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INFLUENCE OF SOAKING TEMPERATURE ON THE PHASE TRANSFORMATION TEMPERATURES AND MICROSTRUCTURE OF Nb MICROALLOYED LOW-CARBON STEELS CONTAINING Mn AND Si[1]

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Abstract
The Advanced High Strength Steels (AHSS) plates have been developed there is more than forty years, e.g. to attend the automotive market in order to reduce fuel consumption and environmental preservation. The low carbon steels with dual-phase structure exhibit combination of higher resistance and ductility than the ferrite-perlite steels that can obtain with economical addition (Mn and Si). For this work were elaborated in pilot scale three low carbon steel, containing Mn and Si and Nb microalloyed. In order to define the procedure for hot rolling in pilot scale, related to the reheating temperature and the minimum finish temperature in austenite field, were executed two distinct thermal treated (soaking temperature at 1000 and 1230ºC for 360 s and heating/cooling rate of 1ºC/s) in a quenching dilatometer (Adhamel, DT1000). The microstructural evolution before and after the processing were available by microscopy (optical and scanning electronic). The characterization of the steels in study was made with the intention of verifying how the soaking temperature can affected the phase transformation temperature and microstructural changes in which alloys related to chemical composition. The results show that the highest soaking temperature promotes grain growth and higher austenite homogenization.
Key words: Low-carbon steels; Annealing treatment; Phase transformation.

INFLUÊNCIA DA TEMPERATURA DE ENCHARQUE NAS TEMPERATURAS DE TRANSFORMAÇÃO DE FASE E MICROESTRUTURA DE AÇOS BAIXO-CARBONO MICROLIGADOS AO Nb CONTENDO Mn E Si

Resumo
As chapas de aços avançados de alta resistência (A.H.S.S., Advanced High Strength Steels) vêm sendo desenvolvidas há mais de quarenta anos, como por exemplo para atender ao mercado automotivo de forma a reduzir o consumo de combustível e preservação ambiental. Os aços de baixo carbono com estrutura bifásica apresentam combinação de resistência e dutilidade mais elevadas que os equivalentes ferríticos-perlíticos, podendo ser obtidos a partir de adições econômicas (Mn e Si). Para este trabalho foram elaborados em escala piloto três aços baixo carbono, contendo Mn e Si e microligados ao Nb. Com o intituito de definir o procedimento para a laminação a quente em escala piloto, relacionado com a temperatura de reaquecimento e a mínima temperatura de acabamento no campo austenítico, foram executados dois tratamentos térmicos distintos (temperatura de encharque a 1000 e 1230ºC por 360 s e taxa de aquecimento/resfriamento de 1ºC/s) em um dilatometro de têmpera (Adhamel, DT1000). A evolução microestrutural antes e após o processamento foram avaliadas por microscopia (óptica e eletrônica de varredura), com o intuito de verificar como a temperatura de encharque pode afetar as temperaturas de transformação de fase e mudanças microestruturais relacionadas a composição química dos três aços. Os resultados mostram que altas temperaturas de encharque promovem crescimento de grão e maior homogenização da austenita.
Palavras-chave: Aços baixo-carbono; Tratamento de recozimento; Transformação de fase.

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1 INTRODUCTION

Although the dual-phase steels researches have been started some decades behind, where the first developments in dual-phase steel was in 1937. But the great interest in these steels is recent. This accelerated the use of the dual-phase steels that is a class of the high steel low alloys (HSLA).[1-21]

An available resources to maximize simultaneously the ductility and ultimate strength of the steels consists in obtain a more complex microstructures than ferritc and ferritic-perlitic usually presents in low carbon steels. The obtaining of this microstructure in these steels occurs during cooling controlled starting from the intercritic region, where promote a high resistance mechanical and good tenacity to these steels. The dual-phase steel microstructure can exhibit, besides the ferritic and martensitic phases, a few amounts of bainite and retained austenite.

In the present work was studied the correlation between the chemical composition and microstructural evolution during the re-heating step on the soaking temperature and the influence in the phase transformation temperature (A_1, A_3, Ac_1 and Ac_3) in the subsequent cooling at distinct rate, where three Nb Microalloyed Low-Carbon Steels containing Mn and Si were tested.

2 MATERIAL AND METHODS

2.1 MATERIAL

The Nb Microalloyed Low-Carbon Steels containing Mn and Si samples used in this study were supplied by Companhia Siderúrgica Nacional (CSN) Research Center. The ingots of these steels were elaborated in an induce furnace at laboratory and after were hot rolled at 1230°C in pilot scale in order to homogenized the microstructure (this structural condition define the as-received samples). The Table 1 shows the chemical composition of the steels in study.

Table 1. Chemical composition of the steels in study

Alloys	C	Mn	Si	Nb	S	P	Al	Ni	Cr	N
Alloy 1	0.154	1.386	1.405	0.034	0.011	0.022	0.022	0.008	0.018	0.0132
Alloy 2	0.136	1.489	0.948	0.047	0.008	0.019	0.051	0.010	0.020	0.0156
Alloy 3	0.111	1.381	0.985	0.013	0,012	0.022	0.032	0.007	0.013	0.0119

Source: CSN Research Center.

2.2 METHODS

Dilatometric tests, in a Quench Dilatometer (Adhamel Lhomargy, DT1000 model), were performed in order to submitted the steels samples a thermal cycle at distinct soaking temperature (1000 and 1230°C for 360s) after heating at 1oC/s and subsequent programmed cooling rate at 1°C/s. In these tests were possible to observe the phase transformation global kinetic and determine the phase transformation temperature (A_1, A_3, Ac_1 and Ac_3) at particular heating and cooling rates.

The microstructural characterization of the steels in study was analyzed through the optical microscopy and scanning electronic microscopy (Zeiss – DSM 962).

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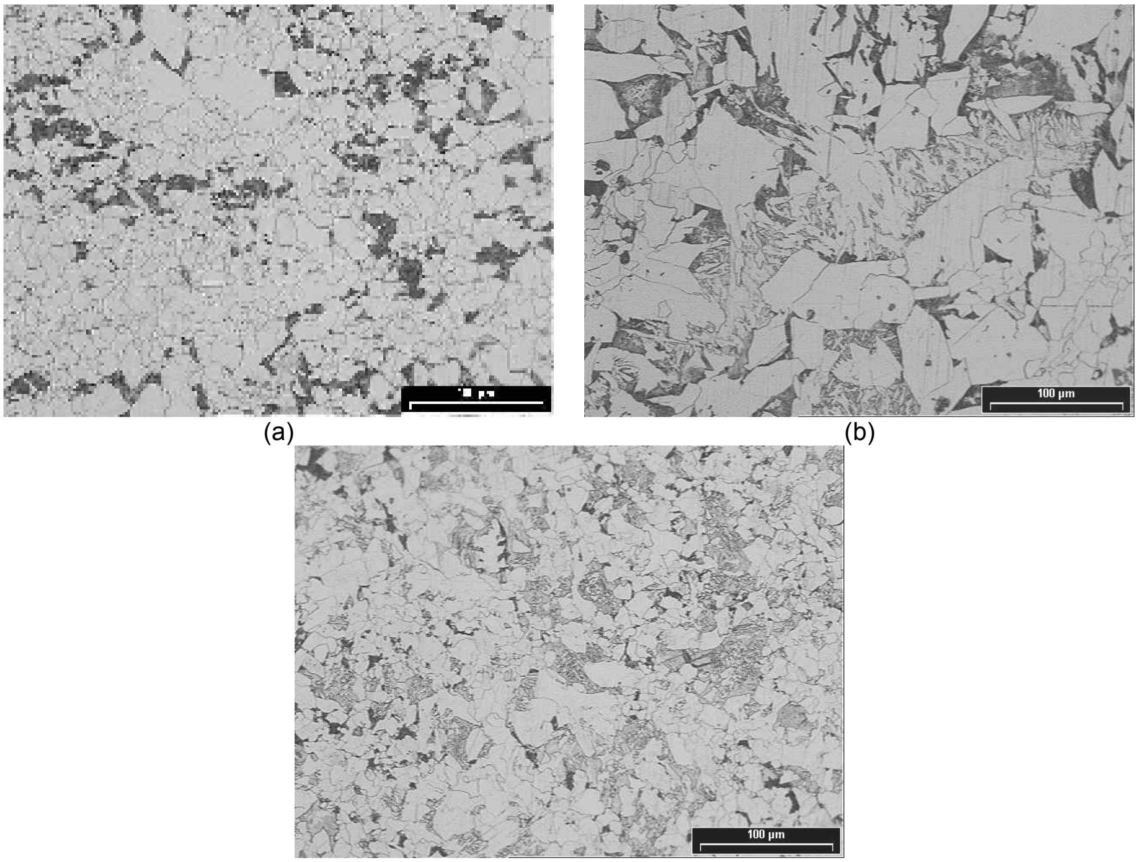
3 RESULTS AND DISCUSSION

The Figures 1 and 2 show the microstructural aspects of steels in study in as-received condition. The three alloys have a ferritc-perlitic microstructure, but the alloy 2 exhibit a little bigger grain size when compare with the others. According to the chemical composition (Table 1) there isn't clearly evidence to justify this different in grain size distribution.



(a) (b) (c)

Figure 1. Microstructure of steels in study in as-received condition: (a) Alloy 1, (b) Alloy 2, and (c) Alloy 3. Optical Microscopy. 200x. Nital 3%.

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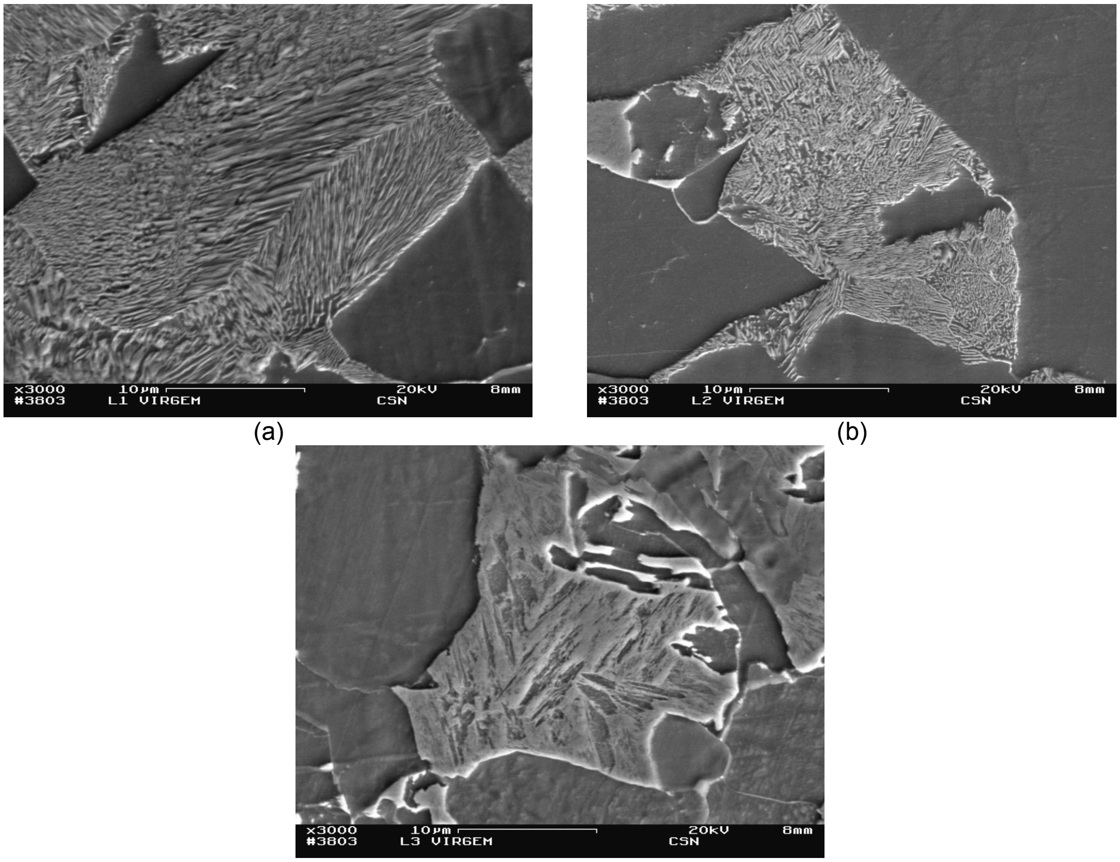


Figure 2. Microstructure details of steels in study in as-received condition: (a) Alloy 1, (b) Alloy 2, and (c) Alloy 3. SEM. 3000x. Nital 3%.

The Table 2 exhibits the phase transformation temperatures on heating (A_1 and A_3) on cooling (Ac_3 and Ac_1) for the three alloys in study. The intercritic region on heating extended to a bit higher temperature for the Alloy 1 (approximately 910^{o}C). In the order side, when it compares the same soaking temperature, the intercritic region on cooling presented at different intervals for each alloy: Alloy 1 (high), Alloy 2 (intermediate) and Alloy 3 (low). If the soaking temperature is increase (1000^oC to 1230^oC), the phase transformation temperatures on cooling (Ac_3 and Ac_1) for all alloy are affected and decreased. This behavior is related with the austenite grain size developed at soaking temperature:[22-23]

- A material with big austenite grain size has less grain boundary area to nucleate the new phases (pro-eutectoid ferrite and perlite);

- The austenite grain size growing decrease the chemical fluctuation on grain boundary by impurity diffusion, precipitate dissolution and improvement of the chemical homogenization inside the grain, these factors increase the energy to nucleate a new phase (pro-eutectoid ferritc and perlite) and dislocated the phase transformation temperature to low values;

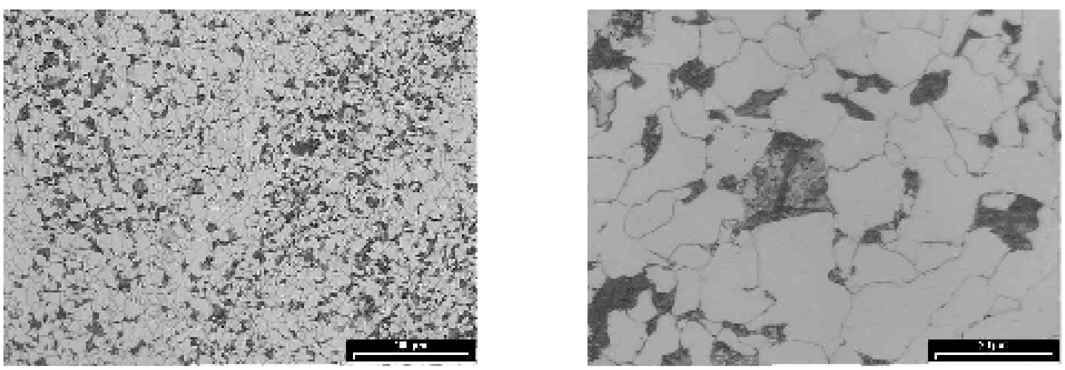
- Finally, a small relation Nb/C (as show Alloy 3 in Table 1, compare with Alloy 2 (intermediate) and Alloy 3 (highest) promote a less effective controlled in austenite grain growth on the heating in austenitic field (above A_3 – Table 2) under a low heating rate (1^oC/s).

Table 2. Phase transformation temperature extracted from Dilatometric Tests for the Alloy 1, 2 and 3

Alloys / Soaking Temperatures	Phase Transformation Temperatures (°C)			
	Heating		Cooling	
	A_1	A_3	Ac_3	Ac_1
Alloy 1 / 1000ºC	744 (*)	912 (*)	807	622
Alloy 1 / 1230ºC	740 (*)	913 (*)	784 (↓)	550 (↓)
Alloy 2 / 1000ºC	731 (*)	879 (*)	787	611
Alloy 2 / 1230ºC	740 (*)	890 (*)	720 (↓)	520 (↓)
Alloy 3 / 1000ºC	720 (*)	896 (*)	745	617
Alloy 3 / 1230ºC	728 (*)	887 (*)	640 (↓)	480 (↓)

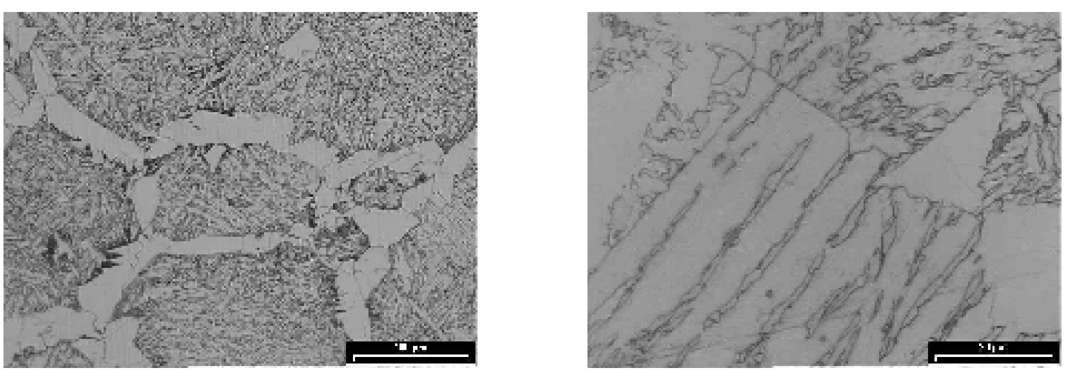
(*) 10°C variations possible are associated with chemical compositions, microstructures and/or residual stress floating due to the mechanical process to prepare the Dilatometric samples from as-received condition.
Source: CSN Research Center.

The Figures 3, 5 and 7 shows the Alloys 1, 2 and 3, respectively, after the thermal cycle with soaking temperature at 1000°C. The Figures 4, 6 and 8 shows the Alloys 1, 2 and 3, respectively, after thermal cycle with soaking temperature at 1230°C. It's clearly to observe the effect caused by increased the soaking temperature in all alloys. The sample thermal treated at 1000°C exhibited a ferritic-perlitic microstructure with typical lamellar perlite morphology, where as the sample thermal treated at 1230°C presented a small amount of pro-eutectoid ferrite and exhibited a started development of spheroidal cementite morphology inside a bigger ferrite grain.



(a) (b)

Figure 3. Alloy 1 Microstructure after submitted at thermal cycle with soaking temperature 1000°C por 360s. Optical Microscopy: (a) 200x, and (b) 1000x. Nital 3%.



(a) (b)

Figure 4. Alloy 1 Microstructure after submitted at thermal cycle with soaking temperature 1230°C por 360s. Optical Microscopy: (a) 200x, and (b) 1000x. Nital 3%.

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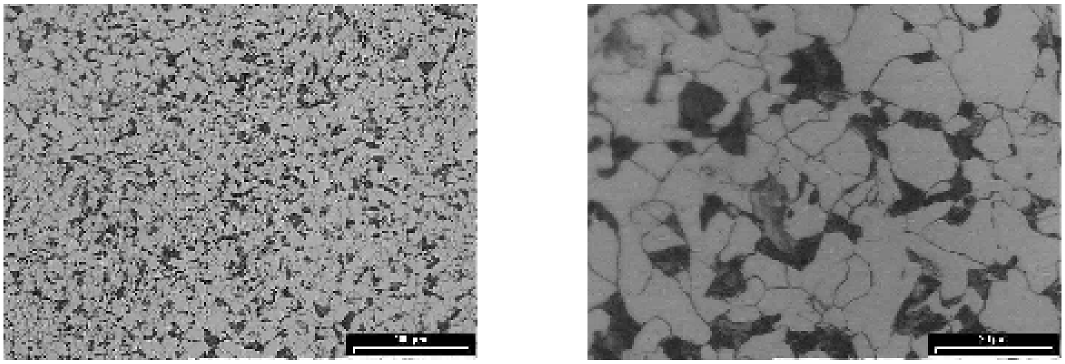
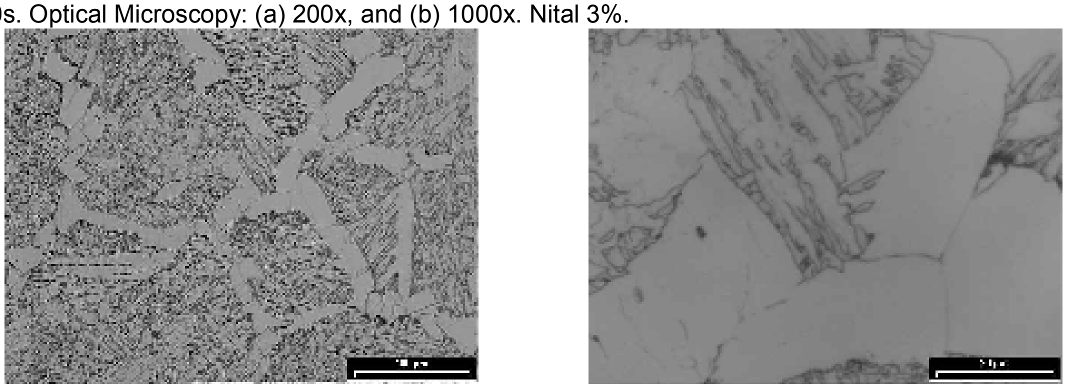


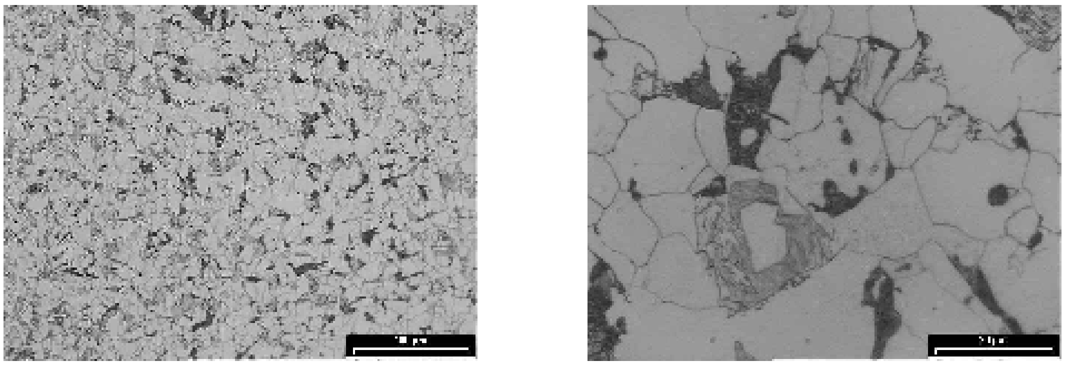
(a) (b)

Figure 5. Alloy 2 Microstructure after submitted at thermal cycle with soaking temperature 1000°C por 360s. Optical Microscopy: (a) 200x, and (b) 1000x. Nital 3%.



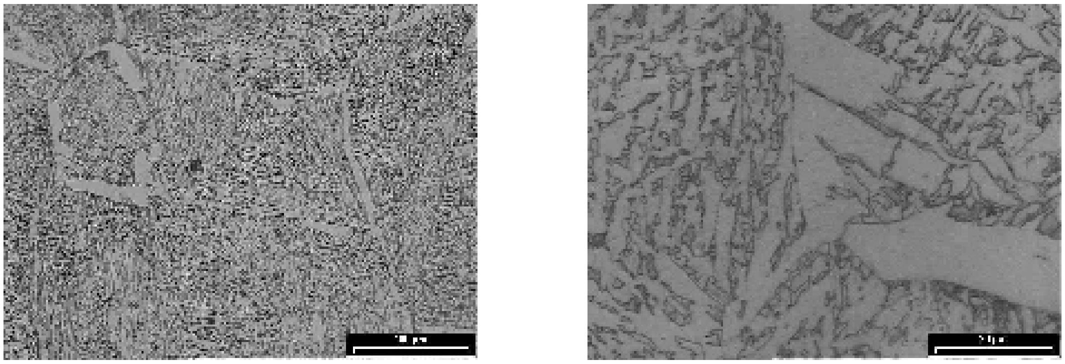
(a) (b)

Figure 6. Alloy 2 Microstructure after submitted at thermal cycle with soaking temperature 1230°C por 360s. Optical Microscopy: (a) 200x, and (b) 1000x. Nital 3%.



(a) (b)

Figure 7. Alloy 3 Microstructure after submitted at thermal cycle with soaking temperature 1000°C por 360s. Optical Microscopy: (a) 200x, and (b) 1000x. Nital 3%.



(a) (b)

Figure 8. Alloy 3 Microstructure after submitted at thermal cycle with soaking temperature 1230°C por 360s. Optical Microscopy: (a) 200x, and (b) 1000x. Nital 3%.

4 CONCLUSION

The results show that the highest soaking temperature promotes grain growth and higher austenite homogenization. This grain growth not occurs during the controlled hot rolling, because the NbC strain-induced precipitation will be responsible by the control and decrease of the hot rolled plate grain size.

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