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Fe-Mn-Ni (Iron-Manganese-Nickel)

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In their review of this ternary system, [1988Ray] presented a liquidus surface with constant temperature contour lines (isotherms) from the early work of [1913Par]. The update of [1994Rag] presented a liquidus projection based on the work of [1985Koc], isotherms on the liquidus surface for Fe-rich alloys from [1986Kun] and two computed isothermal sections for Fe-rich alloys at 750 and 550 °C from [1989Har]. A data compilation from the above studies was given by [1995Vil]. [1997Sch] reviewed the liquid-solid equilibria in the ternary system, based on new results on the liquid equilibria in the binary subsystems. As part of the calculation of phase equilibria in multicomponent steels, [1998Mie] obtained approximate thermodynamic interaction parameters for liquid, bcc and fcc phases in this system Recently, [2009Zha] carried out new experiments on seven selected ternary alloys and presented a thermodynamic assessment covering the entire composition range. They computed a liquidus surface and a number of isothermal and vertical sections. This work will be reviewed briefly in this update.

Binary Systems

There are no intermediate phases in the Fe-Mn system. The prominent feature of the diagram is the presence of the continuous fcc solid solution between γFe and γMn. A thermodynamic reevaluation of this system was presented recently by [2004Wit]. The Fe-Ni phase diagram [1991Swa] is characterized by a very narrow solidification range with a peritectic reaction at 1514 °C, between bcc δ(α) and liquid that yields the Fe-based fcc solid solution. A continuous fcc solid solution denoted γ is stable over a wide range of temperature. At 517 °C, an ordered phase $FeNi_3$ forms congruently from γ. The Mn-Ni phase diagram was reinvestigated recently by [2002Din] and [2007Fra] and their results are in agreement. This phase diagram calculated by [2005Guo] and [2009Zha] incorporating recent results are in agreement. The intermediate phases are: MnNi(HT) (*B*2, CsCl-type cubic), MnNi(LT) ($L1_0$, AuCu-type tetragonal), $MnNi_2$, and $MnNi_3$($L1_2$, $AuCu_3$-type cubic).

Ternary Phase Equilibria

With starting metals of 99.99% Fe, 99.9% Mn, and 99.95% Ni, [2009Zha] arc-melted under Ar atm seven ternary alloys. The samples were annealed at 800 °C for 40 days and quenched in water. The phase equilibria were studied with optical and scanning electron metallography, energy dispersive x-ray analysis, x-ray powder diffraction and differential thermal analysis at heating/cooling rates of 5 °C per min.

In their thermodynamic modeling, [2009Zha] described the liquid, fcc, bcc and *A*13-type cubic phases as substitutional solutions. The magnetic contribution to the Gibbs

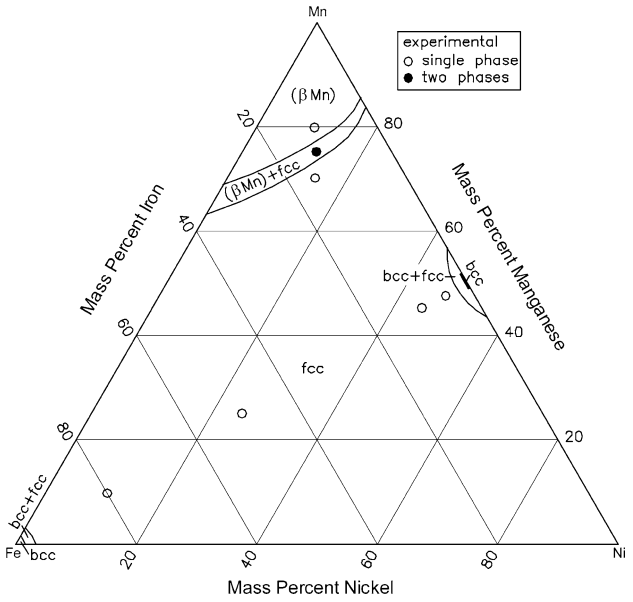

Fig. 1 Fe-Mn-Ni computed isothermal section at 800 °C [2009Zha]

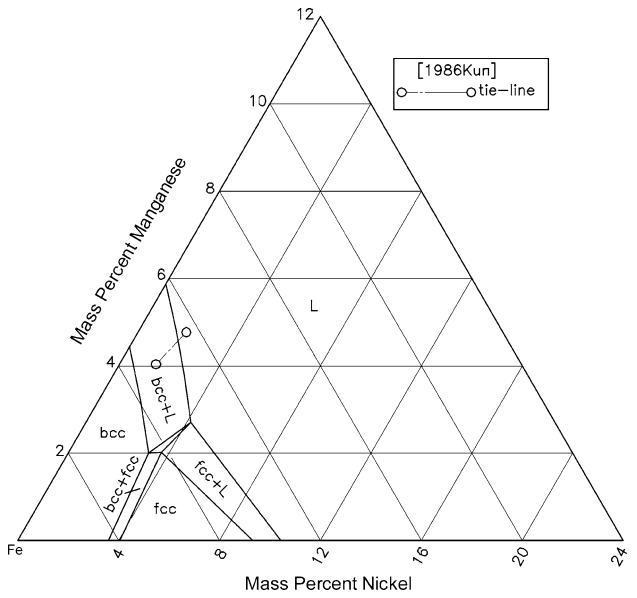

Fig. 2 Fe-Mn-Ni computed isothermal section for Fe-rich alloys at 1508 °C [2009Zha]

energy was taken into account. The bcc → $B2$ and fcc → $L1_2$ ordering transitions were modeled using a single Gibbs energy function by adding an ordering energy term. The binary descriptions from the literature were used. [2009Zha] employed the phase equilibrium data from [1913Par, 1985Koc] and [1986Kun], along with their own experimental measurements in the optimization. The very limited thermodynamic measurements from the literature on vapor pressure and activity of Mn in ternary alloys were also used as inputs.

The isothermal section at 800 °C computed by [2009Zha] is compared with their own results in Fig.1. The agreement is satisfactory. In addition, [2009Zha] computed four isothermal sections for Fe-rich alloys at 1519, 1508, 1505, and 1485 °C, which showed satisfactory agreement with the experimental results of [1986Kun]. The

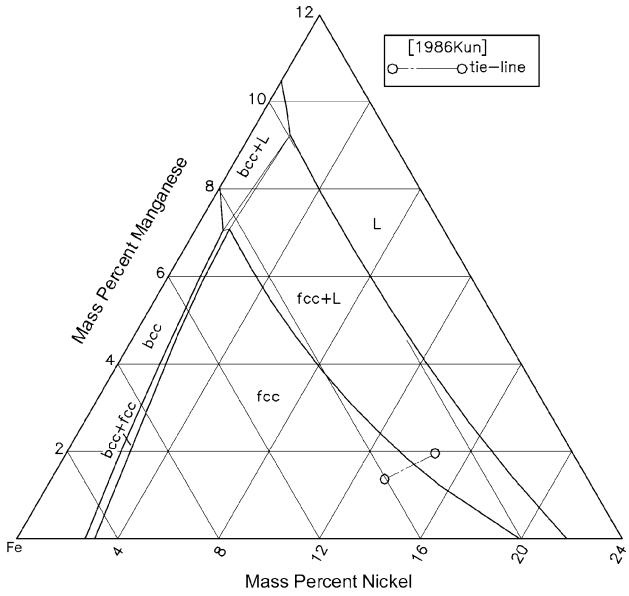

Fig. 3 Fe-Mn-Ni computed isothermal section for Fe-rich alloys at 1485 °C [2009Zha]

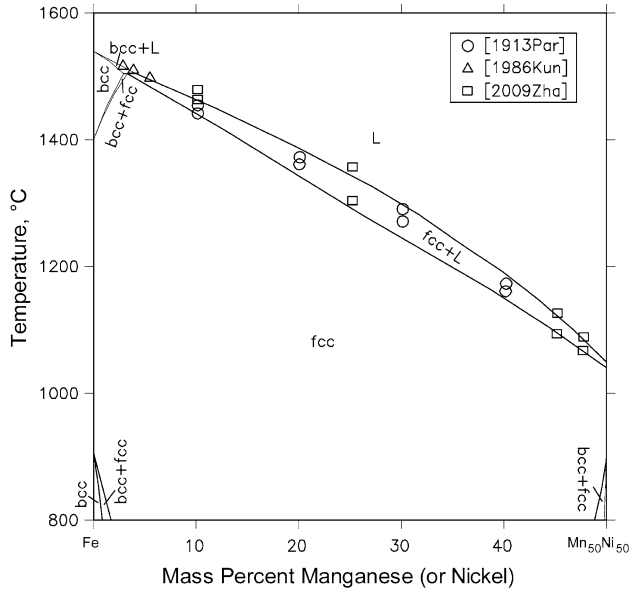

Fig. 5 Fe-Mn-Ni computed vertical section along Fe-$Mn_{50}Ni_{50}$ join [2009Zha]

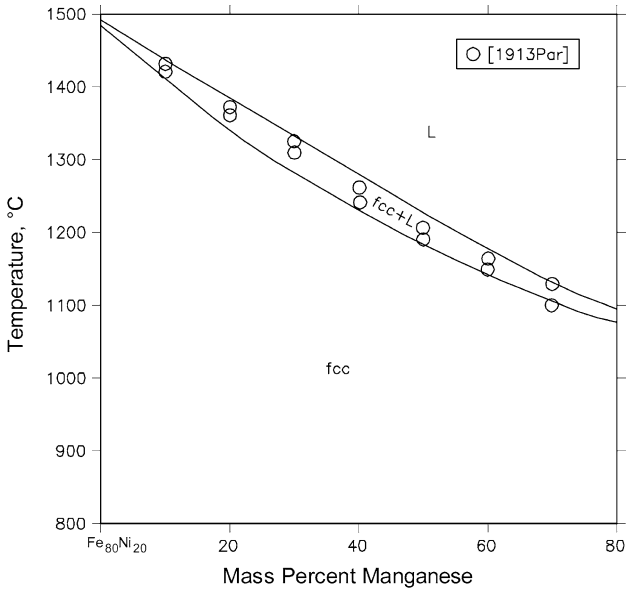

Fig. 4 Fe-Mn-Ni computed vertical section along $Fe_{80}Ni_{20}$-$Mn_{80}Ni_{20}$ join [2009Zha]

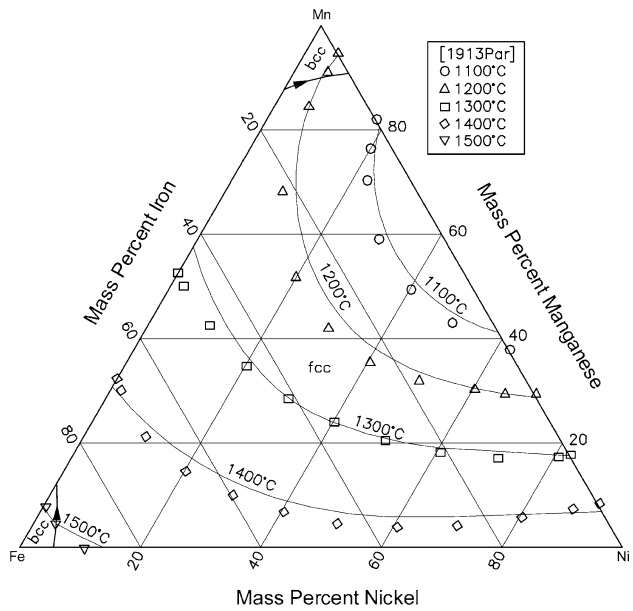

Fig. 6 Fe-Mn-Ni computed liquidus projection [2009Zha]

computed isothermal sections at 1508 and 1485 °C are shown in Fig. 2 and 3.

[2009Zha] computed four vertical sections depicting the liquid-solid equilibria along the $Mn_{90}Fe_{10}$-$Ni_{90}Fe_{10}$, $Fe_{70}Mn_{30}$-$Ni_{70}Mn_{30}$, $Fe_{80}Ni_{20}$-$Mn_{80}Ni_{20}$ and Fe-$Mn_{50}Ni_{50}$ joins, respectively (in mass%) and compared them with the experimental data of [1913Par, 1986Kun] and [2009Zha]. The agreement was found to be satisfactory. Here, two vertical sections along the $Fe_{80}Ni_{20}$-$Mn_{80}Ni_{20}$ and $Mn_{50}Ni_{50}$-Fe joins, respectively, are shown in Fig. 4 and 5. The liquidus projection computed by [2009Zha] is shown in Fig. 6. The primary field of the fcc phase dominates the surface.

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