Microstructural Characterization in Quenched and Tempered High Silicon Bearing Steel

Silicon alloying holds promise for chemical and mechanically stabilizing retained austenite in steels by enriching carbon. However, limited investigations have been conducted on high-carbon bearing steels, which could enhance toughness without compromising wear behavior. This study presents our results, emphasizing microstructural characterization of a high-carbon, high-silicon bearing steel.

High-carbon bearing steels possess excellent hardness, wear resistance, and dimensional stability. However, their limited toughness and ductility impose limitations and shorten the lifespan of components. Although retained austenite, commonly found in commercial steels, can improve those properties, it can also transform into brittle fresh martensite with high carbon content during use, resulting in dimensional changes due to the natural expansion of martensitic transformation.

Nevertheless, alloying with silicon has been proven effective in stabilizing austenite by increasing carbon enrichment to levels that prevent its transformation into martensite [1]. Microstructural analysis of the studied alloy revealed no significant changes up to 200 °C, while atom probe tomography found carbon redistribution within the martensite, likely due to dislocations. Transmission electron microscopy revealed the formation of η-carbide after tempering at 250 °C.

Fig. 1a and 1b depict the quantification of austenite phase and carbon content evolution during continuous heating tempering. Austenite volume fraction showed a slight decrease at two temperature ranges termed “A” and “B”, attributed to the limited formation of ferritic bainite (Fig. 1d), observed after quenching from 400 °C. The bainite morphology displays small leaf-like structures cutting through the retained austenite. No significant decomposition of austenite is noted within the “C” temperature range. However, the retained austenite in this range exhibits a high carbon content, indicating mechanical stabilization with a stacking fault energy exceeding 30 mJ.m^{-2}, making transformation unlikely under applied strain. At 530 °C, austenite gradually loses carbon and decomposes into cementite particles (θ_S), distinct from spheroidized cementite formed during intercritical solubilization, as confirmed by TEM analysis. Within the “D” temperature range, austenite rapidly loses carbon and decomposes into ferrite and cementite.

The results demonstrate a temperature range where austenite can be rapidly thermally and mechanically stabilized, avoiding significant decomposition or the formation of undesired cementite. Silicon alloying showed to be highly effective, even in high-carbon steels, in delaying cementite formation and facilitating austenite stabilization. Austenite stabilization achieved within the 400-470 °C temperature range is sufficient to prevent transformation-induced plasticity effects in bearing steels, improving toughness and ductility while maintaining its good dimensional stability.

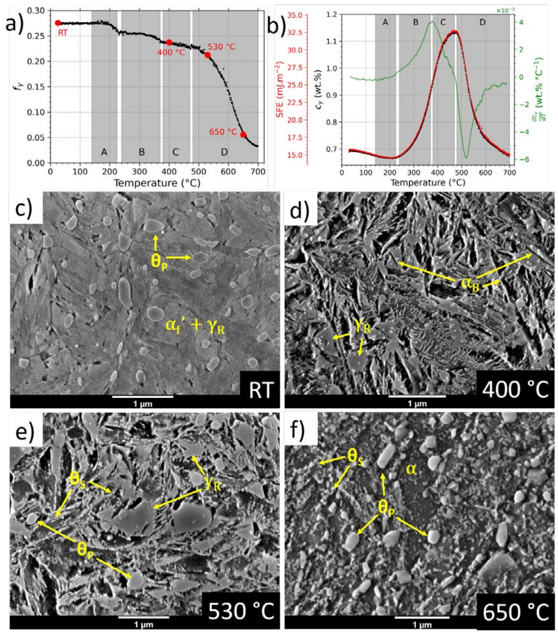

Fig.1 – a) austenite volume fraction and (b) austenite carbon content evolution during tempering at continuous heating. SEM micrographs of (c) initial microstructure and after immediately quenching from: (d) 400 °C, (e) 530 °C, and (f) 650 °C.

References

[1] G.G. Ribamar, J.D. Escobar, A. Kwiatkowski da Silva, N. Schell, J.A. Ávila, A.S. Nishikawa, J.P. Oliveira, H. Goldenstein, Acta Mater. 247, 118742 (2023).

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Giovani Gonçalves Ribamar (Department of Metallurgical and Materials Engineering – University of São Paulo)
E-mail: giovanigoncalvesr@usp.br