



Revista Mexicana de Física

ISSN: 0035-001X

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Sociedad Mexicana de Física A.C.

México

Béjar-Gómez, L.; Medina-Flores, A.; Carreón, H.; Alfonso, I.; Bernal-Ponce, J.; Ascencio, J.A.

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Revista Mexicana de Física, vol. 55, núm. 1, 2009, pp. 110-113

Sociedad Mexicana de Física A.C.

Distrito Federal, México

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Production and characterization of niobium and titanium microalloyed steels

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Recibido el 1 de septiembre de 2008; aceptado el 8 de diciembre de 2008

The mechanical properties and microstructure characteristics of two different low carbon microalloyed steels (Nb and Ti) produced by cast melting in an electric induction oven and submitted at thermo-mechanical controlled processing was investigated by optical and mechanical testing. Carbon content in both micro-alloyed steels was less than 0.08%, the first one steel the content of Nb was 0.03% and the second one was 0.05% of Titanium. Steels were thermomechanically processed and reheated to 1250°C and hot rolled on a laboratory mill at a starting temperature of 1180°C and reduced by rolling from 65 mm to a 13 mm thick plate with a finish temperature of 950°C. The low carbon micro-alloyed steel with 0.03% Nb presented 324 MPa of yield strength and 410 MPa of tensile strength whereas the micro-alloyed steel with 0.05% Ti showed 458 of yield strength and 512 MPa of tensile strength. Both steels presented fine grain of ferrite and perlite.

Keywords: Microalloyed steels; hot rolled; microstructure characteristic; mechanical testing.

Las propiedades mecánicas y caracterización microestructural de dos diferentes aceros microaleados con niobio y titanio, fabricados mediante un horno de inducción eléctrico y sometidos al procesamiento termomecánico de laminación en caliente, fueron investigados mediante microscopía óptica y pruebas mecánicas. El contenido de carbono en los aceros fue menor al 0.08%, un acero fue microaleado con 0.03% de niobio y el segundo con 0.05% de titanio. Los aceros fueron procesados termomecánicamente mediante un recalentamiento de 1250°C en un laminador dúo reversible con una temperatura inicial de 1180°C, con una reducción de 65 a 13 mm de espesor y una temperatura final de laminación de 950°C. El acero microaleado con niobio presentó una resistencia a la cedencia de 324 MPa y resistencia a la tensión de 410 MPa. Mientras que en el acero microaleado con titanio presentó resistencia a la cedencia de 458 MPa y una resistencia a la tensión de 512 MPa. La microestructura obtenida en ambos aceros es del tipo ferrítico-perlítico de grano fino.

Descriptores: Aceros microaleados; laminación en caliente; caracterización microestructural; pruebas mecánicas.

PACS: 81.05.-t; 81.40.-z; 81.70.Bt

1. Introduction

Micro-alloyed steels have an important application where involves low temperature applications, thick materials, and higher grades of low-carbon steel, which demands for steel with higher strength and toughness and good weldability [1-3]. Micro-alloyed steels have small amounts of elements as Nb, V and Ti whose contents vary from 0.001 to 0.1%, which are combined with elements present in the steel (Mn, Si, Mo) to improve mechanical properties and when it is submitted at thermo mechanically process which promotes fine scale microstructure that ensure the high mechanical properties such as strength, toughness, ductility and weldability [1-9] by the formation and precipitation of carbonitrides. It has been recognized that low carbon ferrite and perlite microstructures is the alternative means to strengthening

and toughening steels [10-13]. These microstructures have excellent combinations of strength, toughness and weldability. Two different micro-alloyed steel were produced by cast melting and submitted to thermo-mechanical processing to compare its mechanical properties to structural applications.

2. Experimental procedure

Each micro-alloyed steels were produced in ingots of 60×70×300 mm by casting in an 25 Kg vacuum induction furnace which was operated up to 1650°C to keep steel melted, the deoxidization was carried out with aluminium when the temperature was stable. Mn, Si and Cu elements were added in the furnace. The micro-alloyed elements (Nb and Ti) were added at the end to the process. The ingots obtained were cut and prepared with final dimensions as

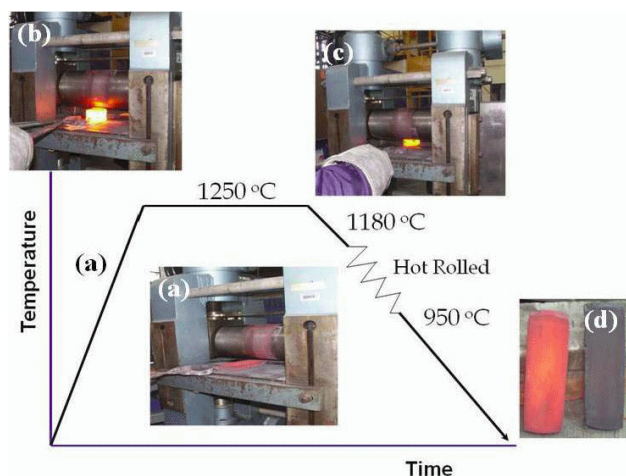
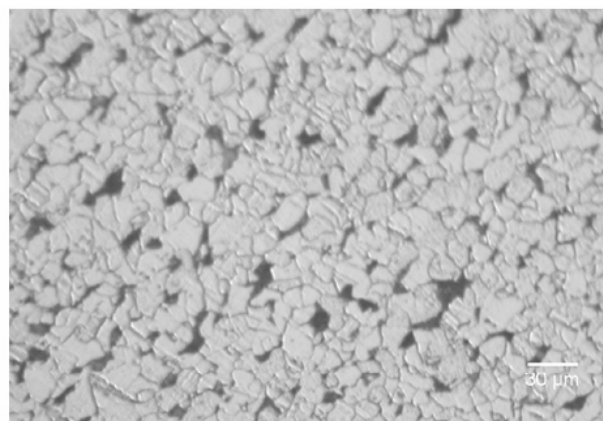


FIGURE 1. (a) Schematic Heat treatment, (b) Star of the thermo-mechanical treatment, (c) Final thermo-mechanical treatment, (d) Ingots produced at the end of thermo-mechanical treatment.



a) 200X



b) 500X

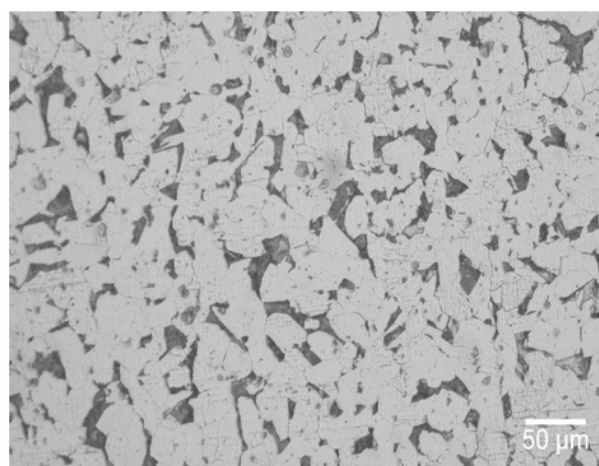
FIGURE 2. Optical micrographs of acicular ferrite in the microalloyed steel with Nb at a) 200X and b) 500X.

follows: $60 \times 70 \times 300$ mm and reheated to 1250°C for two hours, afterwards ingots were hot rolled at initial temperature of 1180°C and a finishing rolling temperature of 950°C on a laboratory mill of 50 tons capacity to reduce de thick from 60

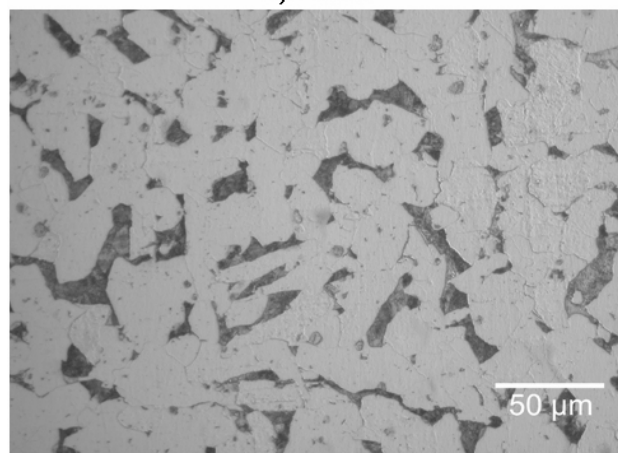
to a 13 mm and then air-cooled to room temperature as shown in Fig. 1. Specimens for tensile and hardness tests were cut from the middle of the rolled plates in a transversal direction according to the standard method of ASTM E-8 (96). Microstructures of the transversal section hot rolled specimens were examined by optical microscopy and the samples were mechanically polished and etched in 2% nital solution.

3. Results and discussion

The chemical composition of the two different micro-alloyed steels is shown in the Table I. The optical micrograph microstructures of the transversal section of the hot rolled for the microalloyed steel with 0.03% Nb and 0.05% Ti are shown in Figs. 2 and 3 respectively. Figure 2 shows the acicular ferrite-dominated microstructure. This acicular ferrite matrix is characterized by the fine equiaxed ferrite with an average grain size of approximately $15\text{--}20\ \mu\text{m}$. The grain sizes depend mainly of the chemical composition of the steel studied in this research work and the thermo-mechanical



a) 200X



b) 500X

FIGURE 3. Optical micrographs of acicular ferrite in the microalloyed steel with Ti at a) 200X and b) 500X.

TABLE I. Chemical Composition of the two different produced Microalloyed Steels (wt.%).

ELEMENT	STEEL (% Nb)	STEEL (% Ti)
C	0.08	0.07
Mn	0.75	1.05
Si	0.08	0.14
P	0.012	0.012
S	0.013	0.015
Cr	0.06	0.048
Mo	0.05	0.042
Cu	0.035	0.027
Al	0.070	0.095
Nb	0.030	—
Ti	—	0.050

TABLE II. Mechanical Properties of Microalloyed Steels.

MECHANICAL PROPERTIES	STEEL (% Nb)	STEEL (% Ti)
Yield strength. (MPa)	324	458
Tensile strength. (MPa)	410	512
Elongation. (%)	32	28
Hardness HRB	70	82

process applied and also the initial and final rolled temperatures. Figure 3 shows the same microstructure and configuration but the average grain size of approximately 25-35 μm . At the same time, the prior austenite grain boundary network is completely eliminated. All of these microstructural characteristics are highly consistent with the definition of acicular ferrite given by Smith [14-17].

The corresponding mechanical properties for the microalloyed steel with 0.03% Nb and 0.05% Ti are shown in Ta-

ble II. The increment of the strength and tensile is because the effect of each alloy component such Nb and Ti given an increase in the steel hardness due to the precipitation phenomena of carbides and carbonitrides which are formed in the boundary between the austenite and ferrite as a result of the refinement of the grain size. It is also important to consider other contribution to strength made by the following elements Mn, Cr, Ni and Mo, It is also important to mention the main roll that Mn plays in increases the resistance by the effect of the hardness by the phenomena of solid solution [1-3,7]. On the other hand, it is well known that grain size refinement is currently a key goal of steels research. Comparing to the API grade HSLA pipeline [18] only the microalloyed steel with 0.05%Ti satisfied tensile and fracture properties for the API-X65. It is due to the less content of %C and the content of microalloyed was higher in the alloy.

4. Conclusion

The paper presents concludes that the:

- Casting and thermomechanical process can be applied to produce microalloyed steels with appropriate compositions to improve strength with microalloyed element as Nb, V and Ti.
- Niobium micro-alloyed steel improved its strength due to the effect of Cr, Mo and Nb.
- Titanium micro-alloyed steel increases its strength due to the effect of Mn and Ti.
- The effect of thermomechanical process and the microalloyed elements additions promote the formation of microstructures of fine ferrite grains.

Acknowledgment

This work was financial supported by CIC-UMSHN. The author would like to acknowledge the UNIVERSIDAD MI-CHOACANA for its value contributions to this paper.

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