A R C H I V E S O F M E T A L L U R G Y A N D M A T E R I A L S
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MODIFICATION OF CHROMIZED DIFFUSION CARBIDE LAYER ON TOOL STEELS USING LASER TREATMENT

LASEROWE MODYFIKOWANIE WŁAŚCIWOŚCI WARSTWY WIERZCHNIEJ STALI NARZĘDZIOWYCH Z CHROMOWANĄ WĘGLIKOWĄ WARSTWĄ DYFUZYJNĄ

Diffusion layers were produced on 102Cr6 tool steel by a pack chromizing method. The layers of 30 μm thickness, composed of M_7C_3 carbides exhibited the hardness of 2000HV0,05.

Surface hardening of carbide layer was performed using CO_2 TLF 2600 Turbo Laser TRUMPH, of nominal power of 2600W. Laser beam was linearly scanned with velocity of 2,5 m/min at two beam powers: 600 and 1200 W. Laser treatment resulted in increasing of layer thickness up to 70μm and a slight drop of its hardness. Martensitic zone 180μm wide was formed in steel matrix under carbide layers.

Na próbkach ze stali 102Cr6 wytworzono metodą proszkową chromowane warstwy dyfuzyjne zbudowane z węglika M_7C_3 o grubości 30 μm i twardości 2000 HV0,05.

Hartowanie warstwy wierzchniej stali z dyfuzyjną warstwą węglikową wykonano przy pomocy lasera technologicznego CO_2 – TLF 2600 Turbo firmy TRUMPH o mocy znamionowej 2600 W. Wiązkę laserową powadzono wzdłuż linii prostej z szybkością 2,5 m/min. Zastosowano dwie wartości mocy wiązki laserowej odpowiednio: 0,6 KW, 1,2 KW. Po hartowaniu laserowym, wskutek zachodzących procesów dyfuzji uzyskano wzrost grubości warstwy węglikowej do 70 μm przy niewielkim obniżeniu twardości. Pod warstwą węglikową w podłożu stalowym powstała martenzytyczna strefa utwardzona o grubości 180 μm.

1. Introduction

Chromized diffusion carbide layers are produced on tools and parts of machines which during their exploitation are exposed to friction wear. Products working in the conditions of static load or small dynamic load, after producing on their surface a hard diffusion layer, need not to be hardened in order to harden the steel matrix. There is no need to harden ,e.g., the tools for plastics processing, bending and forming of non-ferrous metals, gauges, parts for textile industry machines, interchangeable parts of machines for cigarette production, etc [1,2,3].

If the tools and parts of the machines work in the conditions of very high static load or under the dynamic load, hardening of the matrix below the diffusion layer proves necessary in order to prevent its plastic deformation. An appropriate heat treatment is also required when it is necessary to refine the steel grain, coarsened during the process of the diffusion carbide layer production, which proceeds at high temperature and within a long period of time.

Chromized diffusion carbide layers are resistant to oxidation at high temperature and thus little susceptible to degradation during heating and austenitizing of small-size products [4]. A significant difficulty, however, in the application of diffusion carbide layer in order to increase the durability of tools and parts of machines consists in size alternations of the products. These alternations occur both during the production of the layer and ,in particular, during the traditional hardening. The size alternation may be neutralized only by an appropriate selection of initial size of the product on the basis of the conducted tests. It is predicted that the use of laser for the modification of properties of surface layer of a steel product with a chromized carbide layer will in some cases allow to eliminate traditional hardening [5].

2. Objective, range and methods of the research

The objective of the conducted research consists in eliminating the problem of size alternations and numer-

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ous other inconveniences that occur after the traditional hardening of steel products with diffusion carbide layers.

Furthermore, the risk of diffusion layer oxidation during the long process of austenitizing of larger size products is going to be eliminated as well.

The samples used for the research were made of tool steel 102Cr6 in the form of plates of the size 14×14×4 mm. All the surfaces of the samples were subjected to grinding.

For the diffusion processes a mixture consisting of 60% of metallic part – ferrochromium, 39,5% of the filler in the form of kaolin, 0,5% of activator NH_4Cl were used. The samples and the powder were placed in a retort, which was subsequently put into a furnace the temperature of which was 1000°C. The process proceeded within 45 minute of retort heating starting from the ambient temperature to 1000°C, and next 5 hours of annealing at that temperature. After being taken out from the furnace, the retorts were cooled in the open air.

The modifications of the chromized diffusion carbide layer were performed using technological laser CO_2-TLF 2600 Turbo TRUMPH of nominal power of 2600W. The laser beam was scanned along the straight line with velocity of 2,5m/min. Two values of laser beam power were applied, respectively : 0,6 kW and 1,2 kW.

Chemical composition, thickness and hardness of the chromized carbide layer after its formation were studied, as well as chemical composition, thickness and hardness of the carbide layer and the zone hardened after laser modification. In the research there were used an X-ray microanalyzer, microhardness tester and optical microscope.

3. Results of the research

The surface of the chromized carbide layer is silver with a conspicuous lustre. The roughness of the layer is smaller than the roughness of the grinded surface on which it was produced. After laser modification with the beam of 0,6 kW power, neither the colour nor the lustre of the surface changes, and with the beam of 1,2 kW power the surface becomes light mat.

Chromized carbide layers produced on steel 102Cr6 constitute chromium-ferrum carbide M_7C_3 having the structure of a compact palisade of needle and saw teeth-like crystals perpendicular to the surface. The microstructure was revealed by etching: 10g $K_3Fe(CN)_6$, 10g KOH and 100ml distilled water (Fig.1).

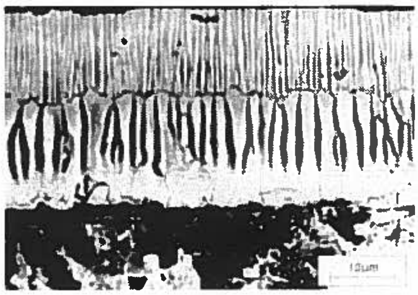

Fig. 1. The microstructure of chromized carbide layer produced on 102Cr6 steel

Since carbide layers are produced at high temperature and within a relatively long period of the diffusion process the steel matrix consists of pearlite with a weakly formed network of carbides around the grains of pearlite.

After the laser modification, under the carbide layer a semicircular hardened zone of amorphous martensite is produced (Fig.2-3). Under the martensite zone the steel matrix is of pearlitic microstructure.

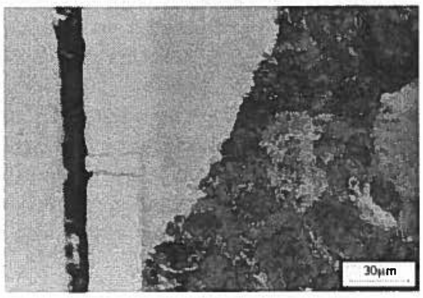

Fig. 2. The microstructure of surface steel with carbide layer after laser modification with the beam of 0,6 kW power

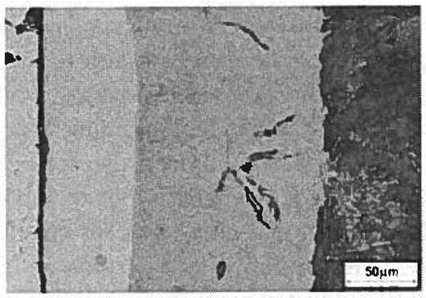

Fig. 3. The microstructure of surface steel with carbide layer and the matrix after laser modification with the beam of 1,2 kW power

Chromized carbide layer produced on 102Cr6 steel is of 28 m thickness. After laser modification with the beam of 0,6 kW power the thickness of the carbide layer does not change, and under the carbide layer a hardened martensitic zone of maximum up to 70 m thickness is produced. After the modification with the laser beam of 1,2 kW power the thickness of the carbide layer increases up to 70 m, and the thickness of the hardened zone to 180 m (Table1, Fig.4).

TABLE 1

Thickness of carbide layers and zones after laser modification on 102Cr6 steel

Kind of a sample	Thickness of the carbide layer [m]	Thickness of the hardened zone [m]	Notes
M_7C_3 layer	28	–	
Modified with 0.6 kW beam	28	72	matrix hardening
Modified with 1.2 kW beam	70	180	matrix hardening, increase of layer thickness

* Thickness of the layers and hardened zones were studied in the central place

Fig. 4. Chromized carbide layer after laser modification with the beam of 1,2 kW power. Evident significant increase of the carbide layer thickness

In the chromized carbide layer M_7C_3 chromium concentration achieves its maximum at the surface and amounts to about 60%. Towards the matrix chromium concentration gradually diminishes. Ferrum concentration at the surface amounts to about 50% at the boundary with the steel matrix. (Fig.5).

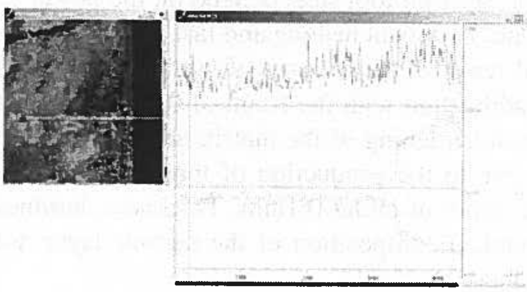

Fig. 5. distribution of chromium and ferrum concentration in the chromized diffusion layer and in the steel matrix before laser modification

After laser modification with the beam of 0,6 kW the distribution of chromium and ferrum concentration in the surface layer basically does not change (Fig.6). After the laser modification with the beam of 1,2 kW the thickness of the carbide layer significantly increases , while the concentration of chromium in the zone closer to the matrix decreases in comparison with the concentration of this element before the modification (Fig.7).

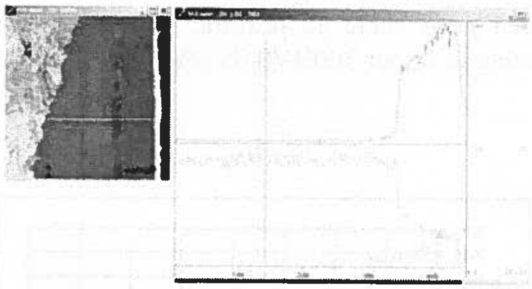

Fig. 6. The distribution of chromium and ferrum concentration in the surface layer and in the steel matrix after laser modification with the beam of 0,6 kW

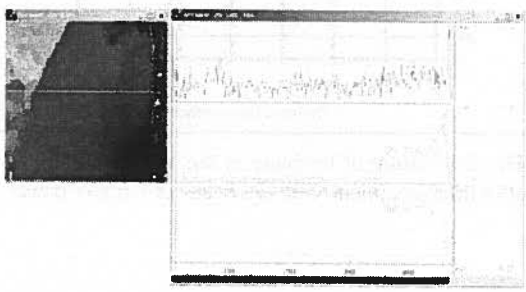

Fig. 7. The distribution of chromium and ferrum concentration in the surface layer and in the steel matrix after laser modification with the beam of 1,2 kW

The hardness of the chromized carbide layer before laser modification amounts to about 2000 HV 0,05 and of the pearlitic steel matrix to about 300HV0,05 (Fig.8).

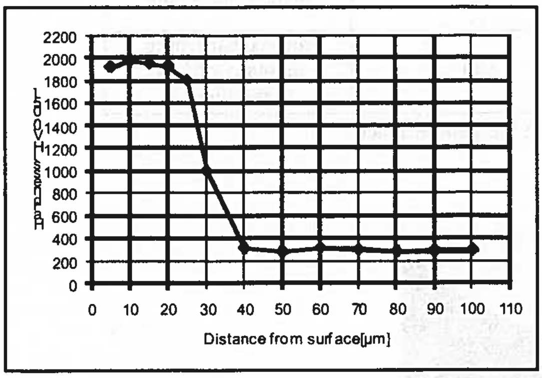

Fig. 8. The distribution of hardness in the chromized layer and steel matrix before laser treatment

After laser modification with the beam of 0,6 kW power the hardness of the carbide layer does not change while under the layer martensitic zone is produced of hardness within the range 600-950HV0,05. Under the hardened zone there is pearlitic matrix of hardness amounting to about 300HV0,05 (Fig.9).

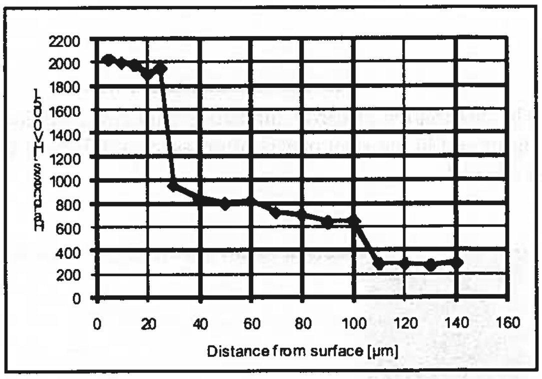

Fig. 9. The distribution of hardness in the chromized layer and steel matrix after laser treatment with the beam of 0,6 kW power

After the laser modification with the beam of 1,2 kW power the hardness of the carbide layer slightly decreases – maximum to 1800HV0,05 at the surface ant to 1300HV at the martenisitc hardened zone. The hardness of the hardened zone amounts to about 300HV0,05 (Fig.10,11)

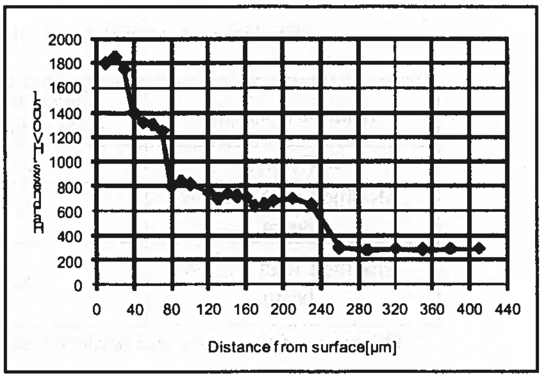

Fig. 10. The distribution of hardness in the chromized layer and steel matrix after laser treatment with the beam of 1,2 kW power

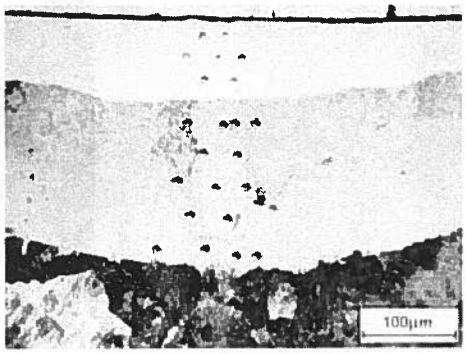

Fig. 11. Hardness indentations against the background of surface carbide layer modified with the laser beam of 1,2 kW power

4. Conclusions

1. The results of laser modification of chromized carbide layer on tool steel depend on the power of laser beam. Fast local heating and fast cooling of the material result in the changes of surface layer properties.
2. Modification with the beam of 0,6 kW power brings about hardening of the matrix under the carbide layer due to the production of martensitic structure at the depth of about 0,1mm. Thickness, hardness and chemical composition of the carbide layer does not change.
3. Modification with the beam of 1,2 kW power brings about hardening of the matrix under the carbide layer due to the production of martensitic structure at the depth of about 0,2mm. The thickness of the carbide layer increases from 28 m to 70 m, parallel to a slight decrease in layer hardness.
4. The changes of carbide layer properties are caused by the change of its chemical composition. There occurs toward-the -core diffusion of chromium atoms, which having been joined with carbon and ferrum atoms in the matrix cause thickness growth of the layer towards the core.

5. It seems desirable to deepen the research on laser modification of diffusion layers on tool steels. The range of the parameters applied for the laser treatment should be extended and there ought to be conducted exploitation research of products with carbide layers hardened with laser treatment.

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