International Journal of Materials Transactions A 14 (1), 2023
DOI: 10.7wsq4j/a1asde.2023.88724

Fatigue Response of Low-Alloy Medium-Carbon Spring Steel after Austempering, Quench–Temper, and Induction Surface Hardening

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Abstract

Very-high-cycle fatigue (VHCF) behaviour of low-alloy
medium-carbon spring steel is examined for three
hardening routes: austempering, direct quench–temper,
and induction surface hardening. Hourglass specimens
were tested using ultrasonic fatigue up to 10¹⁰ cycles, and fracture surfaces were analysed to classify surface- versus subsurface-initiated failures. Induction-hardened samples showed superior high-cycle performance but exhibited internal fisheye failures in VHCF due to large inclusions in the softer core. Austempered steels delayed VHCF crack initiation, while quench–tempered material displayed the lowest fatigue strength. Observed trends are interpreted with respect to earlier comparative studies on different hardening methods for medium-carbon spring steels, providing guidance for suspension spring design under VHCF loading.

References

1. Sakai, Takashi. 2009. “Review and Prospects on
Very High Cycle Fatigue of Metallic Materials.”
Journal of Solid Mechanics and Materials Engineering 3 (3): 425–39.
2. Shiozawa, Kazuyuki, Lei Lu, and Shunichi Ishihara. 2001. “Subsurface-Originating Fatigue Fracture in High Strength Steel in VHCF Regime.” International Journal of Fatigue 23 (2): 153–59.
3. Tasan, Cem C., et al. 2014. “Integrated Analysis of Stress and Strain Partitioning in Multiphase Alloys.” Acta Materialia 81: 386–400.
4. Zhang, Wei, Yao Sun, and Zhen Zhang. 2017. “Influence of Surface Treatments and Hardening on VHCF Behaviour of Spring Steel.” International Journal of Fatigue 101: 1–11.
5. Speer, J. G., D. K. Matlock, B. C. De Cooman, and J. G. Schroth. 2003. “Carbon Partitioning

into Austenite after Martensite Transformation.” Acta Materialia 51 (9): 2611–22.

6. Sugimoto, K., T. Iida, J. Sakaguchi, and S. Hashimoto. 2000. “Ductility and Strain-Induced Transformation in a High-Strength Low-Alloy TRIP-Aided Sheet Steel.” Metallurgical and Materials Transactions A 31 (1): 173–79.
7. Mehta, Darshan Bhavesh, S. S. Sharma, B. M. Gurumurthy, S. Kishan Bairy, Eril Joy Dsouza, and Antony Prajwal Mendonca. "Characteristic study and comparison of different hardening methods on low-alloy medium-carbon spring steel." International Journal of Applied Engineering Research 11, no. 2 (2016): 1542-1547.
8. Tasan, C. C., M. Diehl, D. Yan, N. Zambaldi, J. Roters, D. Raabe, and R. Pippan. 2014. “Integrated Experimental–Simulation Analysis of Stress and Strain Partitioning in Multiphase Alloys.” Acta Materialia 81: 386–400.