



Analyzing the Reliability of Non-destructive Tests using the Modular Modell - a practical approach

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Abstract. Non-destructive testing is an important tool to guarantee the safety of railway traffic.

The infrastructure with tracks, switches and sleepers is regularly tested, the locomotives and wagons with their wheels, bogies and axles as well.

Many years of experience and some events lead in Germany to a good practice in testing the railway components. Now, European authorities are drafting a system of common requirements and standards for the European Railway Market.

The German practice combines an intensive training of the NDT-personnel including sufficient time for practical exercises with organizational measures of the companies, responsible for rolling stock and infrastructure.

Through the example of UT-testing of railway axles it will be shown, how training and organizational measures influence the reliability of such testing.

Changes in the European Railway Sector

The old fashioned public sector of railways with governmental structures has changed to a sector with different private companies and a competition on the market. To stay competitive with other modes of transportation a higher speed of trains and a higher load for cargo trains is needed and delivered. In the same moment the time for maintenance is limited, innovation-cycles and live-cycles of passenger cars and locomotives have become faster. The importance of a low energy consumption and a competitive price lead to lightweight constructions with less safety margins.

Safety of Railway Traffic in Germany

There are 200.000 km of railway routes in Europe, 37.860 km in Germany [1]. The tracks are used by 21608 locomotives, 119 040 cargo wagons and 9253 coaches [2].

In 2014 German railway companies moved in the country 365 Mio. tons of goods and almost 2,7 Mio. People [3].

In 2014 the German railway traffic faced 492 accidents, among passengers with 158 casualties and no fatalities. The majority of those accidents are level-crossing accidents and accidents to persons. Only 4.6 % are connected to technical problems, leading to derailments [4].



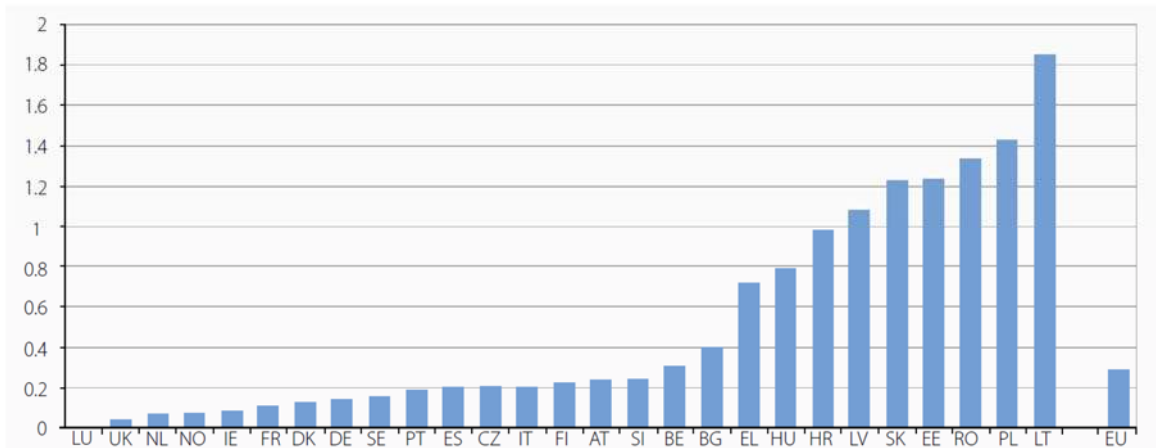


Figure 1: Railway fatalities and weighted serious injuries per million train-km (2007–2012) (4)

It seems that the safety management system of German railway companies is working quite well (Figure 1). The infrastructure with tracks, switches and sleepers is regularly tested, the locomotives and wagons with their wheels, bogies and axles as well. Many years of experience and some events lead in Germany to a good practice in testing the railway components.

Context of Testing in the German Railway Sector

For a first overview it seems practical to identify the influences on the inspection process from outside the organization (Figure 2). As an example, the regulatory requirements for the railway sector are delivered on the national level by the “Eisenbahn — Bundesamt (EBA)” and on the European level by the European Railway Agency. The technical rules are coming partly from DIN and EN Standards.



Figure 2: External Influences on NDT [5]

The European Railway Authorities are drafting a system of common requirements and standards for the European Railway Market. One example is the “Guide for the application of the Art 14 (a) of the Safety Directive and Commission Regulation (EU) No 445/2011 on a system of certification of entities in charge of maintenance for freight wagons”.

In this guide the target of maintenance is described as follows: “When the vehicle is used, it will be more or less damaged and therefore will not remain fully conform to its design operating state. The goal of maintenance is to restore this vehicle in its design operating state”. [6]

The term “Reliability” seems to be known by the authorities in Europe. They require at least the definition of a Maintenance Plan, of Critical Failures, the selection of an appropriate Inspection Method and the definition of an Inspection Interval. Having in mind the “Modular Model of Reliability” [7], this is covering basics demands on the intrinsic capability and organization of NDT.

Several European standardization projects are underway to define common technical rules and procedures to improve the maintenance of tracks and railway cars. One example is the prEN 16910: “Non Destructive testing on Running Gear”, currently out for inquiry and discussion.

In this paper there is no sufficient space to discover other factors, like Safety Culture or the Market Influence. But these influence could be easily analyzed as well.

In the next step the Modular Model (Figure 3) is used to highlight the influences inside the organization on the reliability of the inspection.

German practice for testing of railway axles using UT

Testing of safety relevant parts of railway cars and locomotives has a long tradition in Germany. It is documented that since 1922 Radiographic Methods are used. In the 1950s the first Ultrasonic Inspections where introduced [8]. Over the years a good system of procedures and operator training was developed.

Today, the German practice combines an intensive training of the NDT-personnel including sufficient time for practical exercises with organizational measures of the companies, responsible for rolling stock and infrastructure.

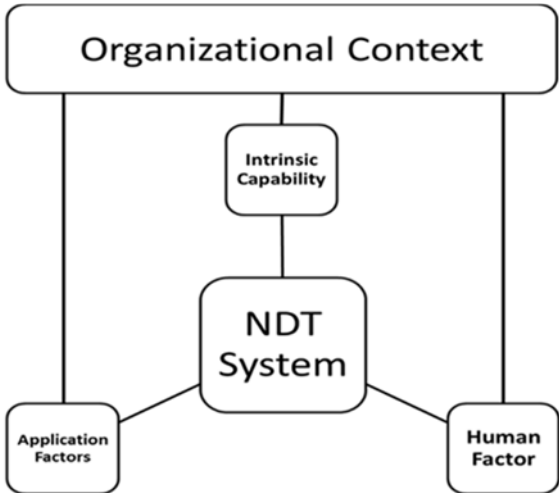


Figure 3: Simplified Modular Model of Reliability in NDT

Human Factor

How efficient is the German training system in the railway sector?

To answer this question, in 2014 the German Society for Non-destructive Testing and the Federal Institute for Materials Research and Testing, Berlin, started a project. The aim was to analyze the results of manual UT-testing of railway axles. The source of the raw material was a training center: The DGZfP training center in *Wittenberge* was collecting a large number protocols of such tests from training, examination and refresher courses. Almost 3.450 protocols were available to be analyzed.

The task was an in-service Inspection using manual UT, the aim to find damages caused by operation through detecting crack type indications. The operators used angle beam probes, the angle of incidence was 45° and 70° (transversal) and the frequency 4 MHz and 2 MHz. A special probe holder allowed to read the position of the probe with angle and depth and to change the beam direction. The evaluation is done using the A-Scan gate with echo height criterion and sound path criterion, the acceptance criterion is the indication of a 2 mm saw cut.

In a first step a data bank was filled with the results from the protocols, linked to a certain number of axles, and compared with the “true” indications evaluated by manual UT and Phased Array UT.

A first graphical display of the test results was irritating: the deviation in echo height was 48 dB, the deviation in the circumferential position almost 30°.

Later on it was learned that tolerances had to be taken in to account, and the echo height has to be evaluated in relation to the initial calibration. For the statistical evaluation of the data, diagrams have been developed with fields of good, acceptable and critical indications.

Nevertheless, certain defects are detected with one type and beam direction only, other defects with other types. But it is the aim of the testing procedure to cover every probable location of defects in the geometry by combining different angles and directions of the sound path. That this approach works is shown in Figure 4.

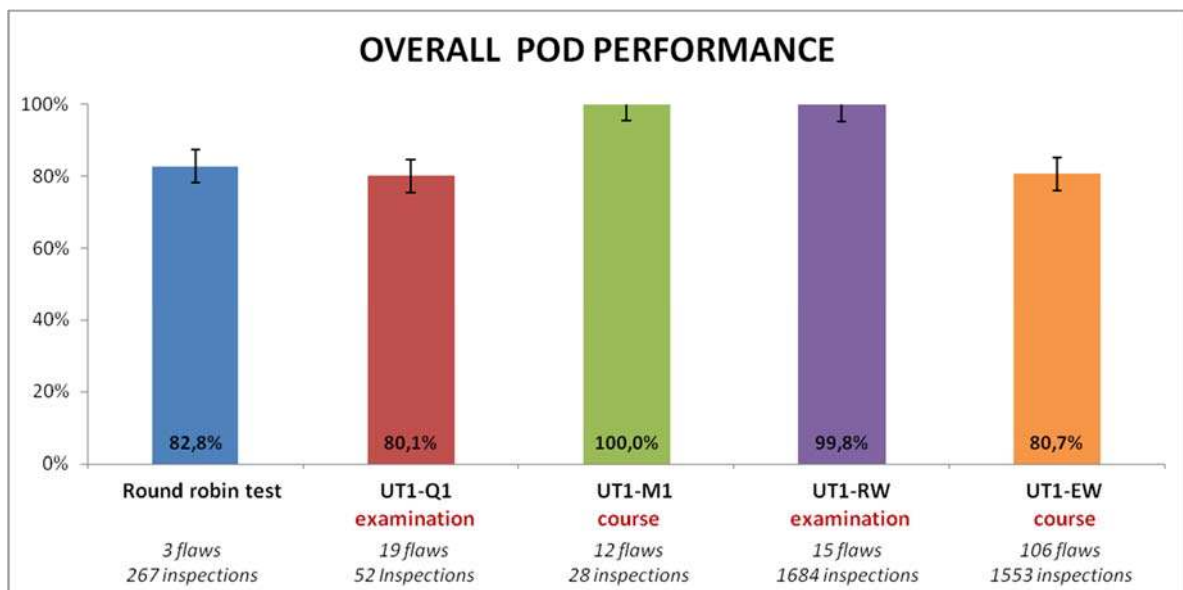


Figure 4 Overall NDT Performance in different training situations [9]

One may be unhappy with a POD of 80% in several courses. It should be taken in to account, that in UT 1 Q 1 and UT 1 EW training is still in the focus. The UT1-RW is the cutting edge of the testing and this POD is very sufficient.

In the German railway-sector training system, operators for manual UT are going a long way. They receive 2 weeks of basic training, followed by one week of additional practical exercise. Another week is dedicated to the test of hollow axles or solid axles before entering the final examination. This is four times more than the minimum training hours of ISO 9712.

The project between BAM and DGZfP has shown the need for such intensive training, and its success as well.

The testing procedures are very often a part of a comprehensive inspection manual, thoughtful drafted, evaluated and released by independent supervisors. During the project it was revealed that the layout of the procedures could be improved regarding understandability and ergonomics.

Intrinsic capability

A closer look on the equipment used in the railway sector shows that mainly long time improved testing technologies are used. The training statistics of the German Society for NDT leads to the conclusion that the mainly used methods are Ultrasonic Testing, Visual Inspection, Magnetic Particle Testing and Eddy Current Testing. Very often different probes and techniques are combined to improve the testing reliability.

A tendency to use mechanized set-ups is visible. It is used to minimize the inspection time, to combine techniques and to avoid routine jobs for the operators.

Application Factors

There are a lot of side effects and influences from the type of inspection, the job characteristics and the environment on the reliability of the NDT.

First, very often there are complex geometries to inspect, since buggies, frames and axles are designed to fulfill many requirements and tasks. This leads to a lot of geometric indications and interferences. To access such geometries a sound stability of equipment and probes is required, tolerances need to be defined and checked.

Second, many trains are inspected in shifts and within a comprehensive time schedule. This can lead to stress and exhaustion, lower alertness.

And last but not least, the work environment with its climate, noise and ergonomics is often not optimal for an inspection task.

Summary

The Modular Model of reliability in NDT is a good and practical aid to gain an overview on the influencing factors for inspections in an industrial area. It can be used as well to analyze

a special inspection task in deep. Knowing the factors is the first requirement to control and optimize them.

A next step is the evaluation of single factors using a simulation, POD-experiment or a failure-mode and effect analysis.

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