The influence of the laser doping with boron on a steel 30MnB4 structure and properties

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Summary

The results of the research of the laser remelting of the steel surface 30Mn4B with the metallic boron layer on structures and microhardness changes have been presented in the paper. The surface layer of the tested steel was remelted with the laser of a continuous work. The power density was from $1.7 \times 10^4$ to $3.0 \times 10^4$ W/cm$^2$. The metallographic tests were conducted (LM and SEM) of the received structure and the microhardness measurements of the layers rising during the machining. The relation between the power density of the laser beam falling on a material, and a geometry of the remelted layers and their microhardness.

Key words: steel, remelting of the surface layer, laser machining, alloying

1. Introduction

The exploitation features of the machines and devices are the resultant of the factors connected with the problem of production, type of applied materials, or the mechanical properties of the applied materials that result from their structure, chemical composition or the applied method of material refining or its surface layer.

The correctly shaped surface layer provides the optimal exploitation properties during the device operation, giving both permanence and construction reliability. On the working layer of the surface there are tribological processes, fatigue or connected with the environmental influence. The necessity of optimal choice of the heat treatment is needed or surfacing treatment for the receiving the demanded structural changes leading to the thickness increase, tribological resistance or the fatigue strength.

Controlling the treatment parameters we can shape the properties of the surface layer by receiving the structures characteristic with huge fragmentation, wide solubility of the atom additive and the increase of the defects concentration. Apart from the structure, the factors influencing the exploitation properties of the elements that are remelted with the laser beam, are the own stresses. Designing the heat treatment, one approaches to produce the own stresses on the surface layer, that will influence the increase of the material strength. In most cases, it is beneficial for the surface material to have own stresses, the pressing ones, and in the core, the stretching ones. The type, size and gradient of own stresses strictly depend on the material quality and treatment parameters [1-6].

The knowledge of these terms allows for the proper choice of the parameters of shaping the surface layer with surface refining of the machine and device elements.

The analysis of the parameters of laser treatment influence on geometry, structure and microhardness of the surface layer of the steel 30 MnB4 with the metallic boron layer have been done in that paper. The relations between the treatment parameters and material structure microhardness have been pointed out and the geometry of the laser remelted layer.

Boron introduced to the steel with the amount of about 0.003%, increases its temper with the carbon content up to 0.6%. With higher content of the boron, the temper of the steel decreases, and the tendency to grow of the austenit grain increases because boron lowers the surface energy of the grain borders. It creates borides FeB and Fe$_2$B with carbon of a huge hardness, that can be made on the elements surface exposed to grinding [7-8].
2. Material and test methodology

The samples made from the steel 30MnB4 with the metallic boron layer were tested, they were in a form of the suspension in the water glass. The samples were remelted with the laser beam CO$_2$ of the continuous work. The power of the laser beam was 1,5 kW, and the speed of the travel towards the treated material $v=0,037$m/s. The samples were remelted with different distance from the focal of the optical covering of the laser beam leading, receiving different diameters of the laser beam on the treated surface, and at the same time different density of power and influence time. Parameters of the laser treatment were presented in table 1.

Table 1. Processing parameters used during the study

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser power</td>
<td>$P = 1,5$ kW</td>
</tr>
<tr>
<td>The travel speed of the laser beam</td>
<td>$v = 0,037$ m/s</td>
</tr>
<tr>
<td>Beam diameter after focusing</td>
<td>$d_1 = 2,5$ mm, $d_2 = 3,0$ mm, $d_3 = 3,5$ mm</td>
</tr>
<tr>
<td>Lens focal</td>
<td>$f = 127$ mm</td>
</tr>
<tr>
<td>Laser beam influence time with the material</td>
<td>$t_1=0,20$ s, $t_2=0,25$ s, $t_3=0,30$ s</td>
</tr>
<tr>
<td>Power density of the laser beam</td>
<td>$Q_1=1,7\cdot10^4$ W/cm$^2$, $Q_2=2,1\cdot10^4$ W/cm$^2$, $Q_3=3,0\cdot10^4$ W/cm$^2$</td>
</tr>
</tbody>
</table>

The microscopic analysis was done of the received structure and the geometry measurements of the laser remelted material layer. Moreover the relation between the laser treatment parameters and geometry of parameters of the remelted layers, microhardness and microstructure were presented too.

The measurements of the geometric parameters of the areas with laser remelting were done on a microscope - Neophot 2 equipped with the system of the image analysis - Multiscan. The metallographic tests were done on a scanning microscope Tesla BS-340.

The microhardness measurements were done on perpendicular sample surface to the treated surface with the use of microhardness meter called Hanneman mph 100. The diagram of the measurements conducted is presented in Fig. 1. The distance between the imprints was 50 µm.

3. Description of the received results

The maximum temperature on the surface of the treated material provided the remelting of the surface layer in all samples. The received surface layer consists of the remelted material zone, heat influence zone and material heated below the temperature $A_c_1$ zone. The shape of the remelted zone depending on the power density of the laser beam flowing on the material is presented in fig. 2, whereas the density, width and surface field measurements after the laser remelting, were presented in table 2.

Table 2. The size of the remelted zone during the laser treatment

<table>
<thead>
<tr>
<th>Power density [W/cm$^2$]</th>
<th>Remelting density [mm]</th>
<th>Remelting width [mm]</th>
<th>Surface field [mm$^2$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1,7\cdot10^4$</td>
<td>0,04</td>
<td>2,4</td>
<td>0,086</td>
</tr>
<tr>
<td>$2,1\cdot10^4$</td>
<td>0,09</td>
<td>2,8</td>
<td>0,228</td>
</tr>
<tr>
<td>$3,0\cdot10^4$</td>
<td>0,19</td>
<td>3,6</td>
<td>0,61</td>
</tr>
</tbody>
</table>

All parameters of the heat treatment included in a paper allowed for receiving the remeltings of the surface layer of the relatively huge width (from 2,4 to 3,6 mm) and little depth (from 0,04 to 0,19mm). In a sample worked out with the laser beam of the power density of $Q_1 = 1,7\cdot10^4$ and $Q_1 = 1,7\cdot10^4$ W/cm$^2$ the remelting zones were achieved of the shape similar to the rectangular (Fig. 2a,b).

The biggest depth and width of the remelting zone (0,19 mm and 3,6 mm) was received in a sample worked out with the power density $Q_3=3,0\cdot10^4$ W/cm$^2$. The smallest density of the remelting was in a sample remelted with the power density $Q_1=1,7\cdot10^4$ W/cm$^2$ and amounted of 0,04 mm.
As a result of the intensive heat carrying within the area of remelting there was a quick crystalization. During the quick heat travelling from the remelting zone by “cold” ground, the process of steel tempering was present.

In the layer of the zone of remelted steel 30MnB4 the cellular structure was present (Fig. 3), consisting of martensite and residual austenite. On the border of the cells there was the compound eutectic system, from products of the austenite and iron boride transformation. The structure hardness in the laser remelting zone was 670-690 HV0.065.

The part of the boride eutectic system in a structure was decreasing in the direction from the surface to the remelting bottom (Fig. 3-4).

Directly under the penetration zone, there was the zone of the heated material observed, to the solidus temperature and the tempered one. In the structure of that zone there is a lamellar martensite and residual austenite (Fig. 5). The amount of the slat martensite packages was about 10 µm.

There were no differences in the structure build in the samples worked out with different power density of the laser beam.
noticed. The power density of the laser beam influenced the density and width of the remelted material layer (Fig. 2).

Fig. 5 The steel microstructure 30 MnB4 after the laser treatment CO₂, the zone of the heat influence, structure: lamellar martensite, residual austenite

The measurements of the structure hardness were made in the laser remelting zone, the heat influence and the core of the material were presented in the Fig. 6. The structure microhardness in the remelted and hardened zone was from 670 to 690 HV0,065. No changes of microhardness were observed in the structure received as result of the remelting with power density within the range 1,7·10⁴-3,0·10⁴ W/cm². The zone microhardness was from 390 to 410 HV0,065, with the thickness of the core of the sample at the level 280 HV0,065.

Fig. 6. Microhardness of the particular zones in of 30MnB4 steel after the laser remelting CO₂

The microhardness decomposition deep into the material for the steel 30MnB4 after remelting with the power density $Q=3,0\cdot10^4$ W/cm² was presented in the Fig 7.

Fig. 7. 30MnB4 steel microhardness in the distance function from the worked surface after laser remelting CO₂

4. Conclusions and statements

Parameters of the presented sample provided the remelting of the surface layer of the material at the depth up to 0,19 mm. In the steel remelting zone 30MnB4 the cellular structure was made. The structure of cells consisted of martensite and residual austenite, at the borders there were compound eutectic system of products from the over-cool austenite and iron boride transition products.

The structure microhardness of the surface layer created after remelting was from 680 HV0,065, in the heat influence zone from 390 to 410 HV0,065. No parameters change of the laser treatment was observed within the range of the applied differences in the structure hardness.

References

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