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Gradient Martensite–Bainite Architectures in Low-Alloy Medium-Carbon Spring Steel via Sequential Induction and Austempering Treatments

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Abstract

Sequential induction hardening and austempering are
applied to a low-alloy medium-carbon spring steel to
generate a through-thickness gradient of martensite and
bainite. Microstructural development is quantified by
optical microscopy, scanning electron microscopy, and electron backscatter diffraction, while hardness and residual stress profiles are measured by nanoindentation and X-ray diffraction. The surface region exhibits refined lath martensite with compressive residual stresses, whereas the subsurface contains carbide-free lower bainite and retained austenite. Four-point bending fatigue tests reveal a significant improvement in fatigue life compared with single-step hardening routes, which is rationalized in terms of delayed crack initiation at the surface and enhanced crack-arrest capability in the bainitic interior. Results are interpreted alongside prior comparative studies of different hardening methods on low-alloy medium-carbon spring steel, demonstrating that hybrid thermal schedules offer a robust pathway to tailor gradient architectures for demanding suspension applications.

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