INFLUENCE OF THE PARAMETERS OF A LAMINATED STRUCTURE ON THE
MECHANICAL PROPERTIES OF TITANIUM ALLOYS

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I. Introduction

Titanium alloys display a great variety of laminated structures. The mechanical properties of semi-finished products with such structures, ductility in particular, vary over a wide range.\(^{1-3}\) Thus, for the two-phase alloys with a laminated structure, BT3-1, BT9, and others in an annealed state the reduction in area varies from very low values (5-10\%) up to relatively high values (30-40\%) approaching the ductility level of these alloys with globular structure. The difference in fatigue strength, fracture toughness, and other properties may also be significant (up to 25-30\%) for various types of laminated structures.

It was found in our earlier investigations\(^{3,4}\) that the microstructural pattern of deformation and fracture of titanium alloys with a laminated structure subjected to tensile bending tests depends on the size of the initial \(\beta\)-grains (\(D\)), on the size of the intergranular \(\alpha\)-clusters (\(d\)), and on the thickness of \(\alpha\)-laminae (\(b\)). The main goal of this investigation was, therefore, to study the effect of the structural parameters \(D, d,\) and \(b\) upon the mechanical properties of various titanium alloys.

II. Experimental Procedure

The study was carried out using rolled rods and forgings of different size made of the \(\alpha\)-alloy BT5-1 (Ti - 5Al - 2.5Sn), the pseudo \(\alpha\)-alloy OT4 (Ti - 3Al - 1.5Mn), and the medium (\(\alpha+\beta\)) alloys VT3-1 (Ti - 6Al - 2Cr - 2.5Mo - 0.2Si) and BT9 (Ti - 6.5Al -
2Zr - 3Mo - 0.2Si). Each alloy was studied in several ingots. The various laminated structures were obtained by changing the conditions of deformation and by preliminary B-heat treatment. The final heat treatment (annealing) was performed at temperatures below that of the (α+β)→β-transition.

The rods and forgings were used for determining the ultimate tensile strength (σ_u), the ultimate elongation (δ), the total reduction of area (ψ), the impact strength (σ_H), the work of fracture under impact bending of specimens with a fatigue crack (a_c_f), the fracture toughness (K_I_C), and the fatigue strength (σ_1).

The mechanical properties, except for K_I_C, were determined on standard specimens by standard procedures. The single-notched specimens 12x24x90 mm in size with a fatigue crack were employed for the fracture toughness tests.

The microstructure of all the specimens was studied after the tests. The dimensions of structural constituents were estimated by the secant method. Several specimens were subjected to the X-ray diffraction study to determine the lattice parameter of the β-phase (a_β) from the line (321)β-Ti, and the total disorientation angle of the α-laminae (Δa) from the broadening of the line (001)α-Ti in some β-grains.

III. Results and Discussion

The dependence of the mechanical properties of the BT3-1 and BT5-1 alloys on the laminated-structure parameters D,d, and b is shown in Figure 1. One of the causes of a considerable scatter in the experimental data is the fact that each diagram is constructed without taking account of the other structural parameters. Nevertheless, these diagrams show a certain relationship between the dimensions of the structural constituents and the mechanical properties, ductility in particular. For instance, as the size of β-grains increases, the ductility decreases in all the alloys, whereas the dependence of the mechanical properties of the (α+β)-alloys on the size of α-clusters and the thickness of α-laminae is pronounced.

When α-clusters grow up to 25-30 μm and α-laminae become as thick as 2.5-3.5μm the BT3-1 and BT9 alloys display a sharp increase in ductility and decrease in strength. With further

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