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Microstructure vs. Impact Toughness Relationship in Hadfield's Austenitic Manganese Steel

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Abstract

Austenitic manganese steels are solution annealed and quenched to remove the embrittling grain boundary carbides present in as-cast condition. Their poor machinability makes the direct assessment of their mechanical properties by specimen preparation and testing expensive. Microstructural characterization is a desirable way to observe if satisfactory mechanical properties have been achieved. However, uncertainties exist in this practice as the grain boundary features are heterogeneously distributed and also a differentiation must be made between thin and thick carbides. The former requires an averaging process over a sufficiently large number of views, and the latter, a minimum 200H magnification. A procedure to evaluate grain boundary coverage by the embrittling constituents, and a relationship between observed coverage and impact toughness are presented.

Introduction

Hadfield's steel heat-treated to a single-phase retained austenite is an inherently tough material. Intergranular embrittlement occurs when grains loose cohesion because of intermediary phases, most notably the presence of hypereutectoid carbide resulting from a slow quench or reheating through the 400-800°C range. The degree of embrittlement depends on the degree of grain boundary coverage and the loss of cohesion of the austenite matrix, by the second phases.

Results and Discussion

Grade B manganese steels were processed in 1½ in., 3 in., 5 in. and 7 in. sections. Charpy specimens were machined by wire electro-discharge machining, tested at room temperature, and metallographic samples were taken from the ends of tested Charpy specimens.

Typically, the grain boundaries had carbide-free areas, thin carbide delineations and "thick" carbides. The microstructures showed that the thin carbides did not gradually thicken, but the thick carbides nucleated and grew laterally along the grain boundaries, (Figure1). A "thick" carbide was defined as one having clear phase boundaries resolved at 200x magnification. [1] The impact toughness was not impaired by the presence of thin carbides, but the thick carbides significantly decreased toughness. A good correlation between impact toughness and fraction of the grain boundary coverage by the "thick" carbides was obtained (Figure 2). This methodology provides greater accuracy in relating manganese steel microstructures to impact toughness.
Relationship between metallographic observation and Charpy impact toughness could be summarized as follows: If the weighted grain boundary coverage > 50%, toughness was poor, (CVN < 20J), on the other hand if the weighted g.b. coverage is < 20% then the steel has excellent toughness (more then 100J).

Reference

[1] S. Kuyucak , P. Newcombe and R. Zavadil (2000). "On the heat treatment of Hadfield's austenitic manganese steels - Part I: step-down temperature and residuals", AFS Trans., Paper No. 00-154.

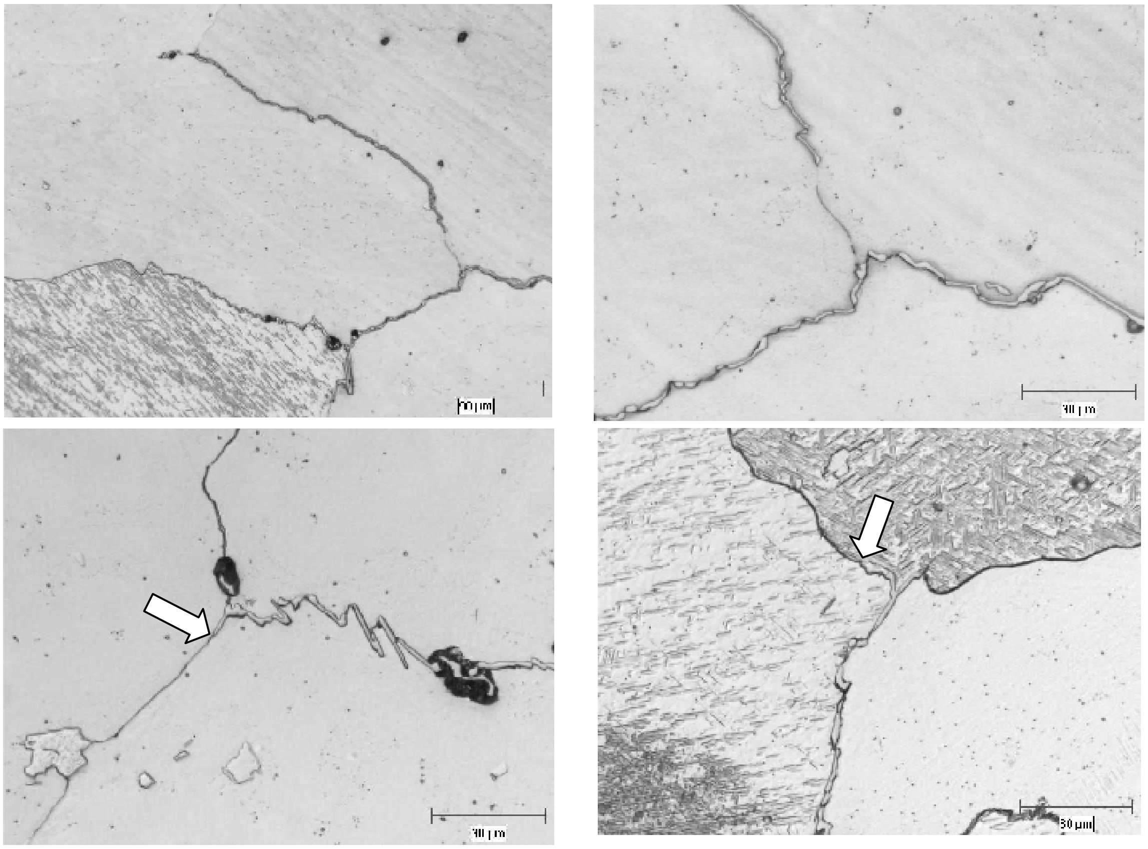

Fig. 1. Manganese steel microstructures showing carbides free grain boundaries thin carbide delineations, and thick carbide films. Thick carbides have a double phase boundary that distinguishes them from the thin carbides. Arrows show transition a thin to thick carbide.

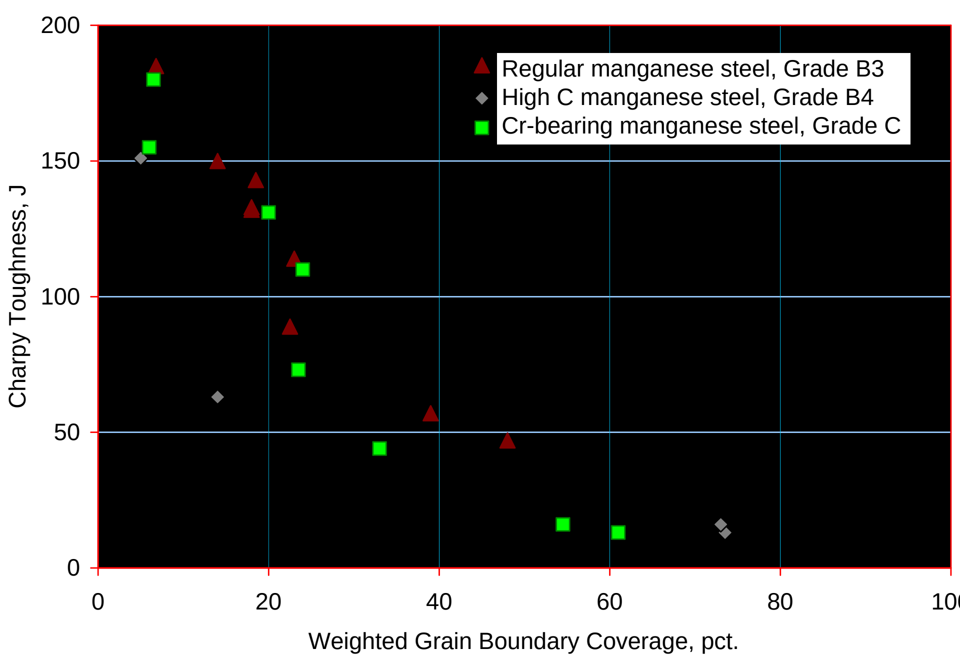

Fig. 2. Correlation between weighted grain boundary coverage by the embrittling constituents and impact toughness

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