EFFECTS OF NITRIDING ON TITANIUM ALLOY STRENGTH AND PLASTICITY

I. M. Pogrelyuk, V. M. Fedirko, and V. A. Lopushans'kii

Nitriding is an effective way of raising the wear resistance of a titanium alloy. The nitrided layer adversely affects the mechanical characteristics, as do the high temperatures used in the saturation. Here we examine the effects of nitriding on the strength and plasticity of pseudo-α and α + β titanium alloys.

The nitriding was done in technically pure nitrogen (GOST 9293-74) without minor additives (H₂O vapor, O₂, etc.). We used small specimens of commercial pseudo-α alloys OT4-1 and VT20 and of the α + β alloys VT6s, VT6, VT14, and VT23. The short-time ultimate strength σᵤ was measured by a standard method,* as were the conditional yield point σ₀.₂ and the relative extension δ.

The highly plastic low-alloy low-strength pseudo-α alloy OT4-1 in a Ti-Al-Mn system on nitriding shows no substantial reduction in the strength characteristics (Fig. 1). After exposure for 10 h at 900°C, the short-time strength was equal to the initial value, while at 800 and 950°C, it was reduced by 7 and 6% correspondingly. At the same time, raising the temperature from 900 to 950°C (10 h) reduced σᵤ by 42 MPa, while on short-time hold (1 h), σᵤ increased by 26 MPa when the temperature was raised from 900 to 1000°C. There was a monotone increase in the short-time strength with the exposure time at 900°C, and after 25 h, σᵤ exceeded the initial value by 7%. The strength characteristics of the alloy on nitriding at a low density in a dynamic nitrogen atmosphere (at 950°C) exceeded by 7-9% not only those of the alloy nitrided in a static atmosphere but also the initial ones, which shows that the strength is dependent on the temperature and time of treatment and on the structural and phase compositions of the surface layers produced during saturation.

There is a substantial loss in plasticity (Fig. 1) from increasing the isothermal hold and the temperature. While the plasticity exceeded the initial value after nitriding at 800°C (10 h) and 900°C (1 h) by 12 and 7%, nitriding at 900°C (10 h) reduced it by 19%. Nitriding in a low-density dynamic atmosphere resulted in a plasticity in excess of the initial values, and substantially higher than after nitriding in a static atmosphere, while at 950°C (1 Pa and 10 h) the minimum level of the state of supply was maintained while accompanied by sufficient hardening in the surface layers.

The medium-strength pseudo-α alloy VT20 is formed in the Ti-Al-Zr-Mo-V system, and its loss of strength from nitriding was the largest among the alloys examined and constituted about 14-18% of the initial value. The short-time strength was almost insensitive to temperature change (900-950°C) with 10-h exposure. When the temperature was raised from 900 to 1000°C with a hold of 1 h, it was reduced by 27 MPa. In contrast to OT4-1, with longer exposures at 900°C, the strength of VT20 monotonically decreased.

The behavior of the plasticity characteristics for VT20 was basically as for OT4-1, with the only difference that nitriding at 900°C (1 h) caused them to exceed not only the initial values but also the values after nitriding at 800°C for 10 h. There was substantial embrittlement after nitriding at 950°C for 10 h and 900°C for 25 h, the values being 5.5 and 4.8% correspondingly. Those treatment states produced a broad nitrided zone with a high microhardness at the surface (80 μm and 8.9 GPa and 95 μm with 8.1 GPa correspondingly), while the maximum values for the plasticity occurred after treatment at 900°C (1 h) and 800°C (10 h), where the specimens had a zone depth of 40 μm and surface microhardness 5.5 GPa for 35 μm and 5.2 GPa correspondingly. Those treatment modes which provide a plasticity margin do not produce sufficient strengthening in the surface layers. When the nitriding conditions provided plasticity not less than the minimum laid down for the material (Fig. 1, 12.9 and 9.9% correspondingly for 850°C with 10 h and 900°C with 10 h), which guarantees the required surface hardening (60 μm with 6.0 GPa and 75 μm with 7.2 GPa correspondingly).

Medium-strength VT6s and high-strength VT6 are based on the Ti-Al-V system; the treatment reduced their strength by 7-12% (Fig. 1). There is only a minor effect on the short-time strength of VT6s from changing the isothermal hold temperature. In 10 h exposure, nitriding at 850, 900, and 950°C produced 961 MPa. At 800°C, this was increased by 20 MPa. A short hold (1 h) on raising the temperature from 900 to 1000°C reduced the strength by 29 MPa, while the conditional yield point increased by 49 MPa. With VT6, short exposure and long exposure (10 h) reduced the strength by 49 and 20 MPa when the temperature was raised from 900 to 1000°C or from 900 to 950°C correspondingly. Increasing the time at 900°C from 1 to 25 h had hardly any effect on the strength of the two alloys. Treating VT6s in low-density flowing nitrogen at 950°C did not have a marked effect on the strength characteristics. The \( \sigma_u \) for the alloy was slightly reduced on using low-pressure nitrogen at 850°C.

There was plasticity loss in VT6s/VT6 after exposure at 1000°C (1 h), 900°C (25 h), and 950°C (10 h), when \( \delta \) was 5.9/6.5, 5.0/4.0, and 6.3/5.4% correspondingly. With 1 h at 900°C and 10 h at 800°C, there was no incidental embrittlement. With 10 h at 850 and 900°C, the plasticity was reduced by 10-13%, but it was still above the minimum specified level.

Low-density dynamic nitrogen reduced the plasticity of VT6s at 850°C by 16-18% but raised it by 48-87% at 950°C by comparison with static treatment. The plasticity also increased as the gas pressure was reduced. However, at 950°C, this occurred only down to 1 Pa, and at \( 10^{-1} \) Pa, the plasticity fell sharply (by 21%). A similar trend occurs for OT4-1, namely 29% reduction (Fig. 1).