Management of longitudinal rail forces by non-destructive SFT monitoring in cw tracks

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1. Abstract

Longitudinal forces are generated in continuously welded (cw) tracks due to temperature changes. The Stress Free Temperature (SFT) defines the ratio of the stresses and therefore is a key track parameter. Safety against buckles and breaks and ride comfort depend decisively on the SFT. Particularly in times of increasing competition, increased prices of raw materials and energy as well as greater track loading, it is important to maximize drive comfort, track safety particularly against excessive stresses and to minimize track maintenance costs with maximum track availability. A new technique enabling reliable non-destructive determination of the actual SFT of the track under traffic for the first time has been further developed, completely redesigned and adapted for this purpose. Measurements to an accuracy of ±3° C and in special cases up to only ±1° C can be made at any hour without rail unfastening providing assurance of track stability and quality, reduction of maintenance costs and decreasing limits to SFT tolerances. The technology, already approved in several European countries, is based on a micro-magnetic method. Thereby, a known interaction between magnetic field and ferromagnetic material to be checked enables the determination of its load stress state. The new development and inspection examples are presented where assurance that the cw track has been welded within the required stressing tolerance was made by SFT measurements excluding any subsequent re-establishment of required stress conditions.

2. Introduction

Safety against buckles and breaks and poor ride comfort depend decisively on the SFT. An assessment of the stability of the cw tracks must therefore be made, including the SFT measurement, where the task of determining the longitudinal stresses acting on a rail of cw railway track is not a simple technical problem. Destructive methods are not expedient, because they require the cw-rail to be cut. A new technique enabling reliable non-destructive determination of the actual SFT of the track under traffic [1] has been further developed for this purpose. The measurement, to accuracy of ±3° C and in special cases up to ±1 °C, can be made at any hour without any rail unfastening. This enables control of the SFT e.g. subsequent to the installation of cw track. The correct neutralization can be checked and dangerous conditions with regard to possible changes of the actual SFT due to heavy track loading or extreme weather conditions can be identified. The technique TRACKSAFE RELEASE presented in this article represents the further development including redesign of the previously used RailScan technique [1, 2]. It is offered as a complete SFT inspection service package leading to lower expenditure, high-precision measurements and the complete documentation of track conditions and safety where the commercial availability of TRACKSAFE RELEASE devices is not excluded in the near future.

The technology is based on a micro-magnetic method where a known interaction between magnetic field and ferromagnetic material to be checked enables the determination of its stress state. A detailed description of the physical background is given in [1] and [3]. Further developments of the last years resulted in a light-weighted non-contact measuring device that allows fast measurement and documentation of the actual neutral temperature of most rail types. The longitudinal stress and the SFT are determined by evaluating the nd parameters. Inspection results are reliable and have been validated by measurement system capability investigations [1] and homologations, e.g. [4].

3. Functional principle

For producing MBN, the rail is energized in the direction perpendicular to the measured cross-sectional area and the magnetic Barkhausen noise emitted from the surface is measured. The MBN is measured at the surface with a sensor containing a ferromagnetic material which is brought into contact with the surface to be measured. Imperfect matching due to unevenness of surface, scale, rust, contamination or paint coating reduces the magnitude of the detected MBN. In order to eliminate inaccuracies resulting from such conditions, the spacing between the ferromagnetic material and the surface being investigated, known as the air gap, is measured and kept within a small tolerance band to provide reliable magnitudes of the detected MBN according to the measured depth of the air gap. If a longitudinal stress is applied to the measured rail, the permeability for the applied magnetic field changes. Tension leads to an increase of the permeability. The greater the longitudinal stress, the greater the increase of permeability. The opposite case applies when compressive stress is applied. With increasing compression the permeability for the magnetic field decreases. The MBN contains the eddy currents of the stress sensitive processes.

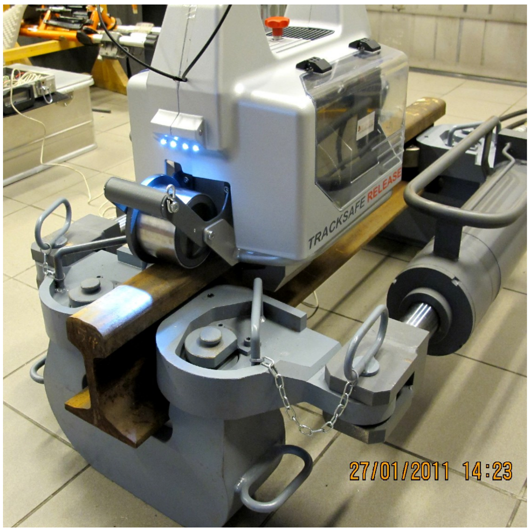

Fig. 1: Performance of a calibration of TRACKSAFE RELEASE in laboratory by means of an optimized rail tensor.

Before measurement, the device is calibrated in the laboratory (Fig. 1) or on site using a mobile and portable rail tensor and calibration rails. Measurements of the MBN are taken for different longitudinal stresses and used to plot a calibration curve of the MBN as a function of longitudinal stress. Before performing the calibration the excitation parameters are also optimized and defined. Calibration curves and excitation parameters are then collected in a data base and are available for all later measurements on the corresponding rail types. Thanks to the further developed and optimized calibration procedure, the complete calibration takes actually only approx. 1-2 hours. Further to this, the use of a new tensor device provides together with the new device generation a much easier handling, the exclusion of operator influence by means of a guided calibration software utility and consequently a higher accuracy.

After this calibration working step the device is ready for the non-destructive measurement in track. Altogether 5 to 10 readings are distributed on a length 5 or 10 meters and consecutively taken and stored in the measuring computer resulting in one SFT value. A recalibration of the different rail types is not required because the device is equipped with self check utility and auto calibration routine allowing monthly control of the correct functionality of the components.

4. Evaluation

After completing the measurements, the SFT is determined and indicated on the computer screen of the device. Results are obtained by evaluating and plotting the measured values of the magnetic parameter and rail temperature versus the longitudinal coordinate and measuring point number and further by depicting the load stress determined by means of the averaged magnetic parameters and the calibration curve. The neutral temperature is calculated by means of the measured load stress σ, the elasticity modulus E, the thermal expansion coefficient α and the measured rail temperature T_{Rail}. The results of the inspected locations are summarized in a report containing all relevant track information, i.e. the measured SFT linked to their location and position in the cw-rail, see also detailed evaluation description given in [1].

5. Further developments and extensive redesign

Fig 2 below gives an overview about the different device generations which have been realized from the year 2000 (Fig. 2 a) until today. The 2009 generation of RailScan already contained significant further developments providing a waterproof function and a minimization of errors due to magnetic and electric properties of the rails to be measured (Fig. 2 b). For the further development of the new TRACKSAFE RELEASE device generation an extensive analysis of the required functionality has been performed resulting in an appropriate complete device redesign (Fig. 2 c).

a b c

Fig. 2: Different RailScan and TRACKSAFE RELEASE device design generations. a: RailScan design from 2000 on, b: RailScan 2009/2010, c: TRACKSAFE RELEASE 2011 after full redesign

Consequently all achieved developments and optimizations have been collected in the new TRACKSAFE RELEASE device generation providing the following main advantages to former states-of-the-art:

- ✓ High performance device with high functionality and ruggedness
- ✓ Optimized construction volume with optimized weight
- ✓ Enlargement of potential measuring time frame
- ✓ Simple, fast, accurate thus reliable probe positioning
- ✓ Universal probe for all rail types
- ✓ Help utilities for the operator during coupling
- ✓ Stable probe closing during measurement
- ✓ Protection of probe and components from water and humidity
- ✓ Optical reduction of cables and connectors
- ✓ Provision of a maximum of free hands during device operation for the operator
- ✓ Upright operator posture
- ✓ Adequately communicated consumption factor (design)
- ✓ Optimized calibration procedure
- ✓ Facilitated working procedure
- ✓ Higher measuring performance (e.g. number of daily measurements increased up to >20 SFTs per 8 hour shift)

6. Application fields and state-of-the-art in practice

Thanks to its accuracy and flexibility, TRACKSAFE RELEASE is versatile and allows widespread use. Examples are the SFT determination for minimizing the areas to be maintained, the detection of locations in which quality and safety are endangered, the determination of zone length affected by rail buckles, fractures and derailment as well as the verification and documentation of cw-rail production assuring that the cw track has been welded within the required stressing tolerance excluding any subsequent re-establishment of required stress conditions.

During the last years, extensive practical experiences could be collected during different inspection and development projects, e.g. in Europe, the U.S. [1] and in Australia [2]. Regular RailScan inspection works have been performed in different applications since 2006. A very interesting perspective for the deployment of the technique is e.g. given in France where the technique is actually used for SFT determination under the names RailScan/TRACKSAFE RELEASE (SNCF) and BoaScan (Scheuchzer) e.g. after track renewal and assuring that the continuously welded high-speed track was welded within the required stressing. For the latter application a measurement at zero load stress is integrated in the measuring procedure providing an increase of the SFT measuring accuracy up to smaller than ±1°C. In Denmark inspections were performed on heavily loaded main-line tracks as well as interurban railways since 2005. Due to the experiences and various investigations according to recognized standards [6] and practical comparison measurements, the RailScan and TRACKSAFE RELEASE technique could be approved as a reliable and satisfactory technique for SFT determination; it was admitted in Banedanmarks directives for the production of cw rails (2007) and has been definitively approved in 2010 by Banedanmark [4].

7. Conclusion

The article presents the progresses of further developments of TRACKSAFE RELEASE technique achieved to the former RailScan technology enabling measurement of the stress-free temperature SFT of stressed track during operation without intervention in the track. This obviates the need for time-consuming, complicated and hence expensive alternative methods that necessarily involve intervention in the cw track. Extensive measuring ability investigations, together with a release and inclusion in the Danish technical guidelines for stress equalization, testify to the fact that the system provides accurate and reliable measurements of the SFT. Even if the technical background is complex the method is simple to employ. By enabling an evaluation of track quality and safety, it contributes to forward-looking and timely maintenance management significantly reducing maintenance costs.

8. References

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