ELECTROLYSITE-PLASMA SMOOTHING OF RELIEF ON TARGETS MODIFIED BY A HIGH-CURRENT RELATIVISTIC ELECTRON BEAM

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The problem of the appearance of a relief on the surface of metals, which was modified by high-current relativistic electron beams, is considered. The technological promise of this modification is shown. The possibility of using the electrolytic-plasma treatment method for smoothing the emerging relief is experimentally investigated. It is shown that electrolytic-plasma processing reduces the surface roughness several times without significantly damaging the modified layer. The obtained results indicate the prospects of using surface modification by high-current electron beams in combination with electrolytic-plasma processing.

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INTRODUCTION

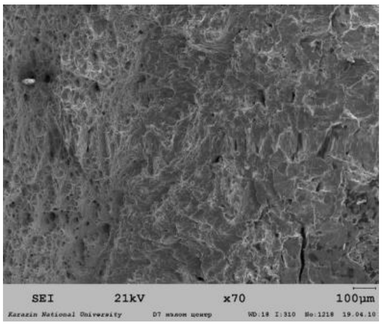
The implementation of manufacturing techniques for metal parts of complex shape is associated with the need to attract efficient methods of finishing processing, which must meet a number of requirements: operational efficiency, the possibility of process automation, and the elimination of anisotropy of residual stresses on the surface. It should be noted that the manufacture of products of complex shape by such methods as casting, processing in the superplastic deformation mode, 3D printing using electron-beam evaporation is associated with the need for finishing processing. Particular attention should be paid to products with a modified surface layer, the thickness of which is from 1 μm to 200 μm. For such products, the use of abrasive processing methods is unacceptable due to the threat of local thinning or complete elimination of the modified layer. As the most obvious example, we can cite the situation with the study of the possibility of using high-current relativistic electron beams (HCEB) for surface modification [1]. Despite the possibility of modifying the surface layer to a depth of up to 200 μm, the disadvantage of this method is the pronounced surface relief, which is unacceptable in a number of technological applications. In this connection, it is advisable to consider the possibility of using electrolytic-plasma processing to reduce the surface roughness of materials irradiated with HCEB.

EXPERIMENTAL SETUP

Stainless steel objects 12X18H10T were irradiated at the accelerator NSC KIPT TEMP-A by electron beams with the following parameters: particle energy 350 keV, beam current 2 kA, pulse front duration 5 μs. The irradiation mode is a single pulse. After that, the state of the surface of the various target regions was studied. Studies of the surface profile were carried out using a multifunctional device "Mikron-gamma". Optical and scanning electron microscopy was carried out using the METAM P-1 and JEOL-840 microscopes, respectively. After the impact on the objects of investigation of the high-current electron beam, the surfaces were subjected to electrolytic-plasma processing. The treatment was carried out at the PER-4M plant, which consists of a reservoir, immersion system objects, power source, control systems, measurement and data collection systems. The electrolyte was a solution $(NH_4)_2SO_4$ with a concentration of 30 g/l [2, 3]. The power source with an output impedance of 0.18 Ohm has an open circuit voltage of 280 V, and provides current to the object to be treated up to 100 A. The source is equipped with a short circuit protection. The control system provides the set mode of operation of the installation, monitoring and indication of the current parameters. The system of measurement and data collection allows you to monitor the voltage and current on the object, as well as the temperature of the electrolyte in the processing area. Voltage and current are measured with accuracy not worse than 0.5 %, temperature – 1 %.

EXPERIMENTAL RESULTS AND DISCUSSION

Irradiation of the targets with the above parameters is accompanied by a complex of action mechanisms: pulsed heating in a gradient field, remitting of the surface layer, ablative release of matter from the surface [4], the appearance of compression-voltage pulses that form internal stresses [5], generation of bremsstrahlung and etc. The consequence of such a complex of effects is a variety of effects: grinding of grain of material, the formation of internal stresses, redistribution of elemental composition, the emergence of new phases. This leads to a change macrocharacteristics: microhardness, conductivity, plasticity [6], corrosion resistance, etc. It is of interest for us to elucidate the possibility of using electrolytic plasma treatment [7] to remove surface irregularities on the surface of materials that have been altered by the action of HCEB. In Fig. 1 shows an example of the microstructure of irradiated targets from steel 12Kh18N10T. The right part of the stainless steel sample (Fig. 1,b) was subjected to beam remitting, as a result of which it became finer-grained and the character of the fracture became more fragile in it, further the pores separating the modified layer from the deep layers are visible. Also on the right side (see Fig. 1,b), there are traces of the surface relief formed as a result of the beam remitting.



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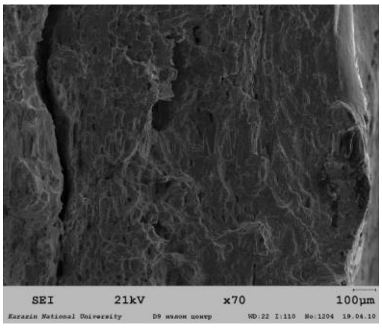


b

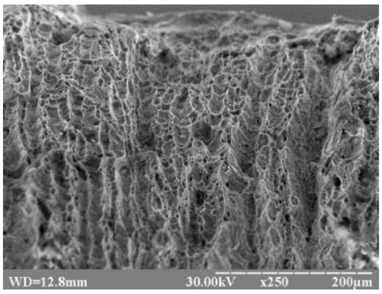
Fig. 1. Examples of the near-surface layer of 12Kh18N10T steel: unirradiated target region (a); the irradiated portion of the target (b)

Surface layer subjected to electron-beam processing in similar steels, for example, steel 45KhN2MFA has a higher value of microhardness, which is 2…3 times higher than the value in the initial material, which is explained by martensitic transformations [8], and the brittle fracture character is also evident (Fig. 2).

It can be seen that the modifying effect of the beam manifests itself in various effects that alter the properties of the near-surface layer, primarily in the change in the state of grain boundaries.

This gives grounds for expecting different intensities of substance removal from the surface processed by the electrolyte-plasma method. At the same time, it is known [6, 8] that the formation of a plasma cloud in contact with the surface being treated is accompanied by fluctuations in the current density and is manifested in cavitation and thermal action on the surface. In this respect, the surface treated with the HCEB is an interesting object for studying the "review" of the crystallization front of the substance melted by the pulsed beam, that is, the PEP is expected to selectively remove the least tightly bound segments the fragments of crystallites and the porous crests that result from the solidification of the ablation products.

As can be seen from Fig. 3 as a result of PEP from the non-irradiated surface, techno-logical impurities are eliminated, as well as traces of rolling, an increase in (a) and(b) is the same.



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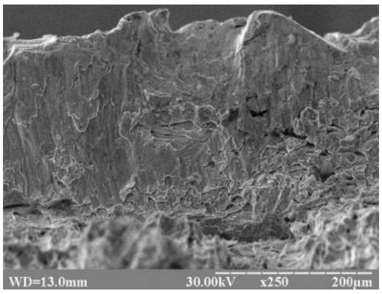

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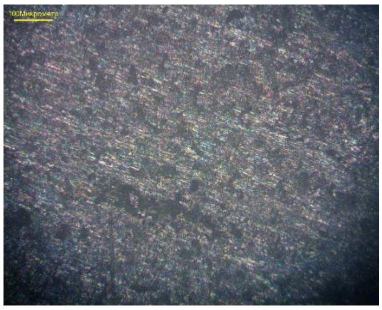
Fig. 2. The areas of the near-surface layer of stainless steel 45KhN2MFA: the unirradiated target area (a); the irradiated portion of the target (b)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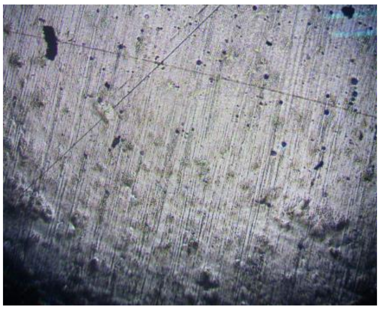
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Fig. 3. Surface of samples from steel 12Kh18N10T to (a) and after (b) PEP

On the trained surface (Fig. 4), traces of the removal of frozen droplets and irregularities that appeared as a result of swelling, as well as the reverse condensation of the evaporated material, are visible.

The PEP removes all types of contamination on the surface of objects while opening pores that were present in the material.

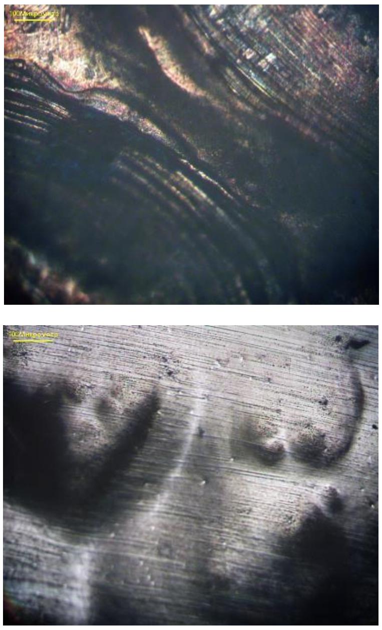

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Fig. 4. Surface of samples from steel 12Kh18N10T, which were preliminarily irradiated with a high-current beam, to (a) and after (b) PEP

The irradiated samples of stainless steel have a relief in the form of a large wavy structure with long periodic protrusions that are placed almost parallel within the wavy structure. The PEP effectively removes these protrusions and smoothest the sharp protruding edges of the larger structures that have arisen as a result of the recrystallization of the melt. As an example, Fig. 5 shows the surface profiles of samples of steel 12Kh18N10T, which were preliminarily irradiated with a high-current beam, to (a) and after (b) the PEP, the processing time is 12 minutes.

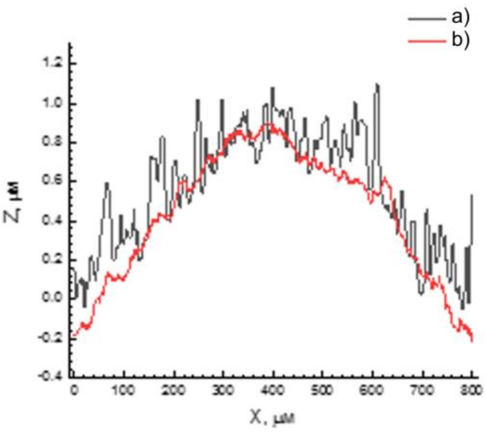

Fig. 5. The surface profiles of samples of steel 12Kh18N10T, which were previously irradiated with a high-current beam, to a) and after b) PEP, the processing time is 12 minutes

It is difficult to determine the precise values of the roughness parameters for surfaces with highly developed relief, since the standard techniques of ISO 4287-2-84 [9] give clearly overestimated results and cannot correctly describe the surface parameters [10]. The experiments on the PEP of stainless steel were carried out with an initial temperature of 60 °C with a further increase to 72 °C. The average weight loss value was 5×10^{-3} g·cm^{-2}·min^{-1}.

CONCLUSIONS

The experiments on electrolyte-plasma processing of previously irradiated high-current relativistic electron beams of the 12Kh18N10T steel surface showed that microroughness, droplets and other small surface elements of the relief can be effectively removed. At the same time, the undulating structure of the relief remains practically unchanged, with the exception of smoothing the sharp edges of the incrustations. In this connection, one can expect that the PEP method will be effective, for example, when polishing surfaces modified by other methods, for example, by electroerosive surfacing [11]. It is also important to study the effect of PEP on the elemental composition of the surface layer and its mechanical properties.

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ЭЛЕКТРОЛИТНО-ПЛАЗМЕННОЕ СГЛАЖИВАНИЕ РЕЛЬЕФА НА МИШЕНЯХ, ОБЛУЧЕННЫХ СИЛЬНОТОЧНЫМ РЕЛЯТИВИСТСКИМ ЭЛЕКТРОННЫМ ПУЧКОМ

Р.И. Старовойтов, А.В. Мигаль, А.В. Мороз, Б.А. Мазилин, С.Е. Донец, В.В. Литвиненко, Ю.Ф. Лонин, А.Г. Пономарев, В.Т. Уваров

Рассмотрена проблема возникновения рельефа на поверхностях металлов, модифицированных сильноточными релятивистскими электронными пучками. Показана технологическая перспективность данной модификации. Экспериментально исследована возможность применения метода электролитно-плазменной обработки для сглаживания возникающего рельефа. Показано, что электролитно-плазменная обработка снижает шероховатость поверхности в несколько раз без существенного повреждения модифицированного слоя. Полученные результаты указывают на перспективность использования модификации поверхности сильноточными электронными пучками в комбинации с электролитно-плазменной обработкой.

ЕЛЕКТРОЛІТНО-ПЛАЗМОВЕ ЗГЛАДЖУВАННЯ РЕЛЬЄФУ НА МІШЕНЯХ, ЩО ОПРОМІНЕНІ ПОТУЖНОСТРУМОВИМ РЕЛЯТИВІСТСЬКИМ ЕЛЕКТРОННИМ ПУЧКОМ

Р.І. Старовойтов, А.В. Мигаль, А.А. Мороз, Б.А. Мазілін, С.Є. Донець, В.В. Литвиненко, Ю.Ф. Лонін, А.Г. Пономарьов, В.Т. Уваров

Розглянуто проблему виникнення рельєфу на поверхнях металів, що модифіковані потужнострумовим релятивістським електронним пучком. Показана технологічна перспективність даної модифікації. Експериментально досліджена можливість застосування методу електролітно-плазмової обробки для згладжування рельєфу. Показано, що електролітно-плазмова обробка знижує шорсткість поверхні в кілька разів без істотного пошкодження модифікованого шару. Отримані результати вказують на перспективність використання модифікації поверхні потужнострумовим електронним пучком у комбінації з електролітно-плазмовою обробкою.