

Analysis of Steel Structures 5140 after Laser Treatment

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Abstract. The main results of analysis of steel structure 5140 after laser treatment are presented. It is found that structural changes have occurred under the influence of heat radiation of the laser. This paper describes and demonstrates the changes. Method of studying the structure of steel, preparation of materials for the study and the method of laser processing are also described.

1. Introduction

At present time there is rapidly developing the production of embossed stamps (cliché). In particular, stamps fabrication by laser technology from hardened metal is very popular. This method of manufacturing avoids the additional processing of the stamp after laser processing of material. However, each material and each laser has its nuances in application to get a specific result. While manufacturing, laser radiation has a thermal effect on the residual material, often modifying its properties, making it difficult to optimize the process and, therefore, requires the study of the processes occurring in the metal.

2. Preparation for the research

It is necessary to choose the material for the work and the processing method before the research.

2.1. Material selection

Structural alloyed steel has a carbon content of 0.40 % and less than 1.5 % of chromium (steel 5140). This grade was chosen as a material for research because of demand in this area, price and wide spread.

2.2. Thermal treatment

Chamber electric furnaces were used for heating, quenching and tempering. Heating temperature for quenching was 850 C, which has allowed to achieve maximum hardness and durability of material. After shutter speed in a furnace the samples were cooled in water. Then there was the low-temperature tempering at a temperature of 200 C for 30 minutes, which made the sample more viscous.



2.3. Laser treatment

The laser complex sample equipped with an ytterbium fiber laser with a pulse repetition rate of 20 kHz was chosen for material processing. The velocity of the beam was 100 mm/s and an average output power of the laser 20 Watts. The number of passes of the laser beam and the pulse duration is varied in this case. [1]

This laser system called Minimarker2 - M20 was chosen due to widespread of the same complexes, a high coefficient of absorption of radiation with a wavelength of 1064 nanometers by metals and high efficiency of fiber lasers (about 25 %).

2.4. Metallographic analysis

The metallographic sections were prepared for carrying out microanalysis on samples by using grinding skins with different grain size of the abrasive. Final polishing was performed on cloth using special polishing pasta made in State Optical Institute. The structure was revealed by etching solution 4% HNO₃ in ethanol.

Structure analysis was performed using an optical research microscope AxioObserver A1.m by Carl Zeiss (Germany) in a software product AxioVision v.4.6.

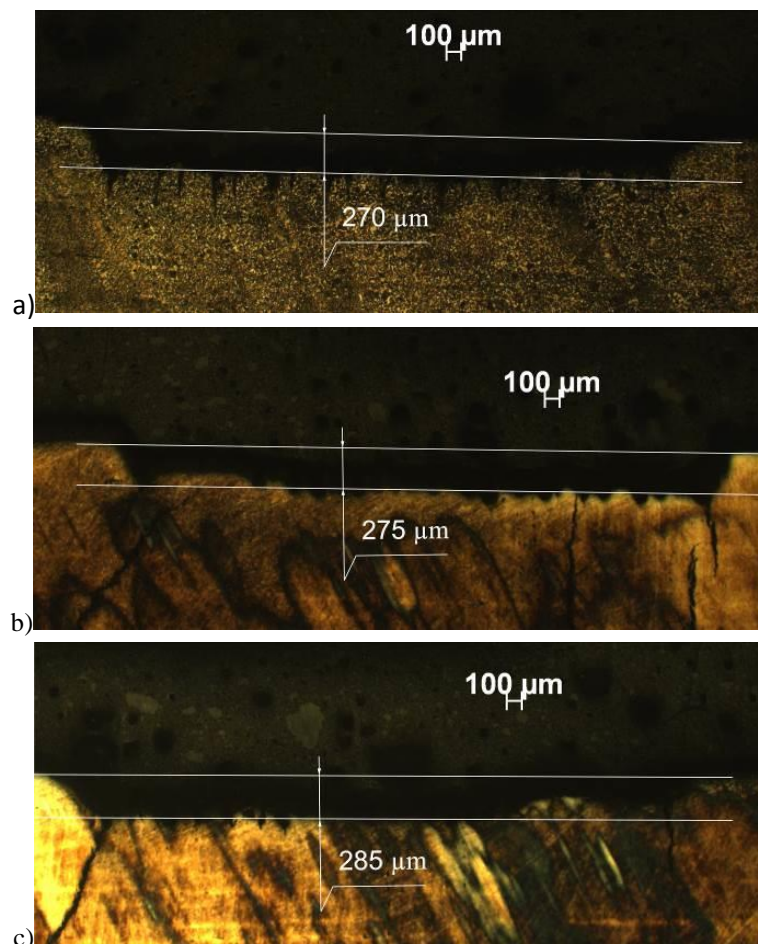


Figure 1. Evaporation material depth in the longitudinal direction of the sectional beam at a pulse width of 200 ns for the treatment of various metal:
1 - annealed 2 - hardened, 3 - hardened and tempered

2.5. Hardness and microhardness analysis

Hardness of the steel in the initial (annealed) condition was measured by the Brinell method, it was HB = 212-217. Hardness of the steel after quenching was 60-62 HRC, after the tempering - 51-52 HRC.

A diamond pyramid under a load of 50 g was pressed into material, and then the hardness was calculated in microscopically small volumes to determine the microhardness.

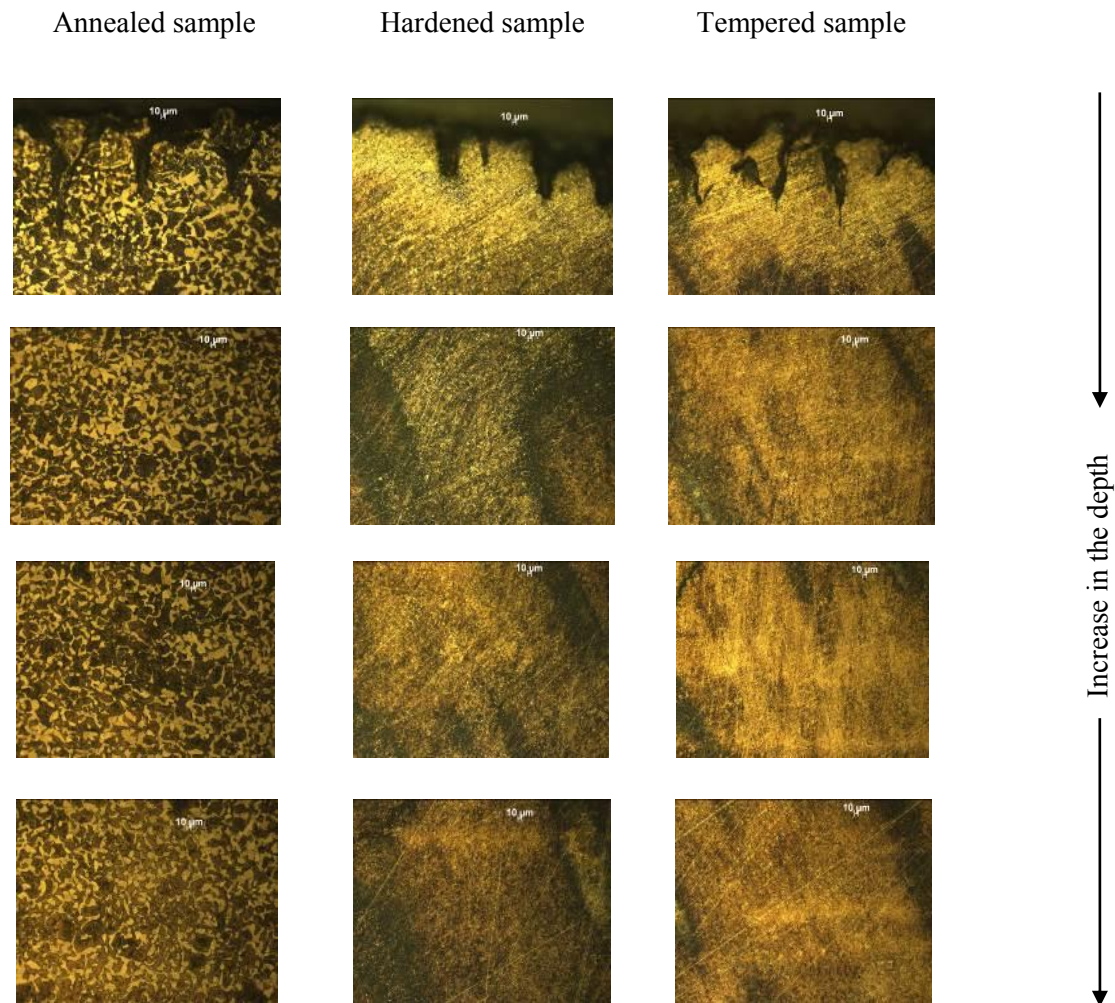


Figure 2. Steel structure at different depths below the zone of laser action

3. The research part

We consider the most profound holes formed during laser beam after 100 passes with the duration 200 nanoseconds in Figure 1. [2]

Thus leads us to believe that the quantity of removed material is independent of the pre-treatment of metal, or depends insignificantly.

Now examine the change in structure of the steel in the area of laser impact.

In Figure 2 it is clear to see that the steel structure doesn't change in all three samples under the influence of laser radiation. Laser processing complex Minimarker2-M20 has no effect on change in the structure and, hence, the properties of the material. It means, that after the metal sample have wells

material within the groove should have the same hardness. [3] For the proof of this supposition microhardness was measured in the direction from the laser impact zone to non-exposed zone. Figure 3 illustrates that the microhardness of the material does not vary in the area of laser impact. [4]

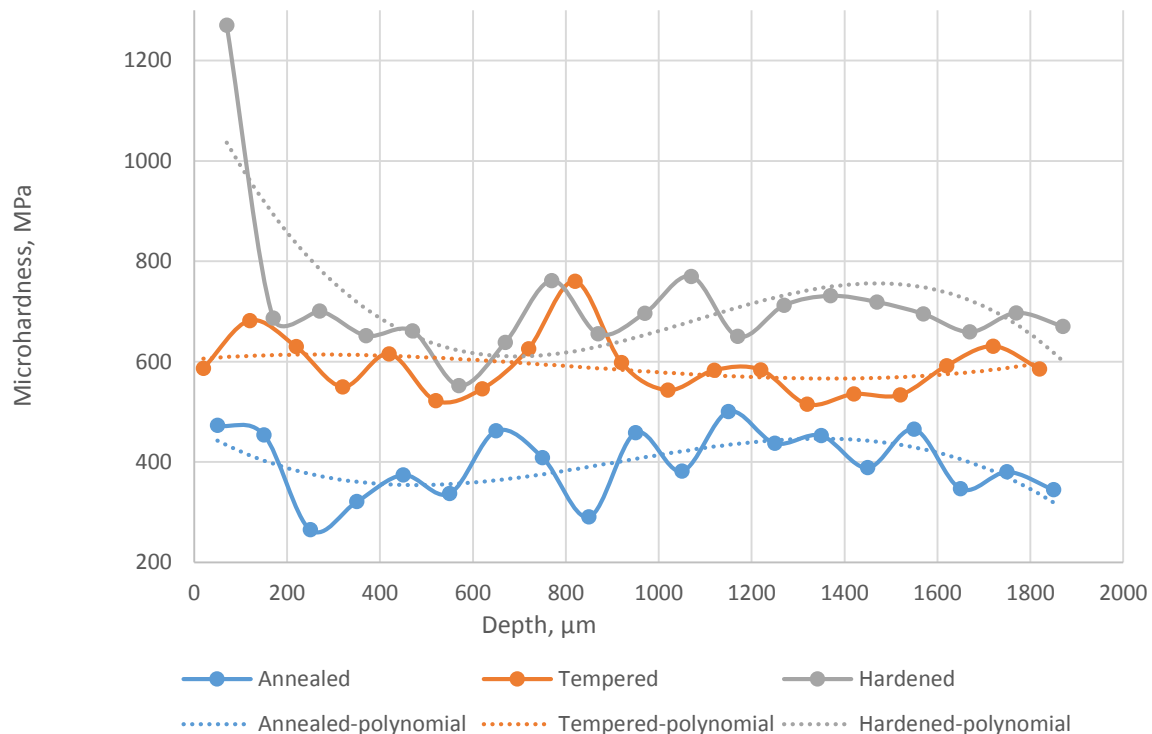


Figure 3. Microhardness of steel at different depths below the zone of laser action

4. Conclusion

It is established that with the increase of pulse duration crater in the alloy also deepens stronger though emission power at pulse durations is less. It is assumed that this happens because of "screening" of radiation, i.e. the absorption of laser emission formed by plasma when exposed laser rays.

It is shown that the quantity of material evaporated by laser radiation is independent on the hardness (pretreating process) of the material.

We also revealed that the investigated steel 5140 changes neither its structure nor the properties after multiple sampling of material by laser. This simplifies the process of manufacturing a cliché in industrial areas without requiring additional research on changes in the characteristics of the samples. It should nevertheless be noted that this conclusion is correct for the steel grade is 5140 when processing its with impulse ytterbium fiber laser with an average output power of 20 watts. [5] In another research, the author of article concluded that the structure of another steel harden with fusion (with a liquid phase) under the influence of the same laser system Minimarker2 - M20.

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