EFFECT OF CONTROLLED ROLLING PARAMETERS ON THE AGEING RESPONSE OF AN HSLA-80 STEEL

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ABSTRACT

Microalloyed steels containing copper in order to promote precipitation hardening are one of the approaches adopted to develop new materials with high mechanical strength but minimized carbon content to assure good weldability. Besides that, the thermomechanical processing of such alloys can eliminate the subsequent quench and tempering heat treatments required by conventional steels. The effects of controlled rolling parameters over the ageing response of an HSLA-80 microalloyed steel with 1.10% copper were studied in this work. The relatively weak influence over the ageing response verified when the reheating temperature was elevated from 1100°C to 1200°C indicated that copper precipitation is the main mechanism behind the hardening promoted by the ageing treatment; niobium had a secondary role. The strain degree applied during the roughing phase increased the ageing response of the alloy, but a increase in the strain degree applied during the finishing phase had no effect over this aspect. Also a finishing temperature variation did not affect significantly the ageing response of the HSLA-80 steel.

Keywords: HSLA-80 Steel, Precipitation Hardening, Copper, Controlled Rolling

1 INTRODUCTION

Carbon significantly degrades the weldability of structural steels. On the other hand, carbon plays a vital role in their hardening mechanisms. This situation motivated the development of several alternative alloys to produce plates with equivalent mechanical strength but minimized carbon content. One can mention, for example, the hardening through copper precipitation in ferrite of HSLA-80 steel [1].

It is known that the use of accelerated cooling immediately after hot rolling enhances this response and that age hardening response of the as-rolled material if its hot rolling finishing temperature is lower than the alloy Ar_3 temperature [2]. However, the effects of the thermomechanical treatment over the hardening effect promoted by the ageing of a HSLA-80 steel still is not fully understood. The aim of this work is to report some correlations between controlled rolling parameters and ageing response of this steel.

2 EXPERIMENTAL PROCEDURE

The HSLA-80 steel studied in this work was melted in a laboratory vacuum induction furnace. Its chemical analysis was 0.044% C, 0.65% Mn, 0.32% Si, 0.005% P, 0.011% S, 0.013 Al_{sol}, 0.87% Ni, 0.77% Cr, 1.12% Cu, 0.23% Mo, 0.077% Nb and 0.0030% N. The ingot was rough rolled to break and homogenize the as-cast structure. The specimens for the hot rolling tests were machined from these rolled bars.

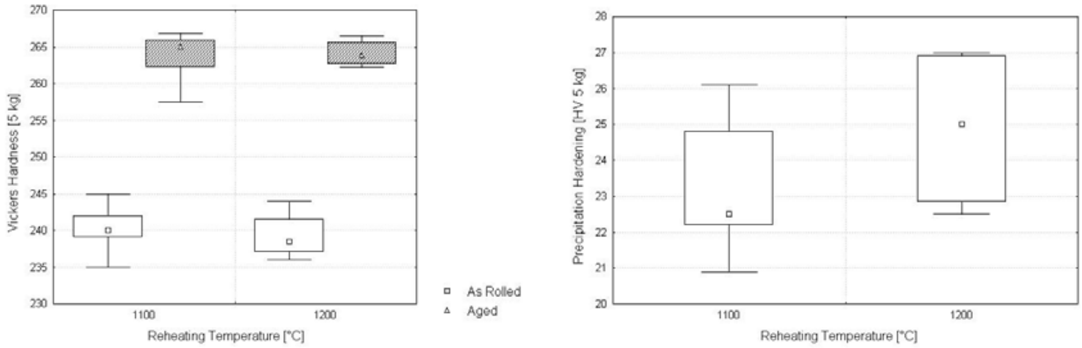
Two series of tests were carried out to study the effect of controlled rolling parameters over age hardening response of HSLA-80 steel. The first one aimed to verify the effect of the strain degree applied to the specimen, while the other was performed in order to study the effect of finishing temperature. Specific details about the trials can be seen in Table 1. Finishing temperature in the first series of tests was 750°C, while this parameter was equal to 700°C or 800°C in the second series. The hardness of as-rolled specimens was measured using the Vickers scale with 5 kg load. After that they were aged at 600°C during one hour and the hardness measurements were repeated.

Table 1: Experimental parameters applied in the controlled rolling tests performed in this work.

Parameters		A		B		C		D	
Reheating Temperature [°C]		1200	1200	1200	1200	1100	1100	1100	1100
Roughing Strain	Real	0.36	0.36	0.69	0.69	0.36	0.36	0.69	0.69
	Nominal [%]	30	30	50	50	30	30	50	50
Finishing Strain	Real	0.51	1.10	0.51	1.10	0.51	1.10	0.51	1.10
	Nominal [%]	40	67	40	67	40	67	40	67
Total Strain	Real	0.86	1.46	1.20	1.79	0.86	1.46	1.20	1.79
	Nominal [%]	58	77	70	83	58	77	70	83
Final Thickness [mm]		17.6	9.8	12.6	7.0	17.6	9.8	12.6	7.0

3 EXPERIMENTAL RESULTS AND DISCUSSION

Figure 1a shows the effect of reheating temperature applied during hot rolling tests over the hardness values of as-rolled and aged specimens; for its turn, Figure 1b shows the precipitation hardening got for this samples. The results indicate that an increase of reheating temperature from 1100°C to 1200°C did not promoted greater final hardness in the as-rolled samples; similar effects were also noted for yield and tensile strength [3]. However, precipitation hardness was clearly greater for the samples reheated at 1200°C, probably indicating a slightly greater effect of a increased amount of solute niobium, but much lower than that observed for copper.



(a) (b)

Figure 1: Reheating temperature effect over a) as-rolled and aged hardness and b) precipitation hardening.

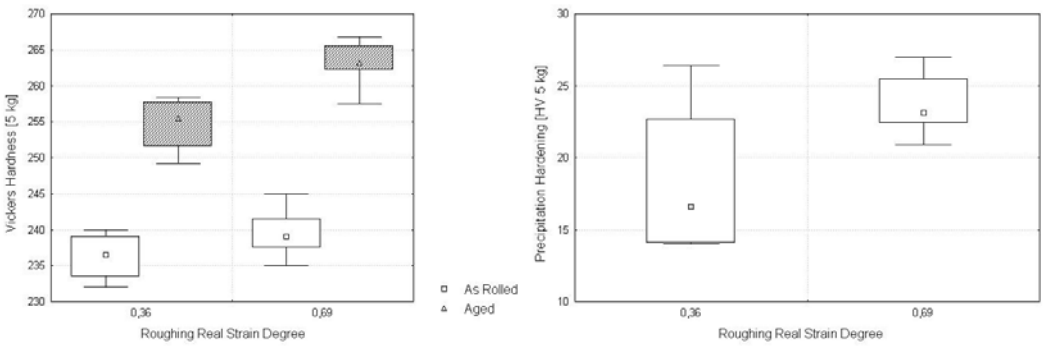
An increase in reheating temperature can promote contradictory effects over the age hardening response of the HSLA-80 steel. For one hand, greater austenitizing temperatures increase the amount of solute niobium, that is, greater precipitation potential during ageing treatment. On the other hand, lower reheating temperatures promote finer austenitic grain size, as shown in Table 2 [4]. Evidence in the literature

[1,5] reports that a finer grain size leads to a finer copper precipitation, increasing its hardening effect. So, the final result from a variation in the reheating temperature over age hardening response will be function of the net result between these tendencies.

Table 2: Effect of reheating temperature and strain degree over austenite mean grain size after reheating and roughing stage of an HSLA-80 steel [4].

T_{reheat} [°C]	Grain Size after Reheating [μm]	Grain Size After Roughing [μm]	
		ε_{esb} = 0.36	ε_{esb} = 0.69
1100	82±4	64±3	24±1
1200	102±4	52±2	32±1

The effect of the strain degree applied during the roughing phase was not very intense for the as-rolled samples, but much more significant in the aged ones, as shown in Figure 2. The enhancing of the ageing response promoted by a increase in the strain degree during the roughing stage can be explained due to the greater grain refining effect verified under these conditions, as shown in Table 2 [4].



(a) (b)

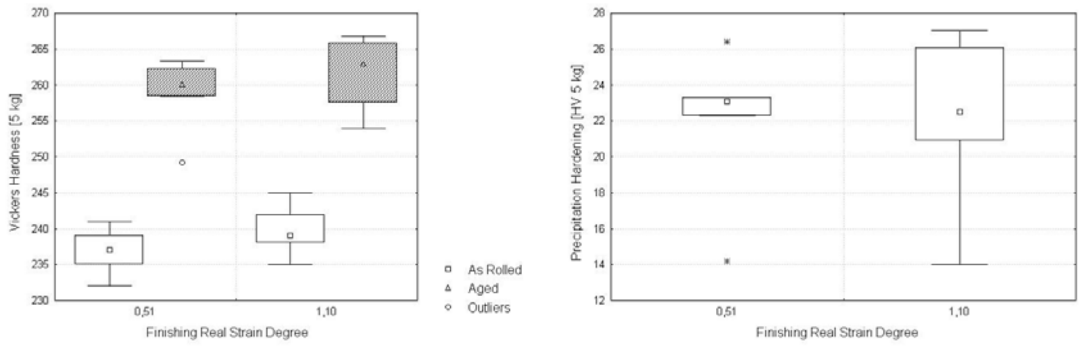
Figure 2: Roughing strain degree effect over a) as-rolled and aged hardness and b) precipitation hardening.

Strain degree applied during the finishing stage had a very modest effect in the hardness of both as-rolled and aged samples and practically no effect in the ageing response, as shown in Figure 3. These results were confirmed by the literature [6]: this loss in the age hardening can be associated to copper precipitation in the strain hardened metastable austenite, at temperatures lower than the Ar_3 point, which did not promotes hardening. The increase in the strain hardening degree of austenite due to the greater finishing strain would enhance this kind of precipitation, counteracting the corresponding grain refining effects over ageing response.

Lower finishing temperatures did not produce significant effects over hardness values got in the as-rolled nor in the aged specimens, as Figure 4 shows. So, as it was previously seen [3], a finishing temperature variation in the 700°C to 800°C range did not influence significantly the mechanical properties of the HSLA-80 steel.

4 CONCLUSIONS

The results of this work show that the effect of process parameters of controlled rolling over the ageing response of an age hardenable HSLA-80 microalloyed steel was not very significant. Apparently most of the hardening effect is due do copper precipitation, with niobium having a discrete role. The increase in the strain degree applied during the roughing phase intensified the ageing response, but no significant effects were detected variations in finishing strain degree or finishing temperature.



(a) (b)

Figure 3: Finishing strain degree effect over a) as-rolled and aged hardness and b) precipitation hardening.

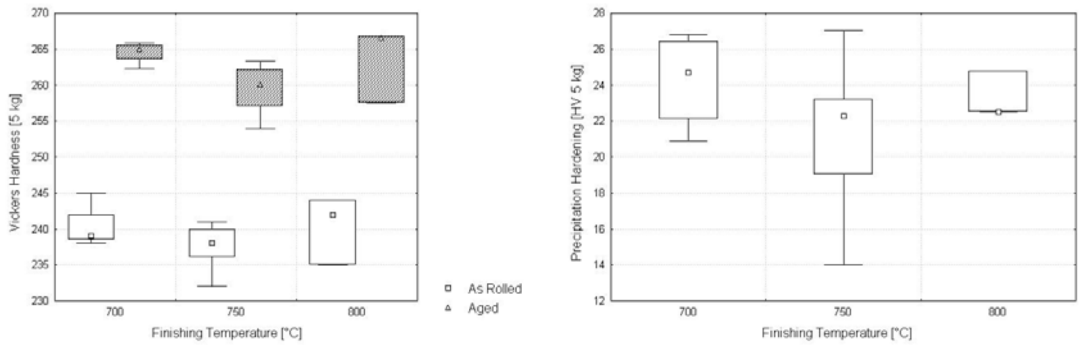


Figure 4: Finishing temperature effect over a) as-rolled and aged hardness and b) precipitation hardening.

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