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Electron Microscopic Assessment of Microstructural Conditioning Capacity for Obtaining Quenching and Partitioning (Q&P) Boron-Steels

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ABSTRACT

The use of advanced high strength steels (AHSS) offers significant possibilities for achieving weight reduction in automobiles, between 25-40% of the total mass, compared to other grades of steel. As a direct consequence of this advantage, AHSS steels are constantly evolving, exhibiting greater mechanical strength, ductility, hardness, rigidity, and toughness to meet the demands placed on each of the structural components that make up a car. This high mechanical performance of AHSS steels largely depends on the careful selection of their chemical composition and the technologies employed that allow for the control of their thermo-mechanical, mechanical, and thermal processing [1]. In this context, the Quenching and Partitioning (Q&P) steel enriched with retained austenite emerges, which is based on the heat treatment proposed by Speer and collaborators [2], and is applied to steels that can undergo phase transformation. As a result, this steel exhibits exceptional mechanical properties, with a tensile strength reaching up to 1700 MPa and a maximum potential ductility of up to 25%. However, the inherent complexity of the composition, microstructure, and parameter control in the production of these steels poses substantial challenges for their acquisition. Under this premise, this work aims to obtain a quenching and partitioning (Q&P) steel from a complex phase steel, focusing on the comparison of key variables such as boron microalloying, partitioning temperature linked to heat treatment, and plastic deformation in relation to specific supply and heat treatment conditions during partitioning (e.g., one spet-P1 and two steps-P2). The exploration of these variables will provide a clearer understanding of how the material's performance can be improved and customized to meet the demands of the automotive industry. For this purpose, a low-carbon boron-microalloyed steel defined as a complex phase was manufactured in an induction furnace with an open atmosphere, and it was identified as CP-B0 for the reference condition and as CP-B60 for the steel containing

60 ppm of boron. With the intention of determining the M_s and M_f temperatures, dilatometry tests were conducted. Subsequently, each steel was treated thermo-mechanically, mechanically, and thermally, categorized into two processing cases differentiated mainly by the austenitizing temperature for quenching (case 1 at 1100 °C with P1 and P2 and case 2 at 920 °C with P1/P2-CD) and without deformation (P1/P2-XD) during partitioning. X-ray diffraction was applied to determine the phases present in the steels, and microstructural characterization was carried out using optical microscopy (OM), scanning electron microscopy (SEM), and SEM-EBSD. The results have shown that boron allows for the refinement of the austenitic grain size from the casting and increases the hardenability of the steel. Thus, after applying the Q&P treatment and, generally, in all the study conditions following the quenching and partitioning (Q&P) process, a microstructure with a bainitic matrix was generated, containing islands of retained austenite (RA-γ), martensite (M), bainite (B), and ferrite. (F). Specifically for case 1 of Q&P-P1, both in boron-free steels and those containing boron, a blocky morphology of retained austenite (RA-γ) was observed, whereas in the case of Q&P-P2, a needle-like morphology of large islands of RA-γ was presented. In contrast, for case 2, the identification of RA-γ was only possible through a phase distribution analysis by SEM-EBSD, due to the high refinement of the austenitic grain (figure 1c), especially for the steels deformed during partitioning. However, a blocky morphology of the M was successfully determined. Therefore, the importance of scanning electron microscopy and EBSD for the microstructural characterization of multiphase steels is highlighted.

Keywords: Advanced High-Strength Steels (AHSS), Boron content, Quenching & Partitioning (Q&P) Steels, Microstructural and Mechanical Characterization, Electron Microscopy Techniques.

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