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SOLID-PHASE METALLURGY IN COMPRESSOR BLADE MANUFACTURING: EFFECT OF ULTRASONIC STRENGTHENING ON SURFACE LAYER PROPERTIES

Purpose. To establish the influence of ultrasonic strengthening with steel balls on surface roughness, residual stresses, microhardness, and surface layer structure of compressor blades manufactured from titanium alloy blanks produced by solid-phase powder metallurgy technology.

Methodology. The study employed specimens manufactured from a powder mixture of VT8-grade titanium alloy components, using the intensive consolidation method – twist extrusion. Blade profile machining was performed by high-speed milling on a 5-axis machining centre. Ultrasonic treatment of specimen surfaces was conducted using steel balls with a 1.6 mm diameter and a hardness of HRC 62–66. Residual stress measurements in the surface layer were performed using the hole-drilling method, microhardness distribution was determined on bevelled sections, and surface profile examination was carried out using a digital profilometer.

Findings. It was established that strain hardening of the surface layer with steel balls in an ultrasonic field for 15 minutes ensures maximum compressive residual stresses in the surface layer (–515 to –520 MPa at a depth of 18–20 μm), uniform distribution of microhardness, and surface roughness not exceeding 0.4 μm. Increasing the treatment time leads to over-hardening and surface degradation. The structure of the treated layer retains the equiaxed bimodal character typical of VT8 titanium alloy.

Originality. For the first time, quantitative relationships have been established between ultrasonic strengthening parameters with steel balls and the stress-strain state, microhardness, roughness, and work-hardening depth of VT8 titanium alloy produced by solid-phase synthesis technology. Scientifically substantiated technological treatment parameters are proposed to ensure the formation of optimal surface layer properties for enhancing the durability of gas turbine engine blades.

Practical value. The proposed technological treatment parameters can be utilized in serial production or repair of gas turbine engine components, particularly in the aviation industry.

Keywords: *solid-phase metallurgy, severe plastic deformation, structure, blades, residual stresses, microhardness*

Introduction. Despite the active development of electric and piston engines, gas turbine engines remain the most sought-after in aviation. Their main advantage is significant specific power. However, unlike other engine types, their primary disadvantages are design complexity and high cost. The principal reasons for this are the substantial thermal and mechanical loads. This necessitates the use of high-strength titanium and aluminium alloys, heat-resistant nickel-based alloys, thermal barrier protective coatings, and coatings to protect aerodynamic profiles from erosive wear. This determines the need for specialized technologies for forming, machining, and heat treatment. Thus, study [1] demonstrates that in compressor blades made from the most commonly used titanium alloys VT6 (Ti-6Al-4V), VT3-1 (Ti-6.7Al-2.5Mo-1.8Cr-0.5Fe-0.25Si), and VT8 (Ti-6.8Al-3.5Mo-0.32Si), steady-state stresses can exceed 800 MPa at temperatures up to 600 °C.

However, the primary challenge in ensuring the structural reliability of blades is not so much the high level of steady stresses as the alternating stresses result-

ing from aerodynamic excitation by stator blades [2]. It is well established that high-cycle fatigue is a principal cause of their failure [3]. Given the thin, aerodynamic blade airfoil, the most effective approach to enhancing fatigue life is improving surface layer quality, which reduces surface roughness, strengthens the surface layer, and induces compressive residual stresses [4, 5]. Taking into account the peculiarities of titanium semi-finished product manufacturing by solid-phase metallurgy technology [6], the investigation and development of methods to ensure a favourable surface-layer condition from a fatigue-life perspective is a relevant objective.

Ultrasonic ball surface hardening (UBH) is currently regarded as one of the most promising methods for engineering modification of the surface layer state in titanium alloys. This is attributed to its ability not only to generate significant compressive residual stresses but also to form multilevel nanograin structures, thereby enhancing the material's operational performance. It is well established that the surface layer is most susceptible to cyclic and aggressive environments, and therefore determines the initiation and propagation of fatigue cracks, the rate of corrosion processes, and the overall service life of aircraft gas turbine engine components. Conven-

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tional surface treatment methods, such as shot peening, have limited potential due to shallower depth of influence and non-uniformity in residual stress formation. For this reason, the implementation of Ultrasonic Shot Peening/Ultrasonic Impact Treatment in modern technological processes is considered one of the key pathways to achieving substantial improvements in the durability of titanium alloys.

Despite the aforementioned achievements, most research focuses on coarse-grained or additively manufactured titanium alloys. For submicrocrystalline titanium alloys obtained by solid-phase synthesis from powders using severe plastic deformation methods, systematic data are scarce. There are no consistent recommendations for selecting UBH regimes that ensure the formation of an optimal stress-strain state in the surface layer without over-hardening, a controlled strengthening depth, the required microhardness, and acceptable roughness. The question of the long-term stability of these characteristics under actual service conditions, which combine high temperatures, cyclic loading, and aggressive environments, also remains open.

Thus, the relevant scientific and technical problem lies in the absence of substantiated technological parameters for ultrasonic ball hardening of submicrocrystalline titanium alloys that would enable purposeful formation of the stress-strain state of the surface layer and ensure the durability of critical aircraft engine components. Its resolution requires comprehensive parametric investigations to establish quantitative relationships between UBH regime parameters and residual stresses, microhardness, roughness, and work-hardening depth, and to develop scientifically substantiated recommendations for the aerospace industry.

Literature review. Ultrasonic ball hardening, the focus of this study, is a variant of ultrasonic shot peening that uses steel balls as the impact medium rather than conventional shot, enabling more precise control of surface treatment parameters. Ultrasonic ball surface hardening is attracting increasing attention from researchers due to its ability to form gradient structures with nanocrystalline zones, enhance microhardness, and generate compressive residual stresses that significantly affect the durability of titanium alloys. Contemporary scientific literature includes numerous works on wrought and cast titanium alloys, as well as on alloys produced by additive technologies. However, the optimization of ultrasonic hardening regimes for submicrocrystalline alloys remains open.

Agrawal, et al. [7] investigated the effect of ultrasonic shot peening duration on commercially pure titanium. It was established that short-duration treatment (60–90 s) promotes the formation of a nanostructured surface layer with improved corrosion properties and biocompatibility, whereas longer exposure leads to excessive surface roughening. These results emphasize the importance of selecting treatment parameters, particularly when the combination of mechanical and biomedical characteristics is decisive.

Cai, et al. [8], using β -forged TC17 alloy as an example, demonstrated that increasing the ultrasonic shot peening intensity from 0.15 to 0.25 mmA on the Almen scale results in a 12 % increase in average compressive residual stresses and a 29 % increase in the strengthened layer depth. However, a simultaneous 27 % increase in

roughness was observed, which may negatively affect operational properties. Thus, the study proves that process intensification does not always yield an unambiguously positive effect.

Sun and colleagues [9] demonstrated that variation in ultrasonic oscillation amplitude during Ti-6Al-4V alloy treatment directly affects residual stress levels and grain morphology. With increased amplitude, compressive stresses of -791 MPa were achieved, accompanied by a 28 % reduction in average grain size. This was accompanied by improved wear resistance, which is particularly important for aircraft components operating under friction and high-temperature conditions.

Yi, et al. [10] demonstrated that eight-minute treatment of TC4 titanium alloys forms a nanocrystalline layer with an average grain size of approximately 75 nm. Microhardness increases from ≈ 330 to ≈ 438 HV, while maximum compressive stresses reach -0.97 GPa, extending to a depth of up to 0.9 mm. These results confirm the high effectiveness of ultrasonic shot peening in creating a favourable stress-strain state.

Research by Zhang and colleagues [11], conducted on additively manufactured Ti-6Al-4V structures by selective laser melting, revealed significant improvements in corrosion resistance after ultrasonic treatment. The authors recorded an increase in corrosion potential, a decrease in corrosion current density, and increases in microhardness and residual stresses. This demonstrates that UBH can be an effective means for enhancing the reliability of additive products.

Qiu, et al. [12] investigated the effect of ultrasonic impact treatment on thin-walled titanium elements with holes. Significant improvements in fatigue-strength characteristics were demonstrated through the introduction of compressive residual stresses and local structural modifications. Such an effect is particularly important for aircraft structures, where fatigue in holes and stress-concentration zones are critical failure factors.

Perevalova, et al. [13] investigated the effect of ultrasonic impact treatment on 3D-printed Ti-6Al-4V structures. It was established that a nanocrystalline layer up to 5 μm thick and a submicrocrystalline layer up to 40 μm thick form, resulting in enhanced microhardness and fatigue life. Similar results were obtained for structures manufactured by Wire-Feed EBM, indicating the universality of the approach.

Avcu, et al. [14] demonstrated that shot peening treatment of powder Ti-6Al-4V alloys obtained by pressing leads to a reduction in crystallite size, a 17 % increase in microhardness, and significant enhancement in corrosion resistance due to the formation of a passivating oxide film. This study confirms that even non-traditional methods of titanium alloy formation respond positively to ultrasonic hardening.

Siahpour and colleagues [15] developed an environmentally friendly ultrasonic pulsating water jet method for treating L-PBF-manufactured Ti-6Al-4V components. The authors demonstrated that the novel approach can achieve an effect similar to conventional USP without using solid shot, thereby reducing the risk of surface contamination and negative environmental impact.

Wang, et al. [16] evaluated the effect of ultrasonic surface rolling and shot peening treatment on the fretting resistance of Ti-6Al-4V alloy. It was established that

both methods enhance fretting fatigue resistance; however, ultrasonic surface rolling produces deeper structural changes and a more stable effect than shot peening.

Thus, analysis of available works shows that although ultrasonic hardening effectively modifies the structure and properties of titanium alloys of various origins, systematic research specifically targeting submicrocrystalline materials is absent. Therefore, the objective of this work is to investigate the effect of ultrasonic steel ball surface hardening on surface roughness, residual stresses, microhardness, and the surface layer structure of compressor blades manufactured from titanium alloy blanks produced by solid-phase metallurgy technology.

Methods. Investigation of surface layer parameters after ball hardening in an ultrasonic concentrator was conducted on the airfoils of actual compressor blades. Blade blanks were manufactured from a mixture of VT8 titanium alloy powder components using the intensive consolidation method – twist extrusion. Semi-finished products with dimensions of $70 \times 28 \times 18$ mm were obtained, from which blade blanks were manufactured according to the methodology described in [17].

Profile forming and blade geometry were achieved through high-speed milling, ensuring the required surface finish ($Ra \leq 0.8 \mu\text{m}$) and the specified aerodynamic design parameters, with deviations not exceeding ± 0.02 mm.

Strain hardening of the surface layer of blade aerodynamic surfaces was performed by the ultrasonic treatment method.

The experimental setup for ultrasonic hardening included an ultrasonic oscillation generator with 400 W of power, equipped with a feedback system to maintain operational stability with $\pm 1\%$ accuracy, and a series of magnetostrictive transducers with a transformation ratio of 1:2.5. System calibration was performed before each treatment cycle using a reference specimen. Steel balls with a 1.6 mm diameter, manufactured in accordance with the requirements of DSTU GOST 3722:2018, were

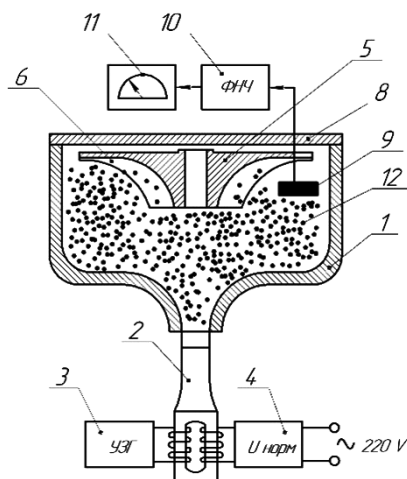


Fig. 1. Schematic diagram of the device for blade airfoil hardening with steel balls in ultrasonic field:

1 – horn; 2 – magnetostrictive transducer; 3 – ultrasonic generator UZG2-4M; 4 – magnetizing system; 5 – chamber; 6 – blades being hardened; 7 – reducer; 8 – screen; 9 – hardening intensity sensor; 10 – low-pass filter; 11 – millivoltmeter; 12 – steel balls

used as hardening media. The horn oscillation frequency was 17.5 kHz, corresponding to the resonant frequency of the “horn–hardening media” system (Fig. 1) and ensuring maximum energy transfer efficiency.

Resonant frequency determination was performed experimentally using two criteria: the maximum kinetic energy level of the balls, which was recorded by the hardening intensity sensor, and the sound pressure level created by the horn walls using an Olympus VT4U-SPL device. The ultrasonic hardening regimes were established as follows: diameter of hardening balls – 1.6 mm; treatment duration – 10–15 minutes for each surface area; treatment intensity – 4.1–4.2 mV; total mass of hardening media – 400 g.

Process quality control was performed comprehensively by monitoring horn oscillation amplitude with a Type 2511 vibrometer, measuring treated surface temperature with a Fluke62 infrared thermometer with $\pm 1^\circ\text{C}$ accuracy, and analysing the acoustic signal during treatment with a B&K 4307/4309 spectrum analyser. Hardening uniformity control was performed by measuring the surface-layer microhardness at points spaced 2 mm apart, with 5 indentations at each measurement point (Fig. 2).

Additionally, surface visual quality was assessed under an MBS-10 microscope at $\times 50$ magnification.

Measurement of values and distribution of residual stresses in the surface layer of blade airfoils was performed using the hole-drilling method, in accordance with the American Society for Testing and Materials standard ASTM E837 [18], on a SINT RESTAN MTS 3000 measurement system, which is part of a specialized system for residual stress determination.

The application of hole-drilling technology enabled establishing the nature of stress distribution in the surface layer of different sections of both concave and convex surfaces of blade airfoils with dimensions not exceeding 20×20 mm. Such blades are widely used in small gas turbine engine designs.

During the experiments, high-speed drilling at 300,000 rpm was employed, minimizing the influence of the machining process on the material structure. This, according to data [19], provides grounds for not considering the drilling process influence on strain gauge measurement accuracy, since at such regimes thermal loading practically does not affect the initial stress state in the material under investigation.

Strain gauge sensors were mounted on the convex surfaces of blade airfoils (Fig. 3), after which high-frequency drilling was performed, with parallel recording of surface deformation changes along three coordinates and synchronous calculation of the plane stress state components. Stepwise feeding of the drilling tool with a $10 \mu\text{m}$ step enabled investigation of the nature of the residual stress distribution in the surface layer to depths of $200 \mu\text{m}$ [20].

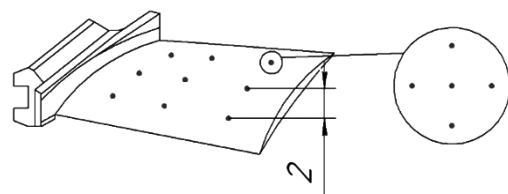


Fig. 2. Schematic diagram of microhardness measurement on the blade surface

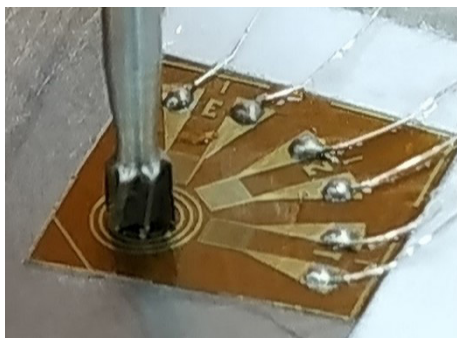


Fig. 3. CUSTOM-SOURCING strain gauge rosette type BX120-ICG on the compressor blade airfoil

Taking into account that the accumulated experience of domestic scientific works in the field of residual stress determination in gas turbine unit components is predominantly based on their measurement by the method of stepwise removal of thin metal layers, residual stress determination of the surface layer was conducted with consideration of two stress state components. This approach enabled obtaining stress values comparable in magnitude to the measurement results, according to the Davydenko N. N. methodology [21].

Deformation parameters of the surface layer were investigated by measuring microhardness at various distances from the surface on “taper sections”. Measurements were performed on a Vickers microhardness tester model MICROTECH® HVA-1 under an indenter load of 50 g. Taper sections were prepared by mounting specimens cut from the blade cross-section according to the scheme presented in Fig. 4, *a*. A grinding angle of 5–9° provides significant magnification of the visible area of thin surface layers for subsequent investigation. The taper section angle was determined from measurements on an X-ray image (Fig. 4, *b*). The degree of work hardening was defined as the ratio of the specimen’s surface microhardness to its core microhardness, expressed as a percentage.

Surface roughness was determined using a HANDY-SURF 45 profilometer-profilograph manufactured by ACCRETECH. The measuring traverse length was 5.6 mm, and the cutoff parameter was set at 0.8 mm.

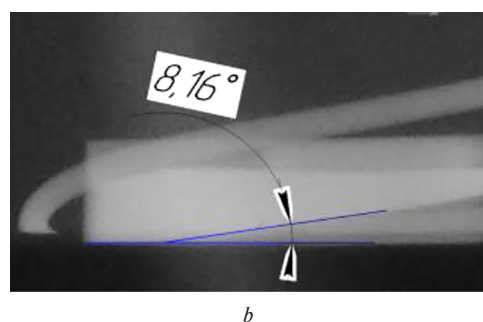
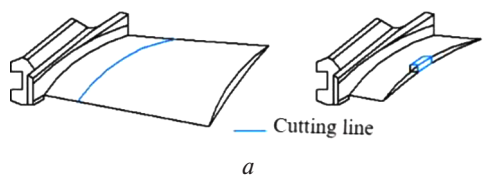


Fig. 4. Schematic diagram of specimen extraction from the compressor blade airfoil (*a*) and determination of the taper angle on the X-ray image (*b*)

The schematic arrangement of the measurement traverse on specimen surfaces is presented in Fig. 5.

Sample preparation for microstructure investigation included sequential grinding with abrasive materials from P80 to P2500, polishing with diamond pastes from 9 to 0.25 μm, and final polishing with colloidal silica 0.04–0.06 μm. After cleaning with distilled water and ethyl alcohol, the surface was etched with appropriate reagents for 5–60 seconds, depending on the material. Quality control included verification of mirror surface without scratches, clarity of grain boundaries, and etching uniformity under a microscope at 100–200x magnification.

Results. The technology for manufacturing components from titanium alloy semi-finished products obtained by powder metallurgy methods (Fig. 6, *a*) with subsequent plastic deformation by severe plastic deformation (SPD) methods (Fig. 6, *b*) involves the application of machining for forming primary surfaces, as well as finishing-strengthening treatment methods. The general technological process flowchart is presented in Fig. 7.

Microstructural investigation using an optical microscope revealed that the twist extrusion process refines the structural components of the blade blank material (Figs. 6, *c, d*). However, even at the magnifications used, precise determination of grain size proved impossible. This indicates the need for additional microstructural analysis methods or the application of higher magnifications or electron microscopy to obtain a quantitative evaluation of structural parameters. At the same time, visual indications of structure modification confirm the effectiveness of SPD in improving the microstructural state of the titanium alloy.

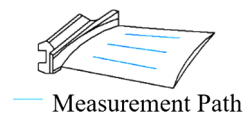


Fig. 5. Schematic arrangement of roughness measurement traverses relative to the specimen surface

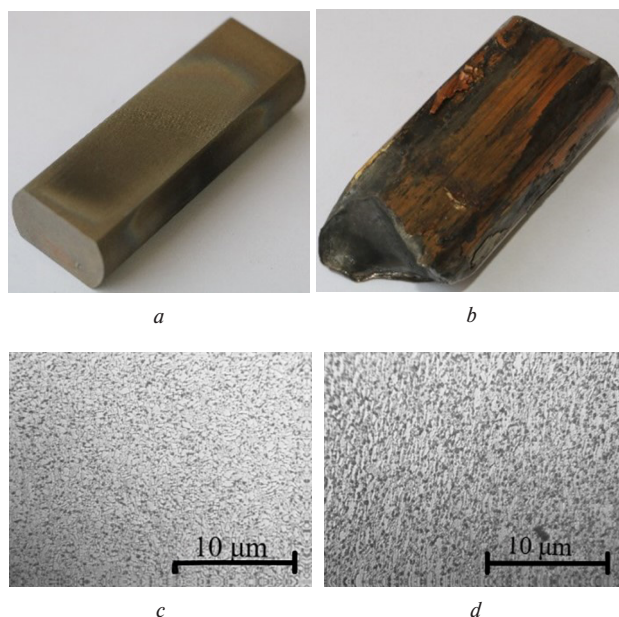


Fig. 6. General view (*a, b*) and microstructure (*c, d*) of VT8 alloy semi-finished product obtained by intensive consolidation technology of powder mixture

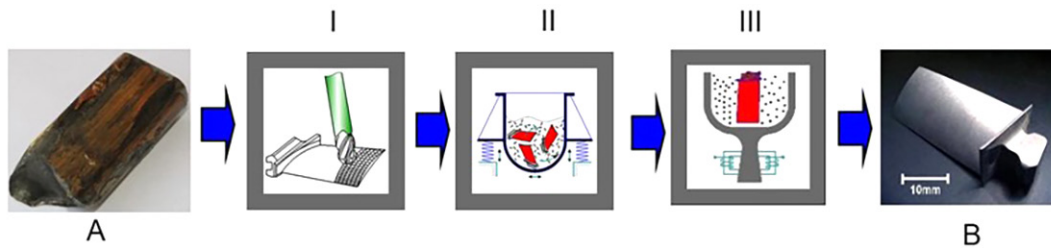


Fig. 7. Schematic diagram of technological process stages for compressor blade airfoil treatment:

I – high-speed milling; II – vibratory polishing; III – ultrasonic hardening; A – semi-finished product obtained by solid-phase metallurgy technology; B – compressor blade

The formation of deformation texture during the extrusion process is confirmed by the distinctly pronounced orientation of structural elements along the direction of blank displacement (Fig. 6, d). Such structure directionality indicates the intensive influence of plastic deformation during processing, leading to grain and phase component alignment in accordance with the applied force vector.

Analysis of surface profilograms of the blade airfoil after ultrasonic hardening indicates that their numerical roughness parameters are practically identical to those of analogous surfaces after vibratory polishing (Fig. 8).

In this case, a smoother, more refined microrelief is visually observed after ball treatment. The analysis of graphical data shows a reduction in sharp angular transitions and local peaks in micro-irregularity areas, indicating a modification of the blade surface character as a result of ultrasonic impulses from the balls.

The radius of curvature of micro-irregularity valleys after strengthening treatment significantly increased from $r = 0.66$ to $r = 0.72$ μm , as recorded in individual profilogram sections. A decrease in the total profile height R_t is observed, as well as noticeable smoothing of micro-irregularity valleys and formation of more gradual transitions between peaks and valleys.

These changes in the surface profile are confirmed by measurement results showing modifications in geometric characteristics without a significant impact on the overall roughness level.

Thus, finishing-strengthening treatment methods for blade airfoils improve surface microgeometric characteristics, including roughness parameters, thereby enhancing surface layer quality.

It was established that, across all investigated ultrasonic hardening regimes differing in treatment duration of 8–18 min, the formation of significant compressive residual stresses across the entire blade airfoil surface is

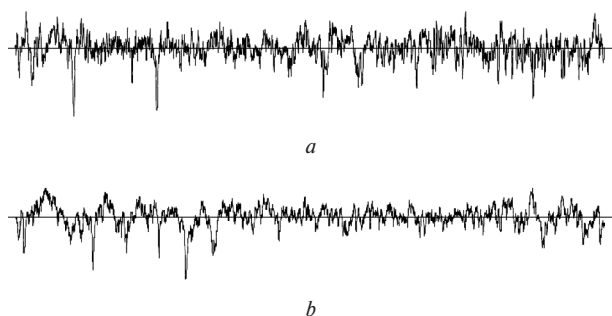


Fig. 8. Surface profile of blade airfoil after vibratory polishing (a) $R_a = 0.22$ μm and UBH (b) $R_a = 0.24$ μm (vertical magnification – 5,000, horizontal – 100)

characteristic. The maximum stress level in the surface layer forms during 15-minute hardening. In this case, their level and propagation depth increase compared to high-speed milling and vibratory polishing with rational parameters (Fig. 9). The distribution in the surface layer showed a subsurface maximum of -515 to -520 MPa at a depth of 18–20 μm , characteristic of shot peening strengthening. The total stress penetration depth was 130–135 μm .

For blades whose surface layers were subjected to ultrasonic hardening, the patterns of microhardness variation with surface-layer depth were investigated. The maximum microhardness was observed on the airfoil surface (Fig. 10). As the distance from the surface increased, microhardness approached that of non-hardened blades. The average microhardness of non-hardened blades was 4,470–4,530 MPa.

The depth and degree of surface work hardening varied with treatment time (Fig. 11). A decrease in the degree of work hardening at hardening times exceeding 14–15 min may be due to over-hardening, indicating the onset of surface layer deterioration.

The change in work-hardening depth can be explained as follows. During ball impact with the hardened surface, part of their kinetic energy was expended on plastic deformation of the metal. As a result, spherical plastically deformed regions formed in the surface layer, whose hardness and strength were higher than in adjacent non-deformed areas. Numerous ball impacts uniformly covered the hardened surface with plastic indentations, consequently forming a thin surface layer with modified physical-mechanical characteristics compared to the material core. The thickness of the deformed layer was determined from the plastic deforma-

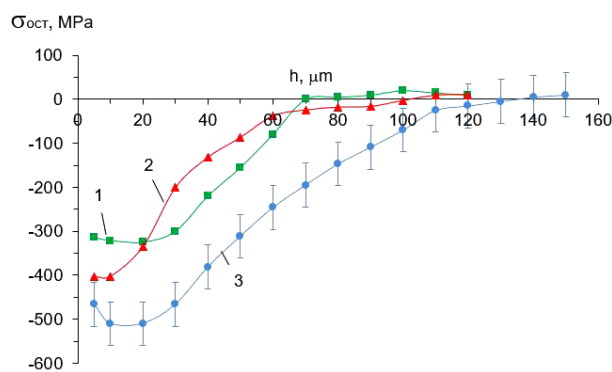


Fig. 9. Distribution diagrams of residual stresses in the surface layer of blade airfoils:

1 – HSM; 2 – polishing; 3 – UBH (15 min)

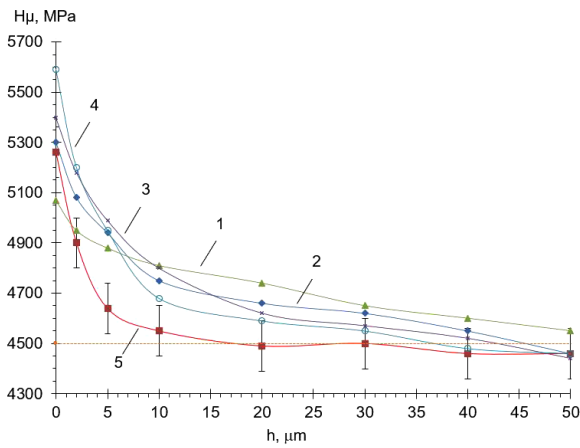


Fig. 10. Microhardness distribution in the surface layer of blades at different ultrasonic hardening durations: 1 – 8 min; 2 – 10 min; 3 – 12 min; 4 – 15 min; 5 – 18 min

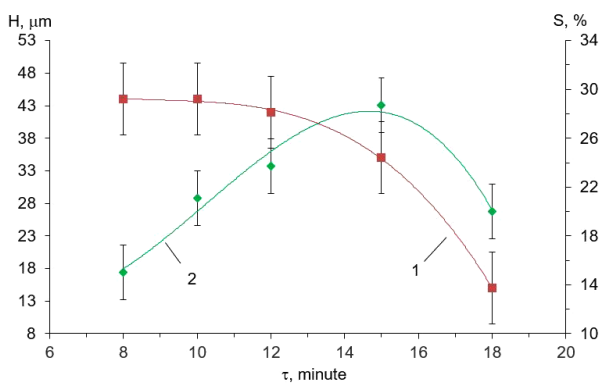
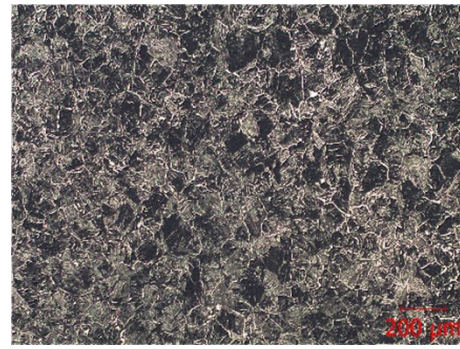


Fig. 11. Dependence of depth (1) and degree (2) of work hardening of the blade airfoil surface layer on ultrasonic hardening time

tion depth measured at individual ball impacts and depended on their mass, flight velocity, impact angle with the hardened surface, and other conditions. Considering that the hardness and yield strength of the surface layer increased during processing, the depth of the plastic deformation region from subsequent impacts was smaller than the already-formed deformed surface layer. Simultaneously with the decrease in the thickness of the strengthened layer due to additional deformation during the hardening process, its wear occurred, caused by the transfer of surface-layer material particles by the balls. As a result of multiple local plastic deformations accompanied by surface-layer wear, the thickness decreased during hardening, and consequently, the work-hardening depth decreased.

Investigation of the surface layer structure of blade airfoils that underwent a complete technological cycle, which included annealing at 650 °C after SPD, forming by high-speed milling, polishing, and ultrasonic ball hardening, enabled establishing that it has a typical (equiaxed, bimodal) type structure characteristic of VT8-type alloys (Fig. 12).

Conclusions. Investigation of the surface layer quality of compressor blades manufactured by solid-phase metallurgy technology (through intensive consolidation of a powder mixture) and formed by high-speed milling, with subsequent vibratory polishing and ultrasonic steel ball hardening, enabled establishing the main patterns



a



b

Fig. 12. Microstructure of the surface layer of blade airfoils from VT8 alloy

of residual stress changes, the degree and depth of work hardening, as well as surface roughness. Based on the analysis of established patterns, rational regimes for the main operations of the technological process were determined. Strain hardening of the surface layer with steel balls in an ultrasonic field for 15 min results in the formation of maximum compressive residual stresses, with a magnitude of -515 to -520 MPa at a depth of 18–20 μm , and a total compressive stress penetration depth of 130–135 μm . Increasing the hardening time beyond 15 minutes results in over-hardening of the surface layer and its deterioration. The airfoil surface roughness does not exceed 0.4 μm , which satisfies the requirements for compressor blade aerodynamic surface roughness. The material structure of the blade airfoil surface layer after forming and finishing-strengthening treatment methods represents a typical (equiaxed, bimodal) type structure characteristic of VT8-type alloys. Considering that strain hardening of the surface layer may redistribute alloying elements throughout its depth and, consequently, modify its properties, the prospect for further research is to study chemical composition changes in titanium alloys in the submicrocrystalline state during plastic deformation.

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Твердофазна металургія у виробництві лопаток компресора: вплив ультразвукового зміцнення на властивості поверхневого шару

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Мета. Встановлення впливу ультразвукового зміцнення сталевими кульками на шорсткість поверхні, залишкові напруження, мікротвердість і структуру поверхневого шару лопаток компресора, виготовлених із заготовок титанового сплаву, отриманих за технологією твердофазної металургії із порошків.

Методика. У роботі використовували зразки, що були виготовлені із суміші порошкових компонентів титанового сплаву, за хімічним складом відповідного ВТ8, методом інтенсивного ущільнення – гвинтовою екструзією. Обробку профілю лопаток виконували методом високошвидкісного фрезерування на 5-ти координатному обробляючому центрі. Ультразвукову обробку поверхонь зразків проводили із використанням сталевих кульок діаметром 1,6 мм із твердістю HRC 62–66. Вимірювання залишкових напружень у поверхневому шарі – методом свердлення малих отворів, визначення розподілу мікротвердості проводили на косих шліфах, дослідження профілю поверхні – із використанням цифрового профілографа.

Результати. Встановлено, що деформаційне зміцнення поверхневого шару сталевими кульками в ультразвуковому полі протягом 15 хв забезпечує максимальні залишкові напруження стиску в поверхневому шарі (–515– –520 МПа на глибині 18–20 мкм), рівномірне розподілення мікротвердості й шорсткості поверхні не вище 0,4 мкм. Збільшення часу обробки призводить до перенаклепу й руйнуванню поверхні. Структура обробленого шару зберігає рівноосний бімодальний характер, типовий для титанового сплаву ВТ8.

Наукова новизна. Уперше встановлені кількісні закономірності впливу режимів ультразвукового зміцнення сталевими кульками на напружено-деформований стан, мікротвердість, шорсткість і глибину наклепу титанового сплаву ВТ8, отриманого за технологією твердофазного синтезу. Запропоновані науково обґрунтовані технологічні режими обробки, що забезпечують формування оптимальних властивостей поверхневого шару з метою підвищення довговічності лопаток газотурбінних двигунів.

Практична значимість. Запропоновані технологічні параметри обробки можуть бути використані при серійному виробництві або ремонті деталей газотурбінних двигунів, зокрема в авіаційній галузі.

Ключові слова: твердофазна металургія, інтенсивна пластична деформація, структура, лопатки, залишкові напруження, мікротвердість

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