MICROSTRUCTURE AND DAMPING PROPERTIES FEATURES OF Ti-Al ALLOYS

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Today, damper metal materials with a porous structure are widely used in passive safety systems for absorbing mechanical energy under dynamic loads. Damping materials based on aluminum foam are the most widespread, due to its sufficient manufacturability and low cost. However, to obtain damping materials with a wider range of properties, the usage of porous products based on titanium, which has the best specific strength indicators, is one of the most promising directions for the development of damping and energy-absorbing materials.

Keywords: amping properties titanium alloys, powder metallurgy, damping capacity

Introduction. Today, materials with a high ability to dissipate elastic strain energy during mechanical vibration or wave propagation are widely used for vibration suppression. This class of materials is known as damping materials. One way to achieve high damping rates is to create porous materials. In particular, porous materials such as aluminum and titanium demonstrate a number of unique physical properties: low thermal conductivity, high specific stiffness, gas permeability and high impact energy absorption [1–3]. The benefit of this material is low density making it suitable for manufacturing lightweight structural components for use in automotive deformation zones. [2]. In general, Ti and its alloys demonstrate higher specific strength than Al alloys, making lightweight porous Ti and its alloys [4] potential candidates for significantly improving crash energy absorber characteristics in the front part of high-speed transport systems. Various methods have been proposed for obtaining porous Ti [4], such as powder compaction (suspension sintering), reactive sintering, sintering of hollow spheres [4] and gas capture technologies. However, these manufacturing methods can provide limited porosity of the material. Recently, the possibility of open cellular porous Ti–Al intermetallic alloys, synthesized through combustion reaction between Ti and Al powders, has been demonstrated [5].

Materials and methods. The material was synthesized using powder metallurgy methods with a hydride approach. Powders of titanium hydride and aluminum PA-2 were used as starting elements. Powders of specified sizes were mixed and pressed. Then the resulting compacts were sintered in a residual vacuum of 10^{-3} Pa and a heating rate of 7 °C/min up to 1250°C. During this process, hydrogen was completely removed from the material Next, an isothermal annealing was conducted at this temperature for approximately 2 hours. After the isothermal annealing process, the material was cooled down in a vacuum together with the furnace.

Results. X-ray phase analysis reveals the presence of two phases, TiAl and Ti_3Al, in the material (Fig. 1). The TiAl phase has a tetragonal lattice, while the Ti_3Al phase has a hexagonal lattice. However, upon detailed analysis of the obtained results, it can be noticed that some diffraction angles of these phases have the same values. For the composition Ti-20Al, the phase ratio was 30TiAl-70Ti_3Al. For the composition Ti-30Al, the ratio between the γ phase TiAl and the α2 phase Ti_3Al is equal.

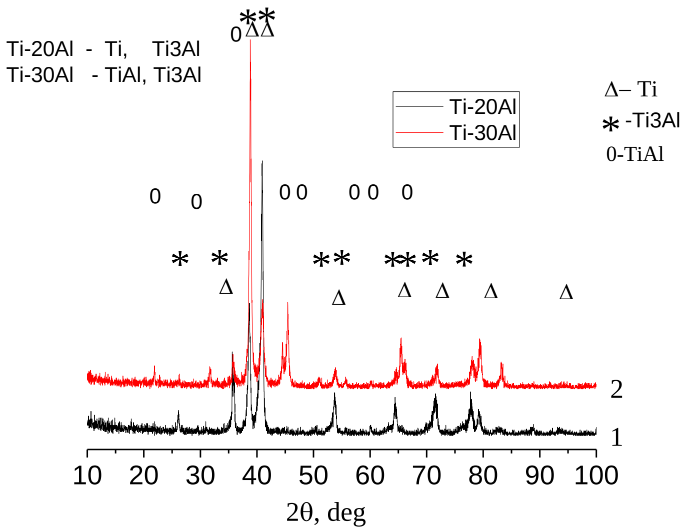

Fig. 1. "θ-2θ" The X-ray diffraction patterns of Ti-Al system samples: 1- Ti-20Al; 2- Ti-30Al (phases TiAl, Ti_3Al).

Figure 2 (a, b, c) shows the microstructure of materials with 20% aluminum. The microstructure is characterized by relatively uniform homogeneity. Inside the pores, a "loose" structure of intermetallic compounds can be observed.

The microstructure of the obtained intermetallic (Ti–30Al), shown in Fig. 2 has a similar appearance. A higher porosity is observed in comparison to the Ti–20%Al material (Fig. 2 a, b, c). Inside the pores, the structure of the material also looks "loose" due to the formation of intermetallics. This structural effect cannot be removed at this sintering temperature, as the melting temperature of the intermetallic is significantly higher.

Fig. 3 shows a comparison of the dependences of the vibration amplitude on time for each material. The time required for each material to cease vibration is a qualitative indicator of its damping capability. For intermetallic materials obtained by this method, the decay time differs slightly. For Ti-20Al, it takes 0.38 seconds for vibrations to cease, while for the Ti-30Al intermetallic, this time decreases to 0.28 seconds. However, the damping coefficients differ by 0.7 (1.7 for Ti–30Al and 1 for Ti–20Al). Ti–30Al demonstrates better damping performance, which can be attributed to its slightly higher porosity and the presence of two phases in the material (i.e., interphase transitions additionally absorb energy). It is also worth noting that the damping curve for Ti-30Al is smoother than for Ti–20Al, which, in the region of active decay, resembles a sinusoid with fluctuations in amplitude, providing a significant contribution to the overall damping capability of the material.

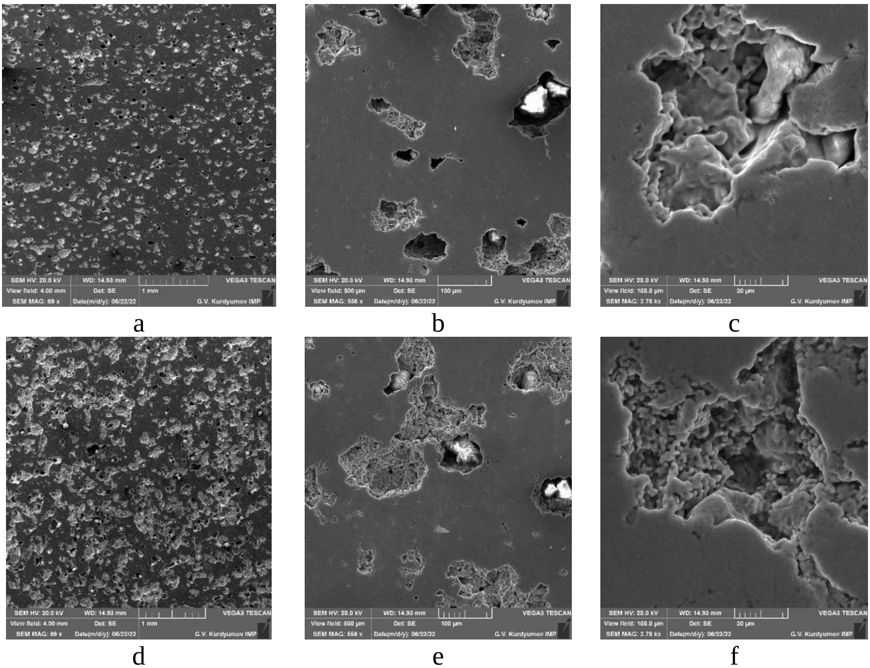

Fig. 2. As-sintered material with 20% (a, b, c) and 30% aluminum (d, e, f).

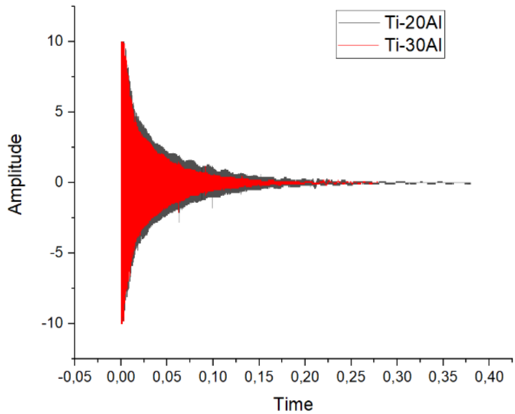

Fig. 3. Comparison of the damping amplitude for two materials with 20% and 30% Al.

Conclusion. Porous Ti–Al alloys were synthesized with different proportions of TiH_2 and Al powder mixtures. There are two phases in material with 20% aluminum: Ti_3Al and pure titanium. The residual porosity of this material is 30%. In the material synthesized with 30% Al, two phases were present: γ-TiAl and α_2-Ti_3Al. The residual porosity was 40%. It was demonstrated that these alloys exhibit a high energy absorption capacity (damping time of elastic waves is 0.3-0.4 seconds, and damping coefficient ranges from 1 to 1.7) due to their porous structure.

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