Research to Evaluate the Remaining Service Life of Aged Rails

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The maintenance of rails incurs enormous expenses, and to prevent rail failure, a number of railway operators in Japan replace them periodically based on the accumulated passing tonnage. As the introduction of lightweight vehicles and rail grinding operation has reduced rail failure at joints in recent years, it is now considered possible to extend the periodicity of such rail replacement. There are several types of rail failure, and cracks at the rail foot are difficult to detect. Star cracks (a type of damage found on rails) at the boltholes of fishplated joints are also often overlooked. The Railway Technical Research Institute (RTRI) has therefore decided to review the periodicity of rail replacement focusing on rail foot cracks (in the case of long-rails or continuous welded rails (CWR)) and star cracks at the boltholes of fishplated joints.

To evaluate the remaining life of rails, the RTRI implemented fatigue tests on welded parts and fishplated joints of rails that had been used in the field. The average accumulated passing tonnage of the rails tested was 380 million tons with Shinkansen CWR. The corresponding figure for rails used in 1,067-mm-gauge sections was 540 million tons with CWR and 330 million tons with fishplated joints. Based on the results of fatigue testing, the RTRI determined the S-N curves of laid rails (see Figs. 1 to 4).

In this context, a dynamic analytical model has already been developed to calculate the bending stress at welded parts, and the RTRI used this model in the study to evaluate the life of CWR. To analyze the dynamic stress at fishplated joints, another model is also available that combines a beam model to calculate the dynamic wheel load on the rail under investigation and a solid model to calculate the stress in the rail using the wheel load thus calculated as an external force. The RTRI verified the appropriateness of these models by implementing on-site measurement.

By applying these study results, the RTRI calculated the stress in the rails under different track and rolling stock conditions, and estimated the remaining life of the rails from the S-N curves and stress values thus obtained.

The RTRI also evaluated the remaining life of the welded parts of rails with boltholes. These rails were once used with fishplated joints, and were later welded to form CWR. Comparison of the remaining life between rails with cracks at the rail foot and those with cracks at their boltholes suggests that the latter retain a longer service life.

After evaluating the remaining life of different types of rail, the RTRI has confirmed that the periodicity of rail replacement can be extended (see Figs. 5 and 6). To achieve this, however, grinding is required for CWR to remove surface irregularity of the rail top. On the other hand, contact between the fishplate and the rail in fishplated joints should be controlled to avoid excessive wear. After discussing these points, several railway operators in Japan have already extended the periodicity of rail replacement in CWR sections.

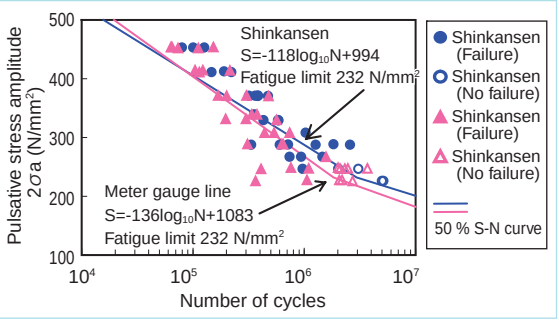

Fig. 1 S-N curve of laid rail of CWR at 50% fracture probability

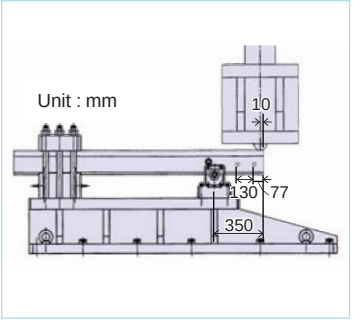

Fig. 2 Bending fatigue test of fishplated joint rail

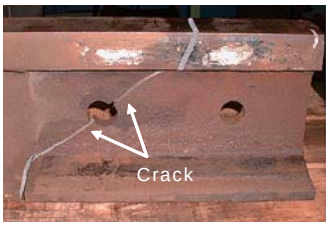

Fig. 3 Example of rail broken in fatigue test

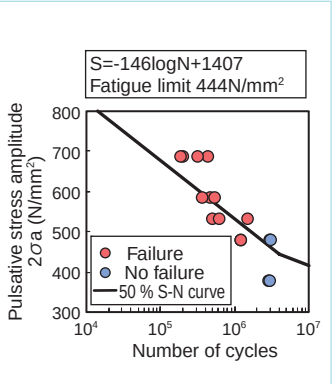

Fig. 4 S-N curve of laid jointed rail at 50% fracture probability

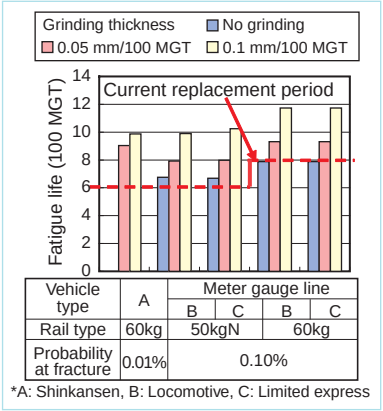

Fig. 5 Example of evaluated fatigue life of CWR

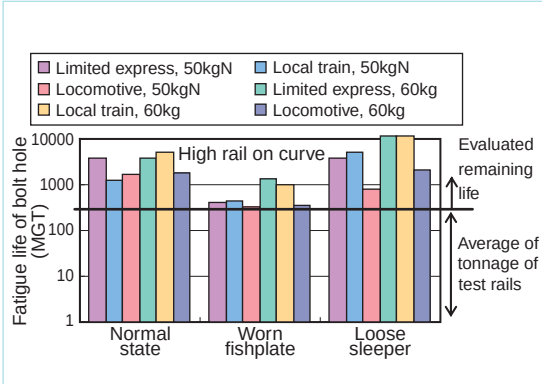

Fig. 6 Example of evaluated fatigue life of bolt holes (Probability at fracture:0.10%)