The mechanical properties of annealed alloys (1 h at 700°C in vacuum) were also determined at high temperatures (Fig. 9). The tests were made at 450 and 550°C on sheet samples 1.2 mm thick. The increase in concentration of chromium increases the strength of the alloy at 450°C. Addition of 3% AI increases the resistance to rupture at this temperature by 12-15 kg/cm².

The increase in concentration of chromium up to 4% increases the resistance to rupture at 550°C, but a further increase in the concentration of chromium does not increase the heat resistance of the alloy. The addition of 3% AI to alloys containing chromium also increases the resistance to rupture at 550°C by 12-18 kg/mm².

The weldability of Ti-Cr and Ti-Cr-AI alloys with argon-shielded arc welding was tested by subjecting the welded samples to bending tests (Fig. 10).

An increase in the concentration of chromium in binary alloys, and in alloys containing aluminum, decreases the weldability. This is due to an increase in the degree of supersaturation of martensite formed in the alloy during welding. When the concentration of chromium is close to its critical concentration, the weld seam is brittle. This is due to the formation of the brittle ω-phase in the alloys. Further increase in the chromium concentration up to 12% sharply increases the plasticity of the welds, because the plastic β-phase is formed in the weld seam.

Apparently a eutectic decomposition during welding occurs in the alloy containing 15% Cr, and the weld seam becomes brittle. In the alloy containing 15% Cr and 3% Al, eutectic decomposition is apparently impeded by aluminum, and the weld seam in this alloy is highly plastic.

**DILATOMETRIC INVESTIGATION OF BINARY ALLOYS OF TITANIUM**

B. A. Borok, E. K. Novikova, L. S. Golubeva, R. P. Shchegoleva, and N. A. Ruch'eva

Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 2, pp. 32-36, February, 1963

We made a dilatometric investigation of Ti-Fe, Ti-Cr, Ti-Co, Ti-Mo, Ti-V, Ti-Nb, and Ti-Ta alloys containing 2-10% alloyed elements and determined the phase composition of these alloys by micrographic and X-ray methods. We also investigated the variation of hardness as a function of heat treatment.

The alloys were prepared by sintering, using a powder of technically pure IMP-1A titanium [1]. The sintered alloys were forged at 700-1000°C into rods 16 mm in diameter. Samples were cut from these rods. Concentrations of impurities in forged samples of technically pure titanium alone were 0.23% Fe, 0.05% Si, 0.1% Ni, 0.027% Ca, 0.0019% H, 0.098% N, 0.20% O, and 0.03% C, and the mechanical properties were: σₜ = 75 kg/mm², σ₈ = 65 kg/mm², δ = 20.4%, ψ = 48.9%, and σ₉ = 5.4 kgm/cm².

Concentrations of impurities in the alloys with iron, chromium, molybdenum, and vanadium were about the same as in technically pure titanium alone. The alloys with cobalt, niobium, and tantalum had a slightly higher concentration of oxygen (up to 0.22%).

The dilatometric tests were made by the standard method on the Leitz dilatometer at 20-950°C in air. Samples of chronin alloys were used as a standard of comparison. The samples were heated at the rate of 3°/min.

The dilatometric curves of annealed* samples do not indicate any transformations. These results refer to single-phase alloys with an α-structure (in an annealed state), two-phase alloys with an α + β-structure or α + intermetallic

* The rods were annealed at 800 and 900°C for 1 h. The cooling rates were 50 and 100°/h.
compound structure, and three-phase alloys with an $\alpha + \beta + \gamma$ intermetallic compound structure. The $\beta$-phase may be stable (in alloys with an isomorphous $\beta$-stabilizer—molybdenum, vanadium, niobium, tantalum) or metastable (in alloys with $\beta$-stabilizers which form eutectics—iron, chromium, cobalt, and nickel). The slopes of the dilatometric curves of annealed alloys (Ti–Fe and Ti–Cr, for example) remain constant, which indicates that the coefficient of linear expansion remains constant.

Dilatometric curves were also obtained with samples quenched from temperatures of the single-phase $\beta$-region.

The phase composition and the hardness of the alloys after quenching and also after annealing are given in the table and in Figs. 1 and 2.

Dilatometric curves for alloys of titanium with elements which stabilize the $\beta$-phase and induce eutectic transformation (iron, chromium, cobalt) have discontinuities at temperatures corresponding to the $\omega$-transformation at certain concentrations of these elements (Fig. 3).

The dilatometric curve for the alloy containing 2% Fe does not have a discontinuity. The microstructure of this alloy after quenching is a two-phase structure which contains $\alpha'$-phase and a small amount of $\beta$-phase. The hardness of the quenched alloy is not great (RC = 37.5); it does not change on annealing.

The alloy containing 4% Fe (critical concentration of iron) has a two-phase ($\beta + \omega$) structure and is very hard (RC = 51.5) after quenching. No compression induced by the formation of the $\omega$-phase is indicated on the dilatometric curve. Expansion induced by the reverse transformation $\beta + \omega \rightarrow \beta + \alpha$ begins at 420°C and terminates at 490°C.

The alloy containing 6% Fe also has a two-phase structure, $\beta + (\omega)$, and its hardness is RC = 44.5 after quenching. During annealing an additional amount of $\omega$-phase precipitates, increasing the hardness of the alloy to RC = 53.

Note: 1) The parentheses enclosing the $\omega$-phase indicate that this phase is precipitated partly during quenching but primarily during annealing; the double parentheses indicate that a small amount of this phase is precipitated during quenching but that most of it is precipitated during annealing; no parentheses indicates that this phase is precipitated during quenching. 2) Samples were heated 30 min before quenching in water.