EFFECTS OF NITROGEN ADDITION ON THE STRUCTURE AND PROPERTIES OF EUTECTOID STEELS PRODUCED BY ROLLING

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INTRODUCTION

Nitroalloyed eutectoid steels with vanadium and/or niobium additions have previously been considered as potential candidates for rail steel applications (1,2). The possible role of the microalloying elements in these high-carbon steels, however, has not yet been totally clarified. The present work has been undertaken in order to study the effect of niobium on the relationship between thermomechanical treatment, microstructure and mechanical properties.

EXPERIMENTAL PROCEDURES

A 0.45% C/1% Mn steel, with and without the addition of 0.03% Nb (steel 89 and steel 8, respectively) were prepared in the form of small 5 kg ingots by vacuum induction melting. In one series of experiments (rolling schedule A), samples were heated at 900, 1000 and 1250°C for 1 hour, followed by an immediate two-pass rolling sequence with a total reduction of 56% in thickness. In another series of experiments (rolling schedule B), samples were annealed at 1250°C for one hour and then cooled to 800°C before being subjected again to the same two rolling passes. In a third series of experiments (rolling schedule C), samples were once more heated at 1250°C for one hour, cooled to 1000°C and then subjected to four rolling passes with a total reduction in thickness of 60%. After rolling, cooling occurred in still air.

RESULTS

Table 1 gives a summary of the results obtained. Total austenite recrystallization and a ferrite pearlite structure were observed in all samples subjected to rolling schedule A. The austenite grain size before and after rolling was always smaller in the niobium steels. After heating to and rolling at 900°C, yield and tensile strength were lower for the
nichrome steel, due to a pronounced grain refining effect of the microalloy addition (reduction in austenite grain diameter by a factor of four). Higher soaking temperatures, on the other hand, favoured the nichrome steels, due to an increasing amount of niobium in solution (according to solubility data \( \text{[9]} \)). 70% of the total niobium addition was in solution at 900 °C, 20% at 1100 °C and 7% at 1250 °C. Niobium dissolved in austenite is known to retard the austenite-to-perlite transformation \( \text{[9]} \). As a result, a smaller pearlite interlamellar spacing should have been responsible for the higher strength observed. The increase in strength, as expected, was always accompanied by a small decrease in ductility.

We precipitation hardening effect due to niobium carbides in the pearlitic ferrite phase was found, as can be verified from Table 2 which shows pearlite hardness at a given interlamellar spacing did not change with the addition of niobium. With respect to pearlite microstructure, the formation of a fibrous form of cementite was observed in addition to the usual lamellar pearlite morphology, Fig.1.

The volume fraction exhibiting the fibrous morphology was found to increase with niobium addition and soaking temperature. Thus this microstructural aspect may have contributed to the strength increase observed.

Comparing tensile properties (Table 3) for the niobium steel as a function of rolling schedule, it may be noted that:

- a decrease in rolling temperature from 1250 to 900 °C (rolling schedules A and 3) resulted in a 62% reduction of yield strength and a 55% gain in elongation, and

- a decrease in rolling temperature from 1250 to 1000 °C in conjunction with an increase of the total deformation from 34 to 40 led to a 41% reduction in yield strength and a 46% gain in elongation.

It may thus be concluded that the addition of niobium to a high-carbon austenitic steel can lead to an increase in strength without compromising ductility provided that the thermomechanical treatment is adequately controlled.

REFERENCES

2. ROBINSON, R.J.P. et alii - Proc. of Conf. HSLA Steels, Nov. 1983, China, ASM, p. 407
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Table 1 - Tensile properties, microhardness and microstructural characterization as a function of rolling schedule and niobium addition

Fig. 1 - Steels B after rolling at 900°C. The cementite seems lamellar at lower magnification (150x), but at higher magnification (6000x) the real fibrous structure appears.