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Comparison of the thermal fatigue surface layers of the X40CrMoV5-1 hot work tool steels laser alloyed

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Methodology of research

ABSTRACT

Purpose: The comparison of thermal fatigue and mechanical properties of the hot work tool steels alloyed with carbide powders has been presented. The effect of laser alloying with powders on the surface layers alloying with HPDL was evaluated.

Design/methodology/approach: In this paper the result of laser surface alloying is discussed. The material used for investigation were hot work tool steels X40CrMoV5-1 and 55NiCrMoV7 alloyed with TiC or TaC using high power diode laser.

Findings: The thermal fatigue resistance measured with the average cracks deep subjected to steel alloyed with TiC powder is few times smaller compared to the steel after a conventional heat treatment, which was used as a reference material. The hardness value increases according to the laser power used in alloying.

Research limitations/implications: It is necessary to continue the research to determine alloying parameters for demanded properties of hot work tool steels surface layers.

Practical implications: The proposed new methods of enhancement fatigue resistant of hot work tool steels was the aim goal of this work.

Originality/value: Laser alloying by using different carbide powders and HPDL laser is a new way to improve the structure and mechanical properties of the hot work tool steels.

Keywords: Tool materials; Hot work tool steel; Laser treatment; Surface layer

1. Introduction

Laser technology is one of the most versatile techniques used in a variety of materials processing for wide range of materials. Lasers are successfully applied in industrial processes including welding, cutting, drilling, ablation deposition and surface treatment. Strongly coherent and monochromatic laser beam focused to small spot produces high power densities. High quality laser beams make it possible to use laser technology for processing which is impossible to carry out with any different techniques. The wide range of applied power and power densities available from lasers and the possibility of accurate laser beam control are features which contribute to its successful application in many different aspects of surface processing. Laser beam of high intensity focused to small spot influences many solid materials changing photons energy into electron, thermal and mechanical energy on the surface of workpiece. There is an opinion that laser manufacturing techniques belong to the most promising and efficient ones, for ensuring the development in many industry branches, and especially those in which materials processing dominates. Thanks to the very precise energy delivery laser radiation makes it possible to carry out the technological operations better or faster within the framework of the technologies known to date. It makes also possible introduction of the new technologies whose realization is impossible when using the conventional power density [1 - 17].

2. Investigation methodology

The material used for investigation were a hot work X40CrMoV5-1 and 55NiCrMoV7 tool steels. Test pieces for the examinations have been obtained from the vacuum melt. After making by machining the O.D. 70 mm and 5 mm thick specimens they were heat treated. After heat treatment the samples surfaces were grind on a magnetic grinder machine to avoid micro cracks. Next the paste of TiC carbide powder was applied on specimens. The powder was initially mixed before with the inorganic sodium glass. ROFIN DL 0.20 High Power Diode Laser (HPDL) was used for alloying. On each sample surface four laser process trays were made with changing the laser power in a range of 1.2 ÷ 2.3 kW.

Metallographic examinations of the material microstructures after laser alloying surface layer were made on Zeiss Leica MEF4A light microscope and on the scanning electron microscope DSM 940 supplied by OPTON in a magnification range of 500 ÷2000x. The observations were performed on the cross section of the sample on each of the remelting trays (Figure 1). The measurements of Rockwell hardness have been performed using Zwick ZHR hardness intender equipped with electronic sensor that allows the direct readout of the hardness values. The wear rate tests have been done on a device prepared according to the ASTM standard.

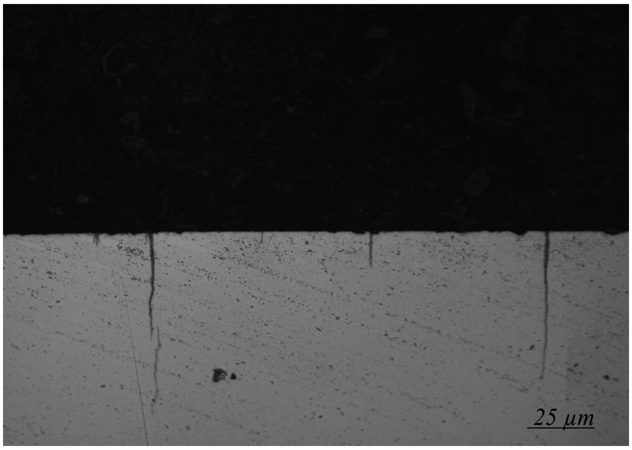


Fig. 1 Cracks after thermal fatigue test on the cross section of the TiC alloyed X40CrMoV5-1 steel with 2.3 kW power laser

3. Investigations results

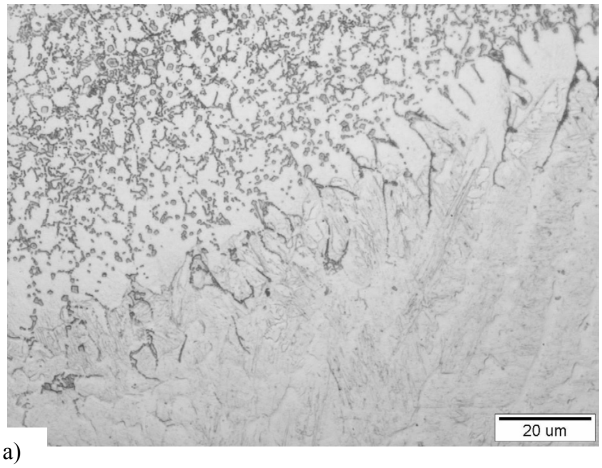
Metallographic examinations carried out on the light microscope confirm that the structure of the material solidifying after laser remelting is diversified, which is dependant on the solidification rate of the investigated steels. There is a clear relationship between the employed laser power and the dendrite size, namely with increasing laser power the dendrites are larger. (Figures 2 a, b).

In the effect of laser alloying with powder of carbide TiC occurs size reduction of microstructure as well as dispersion hardening through fused in but partially dissolved carbides and consolidation through enrichment of surface layer in alloying additions coming from dissolving carbides. Introduced particles of carbides and in part remain undissolved, creating conglomerates being a result of fusion of undissolved powder grains into molten metal base. (Figure 3 a, b).

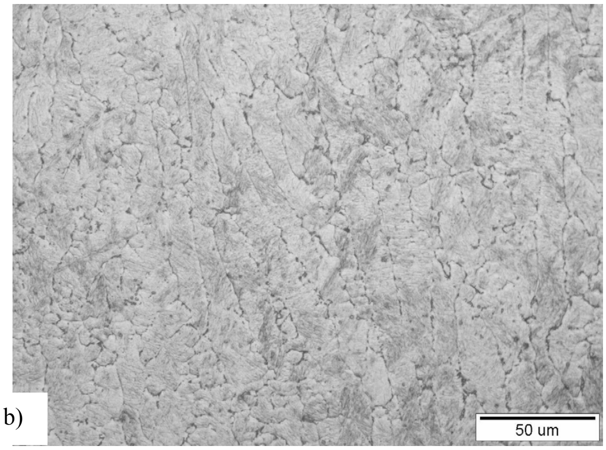
The thermal fatigue investigation were made on the work place described in Ref. no [18]. The resistance to thermal fatigue was measured with the mean depth of cracks. Figures 4 a, b show that the resistance to thermal fatigue of laser remelted X40CrMoV5-1 and 55NiCrMoV7 steels is higher than steel after conventional heat treatment.

Figure 5 a, b present the HRC hardness test results for the surface layer after remelting it with the HPDL high power laser using the TiC carbide. The highest hardness after alloying with TiC is 62,1 HRC for X40CrMoV5-1 and 65,4 HRC for 55NiCrMoV7 tool steels.

Figure 6 a, b show relative mass decrement of samples in the function of laser beam power and powder used to allying.



a)



b)

Fig. 2 Surface layer structure of the test piece from the a) X40CrMoV5-1, b) 55NiCrMoV7 tool steels alloyed with TiC powder using the HPDL diode laser

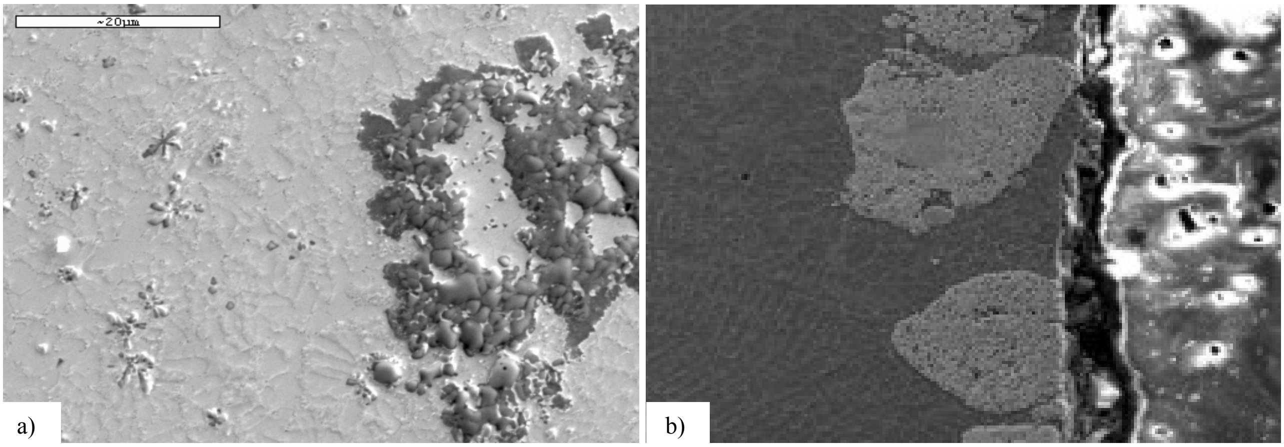


Fig. 3 Microstructure of the surface layer of the a) X40CrMoV5-1, b) 55NiCrMoV7 hot work tool steels alloyed with TiC powder

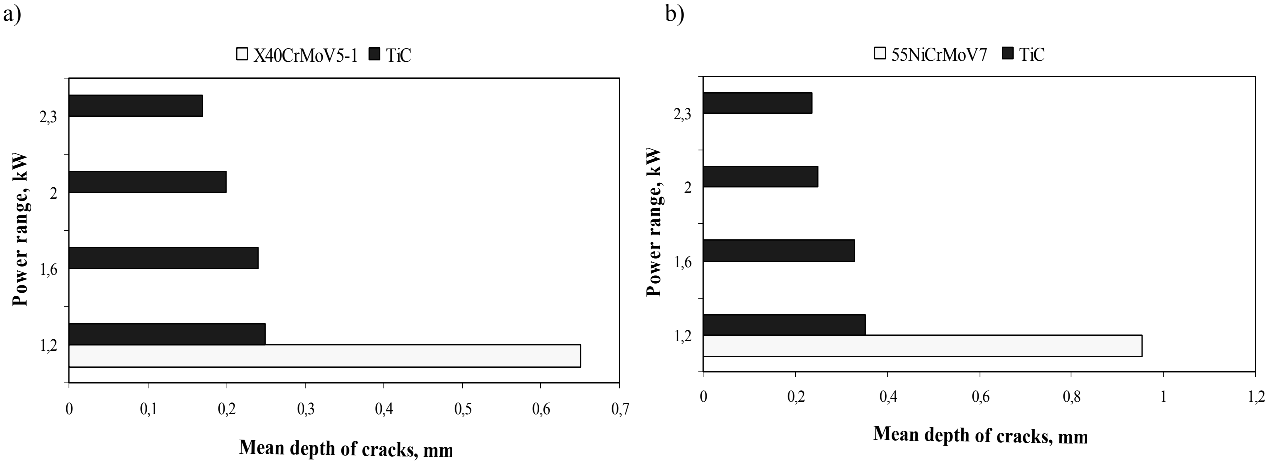


Fig. 4 Mean depth of cracks of surface layer hardness of a) X40CrMoV5-1, b) 55NiCrMoV7 alloyed with TiC powder

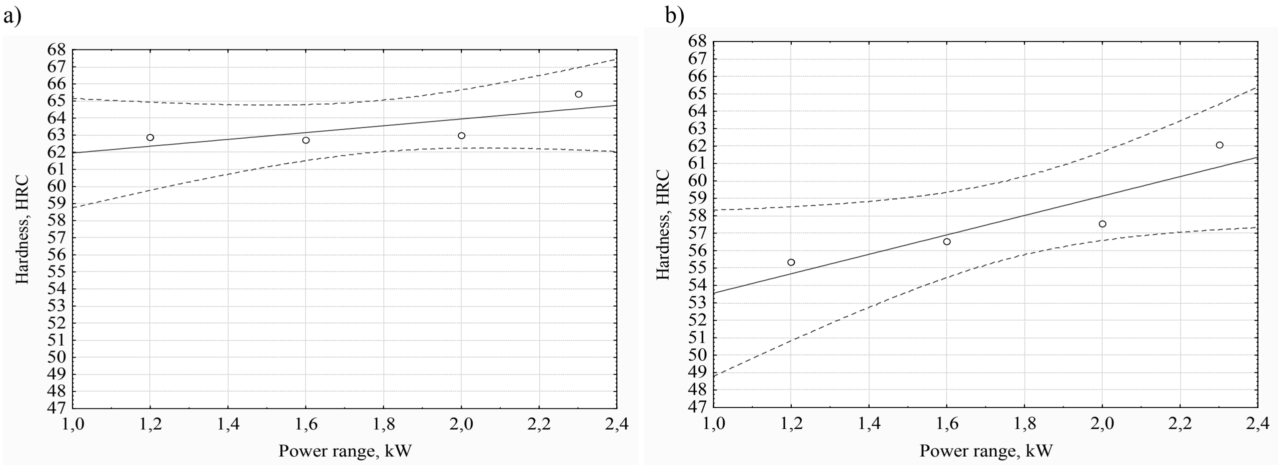
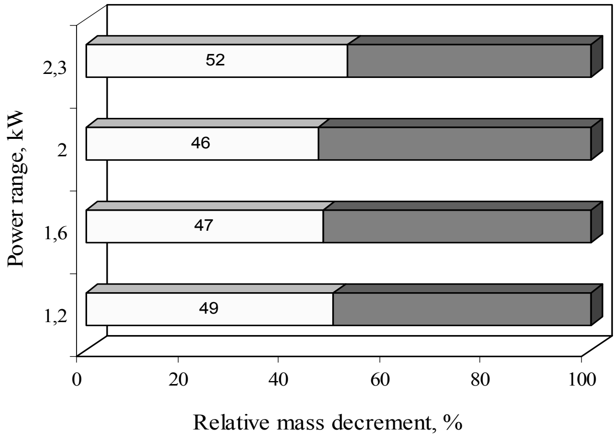


Fig. 5 Average value changes of surface layer hardness of a) X40CrMoV5-1, b) 55NiCrMoV7 alloyed with TiC powder

a)



b)

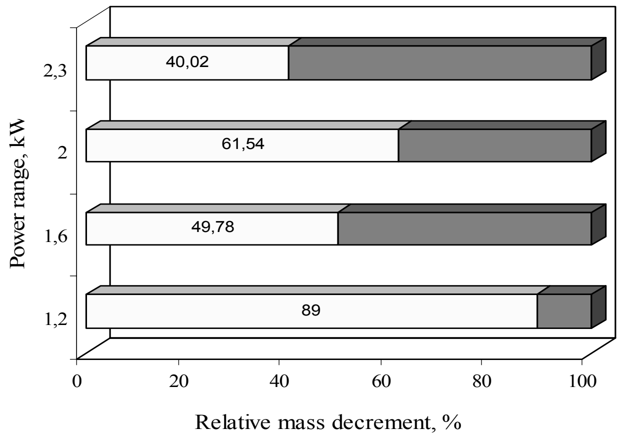


Fig. 6 Relative mass decrement of a) X40CrMoV5-1, b) 55NiCrMoV7 hot work tool steel TiC surface layer alloyed with HPDL

4. Conclusions

The investigations showed that as a result of the applied laser processing there is the increase in the hardness of the surface layers in relation to the output material.

The increase of hardness of surface layer obtained throughout remelting and alloying with TiC carbide by high power diode laser is accompanied by increase of tribological properties, when comparing to the steel processed with conventional heat treatment.

Steels alloyed by powder of TiC carbide show the highest resistance to thermal fatigue while the lowest resistance is characterized for steel after conventional heat treatment. It shows the possibility of applying the worked out technology to manufacturing or regeneration of chosen hot working tools.

Acknowledgements

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