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Wear 258 (2005) 1014–1021
WEAR
www.elsevier.com/locate/wear

Testing of HSH® rails in high-speed tracks to minimise rail damage

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Received 13 June 2003; received in revised form 28 November 2003; accepted 1 March 2004

Abstract

With the beginning of high-speed traffic, the stresses in the wheel–rail interface raised significantly. Wear and especially rolling contact fatigue (RCF) defects became more prominent and very important factors of costs. Theoretical considerations led to the assumption that head hardened rails have a better resistance against RCF defects than rails with as-rolled hardness [F.P. Pointner, F.N. Frank, Rad/Schiene Kontakt: Rollkontaktermüdung an Schienen – Werkstoff oder Beanspruchung? Eisenbahn Ingenieur, vol. 50, Tetzlaff-Verlag, Hamburg, Germany, 1999, pp. 22–26]. To investigate and verify this theoretical evaluation, voestalpine Schienen GmbH and German Railway (DB AG) set a track test program in a joint project. In several trial tracks in high-speed lines of DB AG, the damage behaviour of rails of the grades 800 (220), 900A (260) and HSH® (350HT) was investigated and compared. Furthermore, grinding tests were done to find an appropriate maintenance strategy for these different rail grades. After 3 years time of investigation, it was demonstrated that the rail damage behaviour of the three rail grades was significantly different. It is shown in this article that the use HSH® rails is definitely advantageous because of its better rail damage behaviour. In combination with an optimised maintenance strategy, the service life of rails can be increased and life cycle costs decreased significantly.

Keywords: Rolling contact fatigue; Wear; Corrugation; Rail material; Maintenance strategy

1. Rail damage on high-speed tracks

With the beginning of high-speed traffic in Germany, the loads in the wheel–rail system raised significantly. Due the high stresses at the wheel–rail interface, rolling contact fatigue (RCF) defects such as head checks and squats became more prominent [2].

Additionally, corrugations form also very often on high-speed tracks due to material transformations at the surface. On corrugated rails, a new surface defect, the so-called Belgrospis, was found on rails on high-speed tracks of DB AG. These crack networks that occur periodically on the corrugation top, form because of the high dynamic forces that stresses especially corrugated rails.

Head checks occur mainly in medium and wide curves at the gauge corner. Corrugation, Belgrospis and squats occur mostly on tangents and in large radius curves on both high and low rail.

The damage of the rail surface as a result of rolling contact fatigue increases the maintenance effort and reduces rail service life. Therefore life cycle costs are increased.

2. Development of head hardened rails

The development of RCF defects is strongly influenced by the load and the mechanical properties of the rail material. On one hand, it is important to reduce loads respectively dynamic forces in railway systems, for example, by better track quality. On the other hand, it is tried to reduce wear and the formation of RCF defects by advanced rail materials [3].

In the 1990s, voestalpine Schienen developed the so-called HSH® (head special hardened) rail (350HT). The properties

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doi:10.1016/j.wear.2004.03.050

of this rail aimed mainly on the reduction of rail wear. The high levels of hardness, strength and endurance limit of the fine pearlitic structure of the HSH® rail increase the wear resistance compared to the standard grade 900A (260) by the factor 3 [4].

It was proofed by inspections of rail lines at different railways all over the world that it is possible to prolong rail service life significantly by the use of HSH® rails because of their 3 times higher wear resistance. For this reason, HSH® rails are applied successfully worldwide at various railways, particularly in heavy haul. Also DB AG uses HSH® rails, but they are used up to now only in highly worn curves with radii less than 700 m.

3. Track test of HSH® rails in the network of DB AG

A theoretical evaluation led to the assumption that HSH® rails have a higher resistance to RCF defects [1]. To investigate, quantify and verify the influence of HSH® rails on the rail damage, voestalpine Schienen and DB AG set a track test program in a joint project.

Test sections were installed in high- and medium-speed lines of DB AG. In tangents and wide curves on the high-speed line Hannover-Würzburg (speed 250 km/h, axle load <22.5 t), HSH® rails were compared to the standard grade 900A concerning wear and surface defects, especially corrugations. To investigate wear and the formation of head checks in different rail steel grades, rails of the grades 800, 900A and HSH® were installed in a curve on the medium-speed track Munich-Augsburg (speed 200 km/h, axle load <22.5 t).

4. Track inspection program

On each 120 m long test and reference rail, two measuring points have been defined in the middle at positions of 10 m distance. The measurements were done by the DB System Technology in half-year intervals over a period of more than 3 years. For the documentation of wear and corrugation transversal and longitudinal profile, measurements have been done. The detection and documentation of cracks was carried out, on one hand, by magnetic particle inspection (MPI). On the other hand, the real space depth of the cracks and the angle of crack growth were determined by metallographic methods on rail samples that were cut out at selected positions.

Furthermore, a new developed method of non-destructive testing for cracks and surface defects based on eddy current testing [5] was applied. With this measuring system, is it possible to prove the crack propagation not only on selected measuring points but also throughout the whole length of the test sections. The eddy current testing (ET) allows primarily the evaluation of the length of the detected cracks. By the metallographically determined angle of crack growth, the depth of surface damage by cracks was calculated.

The track section in the medium-speed track Munich-Augsburg was ground at the end of the test period (3 years). In doing so, an appropriate grinding strategy for the three different rail grades was investigated. During grinding eddy current testing was used to ensure that the damaged surface layer of the rails was removed completely. Profile measurements were used to evaluate the material removal necessary.

5. Medium-speed track – test results

On the medium-speed line Munich-Augsburg a test section was installed near Mering. This test section with a radius of 3300 m is highly stressed with daily loads of mixed traffic up to 90,000 t.

In a previous track test, it was determined that this curve is typical for rail damage through RCF defects especially head checks because of its aligning and the superstructure. On rail samples of the grade 900A, that were cut out in 1998, head checks with a depth up to 4.6 mm were found. The rails were not grinded since they had been installed in 1989 and a total load of 300 MGTs was applied.

In 1999 test rails of the grades HSH®, 900A and 800 were installed in the high rail. After that a grinding of the new rails was done.

5.1. Magnetic particle inspection

After 3 years of service life corresponding to a total load of 90 MGTs, all three rail grades showed head checks very clearly, but in a different formation (Figs. 1–3). The foot line of the pictures represents the gauge corner, the upper line the middle of the rail. The head checks appeared not as mostly

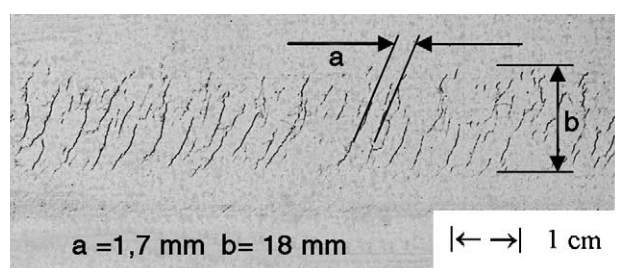

Fig. 1. MPI graph of the rail head surface, grade 800.

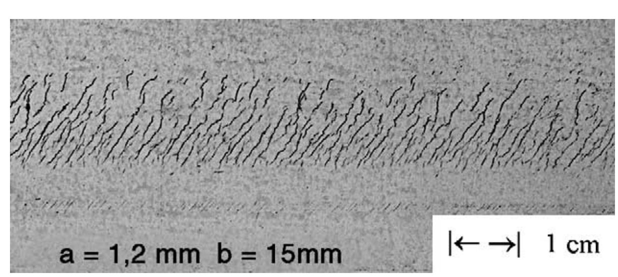

Fig. 2. MPI graph of the rail head surface, grade 900A.