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SP3 Rail for Heavy Haul Railways Utilizing Microstructural Control

1. Introduction

The weight and composition of freight trains on heavy haul railways has increased with the aim of achieving higher transportation efficiency, but the life of rails in such environments is very short. Therefore, rails with higher wear resistance and rolling contact fatigue (RCF) resistance are required.

JFE Steel developed a higher performance rail with higher wear resistance and RCF resistance through microstructural control by alloy design and online heat treatment[1]. This report introduces the basic properties of the SP3 (Super-Pearlite type 3) rail, which is mainly used in heavy haul railways.

2. Concept of Higher Performance

A pearlite microstructure (lamellar structure of layered ferrite and cementite), as shown in **Figure 1**, was selected for the new rail with the objective of wear resistance and RCF resistance, as strengthening the pearlite structure is effective for improving of these properties[2]. The main techniques for strengthening this structure are refinement of the lamellar spacing[3] and an increase in the cementite in the pearlite by addition of carbon[4]. Although steels are generally considered to become brittle as a result of strengthening, in JFE Steel, the C content was set at 0.8%, which is equal to that of conventional rails, in order to increase strength without reducing elongation and toughness. Si and Cr were utilized to contribute to refinement of the lamellar spacing, and the rail heat treatment technology after hot rolling was also optimized[5].

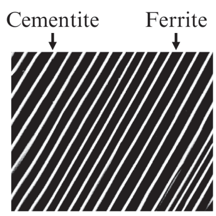

Fig. 1 Microstructure of rail steel

† Originally published in *JFE GIHO* No. 48 (Aug. 2021), p. 102−103

3. Basic Performance and Usage Characteristics of SP3 Rail

3.1 Chemical Composition

Table 1 shows the typical chemical composition of SP3 in comparison with that of the conventional rail used for curve sections of heavy haul railways. In SP3, the pearlite lamellar spacing is refined by adding the alloy elements Si and Cr and optimizing the Mn content[5].

3.2 Mechanical Properties

Table 2 shows an example of the tensile properties of SP3 in comparison with those of the conventional product. These properties satisfied the standards of the American Railway Engineering and Maintenance-of-Way Association (AREMA) applicable to heavy freight railways. Although SP3 displayed higher strength than the conventional rail, its elongation was on the same level, indicating that SP3 has excellent ductility.

Figure 2 shows the typical hardness distributions of SP3 and the conventional rail. Compared to the conventional rail, the Brinell hardness of SP3 was increased about 40 points at the rail head surface and about 20 points at 25.4 mm below the surface.

3.3 Weld Joint Properties

From the viewpoint of maintainability, rails are welded to form a continuous welded rail. **Figure 3** and

Table 1 Typical chemical composition of SP3 rail

	C	Si	Mn	Cr	Others
SP3	0.81	0.54	Reduced	Increased	V
Conventional	0.81	0.29	1.10	0.19	—

Table 2 Tensile properties of SP3 rail

	YS (MPa)	TS (MPa)	El (%)
SP3	996	1 420	13.6
Conventional	883	1 308	11.6
AREMA (High strength)	≧827 (120 ksi)	≧1 179 (171 ksi)	≧10

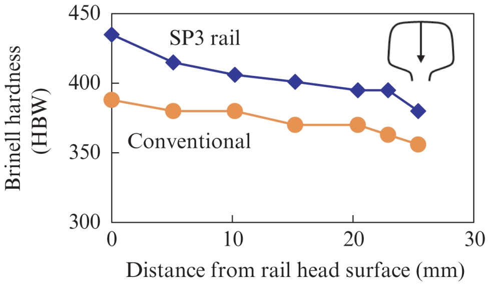

Fig. 2 Typical hardness distributions of rails

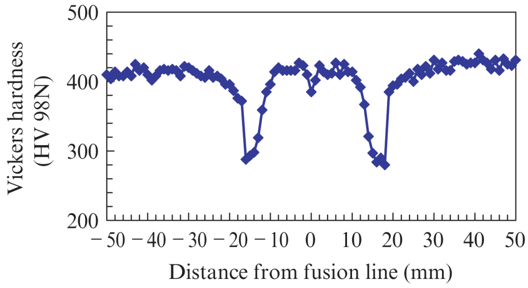

Fig. 4 Hardness distribution in flash-butt welds

Fig. 3 Photograph in flash-butt welds of SP3 rail

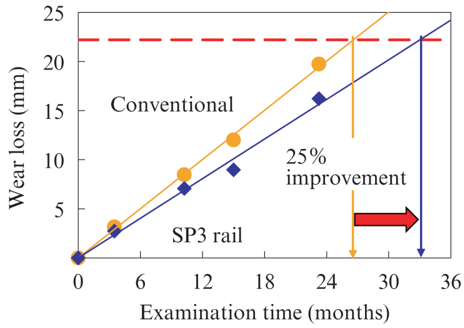

Fig. 5 Evaluation of wear resistance in actual track

Fig. 4 show a macro photograph and the hardness distribution in welds after flash-butt welding of SP3, respectively. SP3 has excellent weld joint properties, as no cracks or other defects were observed in the welds, and the hardness of the welds was on substantially the same level as that of the base metal.

3.4 Evaluation Test on Actual Railroad

SP3 has been installed in curved sections of multiple heavy haul railways, and has been confirmed to provide excellent wear resistance and RCF resistance.

Figure 5 shows an example of the result of an actual track test on a heavy haul railway. The wear resistance of SP3 displayed an improvement of about 25% compared with the conventional rail.

As described above, these tests confirmed that SP3 has sufficiently high performance even in the actual operating environment. SP3 also displayed excellent wear resistance in an installed test at the Transport Technology Center (TTCI: Transportation Technology Center, Inc.) in North America[6].

4. Conclusion

JFE Steel manufactures the high strength rail SP3 for heavy haul railways by refinement of the microstructure through optimization of the chemical composition and cooling technique.

SP3 has been confirmed to have excellent performance, and has been adopted in heavy haul railways in North America, Australia, and South America, where it is contributing to reduction of the frequency of rail exchanges and rail maintenance. In the future, it is anticipated that the needs for SP3 will continue to increase for further improvement of transportation efficiency, and expanded application to heavy haul railways is expected.

References

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