JPEDAV (2010) 31:191–193
DOI: 10.1007/s11669-010-9666-z
1547-7037 ©ASM International

The Cr-Ni-Zr (Chromium-Nickel-Zirconium) System

K.P. Gupta, The Indian Institute of Metals, India

Introduction

The Cr-Ni-Zr system was reviewed by [2000Gup]. In developing high temperature resistant brazing material, the Cr-Ni-Zr system has been studied at the Ni-corner. The results are given here.

In order to discuss the new results on Cr-Ni-Zr system, it is necessary to recapitulate the binary systems. The Cr-Ni system [1991Nas] (Fig. 1) is a simple eutectic system, the eutectic reaction L ↔ α + γ occurring at 1345 °C, where α and γ are the terminal solid solutions of body centered (bcc) Cr and face centered cubic (fcc) Ni, respectively. At the eutectic reaction temperature, the γ phase extends to ~50 at.% Cr and the α phase extends to ~32 at.% Ni. Solubility of Ni in Cr decreases with decrease in temperature reasonably fast down to ~1100 °C. A Ni_2Cr ordered phase forms in the γ phase region below ~ 600 °C. The Cr-Zr system [Massalski2, 1993Oka] shows (Fig. 2) the presence of only one intermediate phase Cr_2Zr which occurs in three polymorphic forms, the αCr_2Zr(ψ_1) exists below ~1592 °C, the βCr_2Zr(β_1) exists between 1592 and 1622 °C, and the γCr_2Zr(γ_1) exists between 1622 and 1673 °C. Two eutectics, L ↔ α + β_1 and L ↔ ψ_1 + α′ occur at 1592 and 1332 °C, respectively. The α′ phase is the terminal solid solution of βZr. A eutectoid reaction α′ ↔ ω + ψ_1 occurs at 831 °C with ω representing the αZr phase. The solubility of Zr in Cr is negligible at room temperature and is ~1.5 at.% Zr at the eutectic temperature 1592 °C. The Ni-Zr system [1991Nas] (Fig. 3) has eight intermediate phases Ni_5Zr(ε), Ni_7Zr_2(π), Ni_3Zr(λ), $Ni_{21}Zr_8$(θ), $Ni_{10}Zr_7$(β), $Ni_{11}Zr_9$(ν), NiZr(ϕ), and $NiZr_2$(ξ). The π, ϕ, and ξ phases melt congruently at 1440, 1260, and 1120 °C, respectively. All the other intermediate phases form through peritectic or peritectoid reactions: L + π ↔ ε, L + π ↔ θ, π + θ ↔ λ, L + ϕ ↔ ν_1, and L + ν ↔ β occurring at 1300, 1180, 920, 1170, and 1160 °C, respectively. Five eutectic or eutectoid reactions: L ↔ γ + ε, L ↔ θ + β, L ↔ ϕ + ξ, L ↔ ξ + α′, and α′ ↔ ξ + ω occur at 1170, 1070, 1010, 960, and 845 °C, respectively. The ν phase undergoes eutectoid transformation ν ↔ β + ϕ at 978 °C. The phases and their structure data are given in the review paper [2000Gup].

[1999Kho] reinvestigated the Cr-Ni-Zr system at the Ni-rich corner, up to ~40 at.% Cr and up to ~30 at.% Zr. The alloys were melted in a water cooled copper hearth, tungsten electrode arc furnace under argon atmosphere. The component elements were Ni of 99.95 mass% purity, Cr of 99.98 mass% purity, and Zr of 99.95 mass% purity. The alloys in cast condition were used for this investigation.

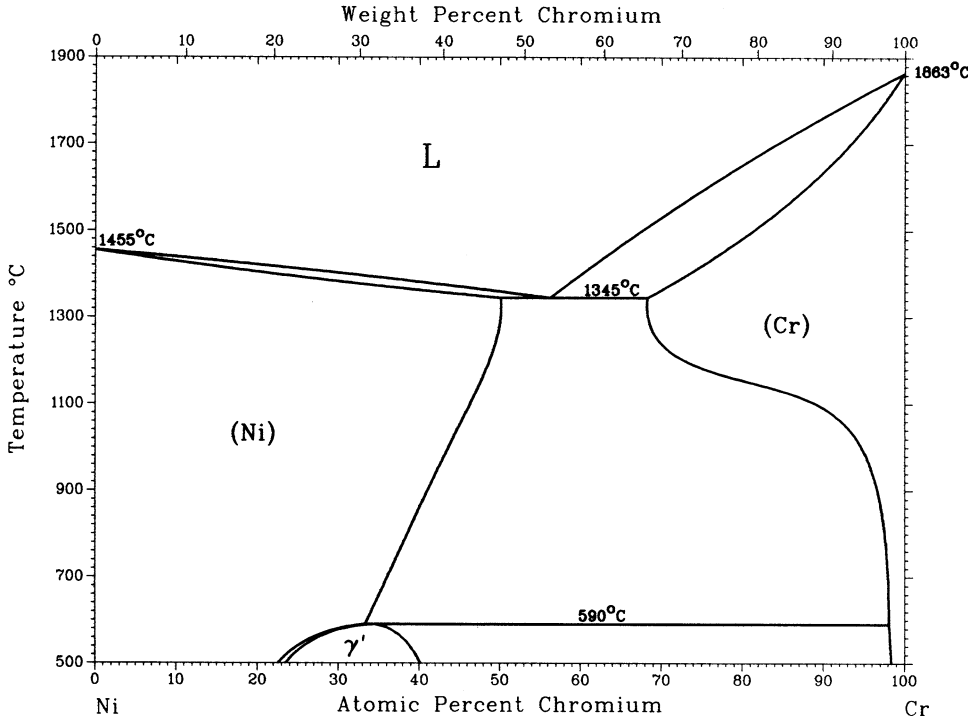

Fig. 1 The Cr-Ni system [1991Nas]

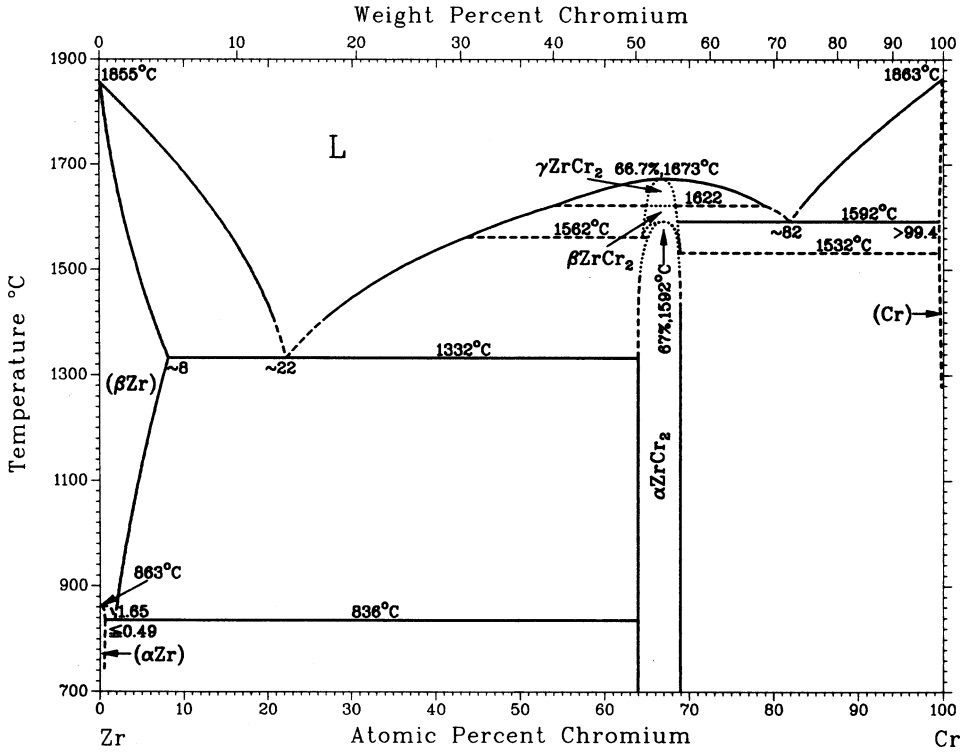

Fig. 2 The Cr-Zr system [1993Oka]

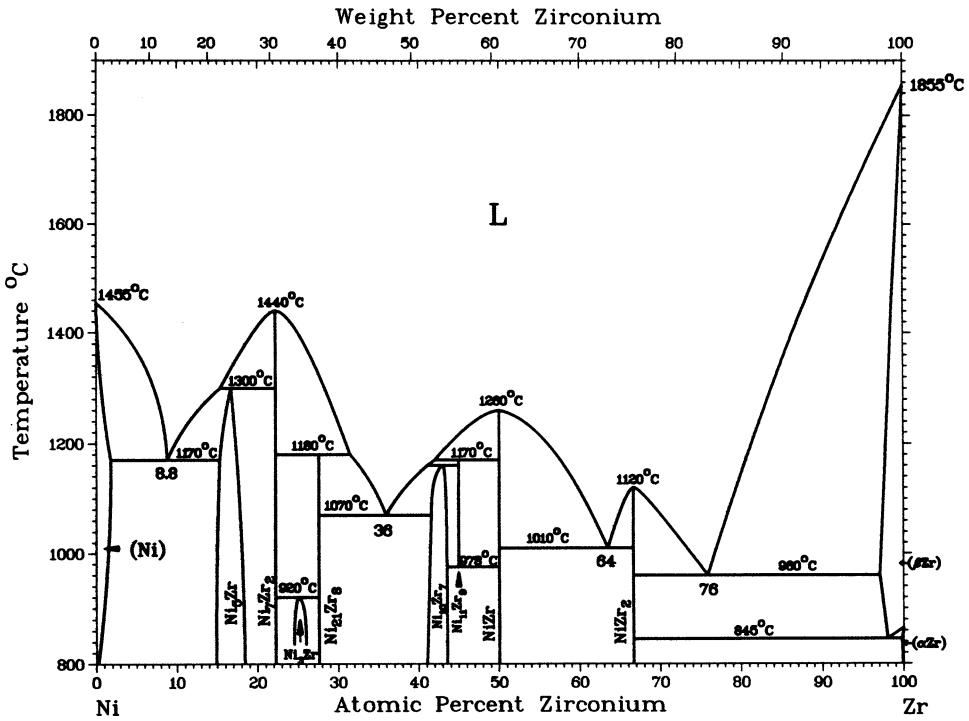

Fig. 3 The Ni-Zr system [1991Nas]

Ten alloys were prepared, of which seven contained 8.8 at.% Zr with Cr varying from 0-30 at.% in steps of 5 at.%, two alloys were binary Ni-Zr alloys containing 16.67 and 22.22 at.% Zr and one alloy with 5 at.% Cr and 22.22 at.% Zr. Metallography, x-ray diffraction (XRD), and thermal analysis were used for characterization of the alloys.

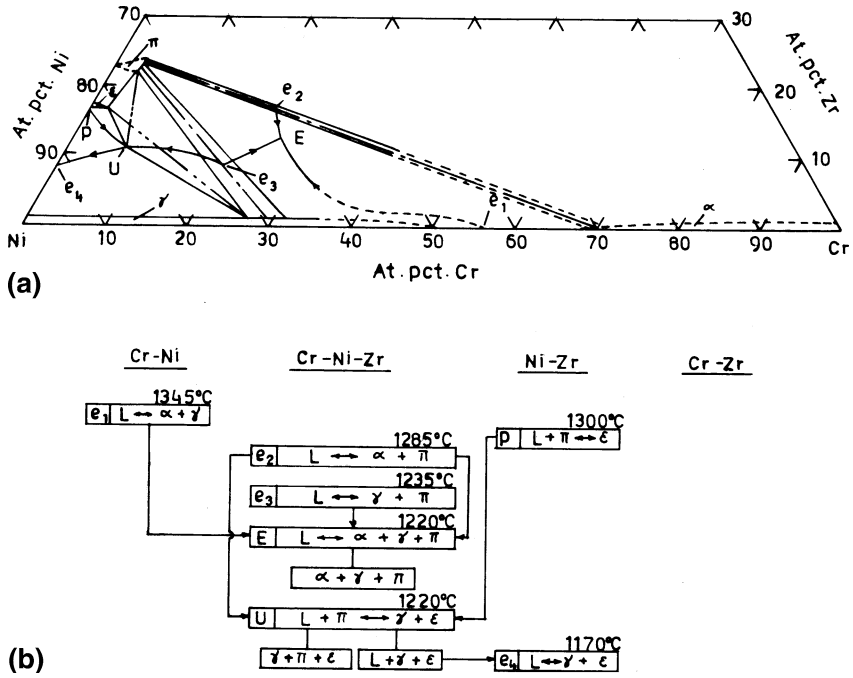

Fig. 4 (a) A partial liquidus projection at the Ni-corner of Cr-Ni-Zr system. (b) Reaction scheme for liquidus projection of (a)

Isothermal section established by [1995Jou] at 1000 °C showed that Cr solid solution (α phase) was in equilibrium with the π phase. In the present investigation the alloy with 5 at.% Cr and 22.22 at.% Zr showed that a eutectic type pseudobinary exists between the π and α phase with a eutectic temperature of 1285 °C, the eutectic composition is given to be at a composition of near $Cr_{24}Ni_{60}Zr_{16}$. Another eutectic type pseudobinary was reported between the γ and π phase with eutectic temperature and composition of 1235 °C and $Cr_{20}Ni_{71.2}Ze_{8.8}$, respectively. Phase analysis of the cast alloys with compositions of 25 and 30 at.% Cr and both containing 8.8 at.% Zr were found to show 3 phases γ + π + α. The three phase equilibrium solidus temperature for the two alloys was found to be 1220 °C, indicating the existence of a ternary eutectic reaction E. The ternary reaction E arises due to the liquid compositions coming down from the three eutectic reactions e_1, e_2, and e_3 occurring at the Cr-Ni binary and the pseudo-binaries α − π and γ − π, respectively. The alloy with 15 at.% Cr and 8.8 at.% Zr was found to have 3 phases γ + π + ε below the solidus temperature 1220 °C. This 3 phase region arises due to a U-type four phase reaction U:L + π ↔ γ + ε. The four phase reaction arises due to the interaction of the liquid compositions coming down from the eutectic point e_2 at the γ − π pseudobinary and a liquid composition coming down from the peritectic reaction p: L + π ↔ ε occurring at the Ni-Zr binary. The four phase reaction also gives a 3 phase equilibrium L + γ + ε at 1220 °C which finally terminate at the eutectic point e_4:L ↔ γ + ε at the Ni-Zr binary. The liquidus projection for the investigated composition of the Cr-Ni-Zr system is given in Fig. 4(a), and the corresponding reaction scheme is given in Fig. 4(b).

References

1991Nas: P. Nash, *Phase Diagrams of the Binary Nickel Alloys*, ASM International, Materials Park, OH, 1991 (Review)

1993Oka: H. Okamoto, *J. Phase Equilib.*, 1993, **14**(b), p 768 (Review)

1995Jou: J.M. Joubert, M. Latroche, A. Percheron-Guegan, and I. Ansara, The Zr-Ni-Cr System at 1000 °C in the $ZrCr_2$-ZrNi-Ni-Cr Region, *J. Phase Equilib.*, 1995, **16**(6), p 485-492 (Phase Equilibria, #)

1999Kho: V.F. Khorunov, V.G. Ivanchenko, and V.K. Kvashitskil, Structure and Phase Composition of Ni-Cr-Zr and Ni-Cr-Hf Alloys and as Brazes, *Avotom. Svarka*, 1999, **11**, p 14-22 (Phase Equilibria, #), in Russian

2000Gup: K.P. Gupta, The Cr-Ni-Zr (Chromium-Nickel-Zirconium) System, *J. Phase Equilib. Diffus.*, 2000, **21**(4), p 402-407

# indicates presence of phase diagram.

Cr-Ni-Zr evaluation contributed by **K.P. Gupta**, the Indian Institute of Metals, Metal House, Plot 13/4, Block AQ, Sector V, Calcutta, India. Literature searched through 1996. Dr. Gupta is the Alloy Phase Diagram Co-Category Program Editor for ternary nickel alloys.