C-Cr-Fe-N-V-W (Carbon-Chromium-Iron-Nitrogen-Vanadium-Tungsten)

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The Fe-9CrWV martensitic alloy steels are used in a wide variety of applications in power generation, petrochemical and nuclear industries. Addition of V with nitrogen can result in VN precipitate particles, which can enhance the creep resistance of the steel. Excessive addition of nitrogen can, however, induce gas porosity in the steel. [2006Yar] prepared 14 steels around the basic composition of this type, in an effort to ascertain the conditions under which gas porosity occurs. Phase equilibrium calculations were done and presented as vertical sections as a function of the concentration of one alloying element, with the other elements kept constant.

Computed Senary Phase Equilibria

Most of the computations were done for the steel designated A2 by [2006Yar] of composition (in wt.%): 0.09C, 0.072N, 7.9Cr, 0.31V, and 2.47W. The computations were done using the TCFE3 steel database [2002TCF] in conjunction with the Thermo-Calc software. The computed equilibrium phase fractions as a function of temperature are shown in Fig. 1. The face-centered cubic (fcc) austenite (γ) does not come into equilibrium with the liquid, but the body-centered cubic (bcc) phase ferrite (δ) does. It is interesting to note that the mole fraction of $N_2(g)$ (denoted Gas by [2006Yar]) peaks approximately at the same temperature as the mole fraction of δ-ferrite. This is consistent with the known result that the nitrogen solubility
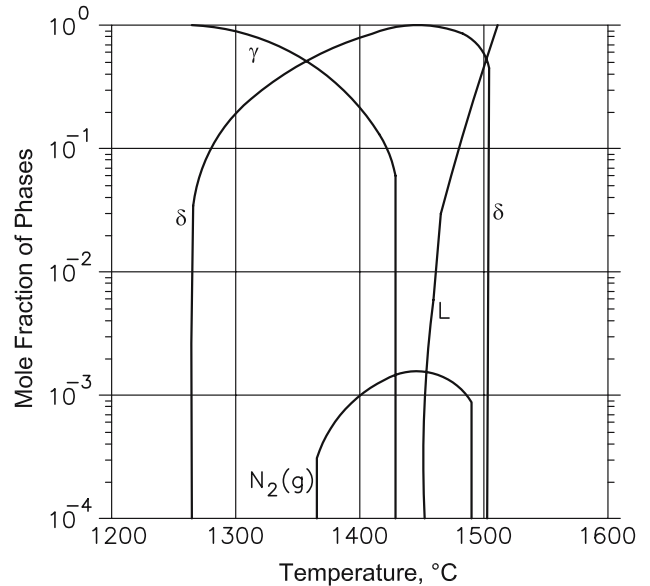

Fig. 1 A2 steel (see text) computed phase fractions vs. temperature [2006Yar]

in δ-ferrite is much lower than in γ or liquid. It may also be noted that there is a temperature range over which $N_2(g)$ and δ are the only stable phases. Gas porosity appears to be associated with the existence of such a temperature range in a steel.
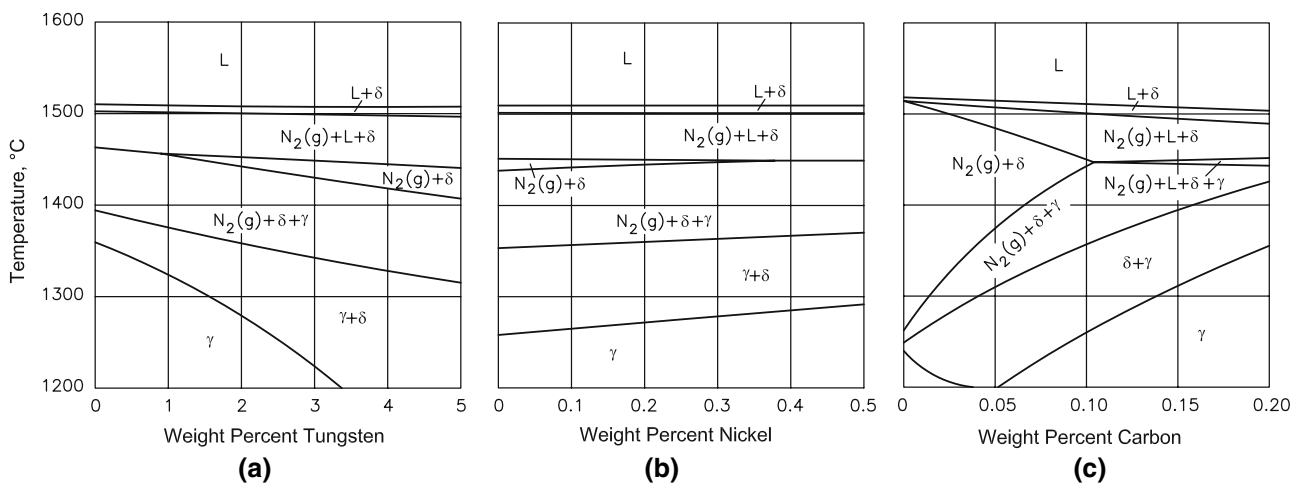

Fig. 2 A2 steel (see text) computed vertical sections as a function of (a) tungsten, (b) nickel, and (c) carbon [2006Yar]

[2006Yar] computed a number of vertical sections for the A2 steel, by varying the concentration of one of the alloying elements (C, N, Cr, V or W) and keeping the other elements constant. Computed sections were presented also for Mn, Mo, Ni or Si. As these elements are not present in the A2 steel, the computation was done presumably by treating one of these as an additional element present. The computed section as a function of W is shown in Fig. 2(a). With increasing W content, the $(N_2(g) + \delta)$ two-phase field broadens and exists over a wider temperature range. This is the typical behavior of a ferrite-stabilizing element. In Fig. 2(b), the vertical section is as a function of Ni content, which is an austenite stabilizer. Beyond 0.4 wt.% Ni, the $(N_2(g) + \delta)$ two-phase field disappears. In Fig. 2(c), the two-phase field is not present above 0.1 wt.% C, carbon also being an austenite stabilizer.

To avoid gas porosity, the composition of the steel should be such that the $(N_2(g) + \delta)$ two-phase field is absent or present only in a small temperature range. Even when this two-phase field is present, kinetic factors such as the rate of δ-ferrite formation versus the cooling rate of the steel through the two-phase range could be deciding factors for the presence or absence of gas porosity.

References

2002TCF: TCFE3 Steels/Fe-Alloys Database, Thermo-Calc Software, Stockholm, Sweden, 2002

2006Yar: V.A. Yardley and Y. de Carlan, Design Criteria for High-Temperature Steels Strengthened with Vanadium Nitride, *J. Phase Equilb. Diffus.*, 2006, **27**(1), p 102-112