JPEDAV (2006) 27:408-409
DOI: 10.1361/154770306X116432
1547-7037/$19.00 ©ASM International

Al-Co-Cr-Ni (Aluminum-Cobalt-Chromium-Nickel)

V. Raghavan

Recently, isothermal sections at 1000 and 900 °C were presented by [2002Bro1] and [2002Bro2] for this quaternary system at a constant Ni content of 70 at.%.

Binary Systems

For brief descriptions of the Al-Cr, Al-Ni, and Cr-Ni binary systems, see the Al-Cr-Ni update in this issue. [2006Rag] gave brief descriptions of the Al-Co and Co-Ni systems. The review by [1990Ish] of the Co-Cr system depicts one intermediate phase σ with the $D8_b$-type tetragonal structure.

Ternary Systems

Updates on Al-Co-Ni and Al-Cr-Ni systems appear in this issue. The data on the Al-Co-Cr system compiled by [1995Vil] gave isothermal sections at 1250, 1175, and 1000 °C. A review by [1990Gup] of the Co-Cr-Ni system presented isothermal sections at 1227 and 1200 °C.

Quaternary Phase Equilibria

[2003Kos] combined the limited experimental data on the quaternary alloys obtained in earlier studies [1997Lit, 1999Kos] with the literature data on the ternary systems to present exploded views of the composition tetrahedron. One such view at 1150 °C is shown in Fig. 1. It mainly indicates the phase distribution in the four ternary systems. Full characterization of the three-dimensional space within the tetrahedron was not possible due to inadequate quaternary information. [2003Kos] also presented an isothermal section of this system at 900 °C at a constant Cr content of 17 wt.%. The optimum composition range of Ni-(12-20wt.%Co)-(17-20wt.%Cr)-(9.5-10.5wt.%)Al was found to correspond to the $B2/\gamma$ eutectic alloys that have a high heat resistance and a structure that has a high thermal stability. Co is effective in stabilizing the $B2$ + (Ni) eutectic structure. However, no complete suppression of the precipitation of the secondary phases (γ', bcc, and σ) is achieved.

With starting metals of Al (≥99.99 wt.%), Co (99.99 wt.%), Cr (99.99 wt.%), and Ni (99.99 wt.%), [2002Bro1] and [2002Bro2] induction-melted four or five quaternary alloys with a constant Ni content of ~70 at.%. The alloys

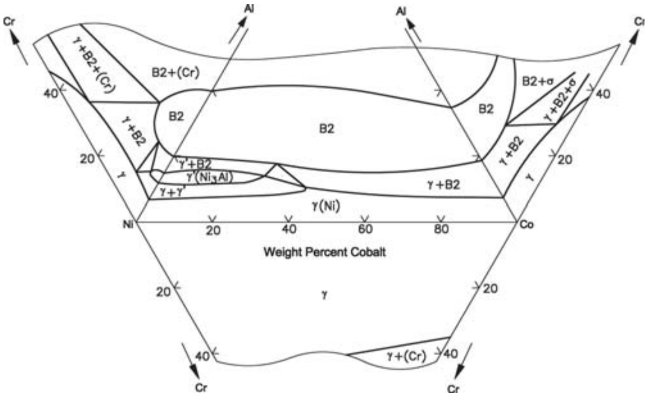

Fig. 1 Al-Co-Cr-Ni exploded view of the composition tetrahedron at 1150 °C [2003Kos]

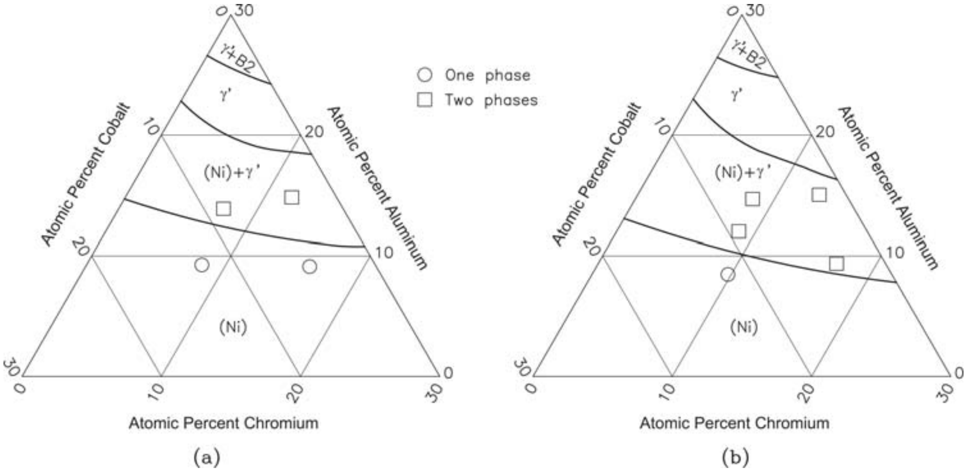

Fig. 2 Al-Co-Cr-Ni isothermal sections at constant Ni content of 70 at.% and at (a) 1000 °C and (b) 900 °C [2002Bro2]

were annealed at 1000 °C for 200 h or at 900 °C for 650 h and quenched in water. The phase equilibria were studied by optical and scanning-transmission electron microscopy. The compositions of the phases were determined by energy dispersive x-ray analysis. The experimental data were used in the thermodynamic optimization using the CALPHAD approach. The isothermal sections computed by [2002Bro1] and [2002Bro2] at 1000 and 900 °C at a constant Ni content of 70 at.% are redrawn in Fig. 2. The $\gamma/(\gamma + \gamma')$ boundary and to a lesser extent the $(\gamma + \gamma')/\gamma'$ boundary move toward higher Al content with increasing temperature.

References

1990Gup: K.P. Gupta, The Co-Cr-Ni (Cobalt-Chromium-Nickel) System, *Phase Diagrams of Ternary Nickel Alloys. Part 1,* Ind. Inst. Metals, Calcutta, 1990, p 5-17

1990Ish: K. Ishida and T. Nishizawa, The Co-Cr (Cobalt-Chromium) System, *Bull. Alloy Phase Diagrams,* 1990, **11**(4), p 357-370

1995Vil: P. Villars, A. Prince, and H. Okamoto, Al-Co-Cr, *Handbook of Ternary Alloy Phase Diagrams,* Vol 3, ASM International, 1995, p 3002-3005

1997Lit: V.S. Litvinov, S.V. Kositsyn and N.V. Kataeva, Phase Instability of Eutectic β/γ Ni-Cr-Al and Ni-Co-Cr-Al Alloys, *Fiz. Met. Metalloved.,* 1997, **84**(4), p. 109-116, in Russian; TR: *Phys. Met. Metallogr.,* 1997, **84**(4), p 397-402

1999Kos: S.V. Kositsyn and N.V. Kataeva, Effect of Cobalt on the Structural and Phase Stability and Properties of Near-Eutectic Ni-Co-Cr-Al Alloys, *Fiz. Met. Metalloved.,* 1999, **88**(3), p 85-98 (in Russian); TR: *Phys. Met. Metallogr.,* 1999, **88**(3), p 288-300

2002Bro1: P. Broz, J. Bursik, M. Svoboda, and A. Kroupa, Theoretical and Experimental Study of the γ and γ' Equilibrium in Ni-Based Superalloys, *Mater. Sci. Eng. A,* 2002, **A324,** p 28-33

2002Bro2: P. Broz, J. Bursik, and R. Picha, Theoretical and Experimental Study of the γ and γ' Equilibrium in the Ni-Al-Cr-Co System, *Intermetallics,* 2002, **10,** p 635-639

2003Kos: S.V. Kositsyn, N.V. Kataeva, I.I. Kositsyna, and V.S. Litvinov, Structural and Phase Diagrams for the β/γ Eutectics in the Ni-Co-Cr-Al System, *Metally,* 2003, (1), p 109-118, in Russian; TR: *Russ. Metall.,* 2003, (1) p 88-95