Improving the Reliability of Aluminothermic Welding

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The aluminothermic welding method adopted in the JR group is the SkV method introduced from Germany in 1979, and in recent years about 25,000 welds per year have been executed. Figure.1 shows the number of aluminothermic welds executed on tracks within the JR group, the number of fractured welds and the causes of the fractures. Around 1988 when continuous welded rails began to be adopted on conventional lines, there was a rapid increase in the number of welds. However, fractures occurred at the base of the rails, and these were caused by lack of fusion. By introducing the application of ultrasonic inspection using the double-probe technique to detect the lack of fusion, the Railway Technical Research Institute (RTRI) succeeded in preventing the fractures. Measures were also taken to ensure that the welding process was carried out correctly, such as prescribing the adjustment method of preheating flames. However, fractures due to centerline shrinkage in the central part of the weld metal at the base of the rails occur almost every year, and measures to deal with this problem were requested. Figure.2 shows an example of the appearance and the fracture surface of an aluminothermic weld that has broken on a conventional line. The fracture occurred in the central part of the weld metal, and centerline shrinkage has been generated at the lower rail fillet, which was rusted in black.

In order to further improve the reliability of aluminothermic welding, we simulated the centerline shrinkage in a test and examined the conditions in which this occurred, as well as looking at preventive measures and a detection method. We carried out aluminothermic welding on RTRI's double gauge test track, then carried out a tensile test to forcibly move the welded rail outward at the weld position. This was based on the assumption that the rail would contract as the temperature decreased during the solidification process of the molten aluminothermic steel (between 90 and 160 sec after pouring the molten steel into the mould). As a result, we were able to reproduce centerline shrinkage similar to that which occurred on the main lines. Figure.3 shows the fracture surface of the centerline shrinkage which occurred under the conditions of a time of 100sec after pouring the molten steel into the mould, and the welded rail was shifted outwards by 0.35mm. The fracture surface pattern is similar to that shown in Fig.2 (b). Further, the locations where centerline shrinkage occurred and the area affected were different depending on the elapsed time from the pouring of molten aluminothermic steel to the shifting of the rails, and the amount by which the rails were shifted (Fig.3 (b), Fig.3 (c)). Even when the rail was shifted by 1 mm or more 90 sec after pouring the molten steel, when it is not yet in the final solidification stage, centerline shrinkage did not occur. Nor did centerline shrinkage occur 160 sec after pouring, when the solidification process had finished, again even when the rail was shifted by 1 mm or more. On the other hand, in the case of the rail being shifted 100 to 150 sec after pouring, centerline shrinkage occurred at many welds and the it was transferred from the base of the rail to the web and head in correlation with the passage of time from pouring of the molten steel (Fig.4). This is because the solidification of molten aluminothermic steel progresses from the base of the rail to the web and head. Sometimes, solidification at the lower rail fillet is delayed compared with solidification at the surface layer of the web (for example, Fig.3 (b)), and it is considered that the centerline shrinkage occurs only at the lower rail fillet depending on the timing and amount of the rail being shifted.

Although we are not able to introduce it here, we are proposing ultrasonic inspection as the detection method for centerline shrinkage occurring at the lower rail fillet and at the base of the rail as well as its criteria for ultrasonic inspection. The remaining task is to propose a measure that prevents occurrence of centerline shrinkage beforehand, and we would like to continue making efforts to eliminate breakage of rails from aluminothermic welds.

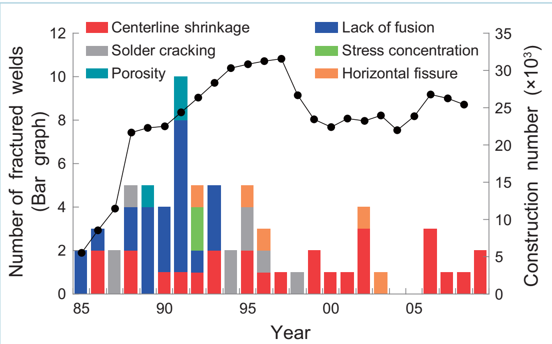

Fig.1 The number of aluminothermic welds executed on JR tracks, and the incidence of fractured welds

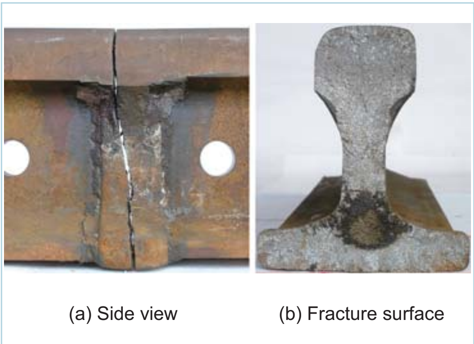

Fig.2 Example of the appearance and the fracture surface at a broken aluminothermic weld

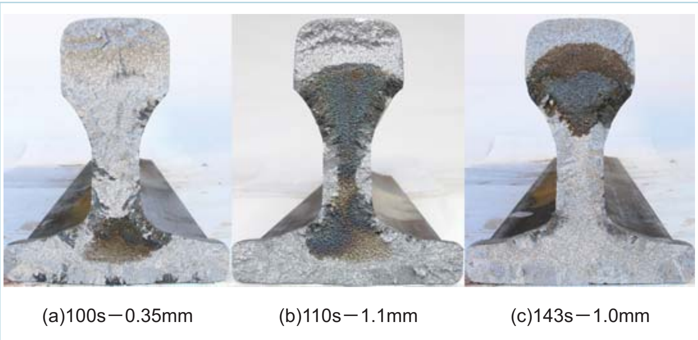

Fig.3 Example of fracture surfaces of the centerline shrinkage reproduced in a simulation test

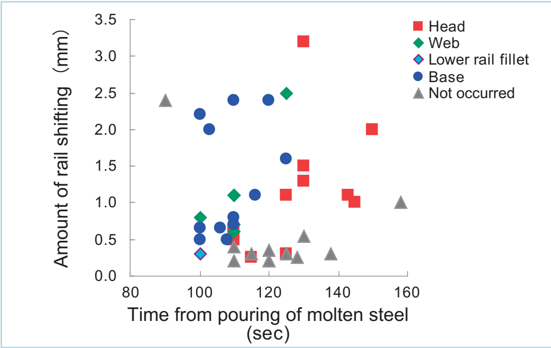

Fig.4 The relationship between the conditions and the affected area of centerline shrinkage occurrences