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Quantification of Internal Stresses of Ni-Based Single Crystals at 980°C

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Various alloy compositions were cast as single crystals in a Bridgman vacuum induction furnace and creep tested at 980°C [1]. The alloy compositions are: pure Ni, the equiatomic alloys CoCrNi and CrMnFeCoNi (Cantor alloy), single-phase fcc (Ni) solid solution alloys (with the composition of the matrix-phase of CMSX-3 and CMSX 4) and two-phase Ni-based superalloys CMSX-3 and CMSX-4. Due to the single crystal state, grain size effects, such as grain boundary sliding and grain boundary diffusion can be excluded. The results identify two major strengthening mechanisms: solid solution strengthening and other mechanisms summarized as precipitation hardening. Configurational entropy does not increase creep strength: The Cantor alloy, with the highest configurational entropy of all alloys tested, shows a weak and similar creep strength at 980°C as pure Ni with zero configurational entropy. The element Re is a very effective strengthener, both in single-phase fcc (Ni) as solid solution strengthener, as well as in two-phase superalloys by increasing the misfit magnitude. Quantitative estimations of different strengthening mechanisms are carried out: internal back stress, misfit stresses, Orowan bowing, and γ'-phase cutting are presented. Finite element simulations allow to estimate the influence of solid solution strengthening of the matrix on the creep behavior of the two-phase superalloys.

Keywords: superalloy, nickel alloys, creep testing, strengthening mechanisms, precipitation hardening, solid solution strengthening, single crystal, high entropy alloys

[1] Uwe Glatzel, Felix Schleifer, Christian Gadelmeier, Fabian Krieg, Moritz Müller, Mike Mosbacher and Rainer Völkl
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