The effect of pretreatment of X12CrNiTi18-10 steel on surface characteristics as a result of laser hardening

N Makhov¹, V Proskuryakov¹, I Rodionov¹, V Koshuro¹, A Fomin¹, S Borodina¹
Yuri Gagarin State Technical University of Saratov, Saratov 410054, Russia

Abstract. The results of studies of the effect of pretreatment of stainless chromium-nickel steel X12CrNiTi18-10 on the morphological characteristics and microhardness of the surface as a result of laser hardening are presented. It was established that with laser modification, a uniformly distributed surface microrelief is formed with a microhardness value of up to 12.58 ± 0.1 GPa.

1 Introduction
Increased values of corrosion resistance, resistance to mechanical stress make stainless chromium-nickel steel X12CrNiTi18-10 (Russian National Standard: GOST 5632-72) the most rational material for use in various industries. However, products made from this alloy, operating under conditions of contact friction or under the influence of various corrosive media, may be subject to premature wear. To extend the service life of such products, methods of surface hardening are used [1].

Today, the most versatile method of surface modification is laser processing. Its main advantages are: the possibility of local impact, the formation of a hardened surface layer with the specified parameters of the structure. It should be noted that in some cases, this method requires the creation of a preliminary surface roughness to provide an increased ability to absorb the energy of laser radiation [2-4].

The purpose of this work was to determine the effect of preliminary surface preparation of steel X12CrNiTi18-10 on the morphology and hardness as a result of laser hardening.

2 Methodology
The studies used samples of stainless steel X12CrNiTi18-10 with dimensions 10 × 10 × 3 mm. The surface of the samples was pretreated in two ways: 1 - by abrasive blasting (ASO) at an air pressure of 0.5-0.6 MPa with particles of electrocorundum powder with a dispersion of 200-250 μm, 2 - by grinding (G) with moisture resistant sandpaper P230 grit.

Laser processing was performed using the installation for thermophysical coherent modification of the surface of the LRS-50A at a voltage of U 250, 300, 350, 400 and 450 V. The duration τ of the impulse effect was 1 ms. The beam was focused on a spot with a diameter of 1 mm. The surface was scanned at a pulse repetition rate of 10 Hz and an overlap factor of 0.25.

The magnitude of the open porosity, the linear dimensions of the grains and pores, and the thickness of the coating were determined using the metallographic micrographic image processing computer program according to the well-known method [5]. At the same time, areas of a coating with an area of 5 mm² were analyzed. Microhardness was measured using a PMT-3M hardness tester with a Vickers indenter with a load on the indenter of 1.961 N (ISO 6507-1: 2005).
3 Results

The morphology of the surface of steel modified with laser radiation is structurally heterogeneous (Figure 1).

![Figure 1](Image)

Figure 1 (a, b). The surface of the X12CrNiTi18-10 steel previously subjected to ASO (a) and grinding (b) after laser modification at U = 400 V, τ = 1 ms

The results of the study of the microhardness of transverse thin sections showed that in addition to the formation of the surface layer 1, a heat-hardening zone 2 with a microhardness of up to $6.8 \pm 0.1$ GPa is formed. It should be noted that the average value of the microhardness of the metal base 3 is $2.4 \pm 0.1$ GPa (Figure 2).

![Figure 2](Image)

Figure 2. The structure of the near-surface layer of X12CrNiTi18-10 steel after laser modification with a surface that has previously undergone abrasive blasting is a, with pre-ground surface – b, where: 1 – is the resulting modified layer; 2 – heat-hardening zone; 3 – metal base; 4 – epoxy resin (850 µm optical field of view)

In addition, microhardness measurements were carried out of the most treated steel surface. The maximum microhardness value $H=12.58 \pm 0.1$ Gpa was obtained at a voltage of 450 V and a pulse duration of 1 ms on the surface that had previously undergone abrasive blasting.
Table 1. The results of the average values of the microhardness of the surface of samples of steel X12CrNiTi18-10, obtained as a result of laser hardening in various modes

| \( \tau \), ms | Sample pretreatment method | U, V | H, GPa  |
|--------------|--------------------------|-----|---------|
| 1            | G                        | 250 | 3.34±0.1|
|              | G                        | 300 | 5.38±0.1|
|              | G                        | 350 | 6.81±0.1|
|              | G                        | 400 | 6.68±0.1|
|              | ASO                      | 250 | 7.42±0.1|
|              | ASO                      | 300 | 7.51±0.1|
|              | ASO                      | 350 | 8.25±0.1|
|              | ASO                      | 400 | 9.09±0.1|
|              | ASO                      | 450 | 12.58±0.1|

Analysis of the particle size distribution of the steel surface after laser treatment showed a significant increase in the number of pores and grains with increasing pulse voltage. At the same time, the size of pores and grains remains practically unchanged (Table 2).

When evaluating the total open porosity \( P \) after laser modification, no significant differences were found depending on the method of preliminary surface treatment. According to the obtained data of particle size analysis, it was established that as a result of laser modification, the pretreatment method has a significant impact on the size and number of pores and grains (Table 2).

Table 2. The results of the software processing of the morphological characteristics of the modified surface of the X12CrNiTi18-10 steel under various laser modification modes (the surface area under study \( S = 5 \text{ mm}^2 \))

| Surface pretreatment method | Laser hardening modes | \( \tau \), ms | U, V | Quantity, \( \text{pcs} \) | Average value, \( \mu \text{m} \) | Dispersion, \( \mu \text{m}^2 \) | Quantity, \( \text{pcs} \) | Average value, \( \mu \text{m} \) | Dispersion, \( \mu \text{m}^2 \) | \( P \), % |
|---------------------------|-----------------------|---------------|-----|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|--------|
| ASO                       | 1                     | 250           | 6   | 364             | 4.64            | 23.84           | 426             | 3.45            | 1.13            | 25     |
|                           |                       | 300           | 608 | 4.46            | 18.45           | 686             | 4.51            | 17.38           | 24     |
|                           |                       | 350           | 662 | 4.12            | 17.69           | 667             | 3.44            | 1.03            | 24     |
|                           |                       | 400           | 1787| 4.05            | 10.86           | 2588            | 4.42            | 9.17            | 24     |
|                           |                       | 450           | 1064| 3.88            | 1.67            | 781             | 3.79            | 1.51            | 22     |
| G                         | 1                     | 250           | 225 | 6               | 30.29           | 240             | 4.02            | 1.52            | 14     |
|                           |                       | 300           | 789 | 4.65            | 16.24           | 856             | 4.64            | 15.61           | 26     |
|                           |                       | 350           | 1214| 5.02            | 2.52            | 1434            | 5.35            | 2.97            | 28     |
|                           |                       | 400           | 2553| 4.92            | 9.22            | 1823            | 4.28            | 1.70            | 30     |
|                           |                       | 450           | 1621| 3.83            | 1.64            | 1407            | 3.75            | 1.55            | 25     |

4 Conclusions
It has been established that laser modification of X12CrNiTi18-10 steel with preliminary ASO allows to increase the surface hardness to 12.58±0.1 GPa, with preliminary grinding - to 11.21±0.1 GPa. The formation of a heat-hardening zone with a hardness of up to 6.87±0.1 GPa for an ASO surface and up to 5.82±0.1 GPa for a surface treated by grinding was also revealed.
Acknowledgments
The research was supported by the Ministry of Education and Science of the Russian Federation in the framework of the Program of Scientific Research in Universities (project No. 11.1943.2017/4.6).

References
[1] Rodionov I 2012 Prospective materials 4 36
[2] Akimov O and Alaa F 2015 Newsletter of the National Technological University Kharkiv Polytechnical Institute. Seriya: New Solutions in Modern Technologies 39 3
[3] Fedorov V, Shlykova A and Yakovlev A 2017 Vestnik Tambovskogo universiteta 22(5-2) 1100
[4] Zhu Y, Fu J, Zheng C and Ji Z 2016 Optics & Laser Technology 83 21
[5] Fomina M, Koshuro V, Papshev V, Rodionov I and Fomin A 2018 Data in Brief 20 1409