American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-11, pp-72-75
www.ajer.org
Research Paper Open Access

Features of Laser Borating of Piston Rings

D. Glushkova, Professor, D. Sc. (ENG.), E. Grinchenko, ngineer,
S. Demchenko, P. G.

Kharkiv National Automobile and Highway University, 25 Yaroslava Mudroho str., 61002, Kharkiv, Ukraine

Abstract: *Piston rings in the process of operation are subject to wear. Non-sufficient wear resistance of piston ring materials often limits the growth of productivity of machines and the timing of their operation. It is not always that the desired set of properties of piston rings made of cast iron can be achieved by traditional methods of thermal or chemical-thermal treatment. Thus, application of traditional boridingmethods associated with diffusion of boron into the solid phase leads to formation of the working layer having high brittleness. Therefore, the actuality of the problem is to increase the wear resistance of piston rings without embrittlement. Use of laser heating at boridingprovides the formation of a new layer with special properties. However, the optimum properties can only be achieved after establishing a relationship between the parameters of running a process and the depth of the borated layer. The goal was to determine the effect of laser heating parameters on the structure and depth of the borated layer, since the properties of piston rings depend on the depth of the latter. The studies conducted revealed that the increase in the speed of displacement of the part in the process of laser heating reduces the depth of the borated layer. Such a dependence is observed both at 0.15 mm thickness of coating and at a thickness of 0.30 mm. For all modes of workpiece displacement speed for the used boron containing envelope with the above-specified thickness a higher thickness of the borated layer and the heat affected area corresponds to a higher thickness of coating. Increase ofthe spot size leads to an increase in the depth of the layer. By X-ray and metallographic diffraction there weredecoded the phases and structural constituentsof the borated layer. X-ray diffraction and microstructural analysis revealed an association between the exposure speed and share of high-boron layer structures. It is shown that the borated layer in the ductile iron includes such phases as FeB, Fe_2B, α-phase,and borocementite Fe_3 (B, C).*
The research results can be extended to other parts subject to intensive wear.

Keywords: *piston rings, borated layer, laser heating.*

Date of Submission: 26-08-2017 Date of acceptance: 11-10-2017

I. INTRODUCTION

One way to improve the performance properties of cast iron piston rings, exposed to abrasion, is boriding. However, the use of traditional boridingmethodsassociated with diffusion of boron into a solid phase leads to the formation ofa working layer having high brittleness. Therefore, the actual problem is the development of a different method of surface hardening, not leading to embrittlement. Implementation of such a process can be carried out using laser heating accompanied by surface layermelting. However, this method can be offered to be used in the production only after a detailed study of the relationship between the parameters of process implementation and the depth of the layer, as well as after studying the peculiarities of structure formation under specific conditions of laser boriding. The properties of the product on which a borated layer is applied depend on the depth of the latter.

Analysis of publications shows that the technique of increasing the wear resistance of piston rings by boriding, conducted using non-traditional methods, but using the latest technologies has not been has not been developed so far. In sources [1-3] they proposed to increase durability by either traditional borating, or laser treatment. However, there is no association of these two technological processes.

Implementation of such a process can be carried out by establishing the interrelation between the parameters of laser heating and the depth of the borated layer.

The objective of this work was to determine the influence of laser action parameters into the depth of the borated layer and revealing the features of structure formation of such layers.

II. MATERIAL AND METHODS OF THE EXPERIMENT

The research material applied was ductile iron containing C = 3,47%, Si = 2,15%, Mn = 1.36%. After pretreatment, it had a ferrite-perlite structure (85-90% perlite). The size of nodule corresponds to 3 points. Laser treatment was carried out using the continuous CO_2 laser. At a constant irradiation power they varied the speed of movement of the sample in the range of 2-4 mm/sec. The thickness of coating boron was 0.15 mm and 0.30 mm. Conditional defocusing (F_{cond}) allowed to change the irradiation spot diameter from 2 to 4mm. A mixture of amorphous boron with acetone and zapon varnish was used as a coating material.

The structure, phase composition, the depth of the borated layer was studied by optical microscopy, using conventional and staining etching as well as X-ray structural analysis.

III. RESULTS AND DISCUSSION

With the help of etching by a 4% nitric acid solution, revealing the entire layer structure, it was established that the change in the metal structure as a result of doping occurs only in the melting zone. Study of the profile of the reflow zone boundary indicates that a deeper penetration of the metal matrix occurs near the graphite inclusions that confers the border in waves.

Fig. 1 shows the dependence of the depth of the borated layer on the speed of workpiece displacement for two cases - with a coating thickness of 0.15 and 0.30 mm (curve 1 and 2 respectively).

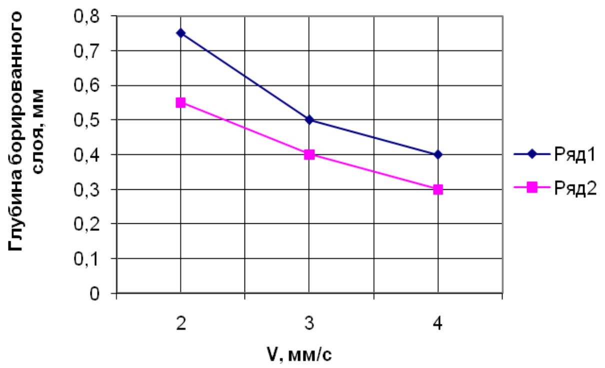
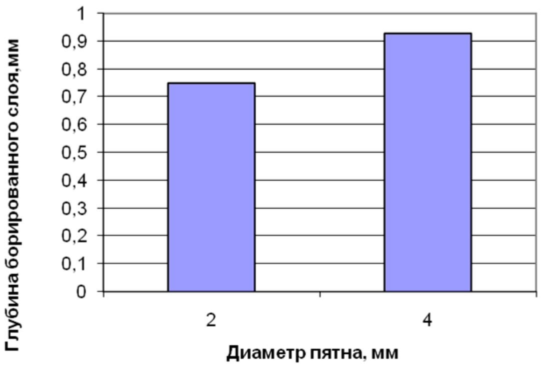


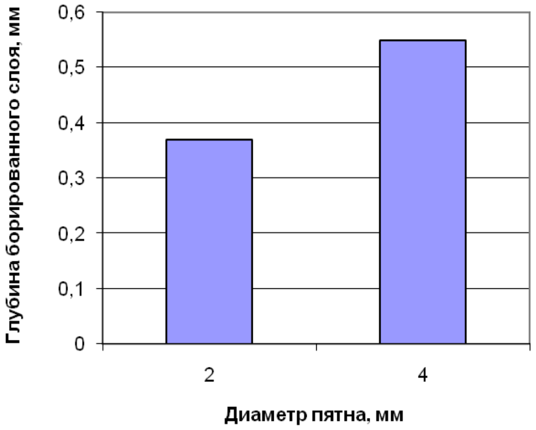
Fig. 1 Dependence of the depth of the borated layer on the rate of workpiece displacement:
1 - 0.3 mm thickness of coating; 2 - 0.15 mm thickness of coating

The graph shows that with an increase in the velocity of sample movement the depth of the borated layer decreases. Such dependence is observed both at 0.15 mm thickness of coating and at a thickness of 0.30 mm. Over a full range of speeds of workpiece movement for the applied boron containing coating with the specified thickness a greater thickness of the borated layer and HAZ corresponds to greater thickness of coating.

Fig. 2 shows a histogram of the depth of the borated layer with a thickness of 0.3 mm and the workpiece velocity of 2 mm/s for the spot diameter 2 and 4 mm, and Fig. 3 presents the same histogram in case of specimen velocity of 4 mm/sec.



Depth of the borated layer
Spot diameter, mm
Fig. 2 histogram of the borated layer depth with a thickness of 0.3 mm and specimen velocity of 2 mm/s for different diameter of the spot



Depth of the borated layer
Spot diameter, mm

Fig. 3 Histogram of the depth of the borated layer with a thickness of 0.3 mm and specimenvelocity of 4 mm/sec for different spot diameter

The above histograms show that the variation of defocusing conditions, the consequence of which is the change of the spot diameterirradiation, results in a noticeable change in the depth of the layer of laser doping. Thus, reducing the defocus, ceteris paribus, the result of which there is a decrease in spot diameter, it causes a decrease in the depth of laser irradiation.

It can be assumed that the resulting effect is due to a significant increase in the surface temperature resulting in intense evaporation of the coating layer, increasing the energy costs for evaporation.

X-ray analysis showed that the borated layer in the ductile ironcontains such phases as Fe_B, $Fe2_B$, α-phase, borocementite Fe_3 (B, C).

A comparison of microscopic and X-ray analysis with diagrams of state Fe-B and $Fe\text{-}Fe_2B\text{-}Fe_3C$ revealed that these phases at crystallization of melt can form throughout the volume of the molten layer various structural components: a mixture of peritectic type ($FeB + Fe_2B$), hypereutectic, eutectic and hypoeutectic structures.

Differentiation of phases in various structures is carried out by the method of coloring etching;by the analysis of primary crystalsforms. Excess α-phase is formed from γ-phase primary crystals according to the martensitic mechanism. Borocementite Fe_3 (B, C) and borides FeB, Fe_2B differ by metallography–by excess crystals form and the behavior during staining etching.

Primary borocementite crystals present plate-clustering - flat dendrites, which in cross sections are perpendicular to the surface, are detected in the form of thin strips. In accordance with the ternary diagram borocementitecan be formed not only by direct crystallization from a liquid solution, but also as a result of peritectic transformation [2].

Structurally-free crystals of borides Fe_2B are observed in the form ofrodlet crystals having in the cross-section the shape of squares, rhombus, triangles, i.e.of all possible cross-sections of the tetragonal prism.

Eutectic components of structures in the borated layer are characterized by a definite structure diversity and dispersion. The eutectic point in different layers and within the same layer is different by both different dispersion ability and various quantitative relation between the phases.

Comparing the patterns of layers with the comparable depth illustrates the effect of coating depth on the structure. For example, a three-zone layer with predominance of eutectic and hypoeutectic structures can become dual-zone with hypereutectic and eutectic zones with a predominance of the first one when changing the thickness of coating from 0.3 to 0.15 mm.

With increasing the exposure rate, under otherwise equal conditions of treatment there is a decrease in the depth of the layer, i.e.the volume of the molten metal bath decreases and consequently- the amount of boron dissolved in it increases therein. Thedata of X-ray diffraction and microscopic analysis reveal a change in the layer composition. X-ray diffraction showsan increase in the intensity of borocementite lines with the growth of irradiation rate, and microstructurally it is revealedby an increase in the share of structures with a high content of boron.

IV. Conclusions

1. It was established that when conducting laser boriding with an increase in RMS-velocity of sample movement the depth of the borated layer decreases.
2. The histograms of the borated layer indicate the increase of the latter with an increase of the irradiation spot diameter from 2 to 4 mm.
3. X-ray and metallographic diffraction detected the phases and structural composition of the borated layer.
4. The effect of coating thickness on the structure is established.
5. X-ray and microstructural diffraction analysis revealed a connection between the RMS-irradiation growth and the share of high-boron structures in the layer.
6. The results of the research can be recommended for implementation in production of both piston rings and other parts made of ductile iron subjected to wear during operation.

REFERENCES

[1] Технология конструкционных материалов и материаловедение / И.П. Гладкий, В.И. Мощенок, В.П. Тарабанова, Н.А. Лалазарова, Д.Б. Глушкова. – Х.: ХНАДУ, 2014. – 464 с.
[2] Григорьянц А.Г. Основы лазерной обработки материалов / А.Г. Григорьянц. – М.: Машиностроение, 2009. – 272 с.
[3] Матвеев Ю.И. Повышение долговечности деталей с использованием лазерной обработки / Ю.И. Матвеев. – Новгород, 2003. – 329 с.
[4] Дзюба Ю.Н. Упрочнение изделий из высокопрочного чугуна / Ю.Н. Дзюба, А.П. Любченко, Д.Б. Глушкова, В.П. Тарабанова // Вестник ХНАДУ: сб. науч. тр. – 2003. – Вып. ____. – С. 72–74.

D. Glushkova Features of Laser Borating of Piston Rings.” American Journal of Engineering Research (AJER), vol. 6, no. 11, 2017, pp. 72-75.