Determination of the lattice misfit and strength in dependence of temperature of precipitation strengthened Co-base superalloys

S. Neumeier¹, L. Freund¹, A. Stark², F. Pyczak², M. Göken¹

¹Institute I: General Materials Properties, Universität Erlangen-Nürnberg, Martensstraße 5, 91058 Erlangen, Germany
²Institute of Metal Physics, Helmholtz-Zentrum Geesthacht, Max-Planck-Straße 1, 21502 Geesthacht, Germany

In 2006, Sato et al. [1] discovered the possibility of hardening Co-Al-W alloys with coherent, L1₂-ordered γ’ precipitates resulting in alloys with very good mechanical properties at high temperatures. The γ’-volume fraction and γ’-solvus temperature, the thermal expansion of both phases and the lattice misfit between them leading to coherency stresses are important parameters which influence the mechanical properties of an alloy.

In the conducted experiment at HEMS beamline, two newly developed γ’ strengthened wrought Co-base superalloys have been investigated. The cylindrical samples were heated in steps of 50°C from RT to 1050°C to determine the lattice misfit over temperature and γ’-solvus temperature. Additionally, both alloys have been deformed in-situ at different temperatures in a deformation dilatometer DIL850 A/D. First results for this deformation process are shown in Figure. 1.

![Graph showing stress-strain curves and diffraction spectra](image)

Figure 1: (a) Stress-strain curves for both alloys at different temperatures, (b) diffraction spectra of CoWAlloy1 and 2 during deformation at 1000°C.

Both alloys show a strong decrease in strength above a certain temperature. The main difference occurs at 1000°C, where the yield strength of CoWAlloy2 has already decreased to about 120 MPa, while CoWAlloy1 still possesses rather high yield strength of about 400 MPa. The diffraction spectra of both alloys at this temperature show that for CoWAlloy1 the ordered γ’-hardening phase is still present at that temperature, while for CoWAlloy2 it has already dissolved. This indicates that the γ’-solvus temperature for CoWAlloy2 is between 950°C and 1000°C and for CoWAlloy1 between 1000°C and 1050°C, respectively. This is supported by the diffraction data acquired during heating of CoWAlloy1 shown in Figure 2. The 001 superlattice reflection is vanishing during the heating step at 1050°C, which again indicates the γ’-solvus temperature in that regime. Besides, Figure 2 clearly shows the thermal expansion of the lattice plane distances. From these measurements, lattice parameters for γ and γ’-phase have been determined at different temperatures and the misfit has been calculated (Figure 3). The diffraction profiles of the fundamental 002 reflections show the γ’ sub peak (0) occurring at lower diffraction angles than the γ sub peak (1). The γ’-phase has therefore a higher lattice parameter which leads to a positive lattice misfit.
Figure 2: (a) Intensity dependent on diffraction angle and temperature for CoWAlloy1. The arrow marks the disappearing 001 superlattice reflection of the ordered hardening phase $\gamma'$. 

Figure 3: Selected diffraction peaks at different temperatures: (a) 001 superlattice reflection at room temperature, (b) 002 peak at room temperature, (c) 001 peak at 1000°C, (d) 002 peak at 1000°C.

The misfit is strongly decreasing with temperature as can be seen by the peaks of $\gamma$ and $\gamma'$ overlapping stronger at 1000°C. The determined lattice misfit is 0.48% at RT and 0.23% at 1000°C, respectively. The knowledge of these parameters especially in dependence of temperature is essential for the understanding of the mechanical properties of this new class of high temperature materials. Based on these results, further alloys with tailored misfit and $\gamma'$-solvus may be developed to fit the special needs of wrought high temperature materials especially in terms of high strength on the one and good workability on the other hand.

References