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Prior austenite grain boundary embrittlement of low alloy steel by boron*

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A previous study of reheat cracking in a CrMoV steel (Ducol W-30), in which the fracture toughness of the coarse grain size region of the h.a.z. was measured as a function of temperature, revealed a large decrease in toughness at 600 °C accompanied by prior austenite grain boundary (p.a.g.b.) fracture (Ritter & McPherson 1974). This severe embrittlement was eliminated if the steel was heated to 680 °C before testing at 600 °C suggesting that the effect may have been associated with a p.a.g.b. segregation effect. This hypothesis has been examined by comparing the degree of embrittlement at 600 °C of specimens with stimulated h.a.z. microstructures prepared from laboratory heats, with the same alloying element composition as the commercial steel used previously, but doped with the trace elements, S, P, As, Sb, Sn, Cu, Al and B, singly or in various combinations.

P.a.g.b. fracture was not observed in steels doped with S, P, As, Sb or Sn; however, some evidence of p.a.g.b. embrittlement was noted in steels containing Cu and/or Al although the degree of embrittlement, as assessed from constant load rupture tests, was much less severe than that observed in the commercial steel (Presser & McPherson 1977).

Severe embrittlement was observed in steels doped with traces of boron (3–10 μg/g) in the presence of Al. Embrittlement was only observed if the steel had been austenitized at temperatures greater than 1100 °C, and the effect was removed if the specimen was held at *ca.* 900 °C during cooling or if reheated to 650–900 °C. The same effect was observed in the commercial steel, which contained B at 6 μg/g.

These results are consistent with an embrittlement effect associated with the well documented segregation of B to austenite grain boundaries at high temperatures. The absence of embrittlement in steels austenitized at temperatures lower than *ca.* 1100 °C then arises because the B, present initially as $M_{23}(C, B)_6$ or BN, has not dissolved appreciably in austenite within the time available. Holding at 900 °C during cooling from high austenitizing temperatures results in removal of B in solution as relatively large precipitates of $M_{23}(C, B)_6$. In the absence of Al which acts as a scavenger for nitrogen, B is removed from solution in austenite as BN.

The mechanism by which B influences p.a.g.b. fracture is not clear from the present study. In view of the extremely low solubility of B in ferrite, less than 1 μg/g at 600 °C in pure Fe (Brown *et al.* 1974), the effect may arise from the formation of a critical distribution of B containing precipitates on p.a.g.bs during reheating to 600 °C, rather than retention of segregated B in solution.

Steels containing the alloying elements Cr, Mo and V are known to be particularly susceptible to reheat cracking. It is suggested that this is because these steels have high matrix creep strength in the temperature range 550–650 °C resulting in relatively high grain boundary stresses under conditions in which p.a.g.b. embrittlement occurs.

References (Presser & McPherson)

Brown, A., Cornish, J. D. & Honeycombe, R. W. K. 1974 *Metal Sci.* **8**, 317.
Presser, R. I. & McPherson, R. 1977 *Scr. metall.* **11**, 745.
Ritter, J. C. & McPherson, R. 1974 *Metals Technol.* **1**, 506.

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* Extended abstract.