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INFLUENCE OF LASER ALLOYING WITH AMORPHOUS BORON ON STRUCTURE AND MICROHARDNESS OF 41Cr4

WPŁYW STOPOWANIA LASEROWEGO BOREM AMORFICZNYM NA STRUKTURĘ I MIKROTWARDOŚĆ STALI 41Cr4

Influence of laser alloying on structure, and microhardness of surface layers was investigated. Alloying depended on laser re-melting of 41Cr4 steel's surface layer with coated paste containing amorphous boron. In order to produce those layers, the technological laser TRUMPF TLF 2600 Turbo CO_2 of the nominal power 2.6 kW was applied. Boriding was carried out with laser power P=0.91 kW, P=1.3 kW and with laser beam scanning rate v in ranging from 0.17 m/min to 5.76 m/min, and with beam diameter 2 mm. Influence of laser treatment parameters on thickness of melted zone as well as microstructure of surface layer was tested. Microhardness was tested along the axis of melted zone, perpendicular to scanned surface. In order to measure microhardness Vickers' method with tester Zwick 3212 B was applied. On the base of microhardness profile analysis, the dependence of the average hardness in melted zone on laser beam scanning rate was determined. With increasing scanning speed average microhardness in remelted zone increase from 600 HV to 1600 HV. To observe microstructure optical microscope Metaval as well as scanning electron microscope Tescan VEGA 5135 were applied. Tests proved diversified structure of surface layer, depending on laser treatment parameters. Structure had an eutectic character with large refinement when a higher scanning speed was used. Thickness of melted zone with used parameters could obtain from 77 μm to 795 μm was obtained. Results were compared with those prepared by laser re-melting of diffusion borided layer. It was found that both structures and microhardness was similar.

Keywords: laser boriding, microstructure, microhardness, laser treatment parameters

W pracy zbadano wpływ stopowania laserowego na strukturę i mikrotwardość warstwy wierzchniej. Stopowanie polegało na przetapianiu laserem warstwy wierzchniej stali 41Cr4 pokrytej pastą zawierającą amorficzny bor. Do wytwarzania warstw został zastosowany laser technologiczny TRUMPF TLF 2600 Turbo CO_2 o mocy nominalnej 2,6 kW. Borowanie zostało przeprowadzone przy mocy lasera P=0,91 kW i P=1,3 kW oraz przy szybkościach skanowania wiązką w zakresie 0,17 m/min do 5,76 m/min, przy średnicy wiązki 2 mm. Zbadano wpływ parametrów obróbki laserowej na głębokość strefy przetopionej i mikrostrukturę warstwy wierzchniej. Mikrotwardość została zbadania wzdłuż osi strefy przetopionej prostopadle do skanowanej powierzchni. Mikrotwardość badano metodą Vickers'a przy użyciu twardościomierza Zwick 3212B. Na podstawie analizy profili mikrotwardości została wyznaczona zależność średniej mikrotwardości w strefie przetopionej od szybkości skanowania wiązką lasera. Ze wzrostem szybkości skanowania średnia mikrotwardość w strefie przetopionej wzrasta z 600 HV do 1600 HV. Do obserwacji mikrostruktury został użyty mikroskop Metaval, jak również Tescan VEGA 5135. Badania wykazały zróżnicowaną strukturę warstwy wierzchniej zależną od parametrów obróbki laserowej. Struktura ma charakter eutektyki z dużym rozdrobnieniem, gdy została użyta wyższa szybkość skanowania. Grubość strefy przetopionej uzyskana przy stosowanych parametrach wynosi 77 μm do 795 μm. Wyniki zostały porównane z wynikami badań dyfuzyjnych warstw borowanych przetapianych laserowo. Wykazano, że struktury i mikrotwardości są podobne.

1. Introduction

Laser treatment is a very interesting process of modern manufacturing. Laser alloying offers new ways of making surface layers, which are difficult to be created with many other technologies [2,4,6]. Insertion of boron to steel by thermochemical treatment is a well-known process of improving surface layer parameters [1,3]. Diffusion borided layers exhibit high hardness (about 1800 HV) and wear resistance.

Boride layers can be laser modified [1,5,6,9]. Laser surface modification of boride layers can be made with or without remelting of boride layers. Laser modifications without remelting are carried out with a lower laser power and lead to globularisation of boride structure and hardening of steel in the heat affected zone.

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Laser modification with remelting is carried out with higher laser power and lead to remelting of surface layer which crystallize into the as eutectic structure composed of martensite and iron borides. Fe_3B boride can occur in remelted structure [5,6,9].

This paper presents the method of preparing boride layers using laser alloying of surface layer with boron. Although this method is currently not strongly recognized, it seems an interesting method of the surface modification [2,6,7]. Laser alloying allows to create a new type of surface layers with good mechanical and exploitation properties.

2. Experimental procedure

The material used in this study was 41Cr4 steel. Material was prepared as 20 mm diameter rings with 12mm diameter hole and 12 mm high. Steel's chemical composition is presented in Table1. Rings were hardened and tempered at 570 °C. For the experiment's sake, external cylindrical surface was coated by amorphous boron bounded with silicate solution with thickness around 40 μm.

TABLE

Chemical composition of 41Cr4 [wt %]

C	Mn	Si	P	S	Cr	Ni	Cu	Mo
0,43	0,64	0,29	0,017	0,026	1,02	0,1	0,09	0,02

Boriding was carried out on Trumpf TLF 2600 Turbo laser using two power levels P=0.91 kW , P=1.3 kW with laser beam scanning rate v ranging from 0.17 m/min to 5.76 m/min, with beam diameter 2 mm. Samples were tracks parallel to cylinder generating line. After boriding in half of tracks length cross section was prepared. Samples were etched with 2% Nital reagent.

Structure of the tracks was observed using the optical microscope Carl Zeiss Metaval and the scanning electron microscope Tescan Vega 5135.

Microhardness was tested along the axis of the melted zone, perpendicular to scanned surface. In order to measure microhardness, Vickers' method with 0.981 N load with tester Zwick 3212 B was applied. On the basis of microhardness profile analysis, the dependence of the average hardness in melted zone on laser beam scanning rate was determined.

3. Results and discussion

Microscopic observation of tracks on cross section showed differences in dimensions of tracks and their structure. Tracks' structure is composed of melted zone, heat affected zone and core. Thickness of the melted zone with used parameters could obtain from 77 μm to 795 μm. Optical microscopic images of a single track are presented on Figures 1 and 2.

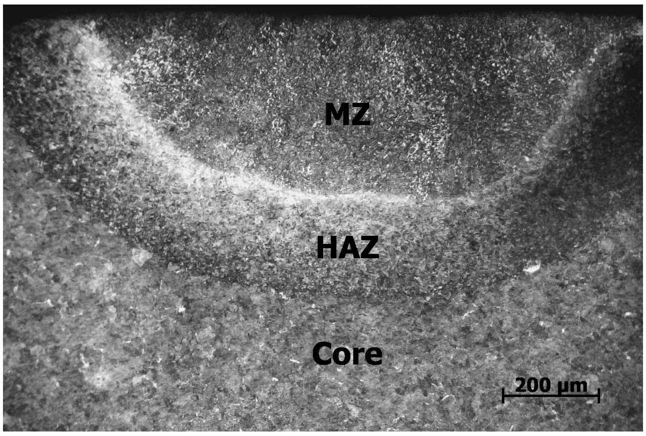

Fig. 1. Microstructure of laser borided track (optical microscopy), P=0.91 kW, v=0,67 m/min; MZ – melted zone, HAZ – heat affected zone

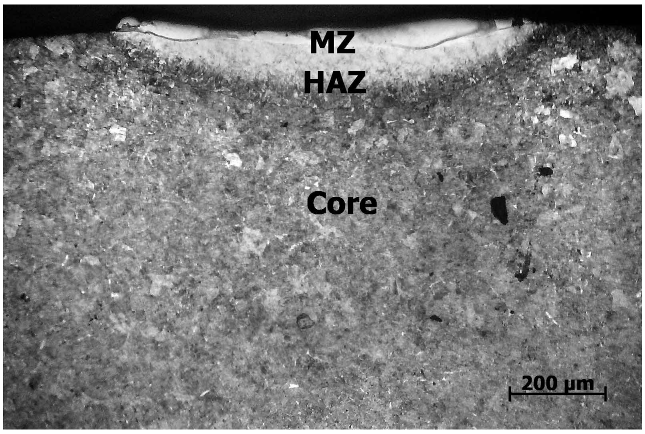

Fig. 2. microstructure of laser borided track (optical microscopy), P=1,30 kW, v=4,48 m/min; MZ – melted zone, HAZ – heat affected zone

The melted zone may can have different eutectic morphology, depending on the parameters used while laser treatment process, and it is sems to be probably connected with track dimensions. The higher scanning rate was used the larger refinement was observed. SEM images in secondary electron contrast of the melted zones near surface with different laser treatment parameters are presented on Figure 3 and 4. The structure was similar to structures prepared by laser melting of diffusion borided layers [5,9].

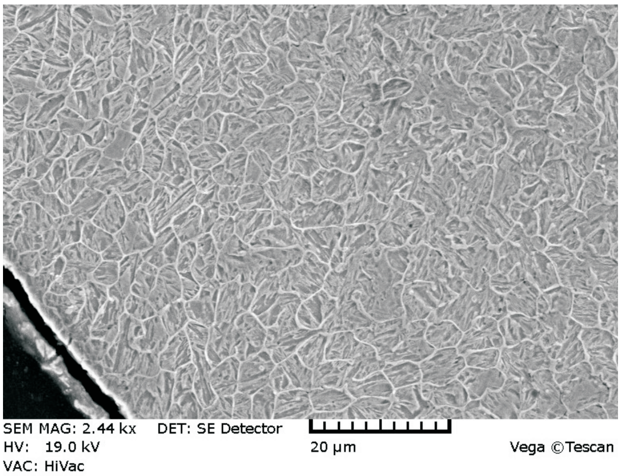

Fig. 3. Microstructure of melted zone near surface (SEM magn. 2.44 kx), *v* =0.67 m/min, P=0.91 kW

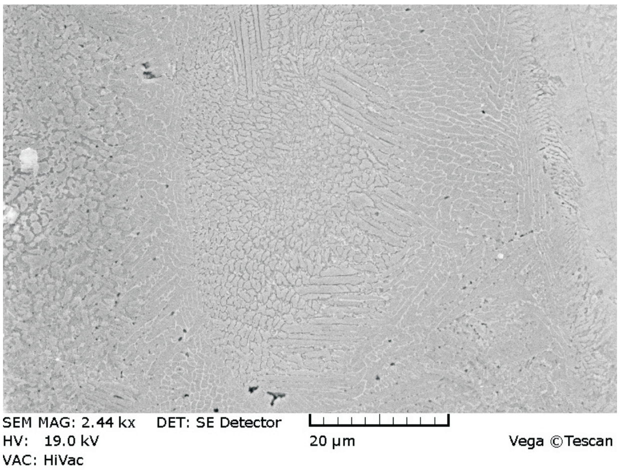

Fig. 4. Microstructure of melted zone near surface (SEM magn. 2.44 kx), *v* =4.48 m/min, P=1.30 kW

Microhardness tests showed gradual hardness profiles in borided layers presented on Figure 5 and 6. Microhardness of melted zone is dependent to on laser treatment parameters. High hardness was obtained with high scanning rate and medium laser power around 1600 HV. Was observed that depth of melted zone had significant influence on hardness and structure of melted zone. Comparison made between tracks with different depth (Fig.1 and Fig.2) showed that structure (Fig. 3 and Fig. 4) is differ from one another. Microhardness profiles (Fig. 5 and Fig. 6) show distinction between tracks with different depth and structure. When the melted zone was shallow microhardness was high and structure had larger refinement. Using identical values of beam power, hardness increased together with scanning rate.

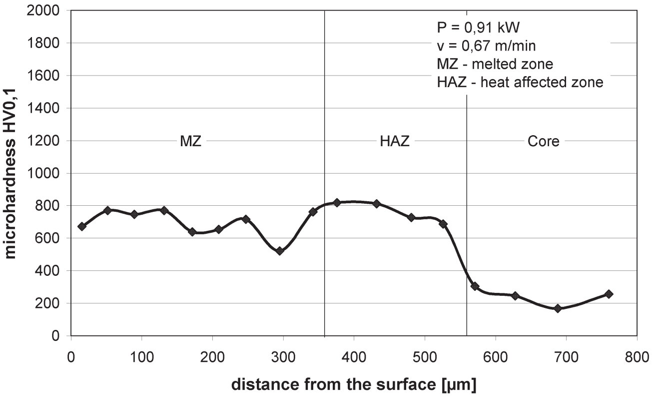

Fig. 5. Microhardness profile of laser borided track

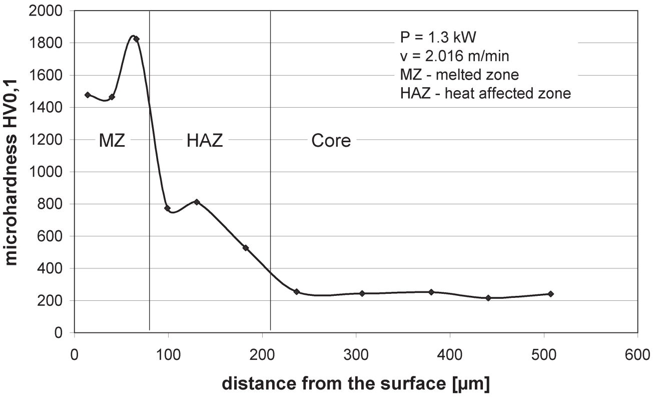

Fig. 6. Microhardness profile of laser borided track

Microhardness of melting zone (MZ) can be high, and near to diffusion boride layer hardness measured on cross section [1], which was in range from 1400 to 1800 HV (1.3 kW) [8]. Microhardness of the heat affected zone was around 900 HV and was higher than martensite structure hardness after typical hardening. It was found that structures and microhardness were similar to laser remelted diffusion borided layers [5,9].

4. Conclusions

Surface of 41Cr4 steel modifying by laser boriding showed borided tracks have multizone microstructure composed of the melted zone, heat affected zone and core, which can have diversified hardness. Dimensions of zones are dependent on laser treatment parameters. Microhardness of melted zone is diversified and dependent on laser treatment parameters and can be high, around 1600 HV (1.3 kW). The average hardness increases together with scanning rate. Microstructure of melted zone is dependent on laser treatment parameters, and connected with track dimensions. When the melted zone is shallow, microhardness is high and structure has larger refinement.

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REFERENCES

[1] A. Pertek, Kształtowanie struktury i właściwości warstw borków żelaza otrzymywanych w procesie borowania gazowego. Monografia, Seria: Rozprawy, nr 365, Wyd. Pol. Poznańskiej, Poznań, (2001).

[2] J. Kusiński, Lasery i ich zastosowanie w inżynierii materiałowej. Wyd. „Akapit", Kraków, (2000).

[3] K. Przybyłowicz, Teoria i praktyka borowania stali. Wyd. Pol. Świętokrzyskiej, (2000).

[4] A. N. Safonov, Osobiennosti borirovanija żeleza i stalej s pomoszczju nieprierywnogo CO_2 lazera, Metalovedenije i Termiceskaja Obrabotka Metallov 1 (1998) 5-9.

[5] M. Kulka, A. Pertek, Microstructure and properties of borided 41Cr4 steel after laser surface modification with re-melting. Appl. Surf. Sci. **214**, 278-288 (2003).

[6] P. Gopalakrishnan, P. Shankar, R. V. Subba Rao, M. Sundar, S. S. Ramakrishnan, Laser surface modification of low carbon borided steels, Scripta Mater. **44** 707-712 (2001).

[7] M. Paczkowska, W. Waligóra, Ocena wpływu szybkości chłodzenia na efekty borowania laserowego żeliwa sferoidalnego. Inżynieria Materiałowa **27**, 3, 498-501 (2006).

[8] K. Wiśniewski, A. Pertek, Laser boriding of 41Cr4 steel. I International Interdisciplinary Technical Conference of Young Scientists InterTech 2008 Proceedings, 245-247 (2008).

[9] A. Pertek, M. Kulka, K. Wiśniewski, Laser surface re-melting of borided layer, Inżynieria Materiałowa **28**, 3-4, 800-803 (2007).

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