EFFECTS OF PRESSING TEMPERATURE ON THE CONSOLIDATION OF TITANIUM NICKELIDE POWDERS

V. E. Panin, A. I. Slosman, B. B. Ovechkin, and S. N. Kul'kov

The plastic aftereffect and the shape memory effect hinder the manufacture of high-density materials based on titanium nickelide by traditional powder metallurgy methods. Studies have been made on the effects of temperature and pressing pressure for powders containing titanium nickelide on the elastic aftereffect, crystal growth during the initial stage of sintering, and density of the sintered material. If the pressing is at a temperature exceeding the temperature for the start of the martensite transformation, one can increase the density of the material substantially by comparison with pressing at room temperature. For that purpose, the pressing temperature needs to be raised only to 200°C.

It has been found [1, 2] that traditional powder-metallurgy methods (static pressing with sintering) do not provide high-density components made of composites containing titanium mononickelide. In the mechanical loading (pressing), there is a reversible martensite transformation from the high-temperature phase with a B2 lattice to the low-temperature one with B19. On the subsequent sintering, there is the reverse transformation, which may be accompanied by partial powder shape recovery. This causes the pressing to swell and hinders the attainment of high density. Skorokhod et al. [3, 4] have examined the behavior of titanium nickelike powder and composites based on it during pressing.

High-density components made of titanium nickelide composites can be compacted by hot isostatic pressing [5] or explosive pressing [2]. Under these conditions, the reversible martensite transformations do not occur in the titanium nickelide, which favors making components with minimum porosity. However, hot isostatic pressing requires complicated equipment, and explosive pressing requires special measures because explosives are employed. These and other difficulties greatly restrict the industrial use of those methods.

One can prevent the martensite transformation during pressing and thus eliminate the shape memory effect that causes swelling on sintering by pressing above the temperature at which the martensite transformation starts in titanium nickelide. The impurities and the stoichiometry cause this temperature to vary from 200 to -150°C [6]. The temperature of the B2 → B19 transformation may be raised substantially by the stresses produced in the titanium nickelide. Therefore, during powder composite pressing at room temperature the martensite transformation occurs even if the phase equilibrium temperature is well below the room value. If one presses at a temperature above M_d such that the martensite transformation does not occur, i.e., only the high-temperature B2 phase persists in the titanium nickelide, then the pressing will not expand on subsequent sintering, which gives a denser material.

We checked this from pressing and sintering PN55T45 powder (TU 14-127-184-78) alone or in 1:1 mixtures with titanium carbide powder. The powder was annealed in a vacuum over at 800°C for 1 h before the pressing. Static bilateral pressing was provided in a vacuum chamber (pressure not more than 5 Pa) between 20 and 300°C. The pressures ranged from 100 to 900 MPa. Following pressing and cooling under vacuum to room temperature, the phase compositions were determined with a DRON-3 diffractometer, together with the elastic aftereffect. The sintering was in a vacuum oven at 0.1 MPa and 1280°C (titanium nickelide) or 1350°C (mixture of titanium carbide and nickelide). The densities were determined by hydrostatic weighing after cooling and the porosities were examined metallographically.

The powder has composition inhomogeneity due to the preparation method and has a wide range in the B2 → B19
martensite transformation temperature (from room temperature to \(-110^\circ\text{C}\)). In the initial state, the x-ray pattern shows reflections from austenite and from martensite, which are fairly broad (Fig. 1).

Figure 2 shows the elastic aftereffect as a function of pressing pressure in titanium nickelide powder, 50\% TiC + 50\% TiNi, and powder of VK8 hard alloy, in each case at room temperature. The elastic aftereffect is \(\delta = (V_2 - V_1)/V_1\), where \(V_1\) and \(V_2\) are the volumes of the pressing after loading and after load relief. The elastic aftereffect in VK8 is small (about 2\% at 100 MPa) but increases with the pressure, which is characteristic of an ordinary powder material. The titanium nickelide and the composite showed much larger aftereffects, which decreased as the pressure increased, since the plastic strain associated with the martensite transformation is increasingly accompanied by a mechanism involving irreversible plastic strain. Also, the deformed particles block one another, which hinders the return to the initial shape by reverse transformation.

Specimens containing titanium nickelide show considerable swelling on heating to about 500\°C, whereas there is only about 1\% swelling with VK8 ones. Figure 3 shows this from the volume change on heating (curves calculated from the above formula with \(V_1\) and \(V_2\) taken as the volumes before and after heating). X-ray phase analysis also shows that the proportion of low-temperature phase increases with the pressure (Fig. 4). With pressing temperatures of 20 and 100\°C, the phase