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Titanium: a hydrogen trap in iron*

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The presence of titanium in iron, either as a dissolved substitutional solute or combined as a carbo-nitride, has been shown to affect the susceptibility of these alloys to hydrogen embrittlement. This behaviour is a direct result of the ability of these titanium-rich centres to capture hydrogen. The strength of the interaction ranges from 0.27 eV for substitutional titanium atoms to 0.98 eV for titanium carbide particles. The former is thus a reversible hydrogen trap with a short occupancy time, while the latter is irreversible with a long occupancy time, specifically at room temperature.

After a brief review of the techniques and analyses to obtain the parameters to characterize the above traps, the broader issue of how hydrogen traps can be used to control the degree of embrittlement of structural alloys is considered (Pressouyre 1977), and how this is related to the presence of 'good' and 'bad' traps. When hydrogen damage is manifested by internal irreversible cracking at grain boundaries, competitive traps, which prevent both an increase in the hydrogen grain boundary concentration and localized enrichment at irreversible grain boundary traps, are desired. The most effective of these are predicted to be finely distributed reversible traps. When hydrogen leads to a reduced reduction of area in a tensile test, the theory now predicts that fine irreversible traps should be most effective in reducing susceptibility. Experimental results to support both of these predictions are presented, as well as a consideration of how traps should affect the most dangerous of situations where in critical structural components hydrogen leads to a reduction in the critical stress intensity for cracking, an increasing crack velocity, or both.

All three cases predict that good trapping centres should be finely distributed and can be either irreversible or reversible in nature, so long as the interaction energy for the latter is of sufficient magnitude to avoid these becoming internal hydrogen sources. Bad traps are generally irreversible in nature and are heterogeneously distributed, particularly on grain boundaries or other interfaces that can provide a continuous crack path. These quite general recommendations are discussed in terms of a design philosophy to screen specific residuals and additives to produce alloys more resistant to hydrogen embrittlement.

Reference (Pressouyre & Bernstein)

Pressouyre, G. M. 1977 Ph.D. thesis, Carnegie–Mellon University.

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