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Mechanical properties of the surface layer of the laser alloyed 32CrMoV12-28 steel

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ABSTRACT

Purpose: In this paper it was investigated the influence of the laser treatment, first of all the laser power, to the mechanical properties and structure of the steel surface layer alloyed with different ceramic powders. The purpose of this work was also to determine technological and technical conditions for remelting the surface layer with HPDL.

Design/methodology/approach: This paper presents and discusses the main methodology results of new laser treatment techniques applied in metal surface technology are. There is presented laser treatment with remelting of hot work tool steel 32CrMoV12-28 with ceramic powders especially carbides, oxides and nitrides as well as results of laser remelting influence on structure and properties of the surface of the hot work steel, carried out using the high power diode laser (HPDL). Optical and scanning electron microscopy was used to characterize the microstructure and intermetallic phases occurred.

Findings: A surface layer was coming into existence without cracks and defects as well as has a considerably higher hardness value compared to the non remelted material. The hardness value increases according to the laser power used so that the highest power applied gives to highest hardness value in the remelted layer.

Research limitations/implications: Four choused laser powers were applied for alloying and implicated by one process speed rate. The powders which were used for alloying were of the particle size in the range of 5 to 10µm.

Practical implications: This work helps to use the laser treatment technique for alloying and remelting of hot work tool steel.

Originality/value: The originality of this work is based on applying of High Power Diode Laser for improvement of steel mechanical properties.

Keywords: Surface treatment; Heat treatment; Hot work tool steel; Laser melting

MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

Investigations presented in this paper include alloying and remelting of the 32CrMoV12-28 hot-work tool steel surface layer with the carbides, oxides and nitrides like tungsten carbide, titanium carbide, niobium carbide, tantalum carbide, aluminium oxide, zirconium oxide, boron nitride using the high power diode laser HPDL. The structural mechanism was investigated of surface layers development, effect was studied of alloying parameters, gas protection method, and thickness of layer applied onto the steel surface on structure refinement and influence of these factors on the mechanical properties of surface layer, and especially on its hardness. Development of the surface layer was observed in which the remelted zone, whose thickness is ca. 0.7 mm, heat-affected zone with thickness ca. 1.2 mm, and the transient zone. It was found out that laser remelting and alloying with carbides result in structure refinement in the entire investigated laser power range. The oxides and nitrides ceramic powders are not alloyed with the steel during alloying process. The grain size is up to 35 μm^2 in the remelted zone, compared to the several times bigger grain size of the conventionally heat treated material. The fine grained, dendritic structure occurs in the remelted and alloyed zone with the crystallization direction connected with the dynamical heat abstraction from the laser beam influence zone. The dependence is presented of hardness influence on the laser beam effect on the treated surface, and especially the hardness increase in the alloyed layer. Conventional heat treated steel was used as the reference material. The performed investigation gives grounds to the practical employment of these alloying technologies for forming the surfaces of 32CrMoV12-28 hot work tool steel particularly with the new vanadium and titanium carbide powders using the high power diode laser [1-16].

The purpose of this work is to study the effect of a HPDL laser melting on the hot work tool steel, especially on their structure and hardness. Special attention was devoted to monitoring of the layer morphology of the investigated material and on the particle occurred.

2. Experimental conditions

The investigation was performed on a hot work tool steel 32CrMoV12-28; supplied annealed in form of rods 76 mm in diameter and in the length of 3 m. The chemical composition of the investigated steel is presented in Table 1.

A heat treatment was carried out according to the steps for this steel type. Ceramic powders - Figures 1, 2 and 3 - was put to the so prepared and degreased samples. The powder was initially mixed before with the inorganic sodium glass in proportion 30% glass and 70 % powder. A paste layer of 0.5 mm in thickness was put on. The investigations were carried out at a constant remelting process rate, changing the laser power in a range of 1.2 – 2.3 kW. Next a sample was mounted in the laser holder for remelting. On each sample surface four laser process trays were made of a length of 25 mm, with the power 1.2; 1.6; 2.0; 2.3 kW. Other laser parameters are given in Table 2.

Table 1.
Chemical composition of the investigated hot work tool steel 32CrMoV12-28

Mass concentration of the elements, %								
steel	C	Si	Mn	P	S	Cr	Mo	V
32CrMoV12-28	0.308	0.25	0.37	0.02	0.002	2.95	2.70	0.535

Full protection of the remelted area can be achieved by argon protective atmosphere with the gas flow rate of 20 l/min through a circular nozzle with diameter of 12 mm, which was directed inversely to the direction of the remelting process. For surface preparation the standard metallographic procedure was applied in form of grinding using SiC paper, polishing with 1µm Al_2O_3 polishing paste and drying, the samples were mounted in the thermo hardened resin supplied by Struers. Next the samples were etched in nital at room temperature for the experimentally chosen time selected individually for each remelted area.

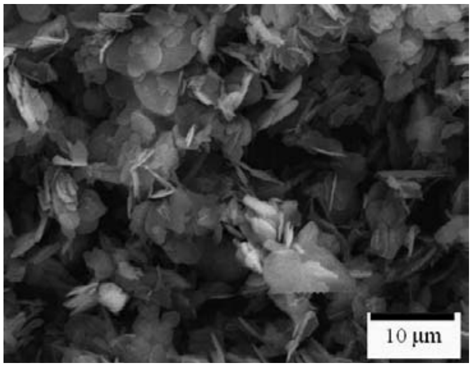


Fig. 1. Boron nitride BN ceramic powder using for alloying with the hot work tool steel

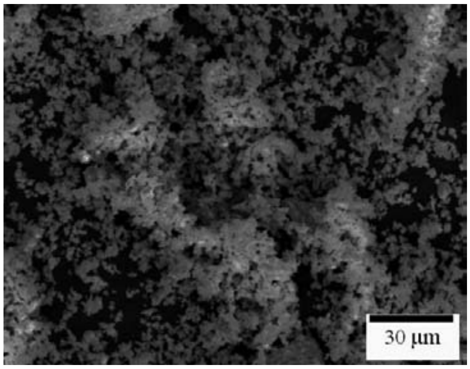


Fig. 2. Tantalum carbide TaC ceramic powder using for alloying with the hot work tool steel

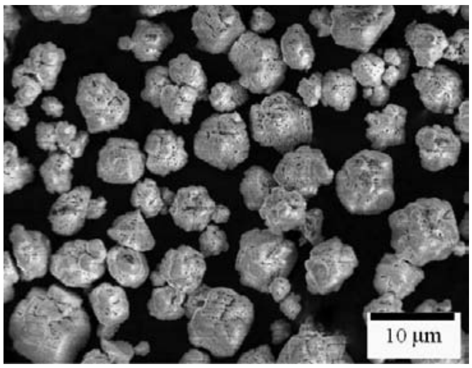


Fig. 3. Aluminium oxide Al_2O_3 ceramic powder using for alloying with the hot work tool steel

Table 2.
HPDL laser parameters

Parameter	Value
Laser wave length, nm	940 ± 5
Power, W	100 ÷ 2300
Power density range of the laser beam in the focus plane [kW/cm²]	0.8 ÷ 36.5
Dimensions of the laser beam focus, mm	1.8 x 6.8

The micrographs of the microstructures and structure investigation was performed using the light microscope Leica MEF4A supplied by Zeiss in a magnification range of 50 - 500x. Metallographic investigations were performed also using the scanning electron microscope DSM 940 supplied by OPTON in a magnification range of 500 - 2000x. For each remelting area Hardness measurements results were registered, for this reason the Rockwell hardness tester supplied by Zwick was used according to the PN-EN ISO 6507-1 standard.

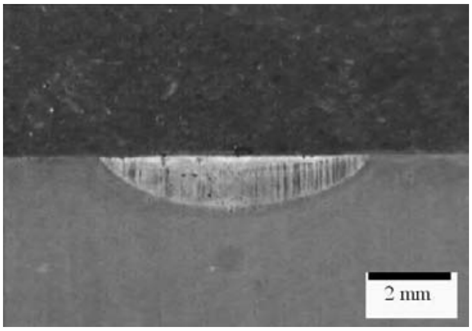
3. Results and discussion

The light and scanning microscope investigations carried out using the high power diode laser allows to compare the surface layer as well as the shape and depth of the remelting area The layers cross section achieving by the alloying process are showed on Figure 4. The results allows to state that there are different zones coming into existence: the remelting zone, the heat influence zone and the non affected zone – steel matrix. With the increasing laser beam power the thickness surface layer increases. Preliminary investigations of the remelted hot work tool steel 32CrMoV12-28 show a clear effect of the laser power respectively 1.2; 1.6; 2.0 and 2.3 kW on the shape and thickness of the remelted material (Figure 4a and 4b).

The hot work tool steel has a ferritic structure with homogeny distributed carbides in the metal matrix in the annealed state. In areas, which are between the solid and molten state dendritic structure with large dendrites can be found. Microstructure presented on Figures 5 to 6 shows this dendritic structure in the remelted area. There are also ceramic particles present distributed in the matrix, here especially TiC particles (Fig. 6.). The required hardenability for this tool steel was achieving after a suitable tempering time, which assures melting of the alloying carbides in the austenite. The particles are homogeny distributed about the surface area. The occurrence of the used ceramic powder occurs only for the carbide powders applied. In case of the oxide powders like aluminium oxide and zirconium oxide and also in case of the nitrides like boron nitride there are no particles present in the surface area matrix, the reason for that is not discovered yet, but a evaporation or dissolving can be the reason for that.

As a result of laser alloying powder the difference of the remelted area thickness among the power of 1.2 kW and 2.3 kW is about 90 % larger for the 2.3 kW power – in case of the Al_2O_3 . For other powders a similar dependence was achieved. Figure 7 shows the hardness measurements results of the remelted surface for 1.2, 1.6, 2.0 and 2.3 kW laser power for each powder used. In general the highest hardness value is achieved for the 2.3 kW laser power.

a)



b)

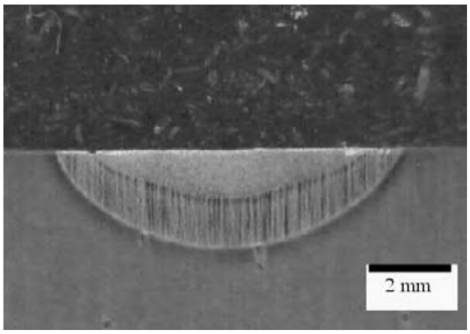


Fig. 4. Shape and thickness of cross-section of the laser remelted samples Al_2O_3 a) 1.2 kW, b) 2.3 kW

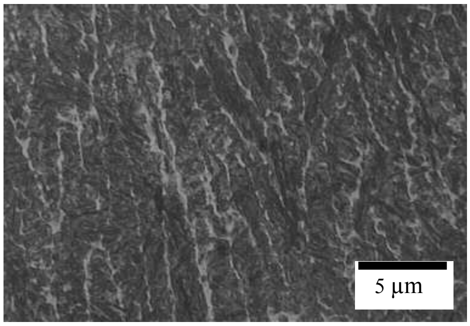


Fig. 5. Microstructure of the 32CrMoV12-28 steel remelted with ZrO_2 powder with laser power 2.0kW

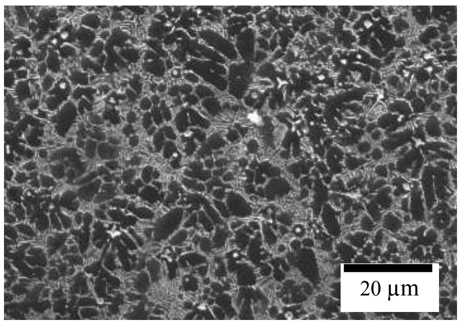


Fig. 6. Microstructure of the 32CrMoV12-28 steel remelted with TiC powder with laser power 2.0kW

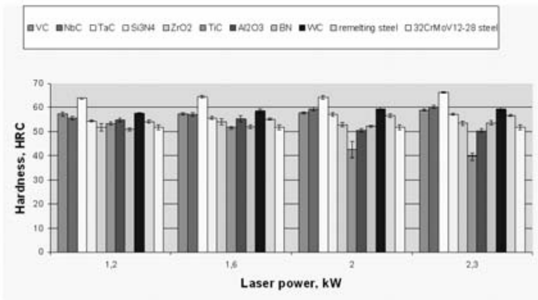


Fig. 7. Hardness measurements results (HRC) of the remelted and alloyed surface

The highest value is achieved for alloyed surface layer with the TaC ceramic powder, the WC alloying has delivered a high hardness increase to compared to the remelting steel only.

4. Conclusions

The investigations in this work makes it possible to conclude, that as a result of laser alloying as well as remelting of the hot work steel 32CrMoV12-28 with the ceramic powder, especially carbides, but also oxides and nitrides a suitable surface layer of high-quality can be possible to obtain. The surface layer in case of alloying with carbides contain no cracks and defects as well as of much more higher hardness value compared to the material which was not remelted. In case of TaC ceramic carbide powder the increasing laser power depth of remelting material is higher and the surface is more regular and what is the most important, the hardness of the surface layer id the highest among all the others ceramic powder used. Also here the hardness value increases according to the laser power used, so that the highest power applied gives to highest hardness value in the remelted layer. Only in case of titanium carbide powder the hardness of the surface layer decreases with increasing laser power used. Also here (TiC) the surface of the remelted area is more regular less rough and more flat with increasing laser power. The investigations on scanning and light microscope reveal a dendritic structure in the remelting zone in samples alloyed with every applied laser power, except the alloying with VC powder, were a grain structure was observed. The dendrite size increases with the increased laser power. Also the wear resistance of the surface layer of the worked steel increases with increased laser power. The resistance increases also compared to the steel remelted only, that confirms the use of ceramic powder for appliance of the NbC and TaC powder as a material for improvement of mechanical properties.

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