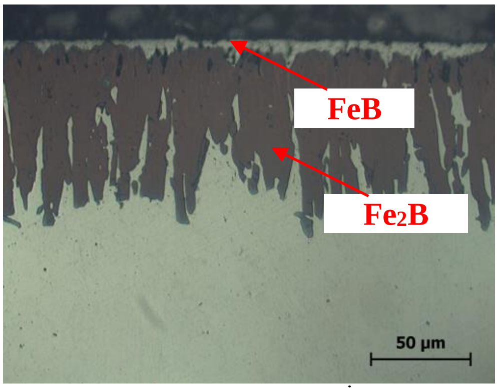

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Fig. 2. Microstructure of diffusion borided layer at 950°C for 4h and quenching and tempering
Rys. 2. Mikrostruktura warstwy borowanej dyfuzyjnie w 950°C przez 4h i ulepszonej cieplnie

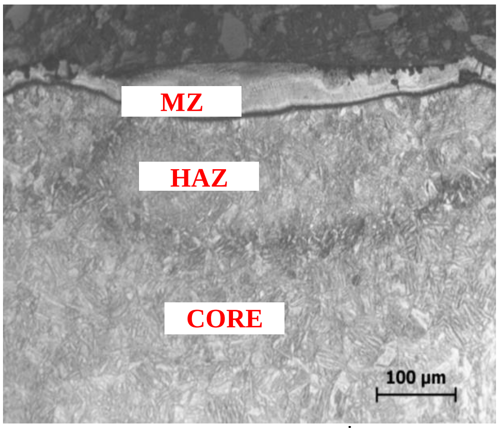

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Fig. 3. Microstructure of Hardox 450 steel after laser boriding
Rys. 3. Mikrostruktura stali Hardox 450 po borowaniu laserowym

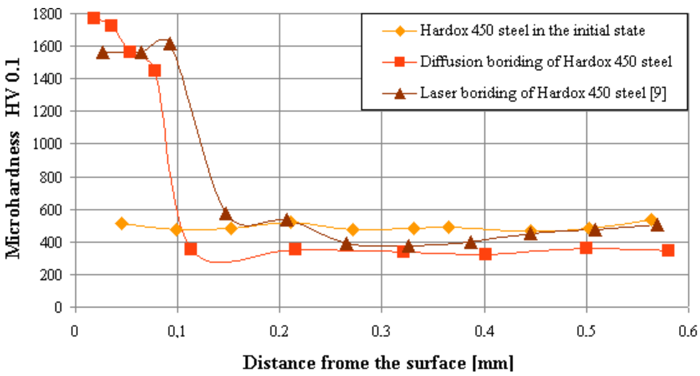

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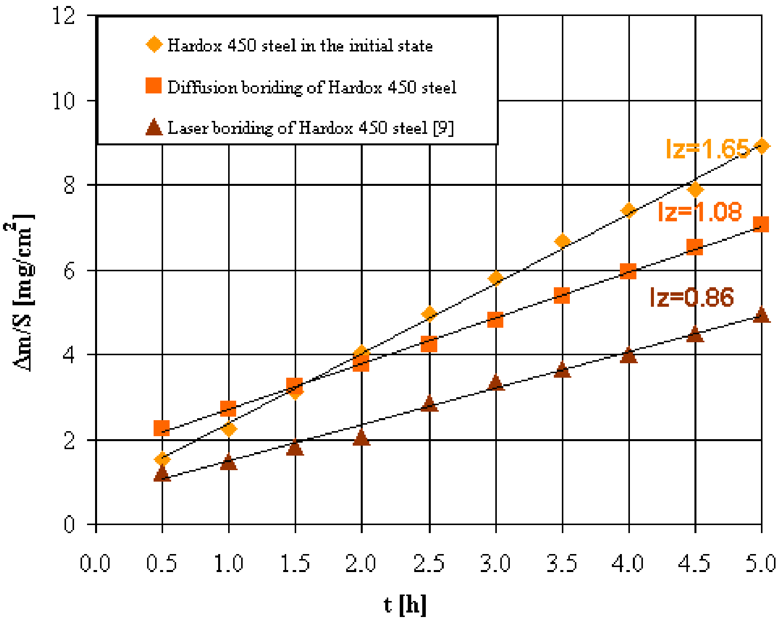
Fig. 4. Microhardness profiles of Hardox 450 steel of initial state, after diffusion boriding and laser boronizing
Rys. 4. Profile mikrotwardości stali Hardox 450 w stanie wyjściowym, po borowaniu dyfuzyjnym i laserowym



Source: own study / Źródło: badania własne

Fig. 5. Wear resistance of Hardox 450 steel: in initial state; after diffusion boriding; after laser boriding

Rys. 5. Odporność na zużycie przez tarcie stali Hardox 450: w stanie wyjściowym; po borowaniu dyfuzyjnym; po borowaniu laserowym

On the basis of shown in Figure 5 it can be concluded that laser diffusion increase wear resistance of Hardox 450 steel. The lowest wear resistance showed sample in initial state Iz = 1.65 mg⋅cm^{-2}⋅h^{-1} then after diffusion borided Iz = 1.08 mg⋅cm^{-2}⋅h^{-1}. The best wear resistance was for sampel after laser boriding, Iz = 0.86 mg⋅cm^{-2}⋅h^{-1}. Such a high rate wear resistance was related to a high boron content in the boride - martensite eutectic.

4. Conclusions

➢ Microstructure of Hardox 450 steel after diffusion borided had a needle-like structure and was closely related to a martensite core. After laser boriding microstructure contained remelted zone (MZ), heat-affected zone (HAZ) and core.

➢ Laser boriding of Hardox 450 steel seems to be the best way to increase the properties of the steel. As it is also possible to use the local treatment compared with diffusion borided.

5. References

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