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THE TRIBOLOGICAL PROPERTIES OF LASER HARDENED STEEL 42CrMo4

WŁAŚCIWOŚCI TRIBOLOGICZNE STALI 42CrMo4 HARTOWANEJ LASEROWO

The paper presents results of research tribological properties laser hardened steel 42CrMo4. Parameter influencing on the quality of the hardened surface was laser head speed. The study was conducted on friction tester pin-on-disc type T-11, and a counter sample disc was silicate. Parameter determining the quality of the surface layer is the intensity of wear. Based on the results we obtain information about the laser head speed to temper steel 42CrMo4 so as to maintain a high resistance to wear.
Keywords: laser hardened, tribological properties, steel 42CrMo4, abrasive wear

W pracy przedstawiono wyniki badań właściwości tribologicznych stali 42CrMo4 poddanej hartowaniu laserowemu. Parametrem wpływającym na jakość hartowanej powierzchni była prędkości głowicy lasera. Badania tarciowe przeprowadzono na testerze typu trzpień-tarcza T-11, a przeciwpróbkę stanowiła tarcza silikatowa. Parametrem wyznaczającym jakość uzyskanej warstwy była intensywność zużycia. Na podstawie wyników badań uzyskujemy informację, z jaką prędkością głowicy możemy hartować stal 42CrMo4 tak aby zachować wysoką odporność na zużycie ścierne.

1. Introduction

By using high-energy surface modification methods of metal materials, new utility properties can be obtained [8]. One of these methods is laser hardening. It is generally used in the production of agricultural machinery working elements, as well as for line elements during production of building products, like: silica brick, concrete pavement [6-7]. Laser hardening position allows for precise control of process parameters. Laser heads are computer controlled. It allows for precise hardening of selected parts of the elements. This saves hardening time and eliminates the need for heating the element. Positions allow for a smooth change of parameters, e.g. laser beam power, head speed. The disadvantage of solutions can be formation of the surface with different properties[9-14]. This may be due to mismatched distance between hardening tracks. When this distance is too large, it can be observed the unhardened area of elements. If the distance between the tracks is too small, it occurs the annealing areas, which reduces the surface hardness[15-18].

In order to improve the plastic properties of hardened surface the laser-hardening process is connected with micro jet cooling system[1-5]. This causes changes in the microstructure of the surface layer. Depending on the cooling gas can get structure of grained martensite. In the case of different types of steel (e.g. NC6, 20MnCr5) the intensity of consumption drops a few to several percent compared to traditional methods of hardening[3].

Alternative methods for the minimizing of wear intensity may be the cladding methods of high erosion-abrasion resistance coating, for example cemented carbides, ceramics materials[19-21]. Often the process of applying such coatings is expensive and laborious. In some cases, the applied coatings are brittle, which eliminates them from the parts of applications. Laser hardening appears to be an inexpensive method, which allows high interference in process control, and obtaining the high-quality surface, e.g. with high abrasion resistance[1,5].

2. Experimental procedure

The steel 42CrMo4 is selected for research. It is used for heavily loaded machine elements, which may be exposed to varying loads[16-17]. It is also used for components exposed to heavy wear, for example plate molds for the production of silicate. Made samples had the shape of a cylinder with a diameter of 6 mm. Their front surface was subjected to laser hardening (Fig. 1) and then tested for abrasion resistance.

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Fig. 1. The sample surface after laser hardening

The hardening process was performed in the laboratory of the Institute of Technical Physics of the Academy of Sciences of Belarus in Minsk with the use of position "Kometa-UNILAM" (Fig. 2). Used laser module is characterized by continuous radiation wavelength λ = 10.6 m and maximum power of 1 kW. The head of the unit is controlled by computer. Table positioning accuracy is 0.1 mm. The lens is made of sodium chloride and has a focal length of a radius of 200 mm. The laser beam during the hardening process of the front surface of sample leaves traces in the form of tracks. The distance between the trucks is 1 mm (Fig. 3). For the test, 4 parts of samples were prepared. Each part consisted of 5 samples with identical hardening parameters. The distance between the trucks is 1 mm (Fig. 3). For the test, 20 samples were obtained. The samples were separated into parts. Each part consisted of 5 samples with the identical parameters of hardening The difference in the hardening process between parts of samples related to the change in speed of the laser head.

Fig. 2. Test stand of the laser hardening „Kometa-UNILAM" [22]

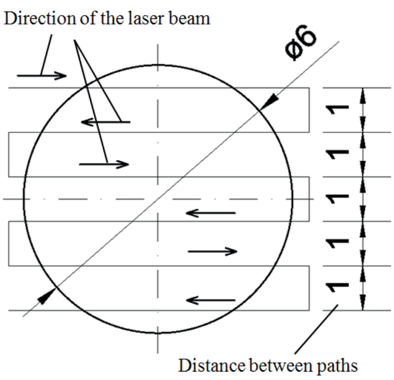

Fig. 3. Paths of the laser beam

Hardening parameters for each sample are given in Table 1.

TABLE 1

Laser hardening parameters

Sample number	Material	Laser power, W	Speed of the laser module, mm/s
1.	42CrMo4	600	10
2.	42CrMo4	600	20
3.	42CrMo4	600	30
4.	42CrMo4	600	40

Friction tests were performed on test pin-on-disk type T-11 (Fig. 4). Tests determined the basic parameters of friction (friction, friction coefficient, wear rate).

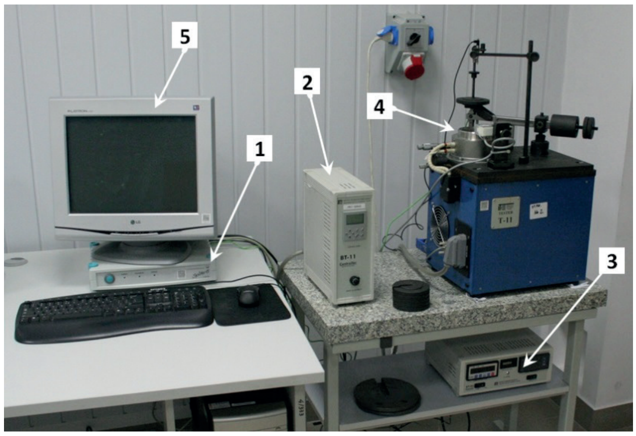

Fig. 4. Schema of the T-11 position for the tribological pin on disc type test: 1 – digital amplifier Spider 8, 2 – controller BT-11, 3 – controller BT-03, 4 – sensors, 5 – a set of computer [3]

Silicate shield was counter sample (Fig. 5.). It was made with a compacted mixture of lime and sand with a particle size 0 ÷ 0.6 mm.

The use of this type of friction pair imitates the intense dry friction wear, which occurs:

- between conveyors for bulk materials (e.g. the aggregate, grain cereals),
- in the process of compaction of granular materials (e.g. production of calcium silicate bricks, paving slabs).

The unit pressure on the counter sample in each test was the same and was p = 1.25 MPa. The exposure time was 20 min.

The intensity of wear was calculated according to the formula:

$$I = \frac{M_1 - M_2}{SF} \left[\frac{mg}{m^3}\right], \qquad (1,1)$$

where: M_1 i M_2 – mass of the sample before and after the friction test [mg], S – path of the friction [m], F – cross-sectional area of the sample [m^2].

$$S = \pi \cdot R_T \cdot t \cdot n[m] \qquad (1,2)$$

where: R_T – radius of friction [m], t – test time [min], n – silicate sample rotation speed.

Fig. 5. Silikate sample.

3. Results and discussion

The microstructure presented in (Fig. 6a) is a result of hardening process. It shows the track path of the laser beam.

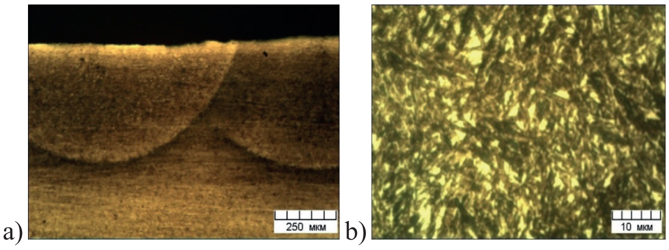

Fig. 6. The microstructure of the sample: a – laser path, b – the center of the laser path

Depending on the speed of the head, tracks of hardened material vary in size The Fig. 7 shows how the shape of the track is changed depending on the speed of the laser head. Microstructure with the overlap tracks was obtained in the whole range of the applied speed. As regards speed of 20 mm / sec, the microstructure is obtained, where clear signs of tracks (Fig. 7a) are not observed on the surface layer and its properties are similar to homogeneity. Above this speed, there are clear signs of tracks (Fig. 7b).

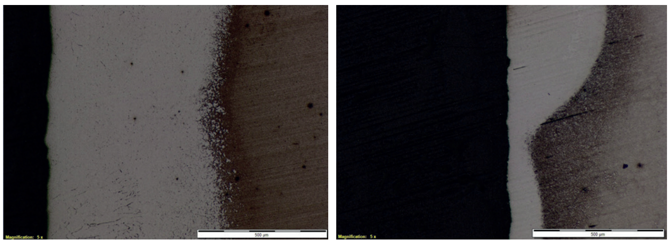

Fig. 7. The microstructure of the hardened steel 40CrMo4 laser at a speed of: a) 10 mm / sec, b) 40 mm / s; magnification x50

The tested samples were measured for distribution of microhardness of the surface layer. Measurements were made in the middle of the hardened track. The measurement was performed to a depth of 1.8 mm. Measurements were made at a distance of 0.2 mm (Fig. 8). The results for the steel 42CrMo4 are shown in Fig. 9-12.

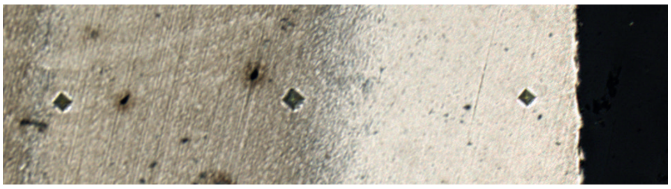

Fig. 8. The distance between the measuring points

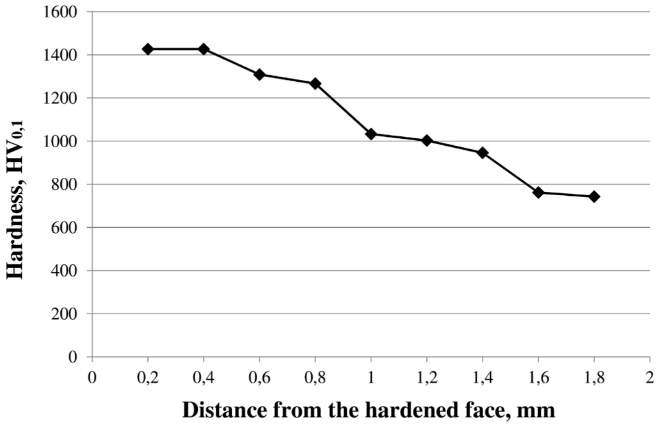

Fig. 9. Hardness of the front sample after laser hardening of 42CrMo4 steel; speed laser head: 10 mm/sec

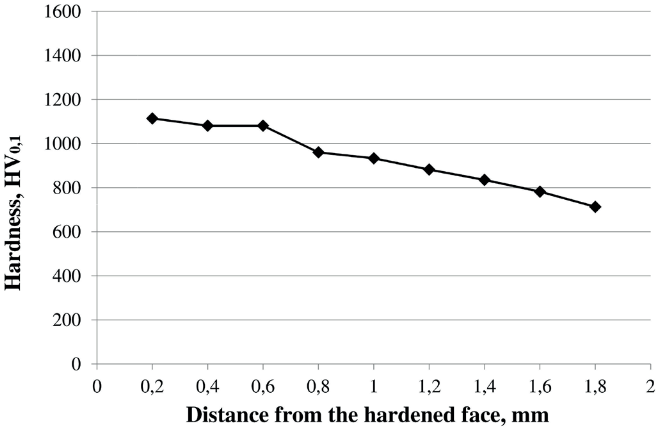

Fig. 10. Hardness of the front sample after laser hardening of 42CrMo4 steel; speed laser head: speed laser head 20 mm/sec

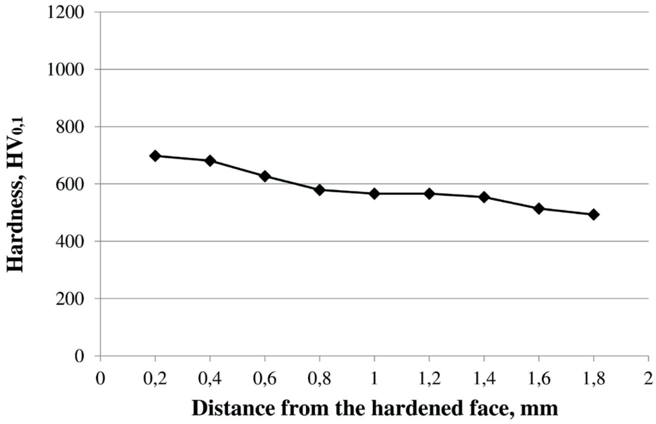

Fig. 11. Hardness of the front sample after laser hardening of 42CrMo4 steel; speed laser head: 30 mm/sec

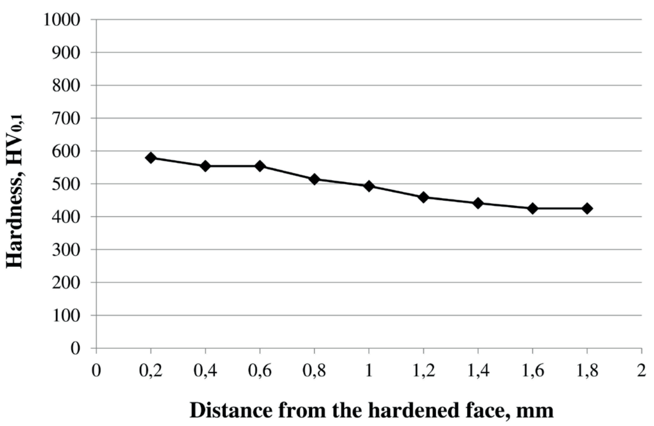

Fig. 12. Hardness of the front sample after laser hardening of 42CrMo4 steel; speed laser head: 40 mm/sec

Hardening with a speed of 20 mm/sec allows for a surface layer of high hardness to be obtained. The measurement of hardness at a depth of 0.6 mm is in the range 1100 ÷ 1400 $HV_{0.1}$. Increasing the laser head speed above 20 mm /sec results in a decrease of hardness and inhomogeneous structure of the hardened layer (Fig. 7b).

The intensity of wear samples was determined in the tribological tests. The results are shown in Fig. 13

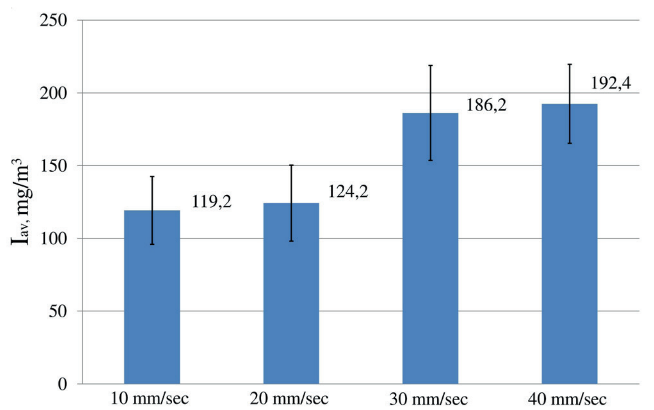

Fig. 13. Summary of the average intensity values and standard deviation

The obtained values correlate with the distribution of microhardness. Samples hardened at a speed of 10 mm/sec are characterized by high resistance to wear. After increasing the speed to 20 mm /sec, the wear resistance is reduced by 4%. Increasing the speed to above 30 mm/sec is followed by a rapid erosion wear by approx. 60% and at a speed of 40 mm/sec, this difference increases to approx. 70%.

During the test, the friction force, which allows for the determination of the coefficient of friction, was registered. The values obtained are shown in Table 2.

TABELA 2

Summary of test results of friction

Research materials and speed laser head	I_{av}, mg/m^3	T_{av}, N	μ_{av}
42CrMo4 – 10 mm/sec	119,2	20,03	0,46
42CrMo4 – 20 mm/sec	124,2	19,87	0,47
42CrMo4 – 30 mm/sec	186,2	21,13	0,46
42CrMo4 – 40 mm/sec	192,4	20,47	0,48

The obtained values of the friction force and the coefficient of friction are changed very slightly depending on the speed of the hardening head. This may be due to the use of a silicate countersample. Friction crumbling lime and sand grains, forming a layer of similar tribological properties during each test

4. Conclusion

The abrasive wear resistance of the steel 42CrMo4 subject to laser hardening depends on the speed of the laser head.

Tested range covered the speed of 10, 20, 30 and 40 mm / sec, and laser power was the same in each test and was 600W. The obtained results allow concluding that:

- 42CrMo4 steel can be hardened by laser, in order to obtain a abrasion resistant layer,
- for speeds of up to 20 mm/sec homogeneous and high hardness structure can be obtained,
- for the speed of above 20 mm/sec, heterogeneously hardened surface layer can be obtained, and the hardness falls twice in the middle of the track,
- laser hardened 42CrMo4 steel at a speed of 20 mm/sec is characterized by high erosive resistance,
- for the speed of hardening of above 20 mm/sec, the wear resistance is rapidly decreasing.

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