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中性子回折法による高鉄道用 S38C 鋼車軸の高周波焼入れ組織と残留歪みの解明

Microstructure and residual strain in induction-hardened high-railway S38C steel axle using neutron diffraction

周　良1),2)、張　晗3)、秦　天宇3)、奥　妮3)、徐　平光4)、蘇　玉華4)、菖蒲　敬久4)、呉　聖川3)
Liang ZHOU1), 2), Han ZHANG3), Tianyu QIN3), Ni AO3), Pingguang XU4), Yuhua SU4),
Takahisa SHOBU4), Shengchuan Wu3)
1)中国科学院高能物理所; 2)中国散裂中性子源; 3)西南交通大学; 4)日本原子力研究開発機構

Abstract: The neutron diffraction has been widely applied to measure the residual stresses for various large-scale engineering components mainly due to the excellent penetrability and the coarse beam spot of thermal neutrons. The gradient residual strain of induction-hardened railway axle S38C steel were complementarily measured by the RESA angle dispersive neutron diffractometer at JRR-3. These results will be of great engineering significance to the assessment of the remaining life of the railway axles.

Keywords：S38C steel railway axle, residual stress, neutron diffraction

１．Research Purposes

High-speed railway has been developing rapidly around the world since Japan's SHINKANSEN bullet trains [1]. Ensuring that axles do not fail is a major challenge for the high-quality operation of high-speed trains [2], and S38C axles (made in Japan) are used in high-speed trains in Japan and China. In these axles, induction hardening causes martensitic transformation of the surface material (about 2 mm deep), forming a gradient microstructure with a depth of about 8 mm, leaving relatively high axial residual compressive stress and tangential residual compressive stress on the surface. As the speed of high-speed railway increases and the operating environment becomes more complex, axle fatigue damage accidents caused by various defects (*e.g.*, foreign object impact, rain corrosion and scratch) are rapidly increasing [3], seriously affecting the operation order and safety assurance of high-speed railway. Therefore, there is an urgent to evaluate the fatigue strength and remaining life of defective axles. Among them, accurate measurement of the residual stress field of defective S38C axles is a technical bottleneck [4].

２．Experimental procedures

Semi-circular ring (91mm radius) samples with a certain thickness (15mm) and long bar samples (length 150mm (axial) × width 15mm (radial) × thickness 15mm (tangential)) were cut from the flawless high-speed railway axle (Fig.1a) for the RESA-1 neutron diffraction measurement [5]. The samples without defects were measured to evaluate the residual strain field of surface layer. The samples with different pits (Fig.1b) through a light gas gun were prepared to evaluate the change of residual strain field of the damaged surface layer. The comb samples after removing the residual stress due to the different radial microstructure of the axle (Fig.1c) were employed to measure d_0 (crystal plane spacing without residual stress).

All samples were measured using a nominal gauge volume of 2 mm × 2 mm × 2 mm, and the triaxial residual strains were analyzed respectively using α-Fe (211) diffraction Gaussian fitting combined with a parabolic background function.

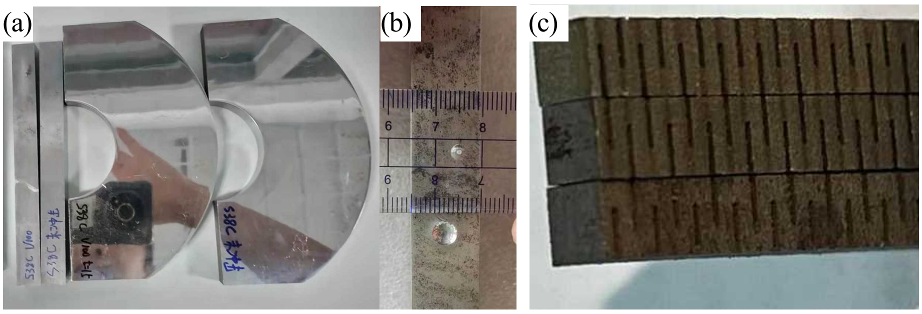

Fig. 1. (a) Semi-circular ring and long bar samples, (b) samples with pits and (c) referring comb samples.

3. Results and discussion

Figure 2 shows a strong hierarchy of stress field resulted from the complete induction hardening: the axial residual stress from surface to core varies from -463 MPa to +112 MPa for the bar sample, and from -420 MPa to +69 MPa for the ring sample; the hoop residual stresses from surface to core varies from -276 MPa to +53 MPa for the bar sample and from -582 MPa to +125 MPa for the ring sample. After a foreign object impact at 125 m/s, the stress field changes as follows: the axial residual stresses from surface to core varies from -782 MPa to +83 MPa for the bar sample and from -840 MPa to +106 MPa for the ring sample; the hoop residual stresses from surface to core varies from -676 MPa to +72 MPa for the bar sample and from -870 MPa to +87 MPa for the ring sample, indicating that under foreign object impact at 125m/s, the compressive stress on the axle surface is strengthened by 300-400MPa, which is effective in improving fatigue life. However, pits caused by the impact may accelerate the propagation of fatigue cracks. Therefore, much attention should be paid to the overall effect of foreign object damage on the fatigue life of the axle.

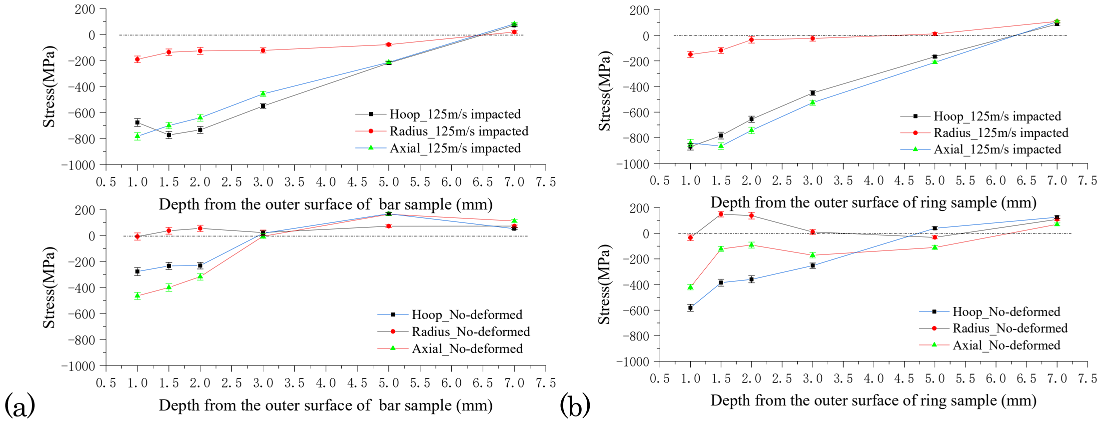

Fig. 2. Residual stress distribution from surface to core of S38C axle. (a): long strip sample, (b): ring sample

4. References

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