Detection and evaluation of rail defects with non-destructive testing methods

Anika DEY [1], Jochen KURZ [2], Lukasz TENCZYNSKI [3]
[1] DB Systemtechnik GmbH Zerstörungsfreie Prüfung und Prüfsysteme, Brandenburg, Germany
[2] DB Systemtechnik GmbH, Brandenburg-Kirchmöser, Germany
[3] DB Netz AG, Minden, Germany

Contact e-mail: anika.dey@deutschebahn.com, jochen.kurz@deutschebahn.com

Abstract. Since the last years a lot of developments were realized in the field of non-destructive testing on rails. In the past the main attention was concentrated upon the inspection of internal rail defects and wear. By now the focus of rail inspection was moved to surface defects induced by material fatigue.

Two frequent rail surface defects caused by the wheel / rail contact are rolling contact fatigue cracks in the gauge corner (so-called Head Check) and Squats.

For an early avoidance of dangerous rail defects and an economic preventive maintenance strategy different non-destructive testing methods are in use on rail tracks.

Overview of the testing methods:

- ultrasonic testing with inspection trains
- eddy current testing with inspection trains
- automatic visual inspection systems
- manual ultrasonic testing
- manual eddy current testing
- eddy current testing on rail maintenance machines

This presentation provides an overview of the functionality and the implementation of the various non-destructive testing methods for both internal and surface rail defects.

Introduction

Rails have to provide a high durability as well as safety and traffic comfort at the same time. For reliable and undisturbed railway operation a regular railway maintenance strategy is essential. In case that the maintenance strategy takes place in time but remains economic, non-destructive testing methods are inevitable implements.

The inspection with non-destructive testing methods on rails will be carried out with three techniques.

One important method that should not be underestimated is visual testing of rails (VT). Another important inspection method for the evaluation of internal rail defects is ultrasonic testing (UT). Lastly the eddy current testing (ET) method is used for the detection of surface defects.

1. Visual Testing

For the identification of surface defects the visual testing is an important inspection instrument. The test personal always has to be attentive during the manual UT- and ET-inspection onto what he/she additionally recognizes with his/her bare eyes. Knowledge of the appearance of the different rail defect types is essential. In sections 1.1 to 1.3 some important rail defect examples will be introduced.

1.1 Head Check

Head Check are surface cracks, which are induced by rolling contact fatigue (RCF) of the surface material due to rail/wheel contact stresses. Head Check develops on the gauge corner with an angle of 20° - 70° to the longitudinal axis and a crack distance between 0,5 – 5 mm mostly, as illustrated in Figure 1. Head Check mainly occurs at the gauge corner of high rails since there the wheel flange pushes forcefully against the rail.

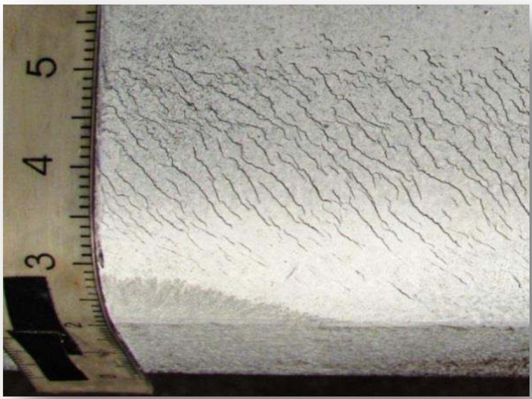

Fig. 1. Magnetic particle testing on a rail with Head Check [1]

1.2 Squat

Squats are damages which occur probably through RCF on the contact surface of the rail head. Predominantly they arise as single defects on tangent tracks or shallow curves with high speed traffic. Squats consist of two main cracks below the surface leading to a subsidence of the running surface. As a consequence corrosion arises in the subsidence becoming visible as dark spots, as illustrated in Figure 2.

Fig. 2. Squats [1]

1.3 Short Pitch Corrugation

Short-pitch rail corrugation appears according to metallurgical transformed material caused by vibrations between wheel and rail. They are mainly occurring on tangent tracks or curves with large radii. Short corrugation distances and bright looking peaks are one visible characteristic, as illustrated in Figure 3.

Fig. 3. Short pitch corrugation [1]

2. Eddy Current Testing

2.1 Application

The eddy current inspection is applied on railway tracks primarily for detection and evaluation of Head Check.

Due to rail steel being ferromagnetic the eddy currents do not penetrate into the material. Therefore they flow along the crack side so that the pocket length of the cracks can be determined in the rail head by eddy current testing (Figure 2). The penetration angle (α) of Head Check is generally unknown. As a result of statistical examinations at cross-sections of rails a mean angle (α) of 25 degrees is estimated. The vertical damage depth will be calculated with the help of the estimated angle and the pocket length of the crack.

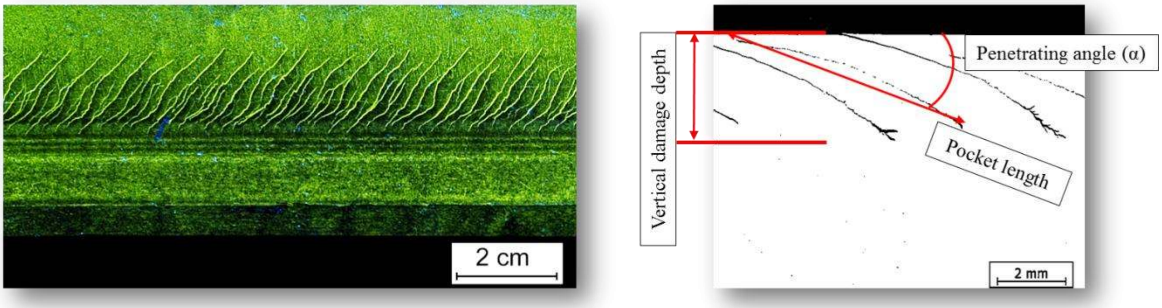

Fig. 4. MT inspection of Head Check (left) / Cross section of Head Check (right) [2]

The eddy current technique is used nowadays on inspection trains, grinding trains and eddy current trolleys in several European countries.

Figures 5, 6 and 7 illustrate the eddy current testing process steps of all inspection systems.

Fig. 5. The eddy current probe runs along the testing area. [2]

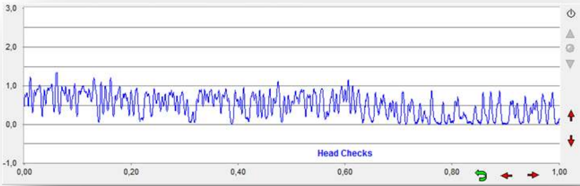

Fig. 6. Recording of the signal amplitudes per meter. [1]

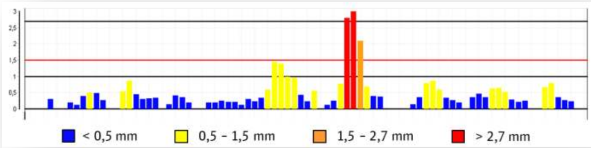

Fig. 7. Analysis report of the max. vertical damage depth per meter. [1]

2.2 Inspection Trains

The eddy current technique on inspection trains is used for general inspection of the railway network. The inspection speed lies in between 50 to 80 km per hour. The inspection results help for planning preventive maintenance actions and for detection of damaged areas for initiation of maintenance procedures.

Inspection trains are equipped with 8 eddy current probes, 4 probes for each rail, as illustrated in Figure 8.

Fig. 8. Probe holder of an inspection train. [3]

2.3 Manual Inspection Systems

Manual eddy current testing systems are used for selective inspection and inspection of railway switches, as well as for areas which are difficult to access by inspection trains. Manual eddy current inspection systems are equipped with 4 eddy current probes, as illustrated in Figures 9 and 10.

Fig. 9. Manual eddy current inspection system “WPG NT”. [1]

Fig. 10. Manual eddy current inspection system “WPG D340”. [1]

2.4 Integrated Systems on Maintenance Machines

Since January 2013 all rail maintenance machines have to document the results of the maintenance operation with an integrated or manual eddy current testing system. The purpose of these requirement is to document remaining cracks as well as the complete removal of damages as a quality assurance for Deutsche Bahn (DB). Thereby it is possible to recognize residual cracks immediately after the process of grinding or milling and to arrange further maintenance activities. These innovations are bringing an important progress to quality management of rail maintenance [6].

The maintenance machines are equipped either with 8 eddy current probes like the inspection trains or with only 4 probes, 2 probes for each rail. It is important that the probes detect exactly the area where residual cracks remain.

3. Ultrasonic Testing

3.1 Inspection Trains

The ultrasonic inspection is applied on railway tracks primarily for detection and evaluation of internal rail defects. The inspection trains are testing the railway network, recording the track conditions, approximately covering 160 km per day with an average speed of 70 km per hour.

Fig. 11. Inspection train of DB "SPZ 3". [3]

The basic configuration of the ultrasonic technique on DB inspection trains consists of at least of a straight beam transducer and angle beam transducers with 35°, 55° and 70° (forwards and backwards), as illustrated in Figure 11.

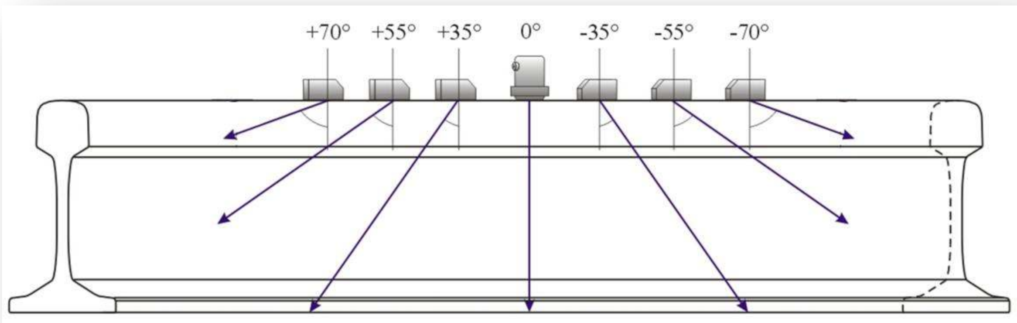

Fig. 12. Ultrasonic transducers for DB inspection trains. [1]

The results of the ultrasonic inspection can be evaluated afterwards with specific software. Figure 12 illustrates an example of typical evaluation software. The left rail is displayed in the upper half and the right rail in the lower half in grey colour. The Y axis represents the overall rail height and the X axis the testing area of one meter. The back wall of the rail foot is shown as a black line. In the case of a rail without defects, there always has to be a back wall as a result of the straight beam transducer. If one or more transducers receive a returned ultrasonic signal of a reflecting surface, for example an artificial reflector or a defect, it will appear in the evaluation software. The colours for every transducer angle are itemized on the left side of Figure 12. This graphical representation is also called "Glassy Rail" [4].

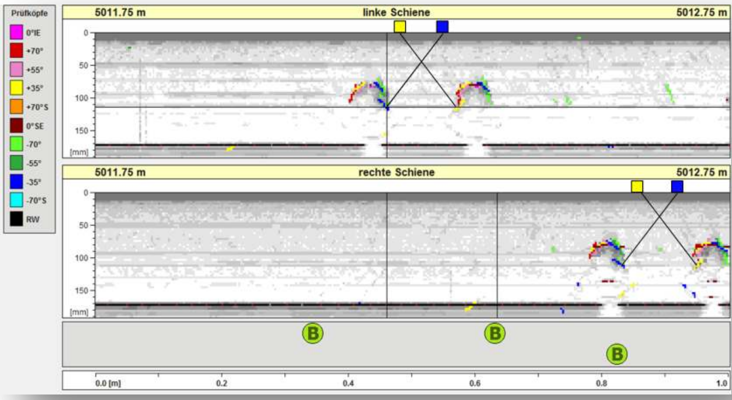

Fig. 13. Result of ultrasonic testing of an inspection train.[3]

The result in Figure 12 is showing the reflection of mostly all transducers at four positions. The first indications start in a depth of 80 mm and the last indications appear in a depth of approximately 100 mm. The reflection of the back wall is missing on these positions. This is a typical reflection of bolt holes. However four indications are inadmissible. The reflection of the +35° (yellow) and -35° (blue) transducers, which are sketched in Figure 12, were induced from saw cuts, as illustrated in Figure 13. These saw cuts simulate inadmissible defects in bolt holes. The evaluator has to document such defects for further activities.

Fig. 14. Saw cuts in bolt holes. [5]

3.2 Manual UT Inspection

As a result of the reports by the inspection trains, ultrasonic test personal has to go to the announced positions in order to verify the defects with manual ultrasonic testing systems to determine the defect size for maintenance activities.

Figure 14 illustrates the manual ultrasonic testing with the SPG3 and the holder of the transducers. This system has one straight beam transducer and four angle beam transducers with 35° and 70° both forwards and backwards. That is the minimum requirement for ultrasonic testing systems at DB network.

Fig. 15. Manual ultrasonic testing system “SPG 3”. [1]

5. Conclusion

Eddy current testing on rails is an important inspection instrument for detection and evaluation of Head Check defects in rails. Additionally it is required for quality assurance after operation of rail maintenance machines.

Ultrasonic testing is a safety related inspection instrument for prevention and removal of inadmissible defects which can lead to accidents.

A relevant and sometimes underestimated method is visual testing. It is always important in combination with manual testing systems that defects on the rail surface can be spotted and identified by the test personal.

The joint application and expedient combination of all three non-destructive methods are the solution for an economical maintenance of rails in track and for warranty of operational reliability.

References

[1] DB Systemtechnik GmbH, I.IVI 2, Department for Non-Destructive Testing, Brandenburg-Kirchmöser, Germany

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