Single-crystal elastic-constants and load partitioning in titanium alloys

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Single-crystal elastic constants (SEC) are fundamental parameters for the behavior of any material under mechanical load. Various methods such as the diffraction-based stress-analysis, elasto-plastic modeling or finite-element modeling rely on SEC as input parameters. Conventional methods to derive elastic constants, for instance ultra-sonic techniques, require single crystals. However, the fabrication of single-crystalline specimens of most engineering-alloys is difficult or even impossible.
Titanium alloys are extensively applied in aircrafts, medical products or consumer goods. Alloys of actual research interest include two-phase (h.c.p. α-phase + b.c.c. β-phase) or β-alloys containing a significant amount of alloying elements. Here, the only experimental way to determine SEC is diffraction on polycrystalline samples under mechanical stress.
Diffraction allows the measurement of lattice strains for each phase in poly-crystalline and multi-phase materials. In a kind of reversal of the classical stress analysis in-situ diffraction studies on polycrystalline samples can be carried out under applied mechanical load. Based on model assumptions for grain-to grain interactions (for instance Voigt, Reuss, Hill approximations), the elastic tensor components (i.e. the SEC) can be calculated by minimization techniques. This method requires to measure changes in lattice plane distances for a series of hkl-reflections as a function of the applied mechanical load. We have applied this method on titanium alloys Ti-6Al-4V (Ti-64, near α-alloy), Ti-3Al-8V-6Cr-4Zr-4Mo (Ti-38644, β-alloy) and Ti-6Al-2Sn-4Zr-6Mo (Ti-6246, α+β-alloy) using neutron and synchrotron diffraction together with specially designed tensile rig which allows to orient the load axis in a Eulerian cradle like manner [1].

In Ti-6246 the five elastic contants in the h.c.p- α-phase and the three elastic constants in the b.c.c. β-phase were determined. However, in two-phase titanium alloys a load partitioning between the stiffer α-phase and the softer β-phase is expected. Hence, the main focus of this study was to analyse the effect of load partitioning on the elastic properties of the constituent phases. Thus, an approach for the load transfer based on the stiffnesses of the phase was implemented in the analysis. By this means the directly measured “apparent” elastic constants of the phases can be compared with “corrected values” for the pure phases. Based on a phase ratio of α:β 78:22% obtained by Rietveld refinement, a load transfer corresponding to 3% increase in stress for the α-phase and 11% decrease for the β-phase was obtained. It was found that the load transfer corrected elastic constants match very well to corresponding values of Ti-64 (α-phase) and Ti-38644 (β-phase) [2].

In the literature values for the elastic constants in β-Ti phase can be found which differ quite significantly. However, our data show a remarkable coincidence for the β-phase in the alloys Ti-38644 and Ti-6246Mo *after applying the load transfer correction* for the two-phase Ti-6246. Thus, our results indicate that the differences in the apparent elastic constants in the β-phase found in different alloys could be related to a load relocation with the present α-phase.

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