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Response of Low-Alloy Medium-Carbon Spring Steel Hardened by Competing Martensitic and Bainitic Routes

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Abstract

This study examines the very-high-cycle fatigue (VHCF)
behaviour of a low-alloy medium-carbon spring steel
subjected to three industrially viable hardening routes:
quenched–tempered martensite, austempered lower
bainite, and a hybrid martensite–bainite microstructure. Axial ultrasonic fatigue tests up to 10¹⁰ cycles reveal distinct S–N characteristics and crack-initiation mechanisms. Martensitic microstructures show early transition to subsurface fisheye failures at inclusions, whereas bainitic structures exhibit delayed VHCF failure and reduced scatter. The hybrid condition combines a compressive surface martensite layer with a bainitic core, shifting critical crack initiation from surface to interior and extending fatigue life across the entire stress range. Fractographic evidence is discussed with reference to previous comparative work on hardening methods for medium-carbon spring steel, underlining the necessity of microstructure design for long-life suspension components.

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