Fracture Surface Analysis of a Quenched (α+β)-Metastable Titanium Alloy

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MATERIAL AND METHODS

Hot-rolled and annealed rods 11 mm in diameter made of VT16 (Ti - 3,33Al - 5,18Mo – 4,57V weight %) were produced by industrial technology at VSMPO AVISMA corporation. The rods were solution treated at a temperature in the range of 700-875 °C (heating step was 25 °C) for 1 hour and water quenched. Quenched rods were separated to dog-bone shape specimens for tensile testing on FP100/1 testing machine in accordance with ISO 6892-1. The fracture surface of tested specimens was studied using scanning electron microscope FEI Quanta 3D.

RESULTS

- According to the data of [1], failure during tensile testing includes the following steps: 1) macroplastic deformation accompanied by necking; 2) origination and development of micropores in the central region of the specimen; 3) interaction of the microdefects and formation of the cup surface normally to the stress axis; 4) slow crack propagation from the cup edge along the conical surface; 5) fast propagation of the crack developing by means of the shear mechanism.
- Fractographic examination revealed that the fracture surfaces were straight with bevels and were characterized by a cup and cone shape after all quenching temperatures [2].
- A dimple configuration of the surface microstructure was observed for all the quenched samples, which argues for ductile failure as well [3].
- Average dimple diameter of quenched specimens correlated with the average β-grain size which was determined by the primary α-phase fraction with the size of about 3 mkm for quenching temperatures in the range of 700…775 °C, 5 mkm for T_q=800°C, 10-13 mkm for T_q=825-850°C and 70 mkm for Tq=875 °C. Thus, we conclude that fracture was initiated at an interphase α/β-boundary, and then it propagated into the β-grain body accompanied by the formation of the dimples which dimensions were comparable to the β-grain size. This is confirmed by the presence of α-particles at the bottom of the dimples.
- In the conical region of fracture surface, the relationship between major and the minor axes lengths (a, b, a1, b1) of the oval decrease as well as the volume fraction of α-phase decrease along with the increasing of solution treatment temperature (Fig. 1, Table 1). This effect is related to the anisotropy of failure process due to the presence of α-phase which HCP-lattice is more anisotropic than BCC lattice of β-phase.
- Elongation of the specimen during tensile testing correlated with the dimensional ratio of central fiber region of cup and the periphery region of cone (Fig. 1, Table 1). For the majority of the specimens, the higher values of the elongation were observed as the width of the cone zone increased and the size of the cup zone decreased (Fig. 1), which is characteristic of ductile materials [7].
- On the fracture surface of the specimens quenched from 750 and 775 ° C, hollows and protrusions develop at the border between the cup and the cone (Fig. 1 c - marked with arrows). The structure of the fracture surface in these regions is similar to the shear zone. However, the crack propagates changing its direction in contrast to the shear zone where the only one direction is typical. We suppose that this effect was due to the strain-induced β-α″-transformation during the tensile test and the appearance of α″-martensite in structure of the alloy, according to the data of [4]. Thus, the unstable failure process can occur due to significant local hardening when passing to the shear zone.

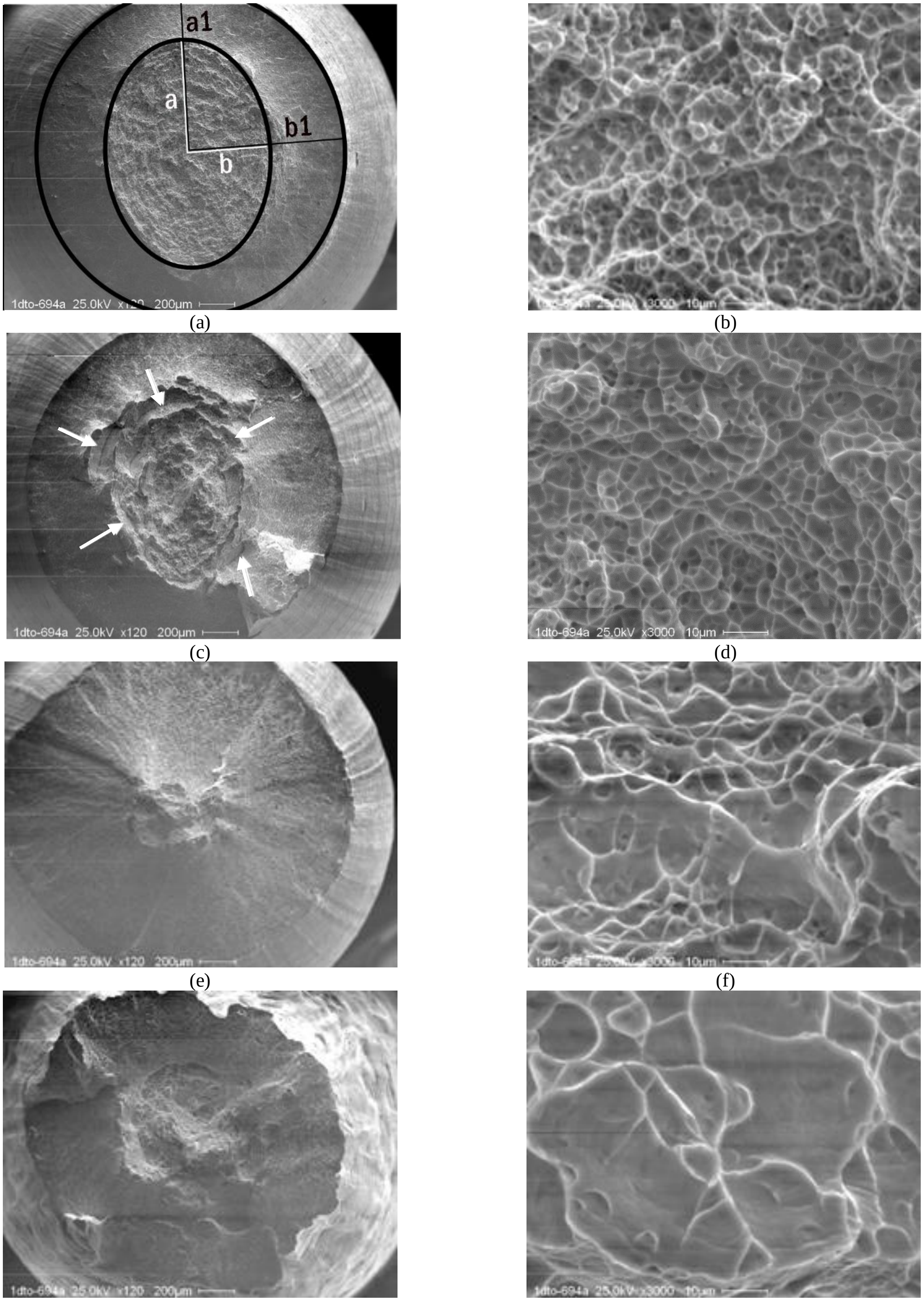

FIGURE 1. Fracture surface structure of VT16 samples solution treated at a, b – 725 °C; c, d – 775 °C; e, f – 850 °C; g, h – 875 °C for 1 hour and quenched.

TABLE 1. Phase composition, elongation and geometric parameters of fracture surface of solution treated and quenched VT16 alloy

T_q, °C	700	725	750	775	800	825	850	875
Phase [4]	α +β	α +β	α +β	β+α+α″	α″+α+ β	α″+α+ β	α″+α	α″+(α)
δ, % [5]	15	18	17	18	20	20	22	23
a, μm	500	500	500	400-450	225	175	150	300
b, μm	700	650	625	585	250-300	250-275	200-275	300
a1, μm	875	885	950	900	950	945	950	875
b1, μm	1000	1000	1000	1000	1050	1000	1000	900
a1-a	375	385	450	475	725	825	800	575
b1-b	300	350	375	415	775	725	762	600
b/a	1.4	1.3	1.25	1.38	1.22	1.5	1.58	1
b1/a1	1.14	1.13	1.07	1.11	1.105	1.06	1.05	1.03

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