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Modelling of gradient layer properties of the 32CrMoV12-27 surface layer alloyed with WC powder

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Analysis and modelling

ABSTRACT

Purpose: The reason of this work was to determine the thermal fatique resistance, the laser treatment parameters, particularly the laser power, to achieve a high value of layer hardness for protection of this hot work tool steel from losing their work stability and to make the tool surface more resistant for work. The purpose of this work was also to determine technological and technical conditions for remelting the surface layer with HPDL.
Design/methodology/approach: In this paper the results of new laser treatment techniques applied in metal surface technology are presented and discussed. There is presented laser treatment with remelting of hot work tool steel 32CrMoV12-28 with ceramic powders especially carbide - WC, 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). Special attention was devoted to monitoring of the layer morphology of the investigated material and on the particle occurred. Optical and scanning electron microscopy was used to characterize the microstructure and intermetallic phases occurred.
Findings: The layer is 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: The results present only four choused laser powers by one process speed rate. Also one powder in form of WC was used for alloying with the particle size of 10µm.
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

1. Introduction

Surface processing will be investigated systematically by means of concentrated energy beams, laser, electron beam, plasma and concentrated solar energy. These techniques are unique for tailoring surface properties such as extended solid solutions, metastable crystalline phases, and metallic glasses [1-6].

Tungsten carbide is a rarely used tool material sometimes used in metal machining because of its high hardness and high resistance to softening at high cutting speed and at high cutting temperature. Tool life is an important parameter to be considered in tool selection since it will affect tool change scheduling, production planning and unit production cost. The tool life of a hot work tool is commonly determined with an actual machining operation by using the tool with a particular work material under certain working conditions to reach the maximum allowable life time. However, this is also an expensive process since a lot of work material is consumed in the test. The major concern of laser alloying is to avoid defects after treatment such as cracking, bubbles and unacceptably rough surface. The second concern is to achieve a maximum hardness in the surface layer to ensure good working parameters [7-9].

Diode lasers have long been used as light emitters in fiber-optic telecommunications, as barcode readers, and for implementing the write–read functions of optical disks. Nowadays, diode lasers do not merely deliver bits but also optical power. They are increasingly found in applications such as materials processing (welding, cutting, drilling, surface hardening, etc.) as well as in printing and graphical arts, in displays, and medical applications [10-15].

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. The structure investigation, and improvement of mechanical properties, is the practical aim of this work, as well as improvement of hardness as a very important property for practical use.

2. Experimental procedure

The material used for investigation was a hot work tool steel; it has been supplied annealed in form of rods. The chemical composition of the investigated steel is presented in Table 1. The samples were heat treated according to the steps for this steel type. Tungsten carbide powder 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 average granulation of the WC powder was 10 µm.

For the experiment a continuous High Power Diode Laser (HPDL) ROFIN DL 020 emitting optical radiation at a wavelength 940 nm was used. To ensure good work parameters the investigations were carried out at a constant remelting process rate, changing the laser power in a range of 1.2 – 2.3 kW. For laser power values of 0.4 to 0.8 kW there are no remelted areas present at all. The samples were 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. It could be determined experimentally, that the full protection of the remelted area can be achieved by means of the 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.

Structure investigation was performed using the light microscope Leica MEF4A supplied by Zeiss in a magnification range of 50 - 500x. The diffraction investigations and examination of the thin foils were made on the JEOL JEM 3010 transmission electron microscope at the accelerating voltage of 300 kV. The diffraction patterns from the transmission electron microscope were solved using a computer program.

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	0.020	0.002	2.95	2.70	0.535

Metallographic investigations were performed also using the scanning electron microscope DSM 940 supplied by OPTON in a magnification range of 500 - 2000x. Hardness measurements results were registered for each remelting area, for this reason the Rockwell hardness tester supplied by Zwick was used according to the PN-EN ISO 6507-1 standard, by a load of 147,2 N for 15 s.

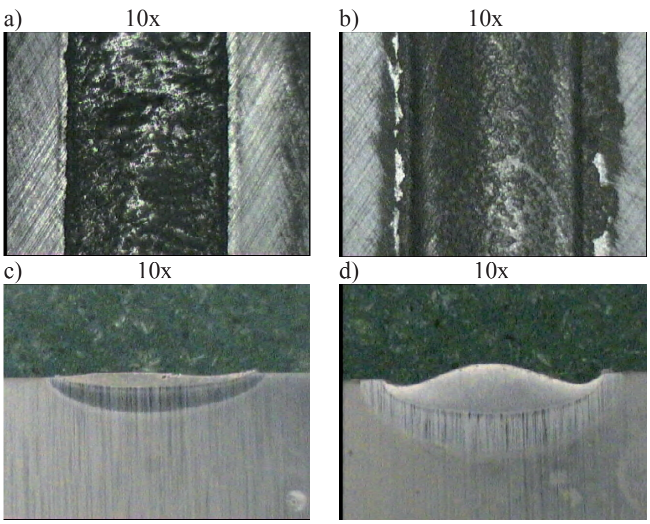


Fig. 1. Shape of the surface layer of the 32CrMoV12-28 steel remelted with WC powder a) WC with laser power 1.2kW, b) WC 2.3 kW, thickness of the surface layer of the 32CrMoV12-28 steel remelted with WC powder c) WC 1,2 kW, d) WC 2.3kW

3. Results and discussion

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 1). It can be seen that with the increasing laser power the roughness of the remelted metal surface increases. The layers are showed on Figure 1. Microstructure presented on Figure 2 and 3 show a dendritic structure in the remelted area. There are also WC particles present distributed in the matrix. There is also a clear relationship between the employed laser power and the dendrite size, namely with increasing laser power the dendrites are larger.

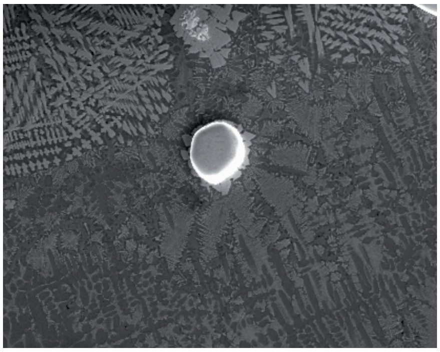
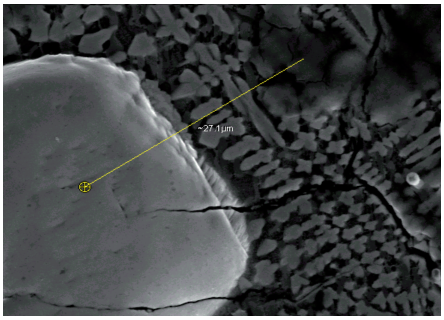
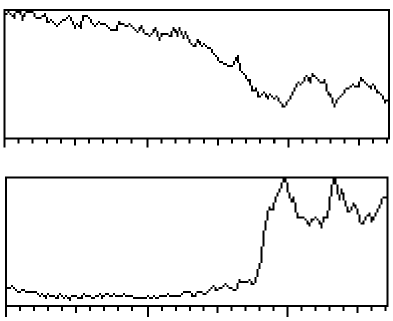


Fig. 2. Microstructure of the 32CrMoV12-28 steel remelted with WC powder with laser power 1.2kW

a)



b)



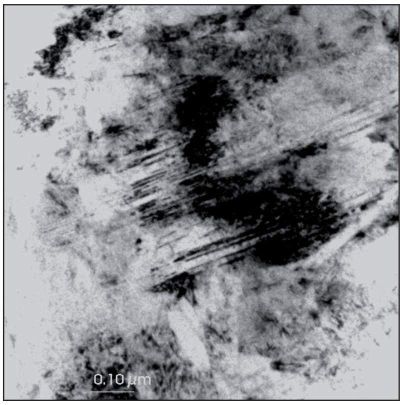
W

Fe

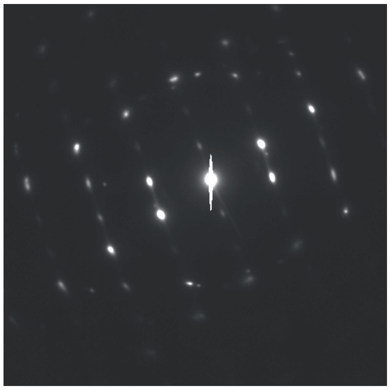
Fig. 3. a) Microstructure of the 32CrMoV12-28 steel remelted with WC powder with laser power 1.2kW, b) EDS line analysis of the alloyed samples

The hot work tool steel has a ferritic structure (figure 4) with homogeny distributed carbides in the metal matrix in the annealed state. The EDS point wise analysis shown in figures 3 and 5 confirms the presence of WC particles in the matrix in form of big conglomerates. The structural 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. It was noticed that the depth of remelting area grows together with the increasing laser power, which was confirmed by the results presented on Figure 1.

a)



b)



c)

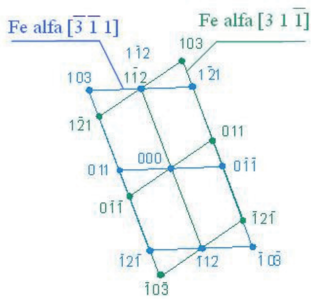


Fig. 4. a) structure of the thin foil of the alloyed hot work tool steel – light field, b) selected area diffraction pattern from the area as in figure a), c) solution of the diffraction pattern from figure

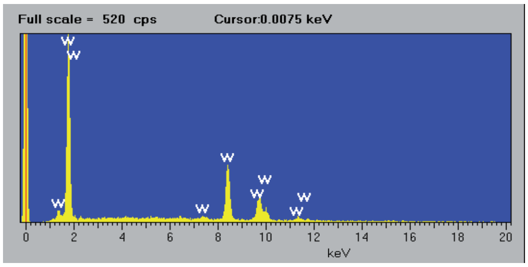


Fig. 5. EDS point wise analysis of the remelted steel (WC particle)

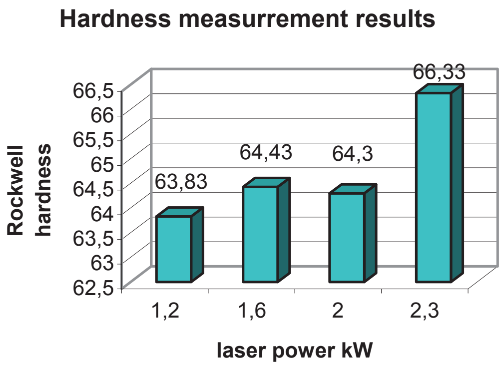


Fig. 6. Hardness measurements results of the remelted surface

4. Conclusions

The performed investigations allow to conclude, that as a result of heat-treatment as well as of remelting of the hot work steel 32CrMoV12-28 with WC powder high-quality top layer is possible to obtain. The layer is without cracks and defects as well as has a considerably higher hardness value compared to the non remelted material. The hardness value (Figure 6) increases according to the laser power used so that the highest power applied gives to highest hardness value in the remelted layer. Together with increasing of the laser power, also the depth of remelting material grows. The surface of the remelted area is more regular, less rough and more flat with increasing laser power. The metallographic investigations on scanning microscope using EDX analysis confirm the occurrence of tungsten carbide WC. WC particles are present in the matrix mostly in form of conglomerates, only a minor part of tungsten is dissolved in steel.

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