Civil aviation regulatory bodies require that new gas turbine designs provide improved operational efficiency and reduced emissions [1]–[3]. As a result, higher engine operating temperatures and faster rotational speeds are needed in order to meet these demands. However, the materials currently used in the hottest sections of gas turbines are already operating at their temperature and strength limits. Therefore, the development of novel materials able to withstand more demanding conditions is necessary. Nickel-based superalloys are currently the only class of materials able to meet the service requirements of components in the hottest sections of gas turbines. Their high temperature properties are derived from the precipitation of coherent L12 - Ni3Al (γ′) particles in the A1 - Ni solid solution matrix (γ), and the lattice misfit between these phases is known to govern a range of high temperature mechanical properties [4]–[7].

Recent work [8] has highlighted that considerable benefits may be achieved through the simultaneous addition of Co and Ti in controlled ratios to nickel-based superalloys, and data indicates that the contribution of coherency strains might, in fact, be dominating the strengthening mechanisms in alloys of this type [9]–[11]. In addition, due to the increased temperatures required in service, maximising the creep resistance of the new alloys is critically important, and creep performance has been found to correlate strongly with the lattice misfit [4]–[7]. Therefore, understanding the effect of both composition and temperature on the lattice parameters and corresponding lattice misfit in alloys with elevated Co and Ti concentrations is particularly important in the development of novel materials for gas turbine applications.

To this end, a series of six γ/γ′ alloys with compositions based on (Ni,Co)100-x(Al,Ti)xCrx, with x=10 and 20, were tested in situ on the C2 High Resolution Powder Diffractometer at 400, 600, 700 and 800°C. The analysis of the results was performed using the Pawley method in the TOPAS academic software package.

The results obtained suggested that increasing the Cr concentration in alloys with similar Ni:Co and Al:Ti ratios causes an expansion in the γ and, to a lesser extent, the γ′ lattice parameters, leading to a decrease in the lattice misfit. Figure 1, shows the temperature dependence on both the lattice parameters and the lattice misfit developed in one of the high Co-Ti alloys tested. The lattice parameters of the phases in all alloys were shown to increase with temperature. However, the lattice misfit was found to behave in a different manner for each alloy tested. These observations offer unique insights into the effects of individual alloying additions and temperature on lattice misfit evolution, knowledge of which is critical to the development of novel nickel-based superalloys.

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Bibliography


