EFFECTS OF THERMOMECHANICAL TREATMENT ON NIOBIUM MICROALLOYED MEDIUM CARBON STEELS

Paulo Roberto Mei (*)
Hans Jurgen Kestenbach (**)

(*) DEPTO DE ENGENHARIA DE MATERIAIS. FEM - UNICAMP - BRAZIL - FAX (0192) 39.3722
(**) DEPTO DE ENGENHARIA DE MATERIAIS. UFSCar - BRAZIL - FAX (0162) 72.7404

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 offer adequate strength to be achieved after air cooling, with obvious cost advantages over the traditional quenched and tempered steels(1). Althrough the market for microalloyed forgings has grown considerally during the last decade, research is continuing with the aim of elucidating relationships between thermomechanical treatment, microstructure and final properties.

EXPERIMENTAL PROCEDURES

Experimental 0.4% C/ 1.0% Mn steels with (steel 4N) and without (steel 4) the addition 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 immediatelly 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, samplès cooled to room temperature in air.

RESULTS

Mechanical properties and the relevant structural parameters after rolling were determined through tensile tests, hardness measurements and quantitative metallography, respectively. Results are given in Table I. In addition, examples 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 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. With respect to microstucture, 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 pro-eutectoid 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(2), and/or by
- the presence of fine niobium carbonitride particles in proeutectoid (3) or pearlitic ferrite 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 60% at 1000° C, while the 34% 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 inrecrystallized 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 1250 to 900°C (Schedules A and B) . On the other hand, a gain in ductility (58.2 versus 44.5% reduction in area) was offset by a drop in yield strength (456 versus 489 MPa) when the rolling temperature was reduced from 1250 to 1000° C and total deformation increased from 34 to 60% (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.H. et alii - In: "Fundamentals of microalloying forging steels."
KRAUSS, G.& BANERJI, S.K., Eds., AIME, 1987, p. 541

(2) MEI, P.R. - Tese de Livre -Docência, Faculdade de Engenharia Mecânica, UNICAMP, S.P., Brazil, Dec. 1989, p. 220

(3) TANINO, M. & AOKI, K. - Trans. Iron Steel Inst., Japan, vol. 8, 1968, p. 337

Series A		σ_y	σ_{max}	Elong.	R.A.	d_γ (μm)		f_α	d_α	S_o	Hp	H_α
steel	temp (°C)	MPA	MPA	%	%	Before	After	%	μm	μm	Vickers	Vickers
4	900	412	661	21.4	60.1	130	44	32.8	5.0	0.19	239	125
4N	900	431	654	22.9	62.1	40	27	35.6	5.3	0.19	218	121
4	1100	380	695	19.4	53.5	300	104	19.8	4.8	0.21	237	129
4N	1100	408	717	16.3	55.8	180	67	24.6	5.4	0.20	247	144
4	1250	399	718	17.0	51.0	400	171	8.6	4.4	0.21	236	136
4N	1250	489	768	15.2	44.5	400	137	15.1	5.0	0.19	284	168

	Se-	σ_y	σ_{max}	Elong.	R.A.	d_γ (μm)	
steel	ries	MPA	MPA	%	%	Before	After
4	B	388	689	18.0	59.5	400	240
4N	B	478	776	14.5	45.0	400	274
4	C	385	668	20.5	59.8	400	-
4N	C	456	746	17.2	58.2	400	-

d_γ =austenite grain size

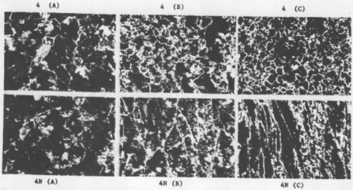
d_α =ferrite grain size

S_o =interlamellar spacing of pearlite

f_α =volume fraction of ferrite

H_p, H_α=microhardness of pearlite and ferrite

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



4 (A) 4 (B) 4 (C)

4N (A) 4N (B) 4N (C)

Figura I : Ferrite - pearlite microstructures after soaking at 1250 ° C, hot rolling according to schedules A, B, and C, and air cooling. Nital, 45x