8306-066

MICROALLOYING AND PRECIPITATION IN Cr-V RAIL STEELS

D. E. Parsons, T. F. Malis and J. D. Boyd
PMRL, CANMET, Energy Mines and Resources
Ottawa, Canada

A STUDY OF ALLOYING EFFECTS in Cr-V rail steels has been carried out to determine the microstructural strengthening mechanisms. The laboratory steels investigated were based on the commercial 1% Cr rail steel chemistry (0.75C - 0.8Mn - 1.25Cr - 0.30Si), and represented two levels of nitrogen (nominally 0.007 and 0.015 wt %), and two types of deoxidation practice. It is found that vanadium microalloying produces a yield stress increment of approximately 90 MPa for low nitrogen steels and 140 MPa for high nitrogen steels. This strengthening effect appears to saturate at approximately 0.15 wt % vanadium, with no further strength increase for higher vanadium concentration. The hardness and UTS exhibit the same variation with vanadium content as the yield stress. There is no consistent effect of aluminum content (deoxidation practice). Several distinct precipitate morphologies, a wide range of precipitate sizes and a non-homogeneous distribution of precipitates are observed. There is also significant partitioning of V, Cr and Mn to cementite. It is suggested that an increase in the amount of coarse, austenite-nucleated V(C,N) and possibly other coarse precipitate modes is responsible for the saturation of the vanadium strengthening effect.

INTRODUCTION

Eutectoid rail steels alloyed with chromium and vanadium have been developed which have higher hardness and better wear resistance than carbon-manganese rail, while maintaining adequate toughness, weldability and a fully pearlitic microstructure (1,2). Several metallurgical studies of the effects of composition on the microstructure and mechanical properties of Cr-V rail steels have been carried out (1-3). These investigations confirm the positive strengthening effect of microalloying with vanadium, but they give conflicting results for the relationship between yield stress and vanadium content. Evidence for vanadium carbide precipitates in such steels has been produced by transmission electron microscopy (2,4), but the details of the precipitation process are not known. In particular, it would be advantageous to understand the relationships between composition, processing variables and V(C,N) precipitation to optimize the properties of Cr-V rail steels. For instance, studies of the effects of cooling rate following rolling in C-Mn-V eutectoid steels indicate that maximum precipitation strengthening occurs at rates of $5°C.s^{-1}$ (5), i.e., approximately 10 times faster than normal rail-head cooling rates.

In the present study, the effects of vanadium, nitrogen and aluminum contents were investigated for a series of C-Mn-Cr-based rail steels, produced by a processing route designed to simulate standard rail production. The objectives were to determine the compositional dependence of the mechanical properties, to characterize the microstructures in detail, and to identify the microstructural strengthening mechanisms.

EXPERIMENTAL

A series of experimental steels, based on commercial 1% Cr rail-steel chemistry (0.75C - 0.8Mn - 1.25Cr - 0.30Si), was prepared as 225 kg heats by air-induction melting with argon cover. Each heat was tapped into a ladle, and cast as four 125 mm x 125 mm x 380 mm rectangular blocks. After the first two blocks of each heat were poured, aluminum was plunged into the ladle, and the remaining two blocks were poured. The compositions of the experimental steels given in Table 1 are the average values for the two blocks of each steel. With the exception of nitrogen, all of the analyses were carried out by direct-reading spectrometer. Total nitrogen contents were determined by a modified Kjeldahl distillation method, and the results were confirmed by analysing selected specimens using a LECO nitrogen analyser. The experimental steels represented (i) two levels of nitrogen by wt %; (low) L - 0.004/0.010 and (high) H - 0.011/0.022; (ii) a range of vanadium contents from 0-0.33;