

# Rail milling in urban environments

Rail milling can provide efficient solutions to the specific challenges of rail maintenance in urban areas.

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LINSINGER high performance milling has become a proven alternative to conventional rail grinding. Especially the requirements and restrictions of urban areas favor the application of rail milling technology: Increased fire danger, noise pollution, environmental aspects, as short maintenance windows, etc. Rail milling can provide efficient solutions by achieving target profiles within tightest tolerances and by removing 100% of the existing surface defects.

## Milling Technology – a short overview

Since the end of the 19th century, stationary milling technology is used to process all kinds of workpieces. Initially applied to manufacture gun barrels, the use of milling quickly expanded to a wide application area. In the 1950ies the Austrian company LINSINGER developed the first stationary rail milling machine. Problems with corrugation as well as transversal profile stability (plastic flow, wear) at several railways in Austria, Germany and Switzerland motivated LINSINGER to look into mobile rail milling. The market was in need of a technology that could efficiently cope with these defects. Finally, in 1995 the world's first mobile rail milling machine was delivered to a customer. It is worth mentioning that this rail milling machine is still in operation today. Since the delivery of this first machine, Linsinger has built and delivered more than 60 machines to customers around the globe. A success story "Made in Austria".



Fig. 1 Rail surface quality after rail milling.

Rail milling can be characterized as a dry cutting process, where material is cut out of the rail surface in form of chips. Contrary to the abrasive process rail grinding, rail milling only puts minimal amounts of energy into the rail surface causing only a minor temperature increase. Any unwanted material transformation at the rail surface can be completely prevented. The process by-products – the milling chips – are efficiently picked up by a vacuum system and are stored on-board the machine for later recycling. Furthermore, no dust and no sparks are produced by this dry cutting process, reducing potential fire danger to a minimum. The milling process itself only requires minimal

operator intervention, thereby reducing the potential for operating errors to a minimum. Rail milling shows clear advantages with respect to adjustable metal removal rates, high precision transversal and longitudinal target profiles as well as superior surface quality. A detailed description of the milling process can be found in [1].

## City challenge

Areas of high population density provide a number of challenges for railway operations, that need to be considered when conducting track maintenance. Short train intervals of metros or commuter rail lines result in continuously high loading conditions for the rail infrastructure.

Having no maintenance windows at all (for 24/7 operations) or only having very short maintenance windows during the night logistically complicate or restrict necessary maintenance activities. Consequently, damage can initiate and grow very quickly.

However, rail damage is not only impacting system safety and shortening rail life but it can also act as a source for increased noise emissions. Singular (wheel burns, welds, etc.) or periodic defects (corrugation) on the rail surface can cause vibrations that impact nearby buildings and their residents/users. Additional noise effects like curve squeal or flanging noise are perceived by riders and nearby residents as very annoying or uncomfortable. Furthermore, conventional rail grinding can cause temporary noise effects by leaving periodic roughness structure on the rail surface (grinding marks). Rail maintenance can only be done during non-revenue service periods, which means especially in cities that it can only be done during night hours. Therefore, also noise development of the maintenance machinery and process itself needs to be taken into consideration.

Nevertheless, it is essential (or even mandatory) to do rail maintenance as otherwise rail life would be drastically reduced and rails would require premature rail exchange. The

requirements of an urban environment increase the complexity of rail exchange thereby increasing the cost factor for this already very expensive process.

#### **Application examples from two cities**

Due to the before mentioned requirements, rail milling represents the ideal solution for efficient rail maintenance in urban environments. Two successful application examples from cities on different continents will be used to analyse the application of this technology in detail.

#### **Australia: Sydney Trains**

More than 5.3 million people live in the Greater Sydney Area. More than 1 Million passengers use the Sydney Trains Train Network every day (more than 365 Mio passengers per year). The network of Sydney trains has a system length of more than 800km and represents a mix of different railway systems: In the city center it shows metro characteristics with its tunnel network, it connects the suburbs with the city center like a commuter railway and it provides intercity services to the rural areas around the city. The Sydney Harbour Bridge (SHB) is a national icon and is the most recognized landmark in Australia and internationally. It is one of the most important bridge connections in Sydney that is used by more than 250,000 railway travelers on a daily basis. The SHB was completed in 1932, with a deck that

provides 8 lanes of road traffic, two railway tracks, pedestrian footways and a bicycle path. Although the bridge was constructed more than 90 years ago it still has not reached full capacity. This is quite remarkable, as similar projects today often painfully miss such sustainability in their planning process. Since it was built, whenever the rails needed maintenance, no rail profiling was ever carried out. Instead the rails had to be (prematurely) exchanged, whenever the wear or damage limit was reached. Especially on a main connection like the SHB, exchanging rails is disruptive and costly undertaking often requiring considerable planning, sometimes years in advance. On regular track segments, Sydney trains uses conventional rail grinding to maintain the rails. However, on bridges Sydney trains does not allow the application of grinding technology. Flying sparks (caused by rail grinding) pose extended fire danger on bridges with wooden decks and/or wooden sleepers. Furthermore, fire or heat sensitive components like cables can also easily be damaged. Finally, cars driving or being parked under or close to the bridge can be damaged by flying sparks. It is worth mentioning that during the extremely devastating bush fire season in 2019 rail milling was still allowed to operate while all rail grinding machinery had to suspend its operation completely.



**Fig. 2** Milling-Truck SF02W-FS milling on the Sydney Harbour Bridge.

In addition, Sydney Trains has a strong focus on environmental aspects of their daily operations. Rail grinding can contaminate the surroundings and especially waterways under the bridge (Sydney Harbour / Parramatta River) by sparks, dust and dropped grinding stone parts/slugs. Rail milling as spark and dust free technology collects the only process by-product – the milling chips – on board the milling machine (99.8% efficiency). The chips can then be returned to the steel-making process as valuable and clean raw materials providing an environmental added value to the process. Besides, Sydney Trains also focused on achievable profile precision as well as surface quality which are both significantly higher for rail milling compared to rail grinding.

Sydney Trains initiated an extensive test phase to better understand and quantify the benefits of rail milling. After successfully finishing this test phase Sydney Trains decided to process the rails on the SHB for the first time in history with rail milling. The damage condition required material removal of up to 2mm to completely regenerate the rails on the bridge. The company LINMAG

Australia Pty. treated all tracks on the bridge in as little as four night shifts utilizing a LINSINGER SF02W-FS Milling Truck. This milling truck allows variable metal removal between 0.1mm – 1mm in one pass. The high-rail vehicle can flexibly travel to the work site either on rail or on road. Due to the successful rail-treatment on the SHB, Sydney Trains decided to use rail milling in the future also on other bridges, in tunnels (no dust, no cleaning effort) and on normal track segments. Despite also utilizing conventional rail grinding for preventive maintenance, it is not possible for Sydney Trains to keep rail damage under control. Consequently, rail milling is required to completely remove all damage with a regenerative approach thereby preventing premature rail exchange.

#### **Canada: Toronto Transit Commission (TTC)**

The subway in Toronto (operated by Toronto Transit Commission – TTC) was opened in 1954 and is the oldest subway system in Canada. More than 1.5 million passengers use the system during regular workdays. With more than 460 Mio passengers in 2019 it is the most utilised system in Canada

and considering the whole of North America it is on rank three right behind New York and Mexico City. The whole subway network consists of 4 lines (two more lines are currently in construction phase) with a total length of 80km. Toronto has a special gauge on the three oldest subway lines and on their streetcar/tramway network. The unusual gauge of 1495mm (4 ft 10 7/8 in, also called Toronto Gauge) was first introduced at the streetcar system at the end of the 19th century. This allowed for horse carriages to use the street between the rails without any problems. The city council was also afraid that freight trains with steam engines would travel through the city on the streetcar network, if they would install standard gauge of 1435mm (at that time freight trains were indeed using tramway networks in several North American cities). When the subway was constructed it was originally planned to also use streetcar train sets in the subway. For this reason, also the subway was constructed with the Toronto gauge of 1495mm as well. Standard gauge is used for the tracks of the recently constructed line 4 (and for the lines currently in construction) [2].

A distinctive feature of North American railway systems is their profile strategy (especially when compared to the European approach). In the 1980ies Heavy Haul railways were struggling with increased profile wear, plastic flow and heavy corrugation. The rail grades at that time did not have advanced wear resistance compared to modern, high strength rail grades today. Intensive research activities at the end of the 80ies and beginning of the 90ies led to the introduction of cyclic preventive grinding (instead of the so far used corrective grinding



only). With this strategy change also special profiles were introduced for curves, that would be very similar to the shape of the naturally worn-in profiles in curves. These profiles had the aim of reducing the contact stresses and thereby reducing wear and damage. Over time additional target profiles for sharp curves (low / high rail), mild curves (low / high rail) and tangent tracks (2-3 different tangent profiles to distribute the wear evenly over the contact area on the rail) were introduced [3]. Nowadays North American heavy haul railways may have more than 10 target profiles in their profile program. It is worth mentioning that North American freight wheel profiles show much higher variation in profile quality and surface condition compared to European rail systems. An adoption of rail profiles to counter the variability in wheel profiles has proven to be a successful strategy. At European railway systems, rail and wheel profiles typically show much lower variation not requiring such a multi profile strategy.

To some extent multi-profile strategies also found their application at North American transit systems. TTC has 5 different target profiles in their specification: Two profiles for tangent track CPC (Center Point Contact) and CPF (Center Point Field), used about 50:50 on their tangent tracks to distribute tread wear over a wider area. One profile for the high rail of a mild curves, HRM (High Rail Mild) and a set of profiles for sharp curves, HRS (High Rail Sharp) and LOW (Low Rail). CPF is applied also on low rails of mild curves. However, transit systems often struggle with the implementation of multiple target profiles for organizational, operational or budget reasons. In reality rail profiles found in track can deviate significantly from the desired

target profiles. In addition, the damage condition of rails will not allow for the application of a cyclic-preventive maintenance strategy. First, a regenerative strategy needs to be applied to prevent premature rail replacement and to be able to benefit from a cyclic preventive strategy in the future.

TTC was already looking into rail milling for several years before deciding to publish the first dedicated tender for rail milling services in North America in Summer 2017. This multi-year contract was won by Rhomberg Sersa North America Ltd. Rhomberg Sersa ordered a LINSINGER rail bound high performance milling machine SF02-T-FS LB that was specifically adopted for the North American transit market. To bridge the delivery time, RS leased a milling truck SF02W-FS from LINSINGER to be able to start in time with contract work in Toronto. TTC worked with the National Research Council Canada (NRC) to reduce the number of target profile from five to two profiles (CPC and CPF) as there are only marginal differences between the relevant sections of the different profiles. It is expected that the combination of restoring the rail shape to the two target profiles in combination with complete damage removal will have a significant impact on rail life. CPC and CPF will be applied in tangent track according to the TTC specification mentioned above. In all curves (mild and sharp) CPC is applied on the high rails and CPF is applied on the low rails.

Milling services started in December 2018 and continued into February 2019. After going through a learning curve (both for Rhomberg Sersa and TTC), 35 milling shifts were successfully finished. Some shifts had to be cancelled (about 2 weeks) due

to cold weather and the TTC cold weather protocol (at or below -15°C). With an active cold weather protocol, all subway trains will be parked in the stations in the tunnels and not in the yards. It is impossible to do any maintenance activities in such a case. TTC was very satisfied with the general results, the achieved surface quality, the resultant cleanliness after milling (no sparks, no dust, no required cleaning activities after rail maintenance) and the productivity of the machine. The new rail milling machine was planned to be on display at Innotrans, however as Innotrans is postponed to Spring 2021, the machine will be shipped to Toronto by autumn 2020. The milling campaign will resume by the end of 2020 with the new machine.

#### **Milling of grooved rails – outlook**

Rail milling machines can also be used to treat grooved rails or embedded rails as used for tramway / streetcar systems. To do this some hardware and software adjustments need to be implemented on a milling machine. Toronto is currently considering to used rail milling also on their extensive streetcar network. Beside the before mentioned Toronto gauge, TTC streetcar tracks have another special property: Toronto does not use grooved rails on many sections of their network. Toronto has installed standard T-Rails embedded in the asphalt of the streets. The “groove” is implemented as a notch in the asphalt on the gauge side of the rails. Despite this special circumstances, TTC streetcar tracks can be classified as “grooved rail like” tracks that will require the implementation of the above mentioned “grooved rail package” on the milling machine.

LINSINGER high performance milling technology provides the optimal solution for rail maintenance in an urban environment. Being able to remove defects completely while at the same time fully restoring the rail profile, minimizing any fire danger, prevention of any environmental contamination as well as the high achievable surface quality tell a clear story in favor of this innovative technology. The successful application on four different continents – not only in city environments – confirm that rail

milling is an effective and economic tool in the rail maintenance tool box.

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Fig. 3 Milling-Truck SF02W-FS at Warden Station at the TTC subway.