An Ultrasonic Flaw Detector for Hollow Axles of Narrow-Gauge Railway Cars

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Hollow axles with an internal bore diameter of 60 mm are used for all Shinkansen cars manufactured in and after 1992. When the cars undergo maintenance, checks are made automatically for flaws using ultrasonic angle beams from the bore surface, as shown in Fig. 1. On the other hand, most of the narrow-gauge cars in Japan are equipped with solid axles, the inspection of which is inherently more difficult in terms of improving precision and automatic flaw detection. Based on the experience of using hollow axles on Shinkansen cars for 15 years or more, therefore, we developed hollow axles suitable for narrow-gauge cars and a prototype ultrasonic flaw detector for use with these axles. Figure 2 shows the concept of hollow axles for narrow-gauge cars. However, some narrow-gauge cars use axles with a journal diameter smaller than that of the Shinkansen cars, and these do not have sufficient space at the end of the axle where a cap is attached with bolts. To cope with this restriction, therefore, we designed the bore diameter of the axles for narrow-gauge cars to be 30 mm smaller than that of the Shinkansen cars. Flaw detection is performed from the bore surface of a hollow axle with a 30 mm bore diameter using a conventional probe having a built-in flat transducer, as shown in Fig. 3. Ultrasonic waves focus at a point inside the axle due to refraction at the bore surface and then disperse on the axle surface being inspected. In addition, the path length of ultrasound propagation increases to the extent that the bore diameter is smaller or the wall thickness is larger, which may cause flaw detection sensitivity to deteriorate. To compensate for this drawback, therefore, we designed and manufactured a special piezocomposite focal probe using a flexible piezocomposite transducer, as shown in Fig. 4. Figure 5 shows the ultrasonic flaw detector developed for hollow axles of narrow-gauge cars. By using this probe, we conducted a test to detect a number of artificial flaws cut on the surface of a model axle. As a result, we successfully detected rectangular flaws, with a length of 10 mm and a depth of 0.3 mm, at the wheel seat of the axle, and others, with a length of 10 mm and a depth of 0.15 mm, in the central part of the axle. This confirmed that the precision of flaw detection with this probe is equal to that hitherto obtained for axles of Shinkansen cars.

To increase the fatigue strength, induction hardening treatment is applied to axles for Shinkansen cars after the normal heat treatment (quenching and tempering) in the manufacturing process. In contrast, only the normal heat treatment is applied to axles for narrow-gauge cars. It is expected, therefore, that the fatigue strength may decrease when a bore is machined in the axles used for narrow-gauge cars. Hence, we performed a full-scale rotating bending fatigue test for a hollow axle, as shown in Fig. 6, with a diameter at the wheel seat of 209 mm and a ratio of the length of the central part to the diameter of 1.3, for narrow-gauge cars at nominal stress amplitude of about 80 MPa at the wheel seat. As a result, we were able to confirm that no fatigue cracks or conspicuous fretting corrosion occurred until the number of cyclic loadings reached 2.3×10^7. This proves that hollow axles have approximately the same fatigue strength as that of solid axles.

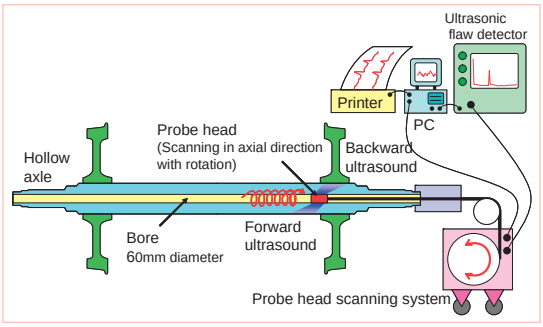

Fig. 1 Automatic ultrasonic flaw detector for hollow axles of Shinkansen cars

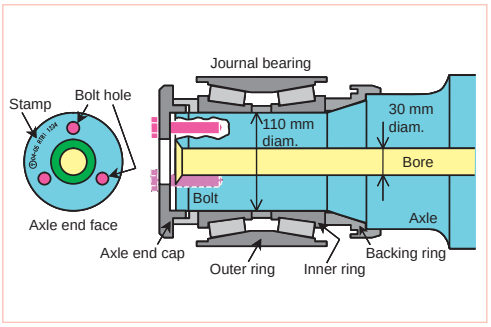

Fig. 2 A schematic view of a hollow axle for narrow-gauge cars

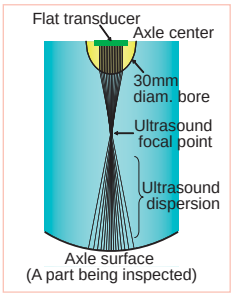

Fig. 3 A schematic view of ultrasound propagation oscillated with a flat transducer

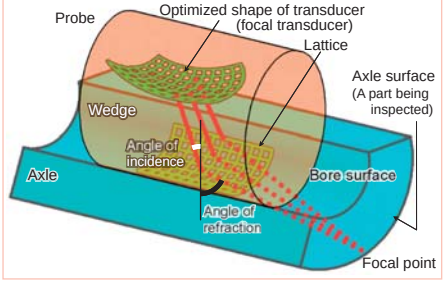

Fig. 4 Design concept for the piezocomposite focal probe

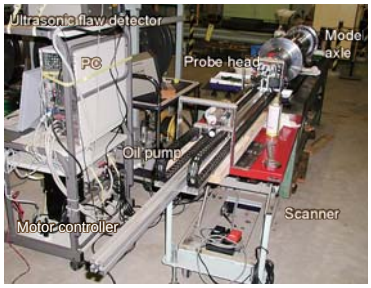

Fig. 5 Automatic ultrasonic flaw detector for hollow axles of narrow-gauge cars

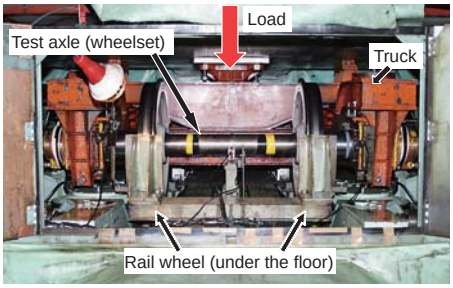

Fig. 6 An axle fatigue test plant