

## INFLUENCE OF LASER BORIDING ON THE MICROSTRUCTURE AND SELECTED PROPERTIES OF STRUCTURAL STEEL WITH BORON

### Summary

The article presents a comparative research of influence of laser boriding on the properties of Hardox 450 and B27 steels. Microstructure, microhardness and wear resistance of the steels were examined.

**Key words:** laser boriding, microstructure, microhardness, fracture toughness

## WPLYW BOROWANIA LASEROWEGO NA MIKROSTRUKTURĘ I WYBRANE WŁAŚCIWOŚCI KONSTRUKCYJNEJ STALI Z BOREM

### Streszczenie

W artykule przedstawiono porównawcze badania wpływu borowania laserowego właściwości stali Hardox 450 i borowej B27. Zbadano mikrostrukturę, mikrotwardość i odporność na zużycie przez tarcie.

**Słowa kluczowe:** borowanie laserowe, mikrostruktura, mikrotwardość, odporność na kruche pękanie

### 1. Introduction

Boronizing is one method of increasing the durability of machine parts and equipment, these layers can be produced in many materials. Typical layer formed on the steel have a characteristic needle like structure and was composed of iron borides FeB and Fe<sub>2</sub>B which is closely associated with the core. The microhardness of layer is about 2000 HV<sub>0.1</sub>. Diffusion boronizing also affects the increasing to wear resistance, heat resistance and corrosion resistance [1, 2, 4-6]. The disadvantage of these layers is the fragility. The friability of these layers is manifested by chipping and peeling from the core under loading [1-6], therefore, and more often used alloying with boron with a laser. 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]. Modern laser technology plays an increasingly important role in industrial applications. Lasers are easily integrated into production lines and laser machining is done very quickly and selectively, allowing it to save time processing.

### 2. Research methodology

The materials investigated were Hardox 450 and boron steel and its chemical composition is given in Table 1.

Laser boriding was relied on alloying with boron on Hardox 450 and boron steel as delivered by the manufacturer. Amorphous boron was applied to the steel in the form of paste having a thickness of about 40 microns. Laser heat treatment (LHT) was carried out using TRUMPF TLF 2600 Turbo CO<sub>2</sub> laser of nominal power of 2.6 kW, which is located in the Laboratory of Laser Technology of Department Division of Machining of Poznan University of Technology. The parameters used in the experiment were: laser beam power P = 1.04 kW, laser beam radiation density q = 33.12 kW/cm<sup>2</sup>, scanning laser beam velocity v = 2.88m/min, distance between axes of adjacent tracks f = 0.5 mm and laser beam diameter d = 2 mm.

Microstructure observations were carried out using Metaval Carl Zeiss optical microscope equipped with a camera Moticam.

To determine microhardness profiles a ZWICK 3212B Vickers hardness tester was used. Indentation load of 100 G and loading time 15 seconds were used in this study, based on the standard PN-EN ISO 6507-1 [11].

Test of resistance to wear by rubbing performed on tribometer MBT-01. A couple pokes worked in the system: sample - rotating ring / counter specimen - carbide plate with a hardness of 1450HV S20S. The tests were performed under dry friction constant load F = 147 N and a rotational speed of the samples v = 0.26 m / s (n = 250 r / min).

Table 1. Chemical composition of Hardox 450 and boron steel

Tab. 1. Skład chemiczny stali Hardox 450 i borowej

Steel	Chemical composition [%wt]							
	C	B	Mn	Si	P	S	Cr	Mo
Hardox 450	0.258	0.002	1.239	0.382	0.015	0.001	0.729	0.033
Boron steel (B27)	0.31	0.002	1.3	0.16	0.017	0.002	0.39	0.022

Source: Own work / Źródło: opracowanie własne

The wear resistance of friction was determined from the weight loss of the sample, referred to the friction surface of the unit time as measured by the intensity  $I_z$ :

$$I_z = \frac{\Delta m}{S \cdot t} \left[ \frac{mg}{cm^2 \cdot h} \right],$$

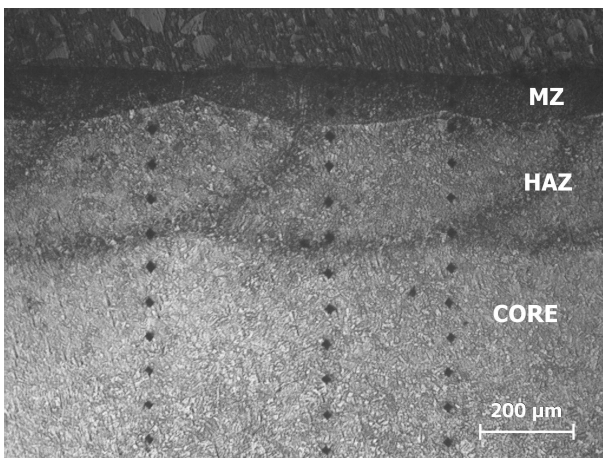
where:

$I_z$  – intensity ratio,  $\Delta m$  – sample weight loss [mg],  $S$  – surface friction [ $cm^2$ ],  $t$  – time friction [h].

Tests of resistance to wear by friction was carried out during 5 h. Measurements of weight loss were performed using an analytical balance with an accuracy of 0.0001g WA34 at intervals, which 0.5h.

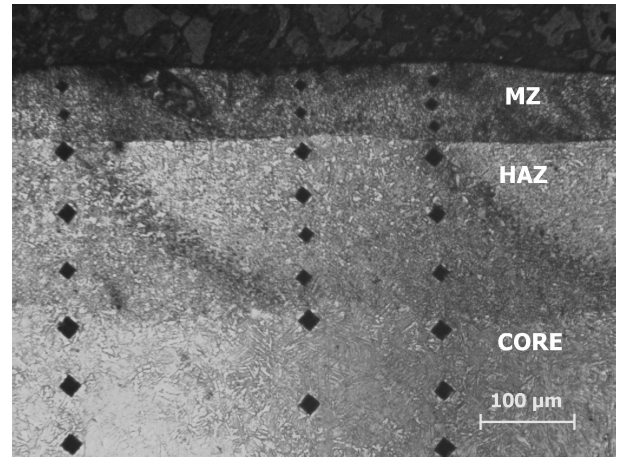
### 3. Results and discussion

Figures 1 and 2 shows the microstructure of Hardox 450 and boron steel after laser boriding. The resulting microstructure for both steel consists of a remelted zone (MZ), heat-affected zone (HAZ) and core (Fig. 1, 2).



Source: Own work / Źródło: opracowanie własne

Fig. 1. Microstructure of Hardox 450 steel after laser boriding; LHT:  $P = 1.04$  kW,  $v = 2.88$  m/min,  $f = 0.50$  mm  
Rys. 1. Mikrostruktura stali Hardox 450 po borowaniu laserowym; LOC:  $P = 1,04$  kW,  $v = 2,88$  m/min,  $f = 0,50$  mm



Source: Own work / Źródło: opracowanie własne

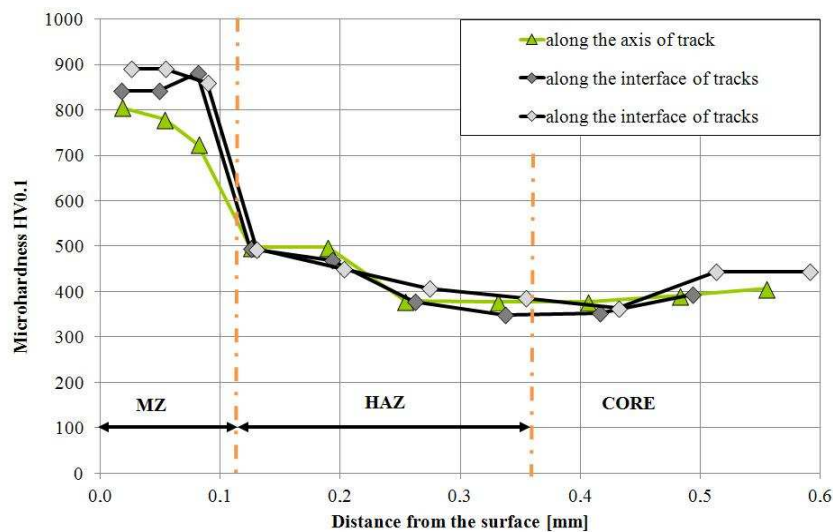
Fig. 2. Microstructure of boron steel after laser boriding LHT:  $P = 1.04$  kW,  $v = 2.88$  m/min,  $f = 0.50$  mm

Rys. 2. Mikrostruktura stali borowej po borowaniu laserowym; LOC:  $P = 1,04$  kW,  $v = 2,88$  m/min,  $f = 0,50$  mm

In remelted zone there is borides- martensite eutectic, of microhardness lower than iron borides. Figure 3 shows the microhardness of Hardox 450 steel after laser boronizing. In the remelted zone microhardness in along the axis of track was about 800 HV<sub>0.1</sub> and decrease to 500÷400 HV<sub>0.1</sub> in heat-affected zone until the sorbite core of microhardness 400HV<sub>0.1</sub>. The microhardness of boron steel (fig. 4) after laser boronizing shows in the remelted zone microhardness in along the axis of track was about 1000 HV<sub>0.1</sub> and decrease to 600÷300 HV<sub>0.1</sub> in heat-affected zone until the sorbite core of microhardness 400HV<sub>0.1</sub>.

Figure 5 shows wear resistance of Hardox 450 and boron steel laser layer was compared. It was found that Hardox 450 steel has a higher resistance to abrasion than boron steel.

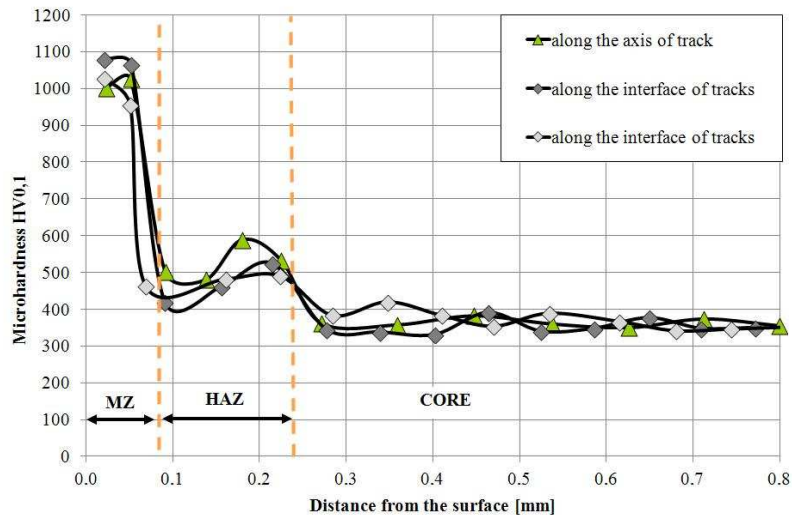
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Source: Own work / Źródło: opracowanie własne

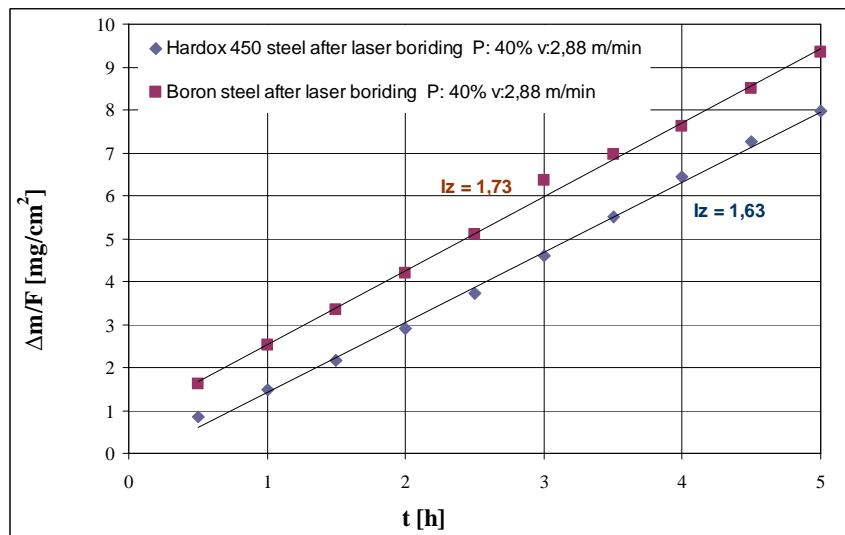
Fig. 3. Microhardness profiles of Hardox 450 steel after laser boriding; LHT:  $P = 1.04$  kW,  $v = 2.88$  m/min,  $f = 0.50$  mm

Rys. 3. Profile mikrotwardości stali Hardox 450 po borowaniu laserowym; LOC:  $P = 1,04$  kW,  $v = 2,88$  m/min,  $f = 0,50$  mm



Source: Own work / Źródło: opracowanie własne

Fig. 4. Microhardness profiles of boron steel after laser boriding; LHT:  $P = 1.04$  kW,  $v = 2.88$  m/min,  $f = 0.50$  mm  
 Rys. 4. Profile mikrotwardości stali borowej po borowaniu laserowym; LOC:  $P = 1,04$  kW,  $v = 2,88$  m/min,  $f = 0.50$  mm



Source: Own work / Źródło: opracowanie własne

Fig. 5. Wear resistance of Hardox 450 and boron steel after laser boriding  
 Rys. 5. Odporność na zużycie przez tarcie stali Hardox 450 i borowej po stopowaniu borem

Hardox 450 steel has a lower microhardness in the remelted zone (MZ) than boron steel, but the microhardness distribution profile is gentler between the melted zone and the core than boron steel. A gentler distribution of microhardness increases of wear resistance.

#### 4. Conclusions

1. The microstructure after laser boriding consists of a remelted zone (MZ), heat-affected zone (HAZ) and core for both steels.
2. The microhardness of Hardox steel is about 800 HV<sub>0,1</sub> in remelted zone and gently falls to the core to 400 HV<sub>0,1</sub> but for boron steel the microhardness in remelted zone is about 1000 HV<sub>0,1</sub> but suddenly drops to the core to 400 HV<sub>0,1</sub>.
3. Wear resistance of Hardox 450 is higher than boron steel because of gentler distribution of microhardness between remelted zone and core.

#### 5. References

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