RAIL MILLING - TO EXTEND THE RAIL-LIFE-CYCLE
FRESAGEM DE TRILHOS – PARA EXTENDER A VIDA UTIL DE TRILHOS*

Karl Berger[1]
Richard Stock[2]
Wolfgang Wiespointner[3]
Michael Berger[4]

Abstract

Rail surface and profile rectification is a well-established process in modern rail asset management that has proven to extend the life of rails and wheels. Traditionally, rail grinding is used to manage rail degradation by applying different strategies such as preventive maintenance or cyclic maintenance. In contrast to the abrasive grinding process, MILLING is a rotary cutting process that is capable of substantial metal removal rates (as required for corrective maintenance interventions) in one milling pass. When analyzing rail milling and grinding technologies in detail, it can be seen that the limitations of one technology can be compensated by the strengths of the other technology and vice versa. This paper gives an overview of the application of the technology and of the machines used in several continents, mainly Europe and Australia.By combining rail MILLING technology and conventional grinding it is possible to create an integrated, modern rail asset management that will maximize rail life while at the same time minimizing operational and maintenance costs.

Resumo

Retificação de superfície de trilhos é um processo bem estabelecido na moderna gestão de ativos ferroviários que comprovadamente prolonga a vida útil de trilhos e rodas. Tradicionalmente, a retificação de trilhos é usada para gerenciar a degradação de trilhos aplicando diferentes estratégias, como manutenção preventiva ou manutenção cíclica. Em contraste com o processo de esmerilhamento abrasivo, a FRESAGEM é um processo de corte rotativo que é capaz de taxas substanciais de remoção de metal (conforme necessário para intervenções de manutenção corretiva) em um único passe de fresamento. Ao analisar detalhadamente as tecnologias de usinagem e esmerilhamento de trilhos, pode-se ver que as limitações de uma tecnologia podem ser compensadas pelos pontos fortes da outra tecnologia e vice-versa. Este trabalho apresenta uma visão geral da tecnologia aplicada e das máquinas usadas em vários continentes, principalmente na Europa e na Austrália. Combinando a tecnologia de FRESAGEM de trilhos e a retificação para obter uma superfície acabada, é possível criar um gerenciamento de ativos de trilho moderno e integrado que irá maximizar a vida útil do trilho ao mesmo tempo em que minimiza os custos operacionais e de manutenção.

Keywords:rail milling, innovation, high performance
Palavras chave: Fresagem de trilhos, inovação, alto desempenho

[1] *Independent Consultant, Engineer, LINMAG / Austria*
[2] *Milling Technology Manager, LINMAG / Canada*
[3] *International Sales Manager, Engineer, LINMAG / Austria*
[4] *Project Coordinator, Engineer,LINMAG / Austria.*

1 INTRODUCTION

The intense usage of structural system components will always result in wear and fatigue of these components. Consequently, maintenance actions or preventive measures are required to extend the lifetime of these components (and the system) and to ensure safety and functionality.
The same approach is applicable for the rail-wheel system. Intense train traffic combined with increasing axle loads cause profile degradation of rail and wheel by wear and plastic material flow. The surface of rail and wheel is further deteriorated by rolling contact fatigue (RCF) defects like head checks, shelling, spalling and squats. Besides, defects like corrugation or wheel-burns can add additional damage by increasing the dynamic loads in the system.
To keep the rail-wheel system in a safe and operational condition maintenance activities are required. Rail surface and profile rectification is nowadays a well-established process in modern rail asset management.

2 RAIL MAINTENANCE

2.1 MAINTENANCE STRATEGIES (FROM “NO MAINTENANCE” TO PREDICTIVE MAINTENANCE)

Rail maintenance aims at keeping the rail in a fully functional and safe condition thereby extending the life of the rail. This is achieved by introducing artificial wear to the rail surface that removes any damaged and/or excess material from the rail surface. Strategic planning and execution is required to achieve the desired result of a defect free rail surface with minimum possible material removal rates. Railway operators can select the most appropriate approach from a number of different maintenance strategies to achieve this goal [1,3]

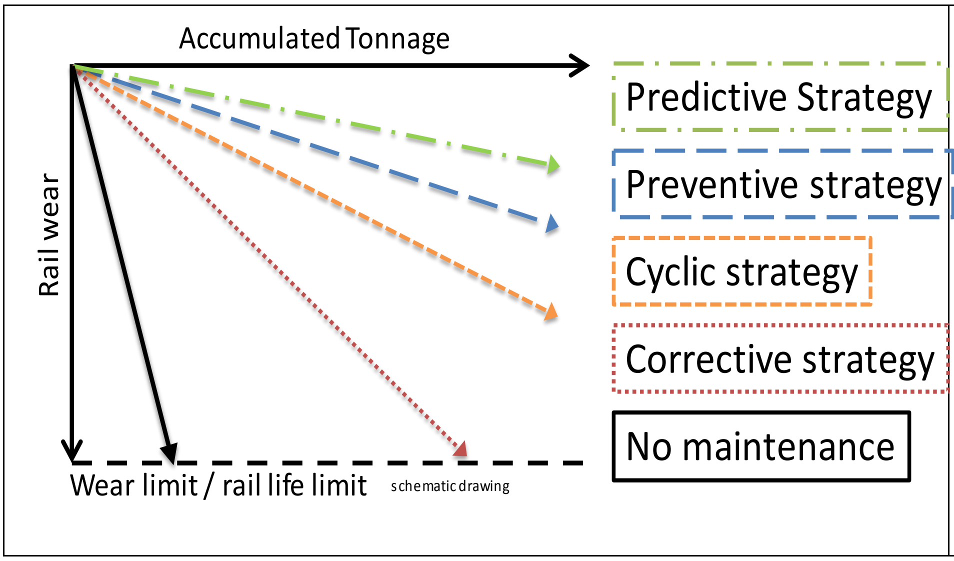

Figure 1: Exemplary comparison of combined wear rates (natural wear by rail traffic and artificial wear by rail maintenance) for different maintenance strategies.

2.1.1 Corrective maintenance

For a corrective maintenance scenario, damage is allowed to grow until it reaches a defined corrective maintenance threshold with respect to its depth. Typically, this threshold is chosen in a way that several corrective maintenance interventions can be done during the lifetime of the rail and that the rail damage does not pose any safety risks.

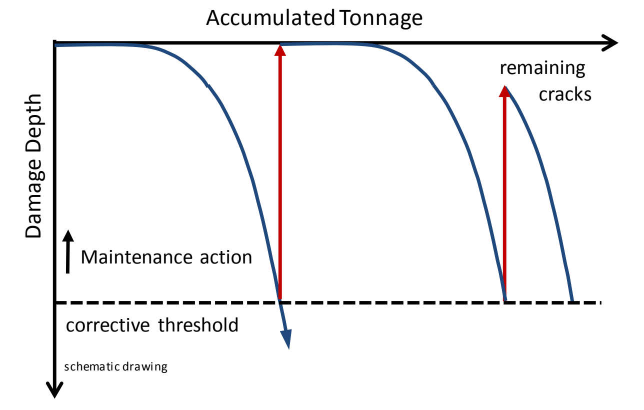

Figure2: Corrective maintenance strategy. Complete damage removal required to gain maximum rail life extension. Remaining cracks significantly shorten time to next maintenance intervention.

2.1.2 Cyclic maintenance

In the case of cyclic intervention, rail maintenance is conducted in regular intervals based on time or load (MGT – million gross tons). Usually these maintenance intervals are based on experience and are chosen so that the developed damage can be economically treated within these intervals with the available maintenance technology.

2.1.3 Preventive maintenance

A preventive maintenance strategy aims at frequent interventions with very low metal removal rates. Damage will be removed at a very early level, right after it has been initiated.

2.1.4 Predictive maintenance

A predictive approach goes one step further compared to a preventive approach. Starting point is a known (preferably) defect free rail condition. Based on regular measurements (regular conditions monitoring, “big data”), known operational conditions (e.g. train frequencies and axle loads) and prediction/simulation models, the current damage condition and the next intervention date is forecasted (Figure 3). With this approach, maintenance activities can be scheduled when they are most (cost) effective. So far no railroad has implemented this concept however some railroads have started exploring its applicability for rail maintenance [2].

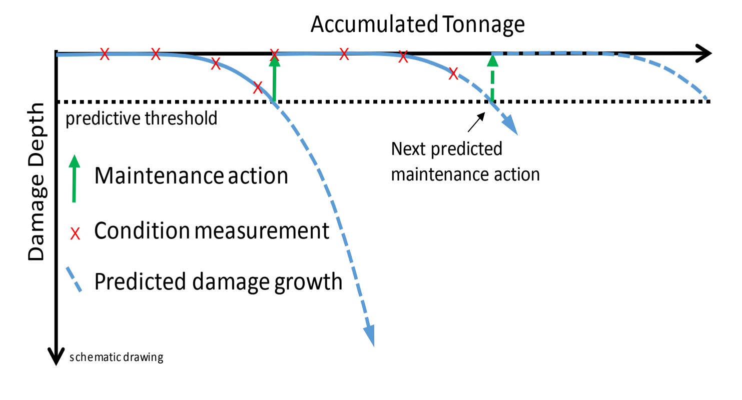

Figure 3: Predictive Maintenance Strategy: Based on regular condition measurements and operational parameters the next intervention activity is predicted by an advanced prediction / simulation model.

2.2 MEASUREMENT TECHNOLOGIES

One key factor for a successful maintenance strategy is the ability to characterize the rail damage condition in advance and directly after each maintenance activity. In Germany, it is standard/required to have measurement capabilities with respect to longitudinal profile, transversal profile and damage depth on maintenance trains [4]. With respect to damage-depth characterization, eddy current or magnetic flux leakage technologies are used. Both technologies have certain (physical) limitations with respect to measurement accuracy and maximum measurable damage depth. Nevertheless, these technologies provide a yes/no crack information and a reliable crack depth indication within certain damage depth classes/ranges [4,5].

3 APPLIED TECHNOLOGIES (From Grinding to Rail Milling)

This paper is focusing on two widely utilized maintenance technologies, rail milling and rail grinding with rotating stones. Besides these two technologies also grinding with oscillating stones, high speed grinding, rail planing and rotational rail planing are used to some extend for rail maintenance [6]. However, these technologies will not be further discussed in this paper due to their minor application significance.

3.1.1 Rail grinding with rotating stones

Rail grinding (with rotating stones) is currently the most frequently applied technology for rail maintenance and has been in use since the early days of railway operation. Rotating grinding stones (rotation around the vertical axis – see Figure 4) are pressed onto the rail surface at fixed angles between +20° (field side) and -70° (gauge side) during continuous forward and backwards motion of the machine. Dependent on the size of the machine (4 stone up to 120 and more stones) low to medium metal removal rates can be achieved in one machine pass. The transversal rail profile can be flexible adjusted by changing the angles of the grinding stones producing several overlapping facets (traces of the longitudinal movement of the grinding stone) resulting in a slightly polygonised profile shape [8].

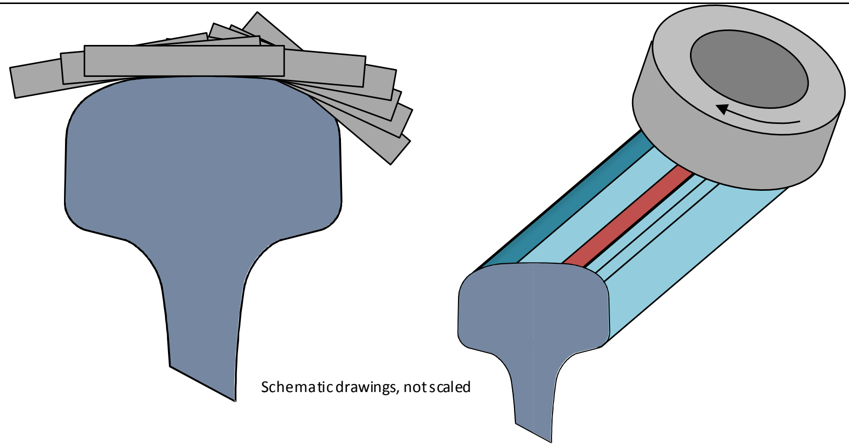

Figure 4: Rail grinding with rotating stones. Left part: flexible profile adjustment by changing the angle of the grinding stones. Right part: Creation of a grinding facet (red) by a grinding stone.

This maintenance process produces characteristic grinding marks / grooves along the rail profile. The surface finish and profile tolerances are defined e.g. in EN 13231-3:2012 [7]. Typical processing speeds can vary between 3 – 15 km/h. Special track work like switches and crossings can also be treated by grinding, however dedicated switch grinding machines are required for such a task. Rail grinding is well suited for a preventive or cyclic maintenance approach. If applied for a corrective maintenance strategy, the process speed of rail grinding will be drastically reduced, as multiple passes of a grinding machine will be required to achieve high metal removal rates. The heat that is produced during the grinding process may cause unwanted material transformations of the rail surface resulting in “white etching layers” (thin martensitic layers on the rail surface) that can act as a starting point for new RCF defects. A characteristic of the rail grinding process is the formation of dust and sparks. This can be a problem in sensitive areas like tunnels or stations resulting in unwanted pollution or fire danger. Especially in dry environments rail grinding can be restricted or even completely banned.

3.1.2 Rail MILLING

Milling of work pieces has been used since the early 19th century due to its precision and high resulting surface quality (compared to grinding processes). Rail milling is a relatively recent technology, introduced about 25 years ago by the Austrian company LINSINGER. Rail Milling is a rotational cutting process that results in the formation of metal chips that are collected and stored on the train for recycling.

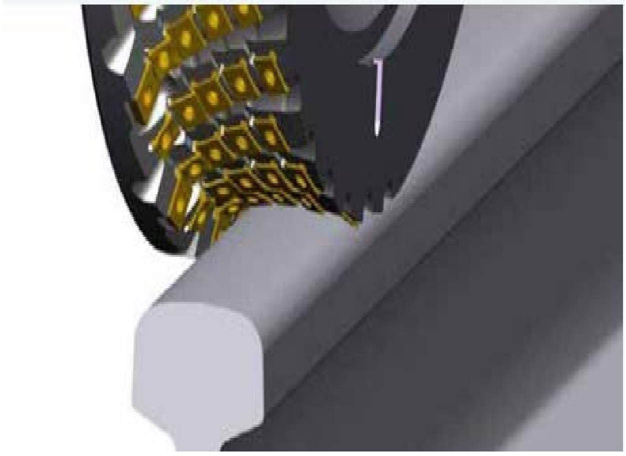

Figure 5: Rail milling: spark free rotational cutting process of a milling wheel (equipped with hard metal cutting inserts) resulting in generation of milling chips.

The target profile is defined by the shape of the milling tool (milling wheel with hard metal inserts) and is fixed for each set of tools. To change to a different rail profile, a different milling wheel with the new target profile needs to be installed on the train, which is a very fast process. Larger milling trains with multiple milling units per rail can have different profiles installed on each set of milling units. This allows an uninterrupted transition from one profile to another. Achievable profile quality is typically at least half of the required tolerances of EN 13231-3:2012 [7]. The milling process is completely spark and dust free which allows applying this process with limited or no special precautions in environmentally sensitive areas like tunnels, stations or zones with general fire restrictions / bans. The generated process heat is transferred into the milling tool and the metal chips. The machined rail surface experiences no significant heat input. Therefore, any unwanted material transformation like "white etching layers" is presumably prevented. The milling process produces a distinctive surface pattern that can sometimes cause temporary noise effects in a transit environment. For this reason milling trains are equipped with a longitudinal grinding wheel with a slight offset angle in reference to the longitudinal rail axis. This process provides an extremely smooth surface finish of the final rail profile. This polishing wheel is completely enclosed ensuring almost 100% of the sparks and dust to be collected on the train. The process speed of rail milling may vary between 400 m/h up to 2000 m/h of finished rail (dependent on machine type). This is generally slower than a typical grinding process. However, this is compensated by the higher one pass damage removal capabilities of the milling technology. Besides a milling machine can process main track as well as special trackwork like switches and crossings. No dedicated switch-milling machine is required for such a task. Milling is perfectly suited for corrective maintenance needs due to its curative capabilities (complete damage removal and high quality profile restoration). Rail milling can also be used for a preventive maintenance strategy. However, economic considerations might favor rail grinding due to the higher process speed for this low metal removal environment. Factors like achievable surface quality might nevertheless ask for rail milling instead of rail grinding for specific preventive tasks. Figure 6 shows one of the applied rail milling vehicles, a road and rail suitable

MILLING TRUCK with one milling axle and one grinding axle for a finishing surface pass.

Figure 6: LINSINGER RAIL Milling Truck SF02W-FS

3.1.3 Complementary Technologies

By looking at the technological capabilities, advantages and disadvantages of both technologies – rail milling and rail grinding – it can be seen that neither of these technologies is intended to replace the other. The strength of one technology can overcome some weakness of the other technology and vice versa. This indicates that both technologies represent truly complementary tools in the maintenance toolbox. Infrastructure owners can choose the suitable maintenance strategy in combination with the adequate maintenance technology to effectively and economically provide a solution to any given rail maintenance need.

4 RESULTS ACHIEVED

The surface conditions after milling are illustrated in Figure (close-up views of the rail profiles at three positions before and after milling at 200x magnification). A distinct surface roughness / unevenness can be seen for the initial rail condition. The rail profile after the milling process shows in contrast a very smooth surface condition in transversal direction.

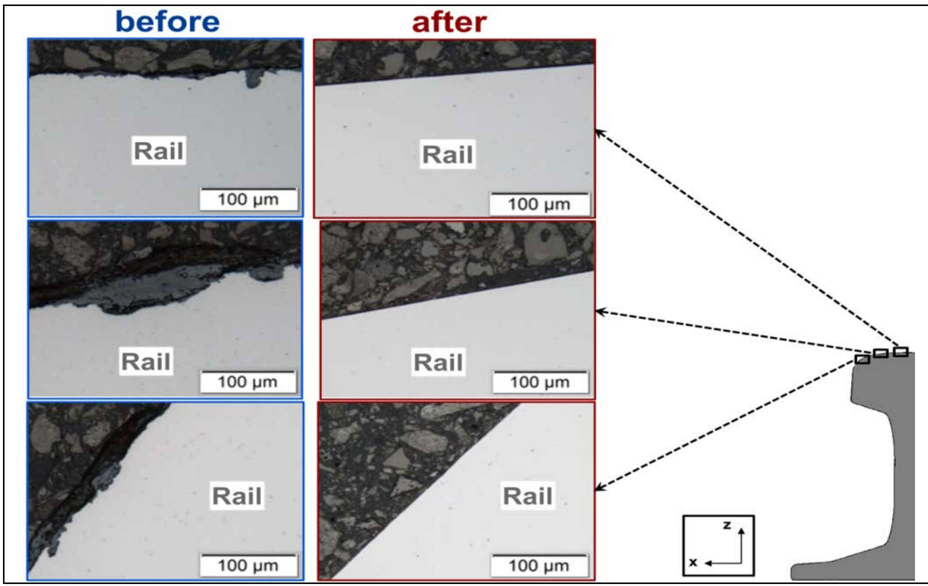

Figure 7: Comparison of rail surface at 200x magnification before and after rail milling. Rail surface significantly smoother after the rail milling process compared to pre-milled condition.

German Railways, Deutsche Bahn (DB) have implemented a rail grade dependent preventive grinding program in order to keep control of damage development and rail profile degradation thereby maximizing rail life [9]. However, due to the size of the network, unforeseen operational changes and limitations can require corrective maintenance actions at specific locations due to extended damage development. The specification of German railways requires rail milling to be used for defect depths greater than 1.0mm [10]. In this specific application example, a side-line of German railways with only 1.25 MGT yearly traffic load experienced an epidemic occurrence of squat/stud defects [11] on an only slightly worn rail profile. Prior to the corrective maintenance intervention, measurements with magnetic flux leakage technology indicated crack depths of up to 6-7mm in severely damaged areas. Due to the nature and depth of the defects the high performance milling machine MG31 (operated jointly by DB BahnbauGruppe and LINMAG GmbH) was chosen to treat the defective sections. This machine is capable of removing up to 4mm of damaged rail material (on top of the rail) in one pass as it is equipped with 3 milling units per rail. According to the pre-measurements a corrective maintenance program with 2 passes of the milling machine was planned to completely remove the damage and restore the rail profile.

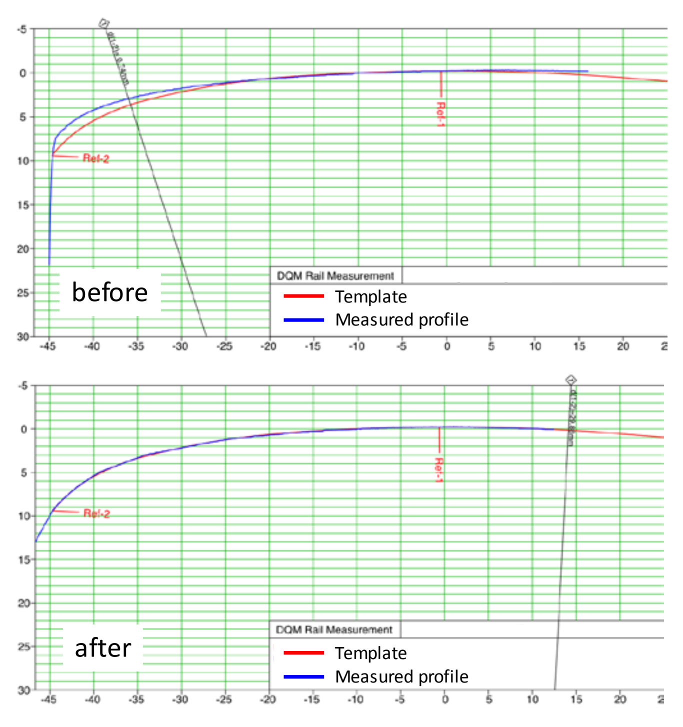

Figure 8: Perfect Re-profiling by Milling to restore a damage free rail condition.

Irish Railways (IR) awarded in 2016 a 7 year maintenance contract to LINMAG GmbH with the aim of providing corrective as well as cyclic-preventive rail milling service. Services have started in late 2016 and up to date more than a full year of rail milling took place. Satisfactory results confirm the outstanding performance of the applied technology. Extended Rail Life of up to 5-7 years justifies the milling technology (rail milling is at least a factor of 10 cheaper than changing rails). Rail breakages were significantly reduced (safety aspect) as well as necessary maintenance intervals for other track related maintenance activities like tamping were increased. In total more than 330km were, so far, processed with an average defect removal of 1,0 mm. The removed material (metal chips) represent 230 ton of premium-quality recyclable / sellable scrap. In contrast, conventional rail grinding would have polluted the track and its vicinity with more than 230t of grinding dust (rail material and abrasives from the grinding stones).

ARTC (Australian Rail Track Cooperation) is operating the Hunter Valley Coal Network in Eastern Australia. Typical yearly tonnages vary between 45 MGT (individual branch lines, empty traffic) and up to 190MGT in the highly loaded track segments close to the port areas [12]. LINMAG Australia is providing milling services to address high priority defect areas that previously would have required rail replacement. ARTC has wide spread shutdowns of their railway system every 6-8 weeks providing maintenance windows mostly between 62 to 96 hours of length. LINMAG is milling in each of these closedowns with the highly flexible SF02 Road-Rail Truck focusing on mainline track as well as switches to remove severe RCF defects and at the same time restore the rail profile according to the desired target profile

5 CONCLUSION

Rail milling technology represents a complementary addition to rail grinding in the rail maintenance toolbox as it shows clear economic benefits in the area of corrective / curative rail treatment. This technology can be applied reliably and efficiently nearly independent of the level of initial rail degradation. Systematic examinations and simulations of the technology confirmed empirical observations about the milling process with respect to surface quality and process heat transfer. Finally, application examples from Europe and Australia confirm that rail milling can be successfully used as a complementary solution to prevent premature rail exchange and economically treat mainline track, switches and crossings resulting in a significant extension of rail life.
It is very important that rail maintenance activities represent only one of several influencing factors of the railway system. Together with rail grades, optimised target profiles, track geometry and also friction management measures these factors will impact the life cycle of the whole system and its individual components. By applying a holistic solution that considers all key factors and their interaction, a sustainable and economic life extension of the whole system will be achieved. Linsinger has produced more than 50 milling machines in the last 20 years covering application areas from Metro operations to heavy haul.This provides a global proveof the technological and economical advantages of rail milling.

REFERENCES

1 Kapoor, A., Fletcher, D., Franklin, F., 2003. The role of wear in enhancing rail life. In Tribology Series, Elsevier, Volume 41, 331-340

2 Hampton, D., Magel, E., Harris, R., 2017. Moving towards predictive grinding. In Proceedings of 11th International Heavy Haul Conference, Cape Town, South Africa, 86-93.

3 Stanford, J., Magel, E., Sroba, P., 2001. Transitioning from corrective to preventive rail grinding on the BNSF railroad. In Proceedings of 7th International Heavy Haul Conference, Brisbane, Australia

4 Dey, A., Hintze, H., Reinhardt, J., 2014. Operation of Railway Maintenance Machines with Integrated Eddy Current Technique – An Overview of the New Requirements in Germany. In Proceedings of 11th European Conference on Non-Destructive Testing, Prague, Czech Republic.

5 Magel, E., 2016. Validating Electromagnetic Walking Stick Rail Surface Crack Measuring Systems. Federal Railroad Administration Report DOT/FRA/ORD-16/23, Washington, USA.

6 Hartleben, D., 2009. Task for mobile railway machining and predestined machining methods. In proceedings of 8th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems (CM 2009), Firenze, Italy, 599-605

7 EN 13231-3:2012. Railway applications - Track - Acceptance of works - Part 3: Acceptance of reprofiling rails in track. European Standard

8 Steenbergen, M., 2016, Rolling contact fatigue in relation to rail grinding. Wear, Volume 356-357, 110–121

9 Heyder, R., Brehmer, M., 2014. Empirical studies of head check propagation on the DB network. Wear, Volume 314, Issues 1-2, 36-43.

10 Heyder, R., Hempe, T., 2009. Maintenance strategies and material concepts to control rolling contact fatigue. In Proceedings of 8th International Conference on Wear and Contact Mechanics, Firenze, Italy, 607-616.

11 Stock, R., Sobiella, S., 2017. Beseitigung von Seriensquats mittels Hochleistungs-Frästechnologie. Eisenbahningenieur, Oktober 2017, 26-30.

12 Schwarzenberger, R., 2017. Milling Down Under: Proven Austrian technology vs. tough Australian rail conditions. Global Railway Review, Issue 5, September, 25-27.