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Short report
Краткое сообщение

Influence of tempering on structure of deposited high-speed steel coatings

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Abstract. The technology of plasma surfacing in a protective-alloying nitrogen medium with an additive powder wire is characterized by high productivity and the possibility of alloying the deposited metal. Durability of metal products depends on microstructure, chemical composition, production technology, modes of thermal and surface treatments. The article presents the results of a study of structure and microhardness of the high speed alloy R18Yu deposited in nitrogen medium on medium-carbon steel 30KhGSA. There were no differences in structure of the surfacing layer up to 4 mm in depth, but after four times high-temperature tempering at 580 °C, structural and phase changes were revealed. The values of microhardness after surfacing and tempering are consistent with the literature data.

Keywords: plasma surfacing, tempering, high-speed alloy, microstructure, microhardness

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Влияние отпуска на структуру наплавленных покрытий из быстрорежущей стали

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Аннотация. Технология плазменной наплавки в защитно-легирующей среде азота с присадочной порошковой проволокой характеризуется высокой производительностью и возможностью легирования наплавленного металла. Стойкость металлических изделий зависит от микроструктуры, химического состава, технологии получения, режимов термической и поверхностной обработок. В статье приведены результаты исследования структуры и микротвердости плазменно-наплавленного в среде азота быстрорежущего сплава Р18Ю на среднеуглеродистую сталь 30ХГСА. Различий в строении наплавочного слоя до 4 мм по глубине не выявлено, но после четырехкратного высокотемпературного отпуска при 580 °С выявлены структурно-фазовые изменения. Значения микротвердости после наплавки и отпуска согласуются с литературными данными.

Ключевые слова: плазменная наплавка, отпуск, быстрорежущий сплав, микроструктура, микротвердость

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Introduction

In recent years, researchers in the field of fundamental materials science have traditionally focused on studying the impact th at structural-phase state of high-speed alloys exerts on the formation of enhanced performance characteristics [1 – 3] and their practical implementation [4; 5].

Heat-resistant, high-hardness steels (R18, R6M5, R2M9, etc.) with excellent service properties are widely employed as surfacing materials in mechanical engineering and metallurgy to protect parts from abrasive wear [6 – 9]. The technology employed is plasma surfacing in a protective-alloying nitrogen medium with an additive powder wire. This technology is highly productive and enables alloying of the deposited metal [6 – 9]. Nitrogen, in the case of wear-resistant coatings, provides increased impact and corrosion resistance [6 – 9]. The resistance of metal products is determined by microstructure, chemical composition, formulation, heat, and surface treatment modes. However, reliable data on enhancing the hardness and wear resistance of high-speed metal obtained by plasma surfacing and subsequent he at treatment is lacking in the literature.

The objective of the present work is to investigate the structure of high-speed steel coating formed by high-temperature plasma in a nitrogen medium and high-temperature tempering.

Materials and methods

We investigated the deposited high-speed alloy R18Yu, additionally alloyed with aluminum and nitrogen, possessing the following chemical composition, wt. %: C 0.87; Cr 4.41; W 17.00; Mo 0.10; V 1.50; Ti 0.35; Al 1.15; N 0.06. The base material is 30KhGSA steel with the following chemical composition, wt. %: C 0.3; Cr 0.9; Mn 0.8; Si 0.9.

As described in the works [8; 9], ingot deposition was performed using the installation for plasma surfacing of rotation bodies in the thermal cycle with low-temperature heating. The surfacing mode remains consistent with the one outlined in [8].

Samples were cut from the upper layers of the deposited metal using a spark cutting machine and subjected to heat treatment (heating temperature reaching 580 °C, with a 1 h holding time and four tempering cycles). The metallographic study employed the OLYMPUS GX-51 optical microscope. For obtaining EDS mapping images and profiles, the KYKY-EM6900 scanning electron microscope was utilized.

Microhardness was studied using the Vickers method with an HVS-1000 measuring device, employing a 1 N indenter load.

Results and discussion

According to classical ideas, the structure of the deposited layer forms as outlined in [10]. The carbon-depleted α-solid solution precipitates from the liquid. Subsequently, the peritectic reaction ensues, leading to the formation of γ-mixed crystals. This reaction occurs at the phase interface, and the resulting γ-crystals act to isolate the core of α-crystals from the more carbon-rich liquid. The peritectic reaction can only proceed if carbon and alloying elements diffuse from the liquid solution through the γ-phase. However, this process is rarely observed under real surfacing conditions, where the surface-deposited layers cool down rapidly. Consequently, the structure retains a certain amount of α-phase, a quantity influenced by the cooling rate of the surface layer [10].

Upon subsequent cooling, the eutectoid decomposition of the α-phase takes place, resulting in the formation of an α-eutectoid. This eutectoid comprises a dispersed mixture of austenite and carbides of the Me_6C type, as well as cementite-type carbides.

The inhomogeneity of the structure increases with a higher cooling rate, a phenomenon attributed to the gradually occurring peritectic transformation. Following final solidification, the structure features grains composed of three concentric layers: *1* – a core with a two-phase α-eutectoid structure; *2* – an intermediate light layer (during solidification, γ-crystals form here due to the peritectic reaction, and upon rapid cooling, they transform into martensite and residual austenite); *3* – an outer layer with two-phase eutectics of austenite and carbides, which, after cooling, transforms into martensite and carbides [10].

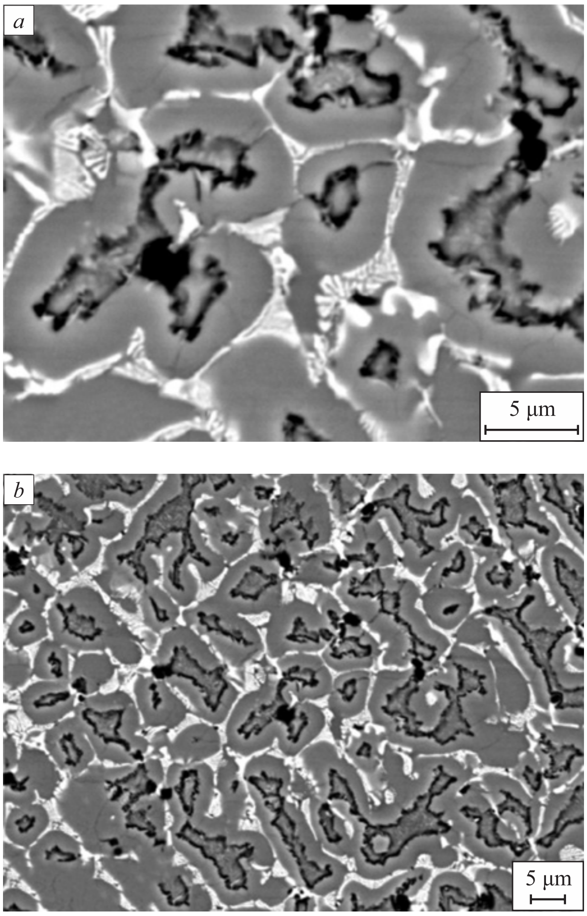
Microstructure analysis through optical microscopy reveals that the structure of the deposited layer exhibits a typical cast structure, with dispersion that is practically independent of the distance from the surface. This consistency may be attributed to the relatively small thickness of the deposited metal and, consequently, the uniform cooling rates throughout the depth of the layer deposited in a single pass.

A more detailed examination at significant magnification using scanning electron microscopy, which allows a focus on structural elements, also demonstrates no discernible differences in the structure of the deposited layer at various depths from the surface (refer to the Figure).

The distinctive light-colored shell exhibits martensite and residual austenite crystals, formed during accelerated cooling from the γ-phase involved in the peritectic reaction. Inside the light-colored shell, primary carbides of the Me_6C with a skeleton-like shape are situated. The presence of these carbides diminishes the toughness of the steel, prompting exploration into methods for mitigating their impact. Dark areas represent a two-phase eutectic structure, which, after solidification, comprises carbides, martensite, and residual austenite.

Given that the surfacing was conducted in a nitrogen medium, it is expected that nitrogen-containing carbides or carbonitrides must have formed. The works [6; 7] have demonstrated the formation of complex carbides such as $Fe_3(W-Mo-N-V)_3C$. It is possible for Fe_4N nitrides to be formed.

Following four cycles of high-temperature tempering at 580 °C with a 1 h holding time and subsequent air



Electron microscopic images of the deposited layer at a distances of 2000 μm (*a*) and 4000 μm (*b*)

Электронно-микроскопические изображения наплавленного слоя на расстоянии 2000 мкм (*a*) и 4000 мкм (*b*)

cooling, structural changes were observed in the deposited layer. In the locations initially comprising martensite and residual austenite, they transformed into tempered martensite with enhanced etchability, releasing dispersed carbides of *Me*C and Me_6C type.

Microhardness on the surface of samples after surfacing and four cycles of high-temperature tempering was automatically measured at 100 μm intervals. The microhardness of the deposited layer was found to be slightly lower than that of the same layer after four cycles of tempering (see the Table).

After four cycles of tempering, as residual austenite decomposed, tempered martensite formed, and dispersed carbides were released. The overall microhardness slightly increased, and its distribution became more homogeneous (see the Table), aligning with data from literary sources [10].

Conclusions

We employed optical and scanning electron microscopy, along with microhardness measurements, to evaluate the effect of tempering on the structure of the R18Yu high-speed steel coating formed by plasma surfacing in a nitrogen medium with a powder wire.

It was observed th at cells with an austenite-martensitic structure formed, and there was a marginal increase in microhardness.

Distribution of microhardness in the deposited layer at different distances from the surface of the test material after surfacing and after four-time tempering

Распределение микротвердости в наплавленном слое на различном расстоянии от поверхности исследуемого материала после наплавки и после четырехкратного отпуска

Microhardness of high-speed steel R18Yu, MPa, at a distance from the sample surface			
after surfacing		after surfacing and high-temperature tempering	
1000 μm	3000 μm	1000 μm	3000 μm
48.20	49.82	55.15	51.72
46.37	45.58	53.88	52.53
46.37	48.13	60.14	51.40
50.45	43.96	50.15	50.52
46.84	47.42	55.28	51.35
41.22	33.59	54.39	63.13
46.99	48.63	54.26	49.30
34.16	44.11	49.13	55.67
46.99	47.31	54.26	51.96
45.43	44.39	55.26	55.25

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Contribution of the Authors

L. P. Baschenko – formation of the main concept, writing the text.

V. V. Pochetuha – processing of the results of optical and scanning electron microscopy.

T. A. Mikhailichenko – measurement of microhardness, analysis of structure of the surfacing layer in depth.

Вклад авторов

Л. П. Бащенко – формулирование общей концепции работы, написание текста.

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