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FEATURES OF LASER BORATING OF PISTON RINGS

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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. Use of laser heating at boriding provides the formation of a new layer with special properties. The research results can be extended to other parts subject to intensive wear.*

Key words: *piston rings, borated layer, laser heating.*

ОСОБЛИВОСТІ ЛАЗЕРНОГО БОРУВАННЯ ПОРШНЕВИХ КІЛЕЦЬ

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Анотація. *Поршневі кільця в процесі експлуатації підлягають зношуванню. Недостатня зносостійкість матеріалів поршневих кілець часто обмежує зростання продуктивності машин і терміну їх експлуатації. Використання лазерного нагрівання під час борування забезпечує утворення нового шару з особливими властивостями. Результати досліджень можуть бути поширені й на інші деталі, що підлягають інтенсивному зношуванню.*

Ключові слова: *поршневі кільця, шар борування, лазерне нагрівання.*

ОСОБЕННОСТИ ЛАЗЕРНОГО БОРИРОВАНИЯ ПОРШНЕВЫХ КОЛЕЦ

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Аннотация. *Поршневые кольца в процессе эксплуатации подвергаются износу. Недостаточная износостойкость материалов поршневых колец часто ограничивает рост производительности машин и срока их эксплуатации. Использование лазерного нагрева при борировании обеспечивает образование нового слоя с особыми свойствами. Результаты исследований могут быть распространены и на другие детали, подлежащие интенсивному износу.*

Ключевые слова: *поршневые кольца, борированный слой, лазерный нагрев.*

Introduction

One way to improve the performance properties of cast iron piston rings, exposed to abrasion, is boriding. However, the use of traditional boriding methods associated with diffusion of boron into a solid phase leads to the formation of a 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 layer melting. 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

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.

Purpose and task of investigation

The purpose of work consists in studying the influence of laser heating on the composition and depth of the borating layer of piston rings.

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.

Laser borating

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).

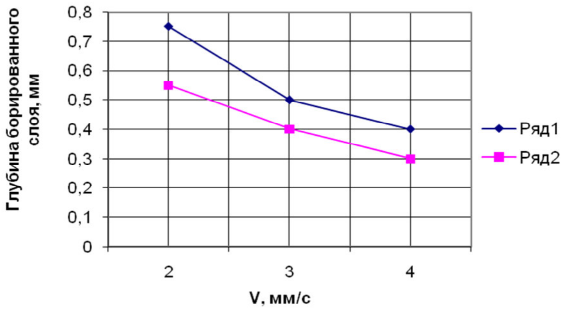


Fig. 1. Dependence of the depth of the borated layer on the rate of workpiece displacement: 1 – 0,3 mm thickness of coating; 2 – 0,15 mm thickness of coating

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/sec for the spot diameter 2 and 4 mm, and Fig. 3 presents the same histogram in case of specimen velocity of 4 mm/sec.

The above histograms show that the variation of defocusing conditions, the consequence of which is the change of the spot diameter irradiation, 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.

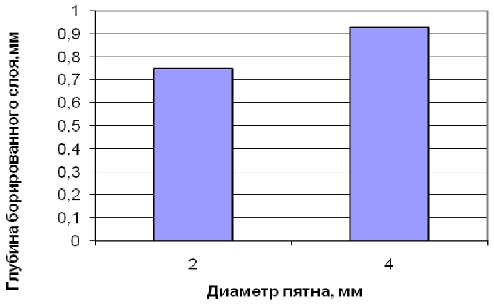
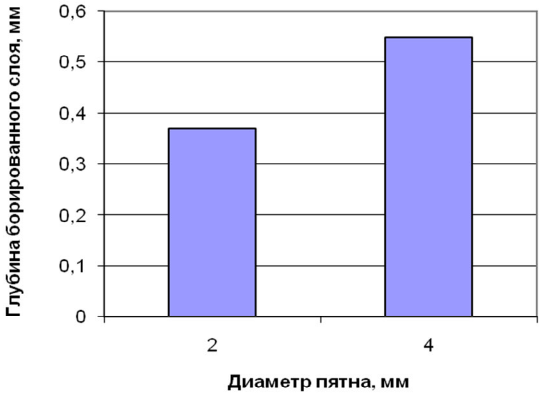


Fig. 2. Histogram of the borated layer depth with a thickness of 0,3 mm and specimen velocity of 2 mm/sec for different diameter of the spot

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.



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 specimen velocity of 4 mm/sec for different spot diameter

X-ray analysis showed that the borated layer in the ductile iron contains such phases as Fe_B, Fe_2B, α-phase, borocementite Fe_3 (B, C).

A comparison of microscopic and X-ray analysis with diagrams of state Fe-B and Fe-Fe_2B-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 crystals forms.

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 borocementite can 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 of rodlet 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. The data of X-ray diffraction and microscopic analysis reveal a change in the layer composition. X-ray diffraction shows an increase in the intensity of borocementite lines with the growth of irradiation rate, and microstructurally it is revealed by an increase in the share of structures with a high content of boron.

Conclusions

It was established that when conducting laser boriding with an increase in RMS-velocity of sample movement the depth of the borated layer decreases.

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.
X-ray and metallographic diffraction detected the phases and structural composition of the borated layer.

The effect of coating thickness on the structure is established.

X-ray and microstructural diffraction analysis revealed a connection between the RMS-irradiation growth and the share of high-boron structures in the layer.

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.

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