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Influence of laser treatment on properties of high speed tool

Wpływ obróbki laserowej na własności stali szybkotnącej

Abstract

The paper presents the results of heat treatment tests of HS6-5-2 high speed steel with laser working in continuous mode. The tests used steel in the delivery state as well as steel after fluid treatment aimed at diffusion enrichment of the surface layer with carbon and nitrogen. The aim of the research is to determine changes in the structure of steel enriched with carbon and nitrogen and then subjected to the impact of the laser beam.

Keywords: laser heat treatment, high-speed tool steel

Streszczenie

W artykule przedstawiono wyniki badań obróbki cieplnej laserem pracującym w trybie ciągłym stali szybkotnącej HS6-5-2. W badaniach wykorzystano stal w stanie dostarczenia, jak również stal po fluidalnej obróbce mającej na celu wzbogacenie dyfuzyjne warstwy wierzchniej w węgiel i azot. Celem badań jest określenie zmian struktury stali wzbogaconej w węgiel i azot, a następnie podanej oddziaływaniu wiązki lasera.

Słowa kluczowe: obróbka laserowa, stal narzędziowa szybkotnąca

1. Introduction

The use of laser machining for parts of machines and tools, e.g. cutters or drills, creates a number of possibilities for improving their functional properties. The demand for new, more durable and harder tools has resulted in the increased interest in new methods of heat treatment [1–3]. One of the methods of obtaining more supersaturated structures with a higher than in the conventional grain refining processing, which arise as a result of the action on high energy material in a short time is laser treatment. Moreover, low costs, the possibility of full automation and high accuracy contributed to the use of lasers for industrial purposes. By using laser, we obtain a hard, abrasion-resistant surface layer of steel while maintaining the ductility of the core [4–7]. In case of laser processing, the power density and duration of laser radiation on the material have a decisive influence on the thickness and structure, and thus the properties of the surface layer [10–12]. The diffusional enrichment of the surface layer with carbon and nitrogen applied earlier is aimed at improving the functional properties of the surface layer of high-speed steels [8, 9]. The purpose of the work is to determine the effect of diffusion and laser treatment on the structure and hardness of the top layer of HS6-5-2 high speed steel tool.

2. Material and methodology of research

The HS6-5-2 high speed tool steel with the chemical composition shown in Table 1 constituted the test material.

Table 1. HS6-5-2 steel chemical composition

C	Mn	Si	Cr	W	Mo	V	P	Co	Cu	Ni	S
0.88	0.40	0.49	4.33	6.61	4.82	2.05	0.03	0.07	0.015	0.15	0.02

Plate-shaped samples with dimensions of 120 x 15 x 8 mm were prepared for the tests. The samples were then subjected to diffusion in coal and nitrogen in a fluidized bed, with the following parameters:

- nitrocarburizing temperature 1153 K,
- time 3.6 ks,
- air excess coefficient α_p 0.22,
- addition of ammonia to the atmosphere of 2.5%.

The sample after diffusion enrichment after being removed from the furnace is cooled in the air. As a result of diffusion enrichment, an enriched layer with a carbon content in the range of 1.1 to 1.3% and nitrogen 0.15% was obtained.

Molecular CO_2, laser was used for the tests, where the active medium is a mixture of gases composed of CO_2, helium and N_2. It emits infrared radiation with a wavelength of 10.63 μm. It is created as a result of the return of CO_2 particles to the basic level.

Laser processing was performed by increasing the focusing size Δf. The laser treatment parameters are shown in Table 2.

Table 2. Parameters of laser treatment

No.	Δf [mm]	Power Q [W]	Speed shift [mm/s]	diameter beam d [mm]	Power density *g* [10^3 W/cm^2]
1.	12	800	12	2.8	13
2.	16	800	12	3.73	7.3
3.	24	800	12	5.6	3.3
4.	28	800	12	6.53	2.4
5.	32	800	12	7.46	1.8

In order to characterize the structure obtained after hardening, tests were carried out using optical and scanning microscopy as well as x-ray examinations. The measurements of the microhardness distribution in the hardened layer of the Vickers method at 100 G load were also made. Metallographic smudges were made in planes perpendicular to the lines (paths) defined by the laser beam. In order to reveal the structure of the zone affected by laser radiation and the structure of the matrix, 5% of nital was used.

3. Results and discussion

The purpose of the work is to determine structural changes of HS6-5-2 steel resulting from the modification of its surface by diffusion enrichment in C and N, followed by laser hardening with a beam of different power density. The size and distribution of microhardness in the hardened layers was also determined. Figure 1 shows the distribution of microhardness of the surface layer enriched with carbon and nitrogen without affecting the laser beam. Figure 2 shows the distribution of microhardness after laser treatment with the power of:

- sample 1 – 13 · 10^3 W/cm^2,
- sample 2 – 7.3 · 10^3 W/cm^2,
- sample 3 – 3.3 · 10^3 W/cm^2,
- sample 4 – 2.4 · 10^3 W/cm^2,
- sample 5 – 1.8 · 10^3 W/cm^2.

In case of sample 1, a hardened layer consisting of four zones was obtained:

- the first zone is made of remelting material,
- second zone – melted,
- third zone – laser hardening,
- fourth zone laser remission.

All zones together have a thickness of 415 μm, assuming, as a criterion, hardness higher than the hardness of the core. The thickness of the melted zone is 190 μm. On this basis, the hardness of this zone was obtained at 750 HV. As we approached the second laser hardening zone, the hardness increased reaching a maximum of 1270 HV at a distance of 260 μm from the surface. The thickness of the third zone is estimated at approximately 100 μm. Then the hardness decreases, but it is higher than the hardness of the core. The hardness of the core is

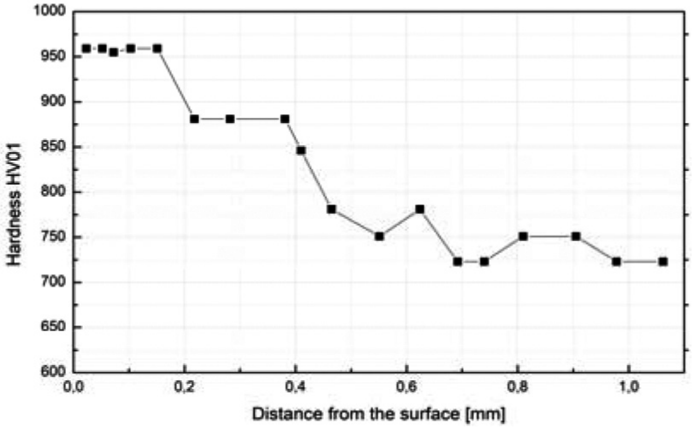

Fig. 1. Distribution of microhardness in the layer enriched in C and N without laser treatment

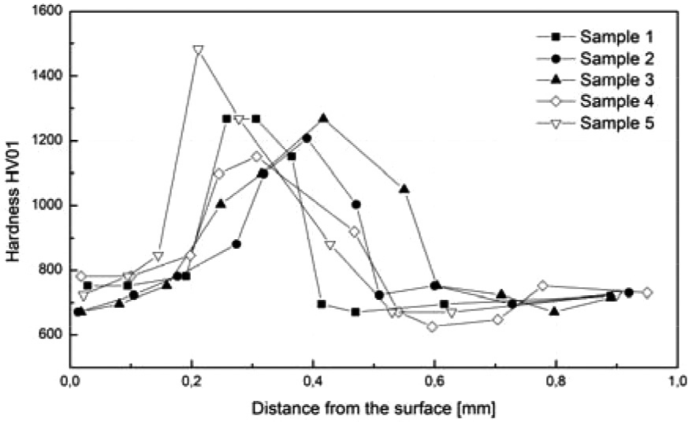

Fig. 2. Distribution of microhardness in the layer enriched in C and N after laser treatment

variable because it reaches values of 670–720 HV, which is related to the bandwidth of the parent material.

The effect of the laser beam on the surface of the sample is related to the change in beam diameter and power density. For sample 1, the beam width was 1.523 mm and affected a depth of 415 μm. For sample 2, the width of the beam impact path was 1.958 mm and the impact depth was 508 μm. Sample No. 3 impact field, the beam width was 2.50 mm and depth was 615 μm. Sample No. 4, the applied power density was $2.4 \cdot 10^3$ W/cm^2, and the resulting hardened area has a width of 2,831 mm and a depth of 692 μm. The last 5 sample using the $1.8 \cdot 10^3$W/cm^2 beam power was acting in an area which was 3.107 mm wide and 246 μm deep. The reduction of hardness in the laser tempering zone is most probably caused by the decay of martensite and the coagulation of carbides. As a result of the conducted treatment, it was found that carbitic type M_4C_3 (V_4C_3) carbides exist in the nitro-nitrided layer. The amount of M_3C and M_2C carbides also increased. In this layer, large quantities of MoC carbide and the Mn_4C type phase of varying composition were formed, while the amount of $M_{23}C_6$ carbide decreased.

4. Summary

The thermo-chemical treatment in a fluidized bed assured obtaining a surface layer with fine-grained martensitic structure with a large number of coagulated alloy carbides formed during cooling due to the decreasing solubility of carbon in the austenite as well as those formed during the carburizing process. As a result of cooling of the samples in the air, the thin surface layer was decarburized. This is confirmed by the reduced amount of carbides compared to deeper situated zones. Saturation with carbon and nitrogen is variable at the thickness of the layer, which manifests itself in the microhardness distribution of this layer (Fig. 1, 2). Microhardness and microstructure testing confirm that along with the change of beam parameters, the width of the hardened layer increased, the depth grew in samples from 1 to 4, while in sample 5 the depth of the hardened zone decreased as compared to other samples. In sample 5, the applied power density turned out to be insufficient to cause a further increase in the depth of the hardened zone. This state of affairs, however, is beneficial.

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