THE STRUCTURE OF THE UNDERSURFACE LAYER OF ALLOYS IN THE REGION OF INFLUENCE OF THE RELATIVISTIC TUBE-LIKE ELECTRON BEAM AND THERMODYNAMIC MODELS

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Influence of the pulse tubular relativistic electron beam on the structure of near-surface layer of steel 45 has been studied. It is shown that in the range of contact between the tubular beams and target the convexity and junction zones are arise. The convexity is characterized by the structure with microporosity and the junction zone has a high porosity. The thermodynamic model is proposed to describe the modulated structures appearing in the irradiated objects.

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1.INTRODUCTION

One of the prospective ways of modifying the properties of materials is the electrophysical treatment [1]. The treatment with the pulse beam of relativistic electrons leads to the alteration of physical and chemical undersurface layer of materials that is often used to obtain durable and protective coatings. At present, the investigations are conducted to develop technologies for the treatment of materials with powerful energy fluxes having the predefined form provided by the configuration of a cathode of an emitter. Due to the heterogeneous distribution of energy through the cross section of the beam the values of the modifiable parameters, e.g. microhardness, are different on the surface and in the volume of the irradiation object. It is emphasized in paper [2] that under the influence of powerful microsecond beams the pressure oscillations are created in the solid target being displayed as wave-like alterations of the microhardness along the irradiated zone. Therefore, it is interesting to study that the structure features of the undersurface layer modified by the tube-like beam of electrons, and to develop the technique of describing the modulated structures and soliton-like states which appear in the irradiated object.

2.EXPERIMENTAL METHODS AND DISSCUSION

The initial plates of the steel 45 of thickness 3 mm were irradiated with the high-current impulse beam of relativistic electron having the density of energy 10^9 $\mathrm{W/sm^2}$ (the beam energy $E_b \approx 0.5\mathrm{MeV}$, the current $I_b \approx 4\mathrm{kA}$, the pulse width $\tau_b \approx 5 \cdot 10^{-6} s$). The cylindrical cathodes were used as the electron emitter, which generated the tube-like electron flux [3]. The rate of cooling of the melted part of the target was of the order $10^6\,\mathrm{K/s}$.

Fig. shows the microstructure of the undersurface layer of steel 45 in the region of the most intensive influence of the pulse tube-like electron beam (the region of influence of the beam edge). The etching of the grinded samples did not show the existence of the crystal structure of the steel 45 plates. This could witness that the condensation of the melted part of the target leads to the amorphyzation of the undersurface layer.

The wave of compression and decompression formed under the beam influence is able to cause both the wavy alteration of microhardness and the heterogeneous distribution of cavitation.

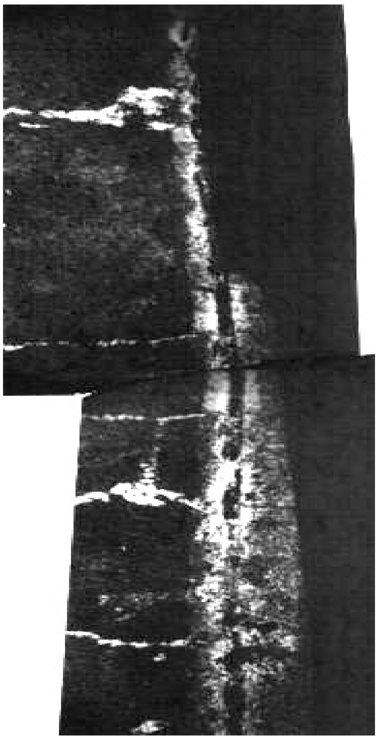
The later is the characteristic feature of the undersurface layer modified by this way. It is possible to distinguish three characteristic zones of the region of influence being considered (fig.). The melted zone has microdispersed cavitation. Then the region with highly pronounced oriented cavitation follows where the size of caves substantially exceeds that size in the preceding zone. The zone of thermal influence is again characterized by the microcaves.

3.THERMODYNAMICAL MODEL

The spatially modulated states with the order parameter $\varphi(x)$, arising in alloys under the beam influence are described with the minimum of the thermodynamic potential pf the form:

$$\Phi = \Phi_0 + \int dx \left\{ (\varphi'')^2 - \gamma(\varphi')^2 + q\varphi^2 + \frac{p}{2}\varphi^4 \right\}. \quad (1)$$

γ, q, p are the material parameters.



____ 15 μm

The microstructure of the undersurface layer of the steel 45 in the region of the most intensive influence of the pulse tube-like electron beam

Such one-component and one-dimensional models are not only the convenient objects for investigating the general aspects of theory but also reflect the concrete situations in different physical systems (modulated structures in ferroelectrics and magnetics [4], spinodal decomposition etc). The analysis of such models could be important for investigating the phase transition of the first and the second order in systems with $d > 1$ because of the special role the (quasi)low-dimensional structures can play in these cases.

Expression (1) differs from that one used in earlier papers devoted to the theory of modulated structures of one-component OP

The power terms in formula (1) describe the formation of the homogeneous OP states, meaning the conventional expansion of thermodynamical potential in the Landau model. The gradient terms in formula (1) provide the appearance of the space inhomogeneous phase described by the expression

$$\varphi(x) = a_0 \cos[b(x - x_0)] + a_1 \cos[3b(x - x_0)] + \ldots, \quad a_{i+1} << a_i, \quad (2)\ (4)$$

which is the solution of the linearized VDE for the functional (1) $\delta\Phi / \delta\varphi = 0$. The consideration of φ^4 (and φ^6) terms, in fact, does not change the linear character of solution (1). This circumstance gave rise to some doubts in the capability of model (1) to describe the succession of phase transitions: normal phase $\to$ modulated phase $\to$ commensurate phase. This succession of phase transitions is successfully described in the theory of the systems characterized by the two-component OP and which have the symmetry admitting the existence of Lifshits' invariants.

In the theory the states of soliton lattice type are known to be the consequence of competition and compromise between the Lifshits' invariants transfering the system into modulated state and the Dzyaloshinsky's invariants $w_a \rho^m (1 + \cos m\phi)$ characterizing the high-order anisotropy and describing the energy of commensurability. From the physical point of view this means that the consideration of the Dzyaloshinsky's invariants open the channel of the energy redistribution among different states by means of, for instance, the transfer processes.

The presented consideration has the character of useful analogy that helps us in finding the partial solutions of equation (2) and in understanding the properties of g -term. But we should keep in mind that the appearance of the modulated structure type solutions are usually connected with the existence of the long-range interactions in the system. Expelling the terms describing the contribution of long-range fields we get the non-local terms depending only on OP. If we do not take into account the concrete mechanism of realisation of long-range interaction, non-linear terms acquire the form.

4. CONCLUSION

It is found that due to the influence of pulse tube,-like relativistic one, the zone subjected to melting and forthcoming condensation has the amorphous structure with the cavitations of different dispersion. The zone of transition to the melted part of the target is characterized with large oriented caves. The analysis of the soliton solutions with allowance for the derivatives of higher orders is the promising apparatus for description of the modulated structures.

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СТРУКТУРА ПРИПОВЕРХНОСТНОГО СЛОЯ СПЛАВОВ В ОБЛАСТИ ВОЗДЕЙСТВИЯ РЕЛЯТИВИСТСКОГО ТРУБЧАТОГО ПУЧКА ЭЛЕКТРОНОВ И ТЕРМОДИНАМИЧЕСКИЕ МОДЕЛИ

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Изучено влияние воздействия импульсного трубчатого пучка релятивистских электронов на структурное состояние приповерхностного слоя стали 45. Показано, что в области контакта стенки трубчатого пучка с мишенью возникает выпуклое образование, характеризующееся мелкопористой структурой, а также переходная зона с повышенной пористостью. Предложена термодинамическая модель описания модулированных структур, возникающих в облучаемых объектах.

СТРУКТУРА ПРИПОВЕРХНЕВОГО ШАРУ СПЛАВІВ У МІСЦІ ДІЇ РЕЛЯТИВІСТСЬКОГО ТРУБЧАТОГО ПУЧКА ЕЛЕКТРОНІВ ТА ТЕРМОДИНАМІЧНІ МОДЕЛІ

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Вивчено вплив дії імпульсного трубчатого пучка релятивістських електронів на структурний стан приповерхневого шару сталі 45. Показано, що у місці контакту стінки трубчатого пучка з мішенню виникає випукле утворення, яке характеризується дрібнопористою структурою, а також перехідна зона з підвищеною пористістю. Запропоновано термодинамічну модель опису модульованих структур, які виникають у опромінюваних об'єктах.