Long-Term Field Durability Testing and Practical Application of Shelling Damage-Resistant Bainite Rail

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A principal factor governing the life of rails is rolling fatigue damage (known as shelling), which tends to occur in rails on which trains operate with a high degree of frequency. Shelling damage can cause rail failure if left unattended for long periods, meaning that railways incur enormous maintenance costs in replacing failed rails and detecting cracks and other faults in them. Against this background, the Railway Technical Research Institute (RTRI) has developed bainite rail (a new rail made of bainitic steel aimed at improving shelling damage resistance) and succeeded in putting it into practical use after checking its characteristics through a long-term durability test in the field, which is outlined below.

The development of shelling damage-resistant rails was previously implemented under a policy aimed at suppressing rolling contact fatigue - a cause of shelling damage - by increasing the strength of rails. Based on this concept, a number of high-strength rails were manufactured on a trial basis and tested after being laid in the field. However, attempts to use these rails failed, as no model survived durability testing without shelling damage. In view of the lack of success in previous developments, the author discarded the conventional policy of increasing rail strength and adopted a new concept aimed at expediting rail wear to an appropriate extent to promote the self-removal of the rolling contact fatigue layer that causes shelling damage (see Fig. 1 for a conceptual drawing of the new developmental policy). In consideration of the laboratory test results, the author set the target rail wear rate of the rail under development at 1.2 times or more that of the standard carbon rails used in the section where specimens of the new rail were tested for durability.

The author selected bainitic steel as a material to satisfy the new concept of development, and had bainite rail specimens manufactured. After implementing laboratory tests to check the performance of the specimens with respect to the specifications and standards to be met for use in the field, the author subjected them to field testing for about 10 years on a narrow-gauge trunk line featuring high-frequency train operation to check their durability and suitability for practical use. For this durability test, the author set five hardness levels within the JIS specification range for the rails tested, and grouped them into three categories: high-hardness bainite rail (HLC, MLC), medium-hardness bainite rail (LC) and low-hardness bainite rail (N1E, N2W).

In the test, the author was able to examine the appropriate level of hardness to attain the targeted wear rate under actual conditions in the field and confirm that the tested rails had shelling damage-resistant features when used as tracks for train operation (see Fig. 2 for the strength levels and symbols of the tested rails).

The durability test proved that the wear amount of bainite rails is scattered in comparatively wide ranges up to an accumulated passing tonnage of about 150 million gross tons (MGT) (in the initial wear zone). However, it becomes smaller thereafter as the accumulated passing tonnage increases (in the stationary wear zone) (see Fig. 3 for the wear amount of different rails). In the stationary wear zone, the volume of wear on the low-hardness bainite rails is 1.2 times or more that found on the standard carbon rails. A survey implemented at an accumulated passing tonnage of about 215 MGT showed that shelling damage had occurred on all the specimen rails except the low-hardness bainite type (see Table 1 for the occurrence of shelling damage on different specimens). The field test was extended up to an accumulated passing tonnage of 320 MGT (over 10 years). Through this study, the author was able to prove that low-hardness bainite rails offer excellent resistance against shelling damage compared with existing standard carbon rails, and succeeded in putting bainite rails into practical use. Bainite rails are now used in areas covered by JR Hokkaido and JR East over a total length of about 44 km.

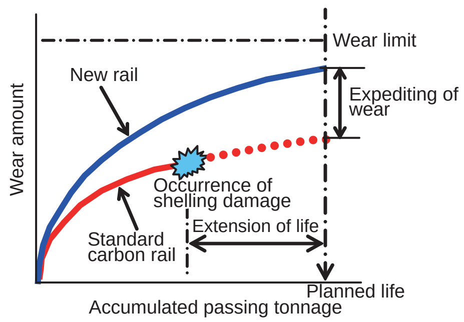

Fig. 1 Conceptual scheme of the new development policy

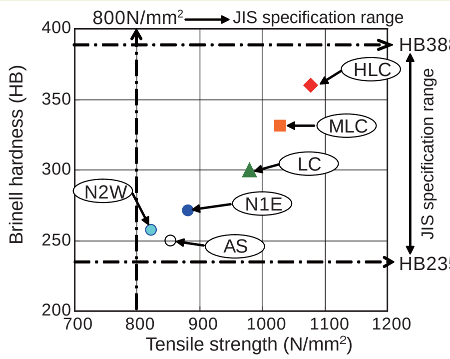

Fig. 2 Strength levels and symbols of specimen rails

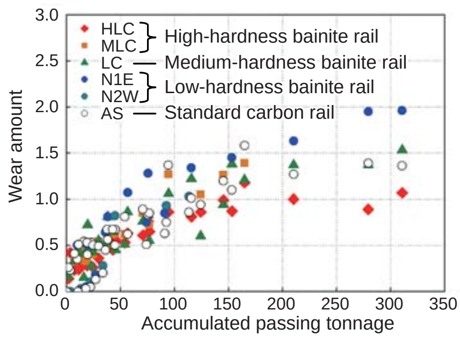

Fig. 3 Volumes of wear on specimen rails

Table 1 Occurrence of shelling damage

Specimen rail	Shelling damage
High-hardness bainite rail	Occurred
Medium-hardness bainite rail	Occurred
Low-hardness bainite rail	No occurred
Standard carbon rail (reference rail)	Occurred