Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

Influence of isothermal bainitic phase transformation temperature on the microstructure and hardness evolution of medium-carbon high strength steel

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ABSTRACT

High-resolution dilatometry was employed to investigate the austempering heat treatment process in industrial mold steel. The samples were fully austenitized at 900 °C and subsequently austempered for 3 hours at temperatures ranging from 380 °C to 450 °C. At 450 °C, no bainitic transformation was observed, while incomplete transformations occurred at lower temperatures, accompanied by martensitic transformation during final cooling. Increasing the austempering temperature from 380 °C to 425 °C led to a reduction in the bainite volume fraction and an increase in martensite content. At 450 °C, the microstructure fully transformed into martensite upon cooling. Mechanical properties were evaluated using micro-Vickers hardness testing for overall hardness and nanoindentation for localized phase hardness measurements. The Vickers hardness increased from 412 HV to 500 HV as the austempering temperature rose from 380 °C to 450 °C, consistent with the higher martensite fraction. Notably, despite significant microstructural differences, hardness values for samples austempered at 425 °C and 450 °C showed considerable overlap. Nanoindentation results revealed that carbon-enriched martensite in samples austempered at 400 °C and 425 °C exhibited nanohardness values of 8.3 GPa and 7.8 GPa, respectively, surpassing the nanohardness of fully martensitic samples at 450 °C (6.9 GPa). In contrast, the nanohardness of bainite decreased from 6.3 GPa to 5.4 GPa as the austempering temperature increased from 380 °C to 425 °C. The microstructural evolution, including bainite and martensite morphologies, plate thickness, and carbon content, was analyzed using electron backscatter diffraction (EBSD) and scanning electron microscopy (SEM). This comprehensive study elucidates the relationship between microstructural changes and hardness variations, providing insights into the effects of austempering temperature on the mechanical properties of industrial mold steel.