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

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INTRODUCTION

Microalloyed 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 microalloy 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 0.8% C/ 1% Mn steel, with and without the addition of 0.03% Nb (steel 8N 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 34% in thickness. In another series of experiments (rolling schedule B), samples were soaked at 1250 °C for one hour and then cooled to 900 °C before being subjeted 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 subjeted to four rolling passes with a total reduction in thickness of 60%. After rolling, cooling occurred in still air.

RESULTS

Table I gives a summary of the results obtained. Total austenite recrystallization and a 100% pearlite structure were observed in all samples subjeted 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 niobium 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 niobium steels, due to an increasing amount of niobium in solution (according to solubility data [3], 2% of the total niobium addition was in solution at 900 °C, 20% at 1100 °C and 70% at 1250 °C). Niobium dissolved in austenite is known to retard the austenite-to-pearlite transformation[4]. As a result, a smaller pearlite interlamellar spacing should have been responsible for the higher strength obseved. The increase in strength, as expected, was always accompanied by a small decrease in ductility.

No precipitation hardening effect due to niobium carbonitrides in the pearlitic ferrite phase was found, as can be verified from Table I which shows pearlite hardness at a given intelamellar 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 microstrutural effect may have contributed to the strength increase observed.

Comparing tensile properties (Table I) 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 B) resulted in a 6% reduction of yield strength and a 5% gain in elongation, and that
- a decrease in rolling temperature from 1250 to 1000 °C in conjuntion with an increase of the total deformation from 34 to 60% led to a 14% reduction in yield strength and a 40% gain in elongation.

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

REFERENCES

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Series A steel	temp (°C)	σ_y MPa	σ_{max} MPa	Elong. %	R.A. %	d_γ (μm) Before	After	S_o μm	H_P Vickers
·8	900	519	969	11.8	35.6	90	42	0.23	300
8N	900	494	959	12.7	36.0	15	10	0.22	306
8	1100	555	991	9.9	31.5	1000	128	0.19	308
8N	1100	577	1015	10.9	33.0	130	70	0.18	321
8	1250	608	1030	8.2	17.3	1800	333	0.18	329
8N	1250	737	1119	4.0	7.2	1000	316	0.16	357

steel	Se-ries	σ_y MPa	σ_{max} MPa	Elong. %	R.A. %	d_γ (μm) Before	After
8	B	606	1028	7.6	15.0	1800	180
8N	B	689	1054	4.2	5.4	1000	695
8	C	558	995	10.8	29.9	1800	-
8N	C	637	1064	9.6	24.4	1000	-

d_γ = austenite grain size

S_o = interlamellar spacing of pearlite

Hp = microhardness of pearlite

Table 1 - Tensile properties, microhardness and microstructural characterization as a function of rolling schedule and niobium addition

1300x 3300x 6700x

Fig. 1 - Stell 8N after rolling at 900 °C. The cementile seems lamellar at lower magnification (1300x), but at higher magnification (6700x) the real fibrous structure appears.