EFFECTS OF THERMO-MECHANICAL TREATMENT ON MEDIUM NICKELALLOYED MEDIUM CARBON STEELS

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INTRODUCTION

Medium carbon microalloyed steels are increasingly being used in the forging industry for automotive components. Addition of the microalloying elements V, Nb and/or Ti offers adequate strength to be achieved after air cooling, with obvious cost advantages over the traditional quenched and tempered steels(1). Although the market for microalloyed forgings has grown considerably during the last decade, research is continuing with the aim of elucidating relationships between thermomechanical treatment, microstructure and final properties.

EXPERIMENTAL PROCEDURES

Experimental 0.42% C/1.02% Nb steels with (steel 48) and without (steel 4) additions of 0.03% Nb were prepared in the form of small 5 kg ingots by vacuum induction melting. Three different rolling sequences were used in order to simulate the effect of varying hot forging conditions on microstructure and mechanical properties.

In the first series of experiments (rolling schedule A), steels were heated during 1 hour at 900, 1100 and 1250°C, followed immediately by two hot-rolling passes with an overall reduction in thickness of 34%. In another experiment (rolling schedule B), steels were kept at 1250°C for 1 hour, cooled to 900°C and again hot rolled by two passes with a 34% reduction in thickness. In the last series of experiments (rolling schedule C), steels were maintained once more at 1250°C for 1 hour and cooled to 1000°C. Four hot rolling passes were then applied with a total reduction in thickness of 60%. After rolling, samples cooled to room temperature in air.

RESULTS

Mechanical properties and the relevant structural parameters after rolling were

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determined through tensile tests, hardness measurements and quantitative metallography, respectively. Results are given in Table 1. In addition, samples of the ferrite-pearlite microstructure after austenitizing at 1250°C are shown in Fig. 1, as a function of rolling schedule. Irrespective of the soaking and rolling conditions employed, final microstructures consisted almost always of ferrite and pearlite only.

In the case of schedule A, two-pass rolling directly after soaking at 900, 1100 and 1250°C lead to complete austenite recrystallization, with the niobium steel consistently exhibiting a smaller austenite grain size before and after rolling. Yield and tensile strength increased with the niobium addition, and such an increase proved more effective at higher soaking temperatures. On the other hand, ductility remained nearly constant despite of the increase in strength, both respect to microstructure, it can be seen from Table I that the presence of niobium was associated with a larger ferrite volume fraction but did not significantly affect the grain size of the proeutectoid ferrite.

The strengthening effect of niobium should thus be explained by

- a smaller interlamellar spacing of pearlite, since niobium in solution in austenite will lead to a lower transformation temperature (11), and/or by
- the presence of fine niobium carbide particles in proeutectoid (13)

or pearlitic ferrites which may lead to precipitation strengthening.

Due to a larger amount of niobium in solution and because of lower deformation temperatures, rolling schedules B and C allowed the traditional effect of niobium on austenite recrystallization kinetics to be observed. Without niobium, recrystallization went to completion after 601 at 1000°C, while the 342 reduction at 900°C produced a partially recrystallized structure. In the case of the niobium steel, partial recrystallization occurred at 1000°C whereas the austenite remained microcrystallized at 900°C.

Comparison between rolling schedules A, B and C at the same austenitization temperature of 1250°C indicates that rolling temperature and amount of deformation may affect the balance between tensile strength and ductility for the microalloyed steel. Thus, a slightly lower yield strength but the same ductility were observed when the rolling temperature was decreased from 1350 to 900°C (schedules A and B). On the other hand, a gain in ductility (38.2 versus 44.32 reduction in area) was offset by a drop in yield strength (424 versus 480 MPa) when the rolling temperature was reduced from 1350 to 1000°C and total deformation increased from 34 to 601 (schedules A and C).

It may therefore be concluded that niobium can be effective in raising strength without compromising ductility if the thermomechanical treatment is adequately controlled.

REFERENCES

(1) WRIGHT, P.E. et al. - in: "Fundamentals of microalloying forging steels."

(2) MEI, P.R. - Teorê de límite. -Docência. Faculdade de Engenharia Mecânica, UNICAMP, R.F., Brazil, Dec. 1989, p. 229


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Table 1: Tensile properties, hardness and microstructural characterization as a function of rolling schedule and microalloy addition

<table>
<thead>
<tr>
<th>Steel</th>
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<tr>
<td>N</td>
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d - austenite grain size
D0 - ferrite grain size
s0 - interlamellar spacing of pearlite
f0 - volume fraction of ferrite
Rp, Rm - microhardness of pearlite and ferrite

Figure 1: Ferrite - pearlite microstructures after soaking at 1250 °C, hot rolling according to schedules A, B, and C, and air cooling. Magn. 40×.