Research of dependence of wearing capacity and resource of the hardened areas of surfaces of details of construction machinery from the profile and structure of cross-section of track hardening at laser processing

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Abstract. The method for increasing the wearing capacity of surface layer of details of construction machinery is proposed. The features of the hardening of the surface layer during laser processing are considered. Experimental studies of dependence of wearing capacity on the profile and cross-section structure of track are shown.

1. Introduction

One of effective methods of improvement of quality of processed surfaces of details and their operational properties are laser processing processes. In this type of treatment there is a change in the physical, chemical, structural condition of surface layer, increasing its mechanical, physical and chemical properties, which provides a quick and favorable transition from initial (technological) quality of surface layer to the optimal working during operation [1-4].

2. Main part

The formation of a regular microrelief allows to operate such parameters of surface, and consequently, contact of surfaces, as its actual area and the actual contact area, and also to create the high-clean surfaces of sufficient oil-absorption capacity, which are completely eliminating such phenomena in operation as setting, fretting corrosion, etc.

Advantages of process of laser processing:

• the energy entered into a processing zone is strictly dosed;
• local processing of surface is possible;
• the total incoming thermal energy is low, which prevents thermal leads of details and minimizes the zone of thermal influence (ZTI);
• heating and cooling of the deposited material is very fast, resulting in an ultrafine coating structure, which is well resists to corrosion and erosive processes is formed;
• the process provides processing to the required depth;
• mixing of the main and deposited materials is minimal, the required composition is obtained in the first layer;
• high performance of processing, which allows processing details of large dimensions.
The microhardness of the applied coatings after laser processing increases on (20...50) %. Fluctuation of microhardness values both on a sample surface, and on depth of the surface layer (in different places) is practically absent (2...4 %). There is a smooth character of the curves of distribution of microhardness on depth is noted. Similar changes are observed in the study of residual stresses. Their size (700...1200 MPa), on the surface of samples, as a rule, is maximum and covers a large depth of a layer of metal (40...60 microns). The distribution curves of residual stresses over the depth of the surface layer also have a smoother appearance compared to the results obtained on samples hardened without coating [5-6]. The stability of residual stresses to relaxation at both at normal and at elevated temperatures (600 °C) is noted.

At impact of a laser beam on a metal surface it is quickly heats up to high temperature and at the termination of radiation is at once cooled [7]. It turns out a kind of hardening of the surface. Such training by a laser beam can be used for processing of steel and cast-iron details for the purpose of increase in their wear resistance.

Wear resistance tests are characterized by a large dispersion of the results even on laboratory samples, and furthermore in units, units or machine in general [8-11]. The dispersion is caused to the difference of geometrical and mechanical properties of friction surfaces in the conditions of their contact, their variability of external conditions and other circumstances. In many cases, the correct conclusions can be made only on the basis of testing a large number of same objects with use of statistical methods of processing of results [12-13]. Schemes of imposing tracks hardening are shown in figures 1-3.

![Figure 1. The dependence of the depth of the hardened layer of high-strength cast iron density of laser radiation power:](image1)

a) Cross section of track hardening by single-channel CO2-laser; b) Scheme of imposing tracks hardening at laser processing by single-channel laser

![Figure 2. Cross section of track hardening by multi-channel CO2-laser](image2)

![Figure 3. Scheme of imposing tracks hardening at laser processing by multi-channel laser](image3)

Signs characterizing a condition of the friction surface are as follows:
– metal breaks and large scratches (bullies), characteristic for hard materials;
– sticking to the surface of one detail of material of another detail (for example, bronze or aluminum alloy on steel);
– scratches on the friction surface located in the direction of movement of details at the same time in lubricant abrasive particles can be found;  
– the acquisition of the surface of steel detail entirely or places the color of copper with a mirror shine (it is observed at friction of steel on bronze or brass in the conditions of greasing by alcohol, glycerin, benzene and other liquids);  
– presence of shiny areas with low roughness on the friction surface  
– the dark color of the friction surface and small roughness without scratches, scrapes and tears of metal; at the same time products of wear represent dark powder of oxide of metal;  
– various defects on the surfaces – cracks directed across the movement, peeling of galvanic coatings, corrosion centers, the presence of colors and others.

After clarification of the reasons of wear of details, increased or inadmissible on intensity, it is possible to recommend depending on circumstances: to improve earning power of rubbing details application of anti-seize means; to increase the wear resistance of details to improve the hardness of material of surface layers or application of special coatings; to change operating conditions of a detail (to reduce vibration or temperature); to make replacement of material of details of a joint; to increase rigidity of a design of knot, or, on the contrary, to reduce it; to improve lubrication conditions; to develop measures to protect the rubbing of the joints against the ingress of dust.

In experimental studies, samples of details made of structural alloy steel 18HGT (table 1) were used. She is used in industry: details working at high speeds with high pressures and loadings; improved or cemented details responsible purpose, which requires increased strength and viscosity of the core, and also high surface hardness, working under the influence of impact loads [14].

| № sample’s | Material grade | Aperture of output radiation, mm | Radiation power P, kW | Linear processing speed, mm/s | Coefficient of overlap of track during hardening k, % |
|------------|----------------|---------------------------------|-----------------------|-----------------------------|-----------------------------------------------|
| 1          | Steel 18HGT    | 60                              | 2,6-2,7               | 10                          | 30                                            |
| 2          | Steel 18HGT    | 60                              | 2,6-2,7               | 10                          | 15                                            |
| 3          | Steel 18HGT    | 60                              | 2,6-2,7               | 10                          | 40                                            |

Main features: 1. ability to resist to big loadings; 2. good strength, which is necessary to perform the functions under the influence of high temperatures. in figures 4-6 cross sections of different samples of surface layer of steel after laser processing are shown.

**Figure 4.** Cross section of track 1 of surface layer of steel sample after laser processing (k=15%)

**Figure 5.** Cross section of track 2 of surface layer of steel sample after laser processing (k=30%)
Figure 6. Cross section of track 3 of surface layer of steel sample after laser processing (k=40%)

In tables 2 and 3 experimental data of the studied samples before and after laser processing are provided.

Table 2. Results of measurements of hardness of surface of samples before laser processing and zones of laser processing

| № sample’s | Material grade | Hardness of main material, HRC | Zones of laser processing without melting |
|------------|----------------|-------------------------------|------------------------------------------|
|            |                | Hardness, HRC                 | Depth, mm                                |
| 1          | Steel 18HGT    | 43-45                         | 61-62                                    | 1,1                                      |
| 2          | 18HGT          | 43-45                         | 60-63                                    | 1,1                                      |
| 3          | 18HGT          | 43-45                         | 60-63                                    | 1,1                                      |

These studies help to study the technical characteristics of machine, to check correctness of the choice of settlement schemes, structural dimensions and parameters of units, to establish a warranty period of service, to identify the most unfavorable in terms of durability, wear resistance, rigidity and other features components and details for development of appropriate structural and technological activities.

Table 3. Test results

| № sample’s | Material grade | Type of processing, hardness (HRC) | m₁, g | m₂, g | Δm = m₁ - m₂ | K = m_{source.mat.} / m_{proc.mat.} |
|------------|----------------|-----------------------------------|-------|-------|--------------|-------------------------------------|
| 1          | Steel 18HGT    | source material, 43-45            | 170   | 150,38| 40           | 0,0330                              |
|            |                | without melting, k=30%, 61 – 62   | 870   | 150,48| 15           | 0,0055                              |
| 2          | Steel 18HGT    | source material 43-45             | 392   | 150,92| 50           | 0,0142                              |
|            |                | without melting, k=15%, 60 – 63   | 308   | 150,42| 82           | 0,0026                              |
| 3          | Steel 18HGT    | source material, 43-45            | 730   | 150,25| 20           | 0,0210                              |
|            |                |                                  |       |        |              | 5,25                                |
3. Conclusions

In the analysis of results of study it is important to compare the data on wear of the studied details obtained at various terms of an operating time [15-17]. It will help to find out regularities of wear process and to resolve an issue of establishment of limit operational gaps and service life of the rubbing joints.

The depth of the strengthened layer is ≈ 1.1 mm. The hardness of the strengthened layer after laser processing is not lower, than after volumetric hardening and is from 43-45 HRC to 62 HRC. No cracks, microcracks, shells, pores were found on any of the studied samples. The resource of the strengthened zone of 1 sample is 1.27 times more, than at 2 and 3 samples since the coefficient of wear resistance of 1 sample is more, than coefficients of 1 and 2 samples. Thus, laser surface treatment increases the hardness of the surface layer of all the materials considered.

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