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LASER TREATMENT OF SURFACES OF TOOL AND PM STEELS AND STEELS WITH COATINGS

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Abstract: Laser treatment of surfaces to improve their wear resistance was under the study. Specimens, made of plain carbon steel C45, tool steel Arne, PM steels Vanadis6 and Weartec® were laser hardened. HVOFS WC-17Co coating and PVD deposited TiN coating on steel substrates were treated applying CO_2 laser radiation, varying scan speed and power. The treated specimens were subjected to microhardness measurements and wear block-on-ring rubber wheel tests. The results of laser treatment showed that the microhardness values increased significantly in comparison with a conventional heat treatment. The wear resistance of all treated surfaces was lower, than in the case of conventional heat treatment methods.
Keywords: laser treatment, surface, steels, coatings.

1. INTRODUCTION

The purpose of this work was to study the potential of laser transformation hardening and laser treatment on four target groups: plain carbon steels, PM steels, steels with thermal sprayed coatings and physical vapor deposited coatings.
In the case of plain carbon steels and PM steels, the possibility of obtaining a harder and more wear resistant surface was researched, in the second case – the opportunity of enhancing these properties for the coating and the substrate, in the third one – the possibility of hardening the substrate steel.

2. EXPERIMENTAL

2.1 Studied materials and coatings

The materials studied include commercial conventional (C45, Arne) and powder metallurgy produced (PM) steels (Vanadis 6, Weartec®).
The chemical composition and initial microhardness of conventional and PM steels are shown in Tables 1 and 2.
The properties of high velocity oxy-fuel sprayed (HVOFS) WC-17Co coating and physical vapour deposited (PVD) TiN coating as well as the microhardness values of the substrates are given in Table 3.

2.2 Laser treatment

The used specimens were of 15 × 25 mm size, except for PVD TiN coated specimens, which had dimensions of 12 × 25 mm. For the current study, the CO_2 TRUMPF TLC 105 laser was applied. The wavelength equalled to 10.6 µm, the diameter of the laser spot – to 0.95 mm, focal length was –1 mm. The shield gas was N_2 at the pressure of 3 bars. No overlapping of laser passes was applied. The principle scheme of laser treatment is presented in Fig. 1.
The preliminary experiments were carried out in two stages. The task of the first stage was to find an optimal laser power value, the task of the second one – to find an optimal scan speed value. The parameters’ values were considered optimal, if they allowed the biggest microhardness values. Final parameters of laser treatment are brought in Table 4.

Table 1. Chemical composition (wt%), initial microhardness of plain carbon steels

Steel	C	Mn	Si	Cr	W	Others	HV0.3
C45	0.45	0.60	0.30	–	–	–	200–235
Arne	1.00	0.95	0.25	1.05	1.40	Cu < 0.30 Mo < 0.30 Ni < 0.35	220–230

Table 2. Chemical composition (wt%), initial microhardness of PM steels

Steel	C	Mn	Si	Cr	Mo	V	HV0.05
Vanadis 6	2.80	0.50	1.00	8.00	13.50	9.80	245 320
Weartec®	2.80	0.70	0.80	7.00	2.30	8.90	340 385

Table 3. Studied coatings and their properties

Type of coating	Substrate	Thickness of coating, μm	Microhardness	
			Substrate	Coating
HVOFS WC-17Co	C45	200	200–235 HV0.3	1400 HV0.3
	Arne	200	205–240 HV0.3	1350 HV0.3
PVD TiN	Vanadis 6	3	245–320 HV0.05	–

2.3 Microhardness measurement

The microhardness measurements in the case of preliminary experiments were carried out at the ZWICK 3212.002 measuring device. The applied load was 4.9 N for HVOFS WC-17Co coating and 2.0 N (the minimal possible) for steels and PVD TiN coatings.

The microhardness measurements, performed at specimens, treated at optimal parameters, were carried out at the Micromet 2001 measuring device. The applied load equalled to 2.9 N in the case of plain carbon steels and HVOFS WC-17Co coating and to 0.5 N in the case of PM steels and PVD TiN coating. Such choice was made on empirical basis. All measurements were started at 25 μm.

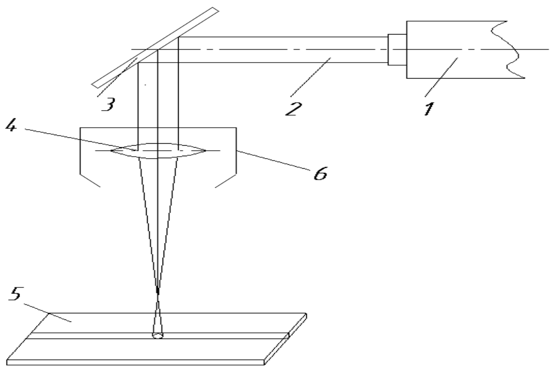

Fig. 1. The principle scheme of laser surface treatment of materials: 1 – laser, 2 – laser beam, 3 – turning mirror, 4 – optical system, 5 – specimen, 6 – nozzle for the gas feed

2.4 Abrasive wear testing

Abrasive wear tests were carried out using the block-on-ring rubber wheel scheme (standard ASTM G65-94). The diameter of ring equalled to 0.08 m, the force was 47 N, speed of rotation was 238.8 rpm, the mass of sand equalled to 1 kg. The experimental scheme of device is presented in Fig. 2

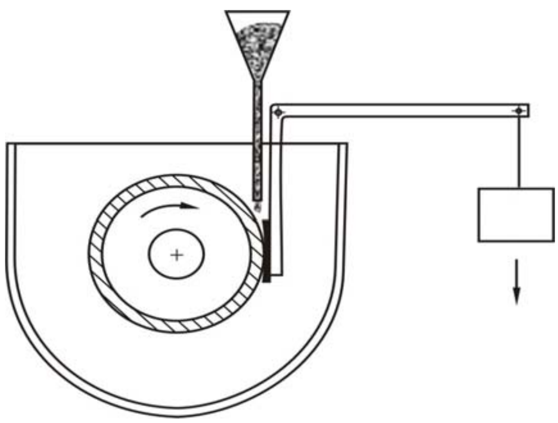

Fig. 2. The principle scheme of the block-on-ring (rubber wheel) abrasive wear tester

Table 4. Optimal parameters of laser treatment

Steel or coating	Power, W	Scan speed, mm/min
C45	300	250
Arne	345	250
Vanadis 6	300	750
Weartec®	225	750
HVOFS WC-17Co	495	300
PVD TiN	350	1200

The wear coefficient was calculated as

$$k = \frac{m_0 - m'}{\rho \cdot F \cdot t \cdot v \cdot r}, \text{ where} \qquad (1)$$

m_0 – initial weight of the specimen, kg,
m' – end weight of the specimen, kg,
ρ – density, kg/m^3,
F – force, N,
t – time of the experiment, s,
v – speed of rotation, rpm,
r – radius of the ring, m.

3 RESULTS AND DISCUSSION

3.1 Laser treatment of steels

3.1.1 Plain carbon steels

Figure 3 represents the microstructure of laser hardened plain carbon steel C45, which appeared during laser treatmtent along the surface. As can be seen from Fig. 3, the transformation zone has a distinct border. No visible crystalline structure is present in the upper part of the transformation zone, in the lower part of the transformation zone cementite seems to remain. In addition to that, it is possible to predict tempering effect at the overlapping place of two zones, as they are of different colour. The probable structures in the transformation zone are martensite near and inside the overlapping place in the upper part, and bainite.

Figure 4 shows the microstructure of laser hardened steel Arne. As can be seen, the laser transformation zone has a distinct border. No crystalline structure is observed neither in the transformation zone nor in the untreated steel, however, it can be assumed that the structure of the laser hardened zone consists of martensite and retained austenite in the upper part, and martensite, retained austenite and bainite in the lower part with possible presence of nitrides, which appeared due to reactions with the shield gas.

Figure 5 illustrates the microhardness distribution inside the transformation zone of the plain carbon steels' specimens.

As can be seen, microhardness values distribute in C45 and Arne steel specimens in a different way. The possible reasons for that can be the appearance of retained austenite in the surface layer of the laser transformation zone on case of steel C45

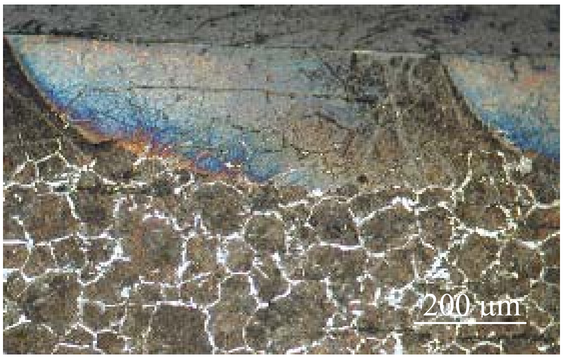

Fig. 3. The microstructure of laser hardened steel C45

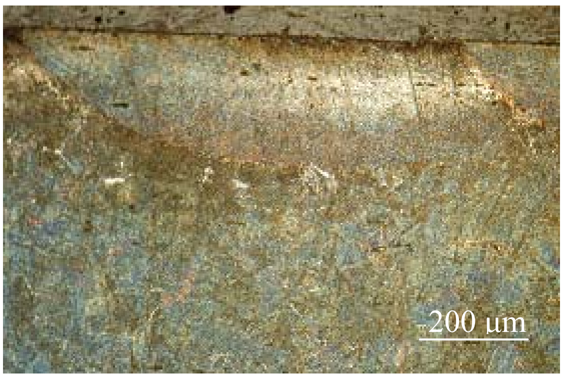

Fig. 4. The microstructure of laser hardened steel Arne

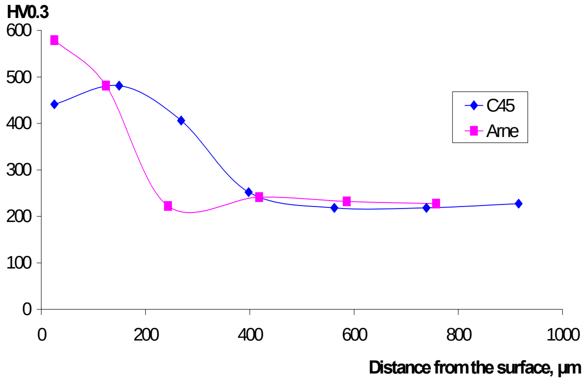

Fig. 5. Microhardness distribution inside the laser transformation hardened zone in C45 and Arne steel specimens

and saturation with nitrides, which appeared in reaction with the shield gas, of the surface layer of steel Arne with the simultaneous diffusion of alloying elements from the bottom subsurface layers.

3.1.2 PM steels

The microstructure of laser hardened steel Vanadis 6 is shown in Fig. 7. As it can be seen, no clear hardened zone is present, and there is no visible evidence of the hardening process.

The microstructure of laser hardened steel Weartec® is brought in Fig. 7. As it can be seen, an increase in the particle size near the surface can be remarked. However, no other evidence of the hardening effect can be seen.

Figure 8 represents the microhardness distribution inside the laser hardened zones of steels Vanadis 6 and Weartec®.

As it can be seen, the depth of the hardened zone reaches maximally 50 µm.

3.2. Laser treatment of coatings

3.2.1 HVOFS WC-17Co coatings

Figure 9 represents the microstructure of laser treated HVOFS WC-17Co coating.

As it can be seen, a transformation zone appears under the coating.

Figure 10 represents the microhardness distribution inside the laser treated zone.

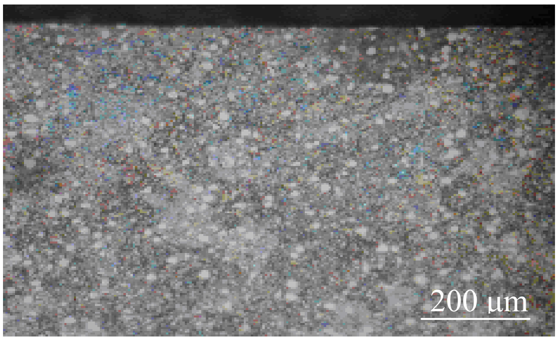

Fig. 6. Microstructure of laser hardened steel Vanadis 6

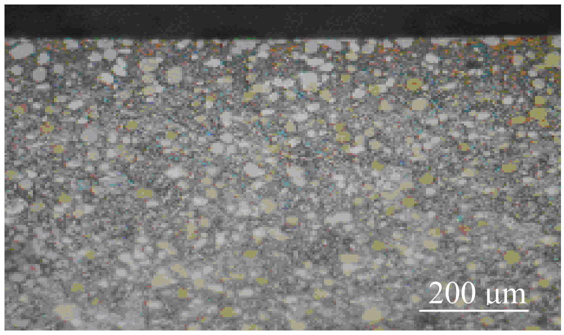

Fig. 7. Microstructure of laser hardened steel Weartec®

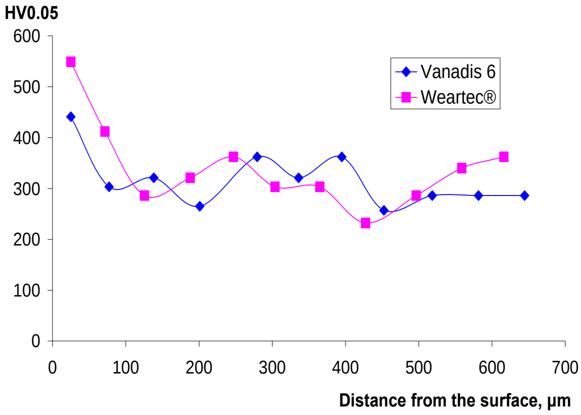

Fig. 8. Microhardness distribution inside the laser hardened zone in Vanadis 6 and Weartec® steel specimens

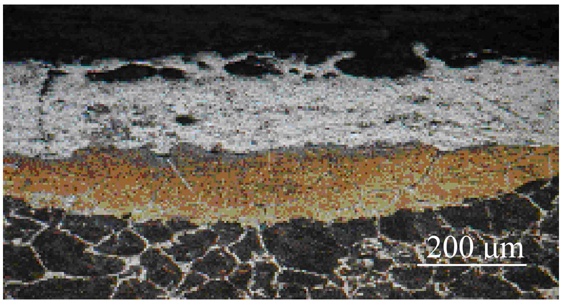

Fig. 9. Microstructure of laser treated HVOFS WC-17Co coating. Substrate – steel C45

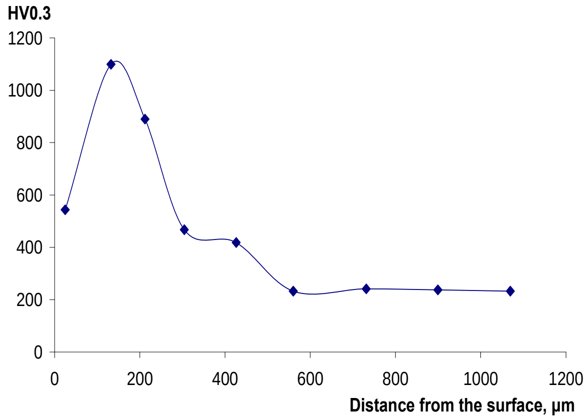

Fig 10. Microhardness distribution inside the laser treated zone of WC-17Co coated specimen

As it can be seen in Fig. 10, laser treatment causes drop in microhardness values in the coating. This can be explained by a burnout of the carbon and alloying elements and the decomposition of WC particles. In addition to that, an appearance of microcracks inside the coating was noticed.

3.2.2 PVD TiN coatings

The microstructure of the PVD TiN coated laser treated steel Vanadis 6 specimen is presented in Fig. 11.

As it can be seen, no visible changes in microstructure of the steel substrate can be observed.

Figure 12 shows the microhardness distribution inside the laser treated zone of PVD TiN coated steel Vanadis 6.

As it can be seen, laser treatment allows increasing the microhardness values of the substrate. However, the depth of the hardened zone doesn't exceed 50 µm.

4. ABRASIVE WEAR RESISTANCE

The results of wear abrasive experiments are shown in Fig. 13. PVD TiN coated specimens were not subjected to abrasive wear resistance, as they are to thin to show any positive results.

As can be seen, only laser-hardened steel Arne specimens show wear coefficient

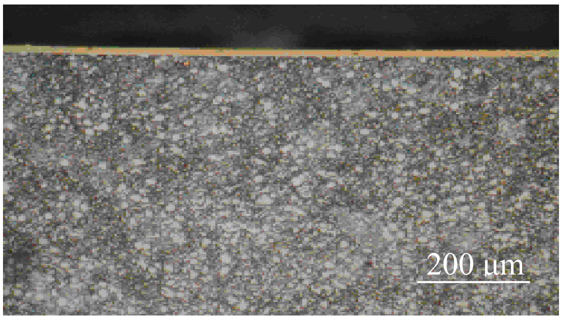

Fig. 11. Microstructure of laser treated PVD TiN coated specimen

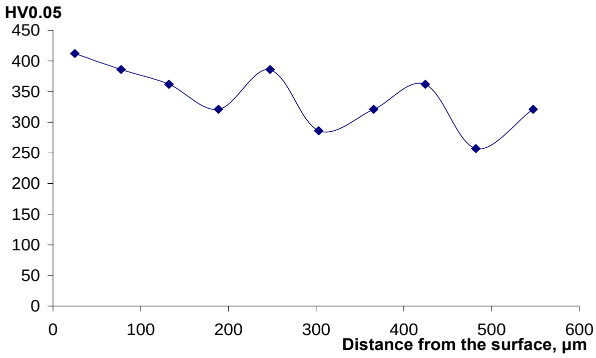

Fig.12. Microhardness distribution in the laser treated PVD TiN coated specimen

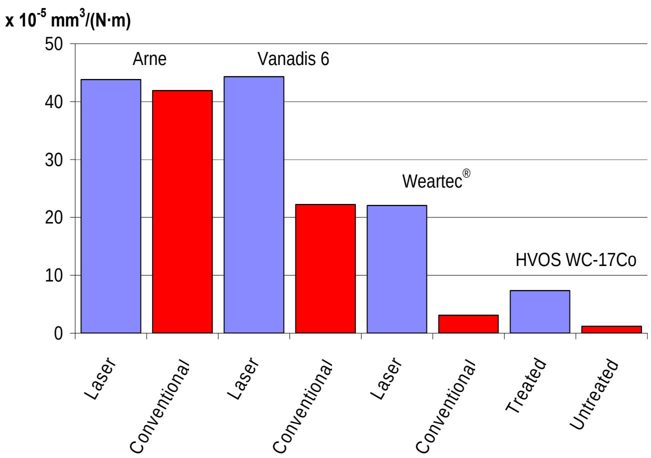

Fig. 13. Abrasive wear resistance of laser treated specimen in comparison with the conventionally treated or untreated ones

values, similar to that of conventionally hardened ones. The reasons for lower abrasive wear resistance in the case of PM steels can be too low hardened depth in comparison with conventional hardening. The lower abrasive wear resistance in the case of HVOFS WC-17Co coating correlates with the drop in microhardness, what can be seen in Fig. 10. As in the case of microhardness values, low abrasive wear resistance can be explained with the burnout of alloying elements, decomposition of WC particles and the appearance of microcracks.

5. CONCLUSIONS

Based on the obtained results, the next conclusions can be drawn:

1. Laser treatment allows enhancing remarkably the microhardness values of presented steels.
2. The microhardness of laser treated HVOFS WC-17Co coatings is lower that the microhardness of the untreated WC-17Co coating due to the changes in composition of coating.
3. Only a small hard zone appears under PVD TiN coating, thus it is doubtful, whether the purposes of the experiment are fulfilled.
4. Laser treatment reduces the abrasive wear resistance in all cases in comparison with conventional treatment.

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