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Investigation of an additive remedy for temper brittleness*

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Analysis of engineering steels by Auger electron spectroscopy has identified phosphorus, and to a lesser extent tin, as the grain boundary segregating impurities that commonly cause temper brittleness (Hondros *et al.* 1976). In the theory of alloy design, a number of remedial procedures can be applied to minimize embrittling effects and thus to realize the natural strength of the alloy without recourse to expensive purification treatments (Hondros & Seah 1977). In the chemical 'fixation' route used here, the active species may be immobilized by a micro-precipitate reaction, which reduces its bulk chemical potential and thus greatly reduces its grain boundary concentration. Following a thorough thermochemical assessment of the feasibility of 'fixing' residuals, the rare earth elements, lanthanum and (to a lesser extent) cerium, were selected as having the best promise because of their higher affinity for P and Sn than for the carbon of the steel.

Measurements on the ductile–brittle transition temperatures were carried out on two archetypal steels, $2\frac{1}{4}$Cr1Mo and $3\frac{1}{2}$NiCrMoV, in both high purity and commercial purity conditions. In the $2\frac{1}{4}$Cr1Mo steel, P was shown to be very embrittling but Sn had little effect. The embrittling effect of as much as 0.02% P could be relieved by an addition of about 0.16% La. Concomitantly, there occurred the detrimental effect of a reduction of upper shelf energy in the ductile region. This reduction is thought to have arisen from the small-scale experiments in the laboratory and is not expected to occur in industrial practice.

The behaviour of the $3\frac{1}{2}$NiCrMoV was similar to the $2\frac{1}{4}$Cr1Mo except that both P and Sn were very embrittling, and the optimum La remedial additions were slightly lower. In both types of steel the phosphorus and tin temper brittleness can be fully removed by an optimum lanthanum addition, given by $La = 8.7S + 2.3Sn + 4.5P$, where the element symbols express concentrations in percentages by mass. Tests with mischmetal also showed this successful remedial action.

References (Seah *et al.*)

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