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Development of alternative as-rolled alloys to replace quenched and tempered steels with tensile strength in the range of 600 to 800 MPa

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Abstract: New structural steels must present hardening mechanisms which does not require the presence of C in order to maximize its weldability, but simultaneously promoting high mechanical strength and toughness. One of the most promising answers to this challenge are steels hardened by copper precipitation, like HSLA-80 or ASTM A710, and the so-called Ultra Low Carbon Bainite (ULCB) steels. The aim of this work was to study the effects of some controlled rolling parameters over the mechanical properties of these new steels. It was verified here that the total strain applied during hot rolling and the finishing temperature were essential to improve the toughness of both alloys; the effect of the former parameter revealed to be more important. The aged HSLA-80 steel showed greater values of yield strength, but lower toughness than the as-rolled ULCB alloy.

Keywords: Microalloyed Steels; Copper Precipitation; Extra-Low Carbon Bainite

1. INTRODUCTION

Extra-heavy high strength structural steel plates, with thickness range between 25 and 100 mm and satisfying at least the specifications of the API 5L-X80 standard for linepipes, require the use of a more complex alloy design than that used for thinner plates. This kind of material must also be easily formed and welded by the customer [1-5].

Two alloy concepts were proposed to fulfill these stringent requirements: microalloyed steels hardened by copper precipitation (ASTM A710/HSLA-80) [6] or through the formation of a tough bainitic microstructure (ULCB - “Ultra Low Carbon Bainite”) [7]. They do not need to be submitted to a quench and temper heat treatment in order to get their final properties. Besides that, they show an extra-low carbon content, as its hardening mechanisms does not depend so much on this element. In the case of the HSLA-80 steel, copper precipitation represents a significant contribution to mechanical strength, whereas in the ULCB alloy this role is played by the bainitic microstructure and by the solid solution hardening effect promoted by substitucional alloy elements [8-12]. These approaches promote better weldability for both alloys, which can represent a 50% cost reduction during the fabrication of components and structures [5].

The aim of this work was to study the effect of thermomechanical processing over the mechanical properties of a copper precipitation-hardened steel (ASTM A710/HSLA-80) and an ULCB steel, as well to compare the characteristics of both alloys.

2. EXPERIMENTAL

The HSLA-80 and ULCB steel studied in this work were produced in a vacuum melting furnace; their chemical analysis can be seen at Table 1. The as-cast ingots were hot rolled in order to break and homogenize the as-cast structure. The rolling test specimens were constituted of a block of each steel held together by a welded steel frame.

Table 1.
Chemical analysis of the steels used in this study (%w)

Aço	C	Mn	Si	P	S	Al_{sol}	Ni	Cr	Cu	Mo	Nb	Ti	B	N
HSLA-80	0,044	0,65	0,32	0,005	0,011	0,013	0,87	0,77	1,12	0,23	0,077	---	---	0,0030
ULCB	0,033	1,93	0,29	0,007	0,011	0,006	0,39	---	---	0,35	0,062	0,029	0,0016	0,0030

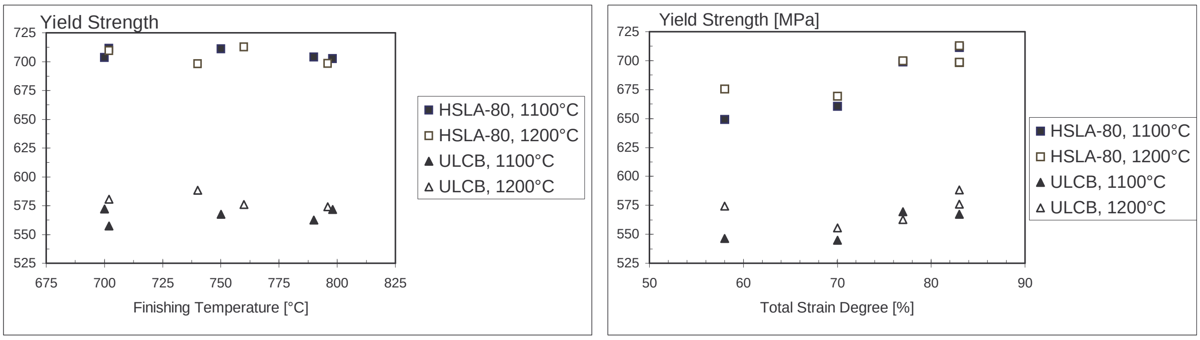
One test series was performed to verify the effect of total strain applied during controlled hot rolling over the mechanical properties of both alloys; total strain varied between 58% and 83% and the aimed finishing temperature was 750°C. Another series of tests was included in order to study the effect of finishing temperature, which aimed values were 700 and 800°C; a total strain of 83% was applied in this case. Two reheating temperatures were used in both test series: 1100°C and 1200°C; austenitizing time at aimed temperature was equal to 15 minutes. All rolled samples were cooled in still air. Temperature evolution of the specimens was measured by a chromel-alumel thermocouple. Samples of HSLA-80 were additionally aged at 600°C for one hour. Tensile and Charpy impact test samples were machined from these rolled samples; Charpy impact tests were performed under a temperature of -20°C.

3. RESULTS AND DISCUSSION

As expected, yield strength increased as total strain applied during hot rolling raised, as shown in figure 2a. The aged HSLA-80 steel samples showed yield strength clearly greater than the corresponding ones of ULCB steel, as well a slightly higher sensitivity towards total strain. The use of a higher slab reheating temperature promoted a slight increase in yield strength, but this effect tended to disappear when greater values of total strain were applied during hot rolling of the steel samples. For its turn, the influence of the finishing temperature over yield strength, depicted in figure 2b, was virtually negligible.

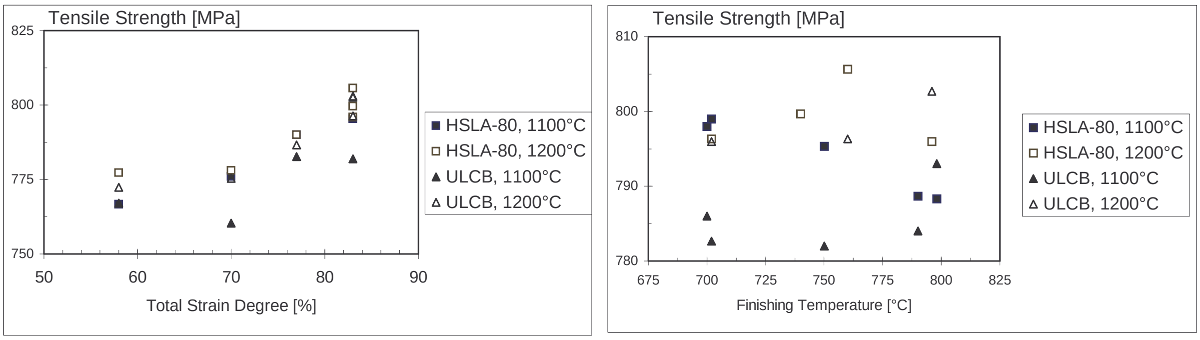
Figure 3a shows that also the tensile strength tended to increasing according to the total strain value applied during hot rolling. The rise in reheating temperature also promoted a slight increase in the tensile strength. Also in the case of tensile strength it was not possible to verify a consistent influence of the finishing temperature, as data present in figure 3b indicates. The flutuactions observed are small and random, particularly in the case of the ULCB steel. The effect of reheating temperature and steel composition were also not apparent.

The effect of total strain applied during hot rolling over steel toughness was very significant for both steels, but particularly for the aged HSLA-80 alloy, as figure 4a shows. The ULCB steel was tougher certainly due to its slightly lower level of strength and had a smaller contribution from precipitation hardening. The samples reheated at lower temperature, 1100°C, tended to be slightly tougher; in the case of ULCB steel this toughness increase was lower and became null for higher strain levels applied during hot rolling. The results exposed in figure 4b show that the increase in the finishing temperature lead to a great decrease in toughness, particularly in the case of the aged HSLA-80 steel. Once more the ULCB steel showed a better performance considering this aspect.



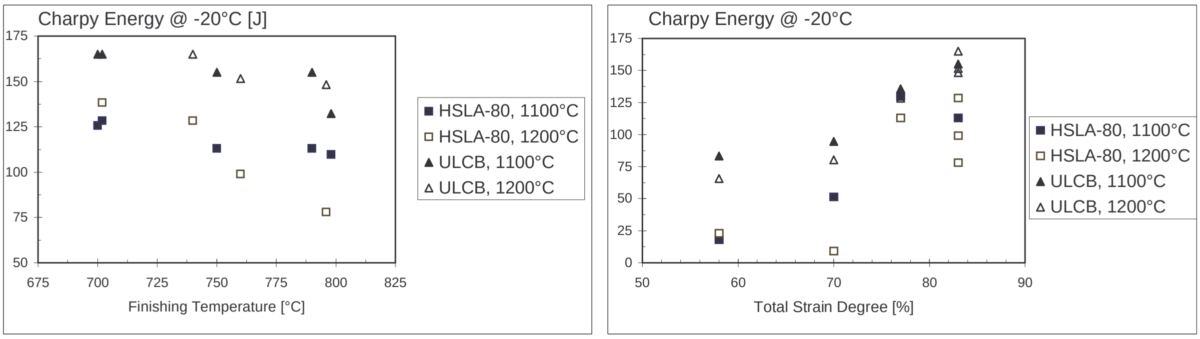
(a) (b)

Figure 2: Evolution of the yield strength of the HSLA-80 (aged) and ULCB (as rolled) steels according to the a) total strain and b) finishing temperature applied during the rolling tests



(a) (b)

Figure 3: Evolution of the tensile strength of the HSLA-80 (aged) and ULCB (as rolled) steels according to the a) total strain and b) finishing temperature applied during the rolling tests



(a) (b)

Figure 4: Evolution of the Charpy energy of the HSLA-80 (aged) and ULCB (as rolled) steels according to the a) total strain and b) finishing temperature applied during the rolling tests

4. CONCLUSION

This work aimed to point the influence of some hot rolling parameters over mechanical properties of new extra-low-carbon microalloyed steels like HSLA-80 and ULCB. The effect of reheating temperature was not very important: generally higher values of such parameter lead to a discreet increase in strength and decrease in toughness levels. Toughness of both alloys was strongly improved as total strain degree during hot rolling increased, particularly for the aged HSLA-80 alloy. The increase in total strain degree also lead to slight higher strength levels in both steels. No effects were detected in the ductility of both materials. The decrease in the finishing temperature also increased markedly toughness of both alloys, but with an effect not as intense as verified for the total strain degree. This decrease in finishing strength barely affected mechanical strength and promoted a very slight ductility increase.

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