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MECHANICAL PROPERTIES OF γ -TiAl ALLOY AFTER SHOT PEENING

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Summary. *Currently, the alloys based on the titanium aluminide are in the great demand in the aerospace industry. This research project studies the mechanical properties of the γ-TiAl alloy with a high content of niobium and the impact of shot peening processing is defined. Strengthening of the surface by shot peening, does not affect the geometry of the parts, but it hinders the development of fatigue processes. Shot peening method can not only provide the extension of construction elements' operation period, but also enhances the mechanical properties of the alloy. Thus it can be stated that the higher durability is caused by the alteration in the structure of the surface layer.*

Key words: *γ-TiAl alloys, shot peening, the fatigue test.*

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Problem setting. The research and elaboration of titanium alloys required by aerospace industry have been carried out for many years. The creation of new space-crafts requires the new materials with the best combination of firmness and weight.

Analysis of the known research results. A lot of foreign companies like General Electric and Rolls-Royce run intensive research of properties of such prospect materials as titanium aluminides and their application in space-crafts and gas-turbine engines for aircrafts.

The alloys on the basis of TiAl (γ-TiAl) titanium aluminides are currently considered to be the most perspective materials in aerospace industry for production of gas-turbine airfoils of new generation [1]. They have a set of unique properties like high temperature of melting (1460 °C), considerable heat resistance and creep strength at high temperatures (600-800°C), high rates of elasticity module and corrosion resistance. But the main advantage of gamma alloys against thermoduric nickel alloys is their low density that is very important for aircrafts. Due to some authors [2] γ-TiAl alloys can substitute the existing nickel ones in gas-turbine engines (Table 1) in future. Nowadays the γ-TiAl alloys are already being used in high-speed low-pressure turbines.

Table № 1

Comparison table of alloys' properties on the basis of Titanium Aluminides, Titanium and Nickel [3]

Type of alloy	Characteristics				
	Density, $\times 10^3$ kg/m^3	Young module, GPa	Firmness boundary at extension, MPa	Relative lengthening, %	Ultimate operation temperature, °C
TiAl	3,6-4,2	160-180	400-650	1-5	800-900
Ti	› 4,5	95-115	300-1300	10-40	600
Ni	8,2-8,9	190-220	250-1300	5-50	1100

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Long-term operation time for machines and their parts depends on fatigue resistance. The fracturing of details usually starts from their outer layers because they are in the most stressed condition as they simultaneously are the boundaries between the phases and impacted considerably by the environment [4].

The reliability and durability of the elements of gas-turbine engines are predominantly determined with the physical & mechanical properties of outer layers. To enhance the fatigue resistance under cyclic and vibration stress they widely use the surface flexible deformation by means of shot-peening with ceramic or steel shot. Such surface processing provides its enhancement. The maximal tense residual stresses and certain depth and deformation rate level emerges on the processed surface.

The surface enhancement due to shot-peening does not twist the geometry of the parts but hinders the fatigability processes that are originated with damage. The latest researches in the sphere of γ-TiAl alloys have been focused on the enhancement of their mechanic properties. According to Lindemann [5] the shot-peening processing is an efficient method of surface enhancement for titanium alloys.

Research objectives. The impact of shot-peening processing upon mechanic properties of γ-TiAl alloys has not been studied yet. Hence, the research objectives are to clarify the influence of surface enhancement of titanium aluminide alloys by means of shot-peening.

Task setting. The research project deals with the comprehensive research of of γ-TiAl alloy specimen based on Ti-45 with contents 5.0 per cent of Niobium. Having been melted the specimens were polished with electrolyte to obtain the original condition (without scratches, tensions, and abrasives). Their surface was further flexibly deformed with ceramic and steel shot-peening. The mechanic tests were carried out on the specimens presented on Figure 1.

a) Ø ~ 8,5 mm, L ~ 50 mm

b) Ø ~ 4,0 mm, L ~ 20 mm

Figure 1. Specimens for mechanical fatigue-test (a) and extension (b)

Fatigue-tests were carried out at room temperature and symmetric cycle frequency 60 Hz. The wrecking exterior was designed with raster electronic microscope at voltage of 15 kW.

The alteration in firmness properties was analyzed after determination of micro-firmness and residual stresses.

Research results: Table 2 represents the mechanic properties of γ-TiAl alloy in terms of extension: E is flexibility module, $\sigma_{0,2}$ – conditional boundary of fluidity, $\sigma_в$ – boundary value of firmness, , δ – relative lengthening.

Table № 2

Experimental data for room temperature extension testing

Surface Condition	E [MPa]	$\sigma_{0,2}$ [MPa]	$\sigma_в$ [MPa]	δ [%]
Initial condition	159	850	916	0,82
After peening with ceramic shot	170	842	994	1,68

Analysis of mechanic extension test indicates that microstructural conditions, created as result of surface shot-peening, is marked with considerably higher firmness rate. The comparison the initial condition with the one after ceramic shot-peening displays that firmness boundary grew on 78 MPa: from 916 MPa to 994 MPa, the flexibility module increased on 11 MPa and relative lengthening skyrocketed from 0,82% to 1,68%.

Thus, the surface shot-peening facilitates improvement of material mechanic properties.

The analysis of specimen microstructure displayed that cracks are formed below the surface as it is shown on Figure 2.

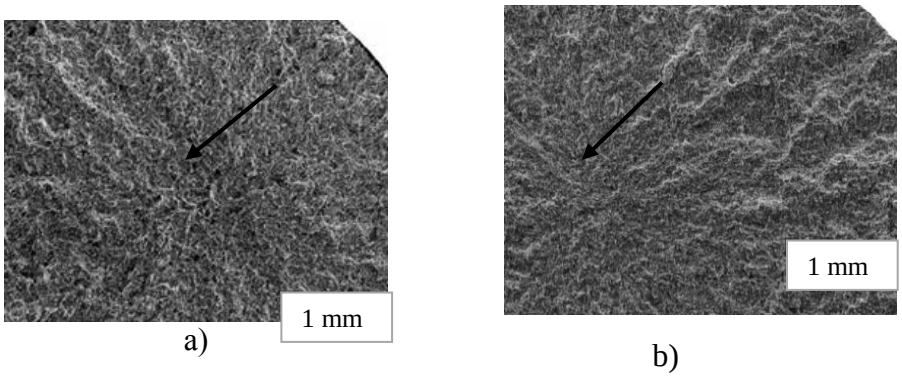

Figure 2. SEM pictures of typical tensile crack: a) after electrolytic polishing, b) after ceramic shot-peening

Figure 3 display s the results of specimen tests for titanium aluminide alloy after ceramic and steel shot-peening.

Both ceramic and steel shot-peening increases fatigability rate in comparison with original condition after electrolyte polishing. The lowest values of fatigue boundary under rotation bend for γ-TiAl alloy occurs after steel shot-peening – σ_a = 700 MPa, and the highest ones – after ceramic shot-peening – σ_a = 775MPa. Thus, one can state that firmness enhancement is stipulated with alterations in the structure of outer layer.

After shot-peening of alloy surface there was spotted the enhancement of micro-firmness, and the rate of residual stresses in the outer layer increased. The expertise of specimen after processing revealed the availability of explicit deformation in the outer layer.

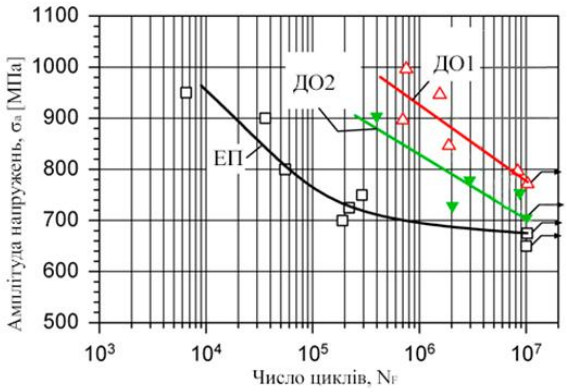

Figure 3. Fatigue curves for γ-TiAl alloy Ti-45 at% Al with contents of niobium of 5,0 at% in initial condition after ceramic (SP1) and steel (SP2) shot-peening

Figure 4 represents the bends exterior after fatigue tests.

The analysis of fracture graphs indicated that fatigue crack starts depth-ward propagating under specimen surface after surface supple deformation with shot-peening.

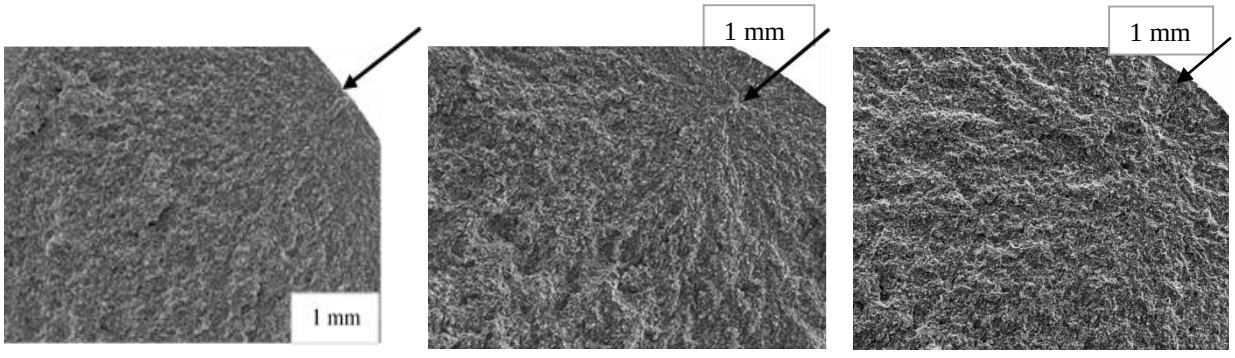

Figure 4. The exterior of cracks after fatigue tests: a) after electrolytic polishing (EP), b) after ceramic shot peening and EP, c) after steel shot peening and EP. The arrows show the crack propagation points

Conclusions.

1**.** Processing of γ-TiAl alloy surface with ceramic shot-peening provides the higher rate of counter-fatigue properties against steel shot-peening.

2. Shot-peening results in outer layer enhancement and an increase of residual stresses there.

3. The shot-peening also increases the operation time of parts and improves the mechanic properties of the alloy.

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МЕХАНІЧНІ ХАРАКТЕРИСТИКИ СПЛАВУ γ -TiAl ПІСЛЯ ДРОБЕСТРУМЕНЕВОЇ ОБРОБКИ

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Резюме. *На сьогодні сплави на основі алюмініду титану представляють найбільший інтерес в авіакосмічній промисловості. Проведено дослідження на механічні властивості сплаву γ-TiAl із високим вмістом ніобію і встановлено вплив дробеструйної обробки. Зміцнення поверхні дробеструйною обробкою не порушує геометрії деталей, але гальмує розвиток процесів при втомлюваності. Завдяки дробеструйній обробці можна не тільки продовжити термін служби конструкцій, а й підвищити механічні характеристики сплаву. Можна стверджувати, що збільшення міцності зумовлено змінами в структурі поверхневого шару.*

Ключові слова: *γ-TiAl сплави, дробеструйна обробка, випробування на втому.*

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