N1-P-040001

STRUCTURE FORMATION IN POWDER MATERIALS OF THE TI-AL-O SYSTEM UNDER REACTION SINTERING CONDITIONS*

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Titanium-based composite powder materials are of great interest due to the unique properties resulting from the synergistic effect of combining the properties of structural elements. Despite a large number of studies in this area, the question of the influence of some complex components on the structural-phase composition and physical and mechanical characteristics of a titanium-based powder composite remains open. These components include oxides of both titanium itself and other metals (Al_2O_3, Fe_2O_3), with which titanium interacts well. In particular, the Al_2O_3 compound has temperature coefficients of linear expansion (TCLE) similar to titanium, which solves the problem of residual stresses during processing. In addition, the oxide phase in titanium composites can be present not only as an inert additive, but also participate in reduction reactions. This is especially important when considering the structure formation of a composite under conditions of nonequilibrium combined technologies associated with sintering and reduction reactions. The problem is aggravated by the lack of adequate models of technological joint processes of sintering and reduction, accompanied by complex physical and chemical phenomena in non-equilibrium conditions under high-energy exposure. The production process of composite materials and products under sintering conditions in various technological processes, including additive technologies, MIM, spark sintering, etc., consists of many interconnected physical and chemical phenomena (for example, the interaction of mass and heat transfer processes with a complex set of chemical reactions and the field of mechanical stresses generated by the change in composition). In this regard, the presented work allows us to expand the understanding of some points that are associated with the interaction of the components of titanium-based powder materials with oxide additives under reaction sintering conditions. In this work, we analyzed the results of reaction sintering of a titanium-based powder material containing aluminum and titanium dioxide as additives. Moreover, the ratio of titanium dioxide and aluminum was calculated in such a way as to ensure the expected reduction reaction (TiO_2 + Al) → (Al_2O_3 + Ti) and the volume of possible synthesized oxide should not exceed 10%. To assess the effect of the mixing procedure in the formation of the structural-phase state, powder mixtures were prepared in two ways. The first way is simple mixing of all components for 4 hours, followed by treatment in an activator for no more than 60 minutes. The second way is two-stage mixing, where first a mixture of aluminum and titanium dioxide was processed in an activator, then titanium powder was added, and mixing was continued in an axial mixer for 2 hours. Specimens with a residual porosity of 35-38% were pressed from the resulting mixtures for subsequent vacuum sintering under controlled heating conditions at a temperature of 1150°C with an exposure of 60 minutes. The sintering results showed that the mixing procedure is of great importance in realizing the reaction sintering and the reduction step. Preliminary mechanical activation of the pair (TiO_2 + Al) did not fully guarantee the implementation of the reduction reaction, and after subsequent sintering, the titanium-based solid-solution phase dominated in the structure, where aluminum and oxygen were actually dissolved. Residual aluminum was also observed in small amounts (no more than 1%). On the other hand, as a result of the simultaneous mixing of all components, the transition of TiO_2 to Ti_2O occurred against the background of the formation of Al_2O_3 and TiAl, which was insignificant in terms of volume. Thus, it was shown that the aluminothermic reduction reaction of titanium from TiO_2 does not go to completion, but stops at the intermediate stage TiO_2 → Ti_2O.

* This research was supported by the Russian Science Foundation (Grant No 22-13-20031).