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Effects of Niobium Microaddition on Carbon Steels

Paulo Roberto Mei

State University of Campinas, Faculty of Mechanical Engineering, 13083-860, Campinas, Brazil.

pmei@unicamp.br

Federal Institute of São Paulo, Mechanical Department, 01109-010, São Paulo, SP, Brazil

paulo.mei@ifsp.edu.br

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Abstract: Niobium is added to carbon steels in small amounts (< 0.1weight %), thus being called a microalloying element, to increase mechanical strength and toughness. When added to steel, niobium is partly soluble in the matrix and another part combines with carbon and nitrogen forming a family of $Nb_xC_yN_z$ precipitates (niobium carbides, nitrides or carbonitrides), where the values of x, y, z depend on the temperature and the chemical composition of the steel. The effects of niobium dissolved in the matrix or as precipitates are distinct and sometimes antagonistic. Thus, two samples of the same carbon steel microalloyed with niobium may differ in: microstructure, ferritic grain size or interlamellar spacing of the pearlite, depending on the thermomechanical processing to which they were submitted, which will result in different mechanical properties. In order to make good use of the possible beneficial effects of adding niobium to carbon steels, it is necessary to clearly understand its complex physical metallurgy. To analyze the effects of niobium, six steels were used (0.2/0.4/0.8 C/ 1 Mn, with and without the addition of 0.03 Nb, weight %). Using an ARL ion microprobe, with oxygen ions and mass spectroscopy reading on niobium steel, after partial isothermal transformation at 700 ºC, we observed the partition of niobium between ferrite and austenite. Thus, the formation of ferrite is slower, shifting the TTT curve to longer times and separating the pearlite and bainite bays. The same occurs in continuous cooling transformation, where the diffusional components (ferrite, pearlite and bainite) are formed at lower temperatures and with a longer time. With pearlite forming at lower temperatures, there is a decrease in the interlamellar spacing, increasing its hardness and, consequently, the mechanical strength. Niobium also forms carbonitrides, and these finely precipitated particles anchor the grain boundary, making it difficult to move and thus producing a smaller austenitic grain size than in steel without the addition of niobium, increasing mechanical strength and toughness of steel.

Introduction

Niobium is added to carbon steels in small amounts (< 0.1 weight %), thus being called a microalloying element, to increase mechanical strength and toughness. When added to steel, niobium is partly soluble in the matrix and another part combines with carbon and nitrogen forming a family of $Nb_xC_yN_z$ precipitates (niobium carbides, nitrides or carbonitrides), where the values of x, y, z depend on the temperature and the chemical composition of the steel. The effects of niobium dissolved in the matrix or as precipitates are distinct and sometimes antagonistic. During the transformation from austenite to ferrite, in order for ferrite to be formed, carbon needs to be rejected to austenite, since its solubility in ferrite is very small (maximum of 0.02% at 726 °C). On the other hand, niobium is more soluble in ferrite than in austenite ($K\alpha/\gamma$=1.8 at 989 ºC), that is, during the formation of ferrite, niobium enriches it (**Figure 1**). The partition of niobium between ferrite and austenite and its precipitation as carbonitrides affect the mechanical properties of carbon steels, and discussing these aspects is the objective of this work.