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Relationship between Residual Stress Distribution and Effective Case Depth of Induction Hardened Axle Shafts

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When induction hardened axle shafts are bent and corrected, plastic deformation occurs in the shaft. As a result, the surface compressive residual stress is relaxed, and there is a risk of a decrease in fatigue strength. It has been reported that the change in residual stress due to bending occurs not only on the surface where compressive residual stress exists, but also on the interior where tensile residual stress exists. In particular, relaxation of compressive residual stress on the convex surface due to bending is caused by stress redistribution due to changes in tensile residual stress. Since the yield stress is small in the interior where the hardness is not increased by induction hardening, plastic deformation is likely to occur due to bending. Therefore, clarifying the relationship between the magnitude and position of the internal tensile residual stress and the hardness distribution (effective case depth) will lead to the prediction of the residual stress distribution after bending.

For three types of induction-hardened shafts with different effective case depths (conditions A, B, and C where the effective case depths are 8.5 mm, 10.5 mm, and 12.5 mm respectively), we measured the hardness distribution and observed the microstructure to quantitatively evaluate the effective case depths. We also measured the internal residual stress distribution by the contour method and discussed relationship between the effective case depths and the residual stress distribution, especially at the position where the tensile residual stress was maximum.

Vickers hardness tests and residual stress measurements by the contour method were carried out. The obtained radial distributions of hardness and residual stress on cross-section are shown in Fig. 1. From this figure, the hardness on the surface increases, and the hardness gradually decreases toward the inside, reaching a constant level of about 250 HV. It was confirmed that compressive residual stress occurred on the surface side and tensile residual stress occurred inside. The position where the positive and negative of the residual stress changes and the effective case depth are almost the same. In addition, it is found that the maximum tensile residual stress occurs at the position equivalent to the internal hardness. Fig. 2 shows the relationship between hardness and residual stress under all three conditions. The internal hardness is 250HV more than 15mm away from surface because it is not hardness tested. From this figure, under all three conditions, compressive residual stress occurs in the hardened layer where the hardness is higher than the effective hardening hardness, and tensile residual stress occurs in the interior where the hardness is lower than the effective hardening hardness. In addition, it was found that the maximum tensile residual stress occurs at the point where the hardness is not increased by induction hardening.

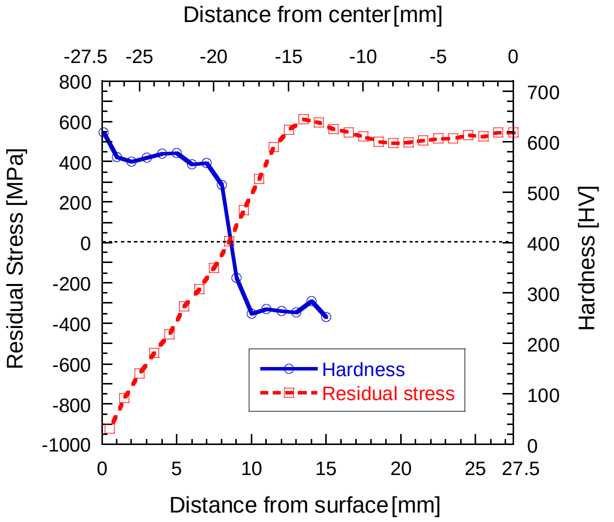

Fig. 1 Radial distribution of hardness and axial residual stress in condition A.

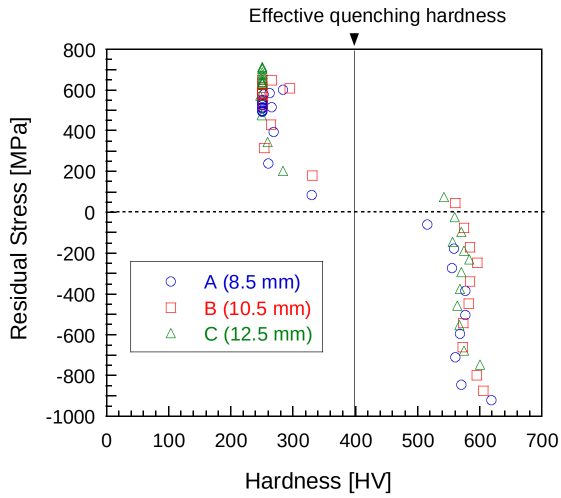

Fig. 2 Relationship between hardness distribution and residual stress distribution.

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