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An assessment of the embrittling effects of certain residual elements in two nuclear pressure vessel steels (A533B, A508)*

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The intergranular embrittlement caused by such impurity elements as P, As, Sn and Sb in ferritic steels can be manifested in several ways: (1) an impairment of toughness or impact transition behaviour (temper embrittlement); (2) a reduction in high temperature ductility and resistance to intergranular failure (creep embrittlement); and (3) degradation in properties at the operating temperature caused by the accumulation of creep damage during a post-weld stress relieving heat treatment (stress relief embrittlement). A detailed study of stress relief embrittlement (s.r.e.) and temper embrittlement (t.e.) in bainitic microstructures representative of those found in weld h.a.zs has been carried out on a number of casts of A533B class 1 (MnMoNi) and A508 class 2 (NiMoCr) steel.

S.r.e. was measured by comparing the tensile ductilities (at 300 °C, $\dot{\epsilon} = 10^{-5}\ \mathrm{s}^{-1}$) of specimens, in the grain coarsened condition, that had been either tempered (ϵ_T) or stress relaxed (ϵ_R) at 615 °C, taking s.r.e. as $(\epsilon_T - \epsilon_R)/\epsilon_T$. It was found that the degree of s.r.e. increased with the residual element content and with the stress level ($\overline{\sigma}$) and strain accumulated ($\Delta\epsilon_P$) during relaxation. Tests on experimental alloys enabled the relative importance of the individual residual elements examined to be determined for each class of steel and thus allowed effective residual element levels to be calculated. These were, for A533B,

$$R = 0.12[\mathrm{Cu}] + 0.19[\mathrm{S}] + 0.81[\mathrm{As}] + [\mathrm{P}] + 1.18[\mathrm{Sn}] + 1.49[\mathrm{Sb}]$$

and, for A508 class 2,

$$R = 0.88[\mathrm{Al}] + 0.53[\mathrm{As}] + [\mathrm{P}] + 1.29[\mathrm{Sn}] + 1.63[\mathrm{Sb}].$$

Though the relative potencies of the various elements are seen to be similar for these materials, there are, as yet, insufficient data to make direct comparisons between the two steels. In each case a graph of s.r.e. against $R\overline{\sigma}\Delta\epsilon_P$ showed close correlation between the data from the experimental alloys and the behaviour of commercial casts.

T.e. was determined from the shift in transition temperature measured in Charpy impact tests on grain coarsened material tempered for 30 h at 615 °C and water quenched or slow cooled at either 20 K/h or 2 K/h. The amount of embrittlement increased with residual element content and decreasing cooling rate ($\dot{T}$). An effective residual element content was derived for A533B:

$$R = 0.08[\mathrm{Sn}] + 0.19[\mathrm{As}] + [\mathrm{P}] + 1.09[\mathrm{Sb}].$$

(S & Cu were found to have an insignificant effect.) A graph of t.e. against $R^2\dot{T}^{-\frac{1}{2}}$ produced a good fit to the data from both experimental and commercial steels.

Comparative tests on grain refined h.a.z. microstructures and parent material showed these to be very resistant to both forms of embrittlement compared with the grain coarsened materials.

* Extended abstract.

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