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REDUCING THE WEAR ON THE WHEELS OF RAILWAY VEHICLES AND INCREASING THE SAFETY OF TRANSPORT THROUGH TARGETED RAIL MAINTENANCE

ZNÍŽENIE OPOTREBENIA KOLIES ŽELEZNIČNÝCH VOZIDIEL A ZVÝŠENIE BEZPEČNOSTI DOPRAVY PROSTREDNÍCTVOM CIELENEJ ÚDRŽBY KOĽAJNÍC

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1 ÚVOD

Due to an increase in train frequency, axle loads and train speeds, wheels and rails are exposed to far more and more varied load situations in much shorter time intervals than ever before. To keep the wheel-rail system in a fully functional, safe, and optimal condition and to maximise service life, rails need to be maintained regularly. Today, infrastructure managers can choose between several established strategies and technologies to control the cyclical contact mechanical changes that occur in the rail. Contact mechanical changes include rolling contact fatigue as well as wear and plastic material deformation. Rail milling is the optimal solution to counteract these problems.

2 THE TECHNOLOGY OF RAIL MILLING

Due to the very high manufacturing accuracy and the excellent surface quality, the milling of metallic workpieces has been established in industry as a proper manufacturing process since the 19th century. Mobile rail milling is a relatively new technology, which was introduced 30 years ago by the Austrian company Linsinger Maschinenbau Gesellschaft m.b.H.. Rail milling is a dry and rotating cutting process in which the driven cutter head, equipped with a large number of carbide tips, moves over the rails and maintains them during in the process. The removed material is collected in the form of chips on the machine moving along the track and stored in a bunker, so that it can be recycled later. The required rail profile (e.g.: UIC60 E2 1:40) for restoring the optimal contact mechanical conditions between wheel and rail is defined by the profile of the cutter head. Any rail profile can be realised.

Rail milling is a non-sparking and dust-free process, which makes it possible to work in environmentally sensitive areas such as tunnels, stations, or areas with special fire protection restrictions, without having to take special precautions. The resulting process heat is dissipated via the carbide cutting tips into the cutter head and via the removed chips [1]. In contrast to other machining technologies, there is no heat input to the rail at all. The heat input could lead to a structural transformation in the material in the machined rail, the so-called "white etching layers", which can have a martensitic microstructure [1-3].

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The milling of the rails creates a periodic surface structure characteristic of the process, also called milling facets, which can lead to a temporary, purely acoustic effect. Depending on the axle loads of the moving trains, this effect disappears after a short time. In order to eliminate this effect immediately, rail milling machines are equipped with a polishing unit. This is used for a subsequent polishing process.

2.1 Sequence and machining states during rail milling

Fig. 1 shows the sequence of rail machining by milling. A cutter head and a polishing wheel are shown with the various machining states on the rail (from left to right). The first condition, marked in red, shows the unmachined rail with any defects and wear conditions. Both the profile deviations and the defect depths are measured in advance in order to adjust the material removal in such a way that a defect-free and true-to-profile rail can be guaranteed after machining. The second condition, marked in yellow, shows the rail surface after the milling process. The defects and were removed without residue and the rail profile was completely restored. Thus, the contact mechanical condition of the rail was already optimized after the first process step and a better condition was achieved than with a new rail, as shown below. One can speak of a better condition because the processed rail has a higher profile accuracy on the track than a rail coming directly from production. In addition, the processed rail no longer has a "rolled skin". The third condition, marked in green, shows the finished rail after the polishing process. A uniform and homogeneous surface structure can be seen on the rail, which is left on the track after the entire milling process. Subsequently, machine-integrated measurements of the transverse profile and longitudinal profile confirm the improved and functional condition of the rails.

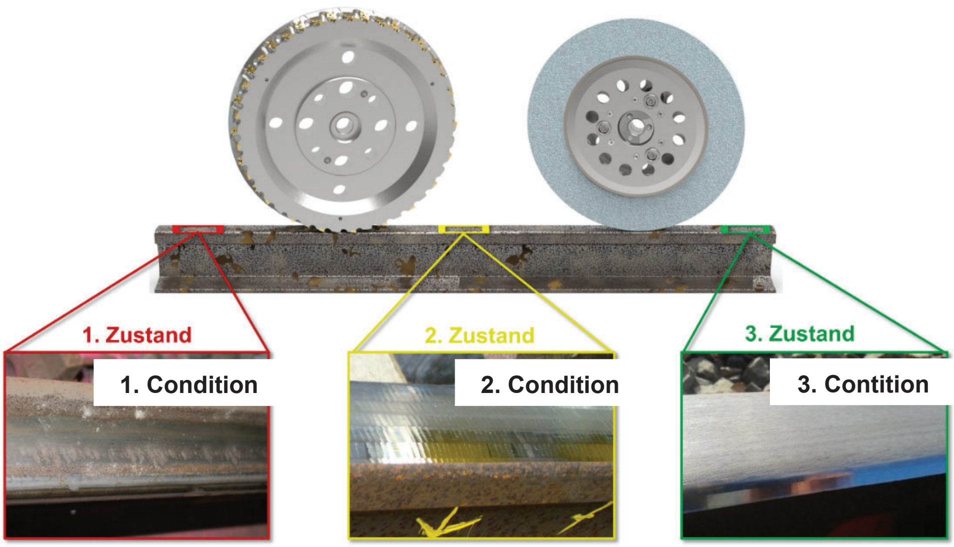

Fig. 1 *The schematic sequence of the rail milling process with the various successive machining conditions*

Obr. 1 *Schematický postup procesu frézovania koľajníc s rôznymi po sebe nasledujúcimi podmienkami obrábania*

2.2 Contact mechanical improvement of a machined rail

In order to be able to optimize the contact mechanical condition of an unmachined and worn rail, it is necessary to know exactly how the interaction between wheel and rail works.

A crucial point for this is the conformity of the transverse profiles of wheel and rail, so that it can be ensured that the contact surface results in an uniform surface. This can only be achieved if the required rail profile is restored as accurately as possible. The maintainer must ensure that the required and prescribed rail profile is restored as accurately as possible. ***Fig. 2*** shows on the left an unworked and worn rail, shown in a slightly transparent green colour in the background, and the worked rail in a grey colour in the foreground. In the case shown, it can be observed that a material removal of 4 mm was needed to restore a rail according to the target profile and free of defects. The profile deviation of the worn rail can be recognised by the fact that the material removal is not constant over the entire transverse profile. The right-hand side of ***fig. 2*** shows a typical re-measurement of the transverse profile. This displays the exact deviation of the actual profile after machining (blue) from the target profile (red). The maximum deviation is 0.14 mm, which is below the permitted tolerances according to standard EN 13231-3.

In this way, milling can be used to ensure that the transverse profile of a rail achieves the optimum contact mechanical condition and contributes the best possible to the conformity between wheel and rail. This reduces the contact mechanical load on the rail and the wheels and extends their service life enormously.

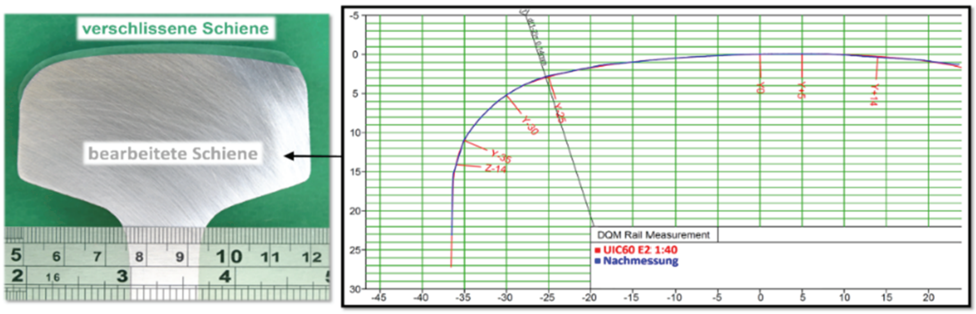

Fig. 2 *An unmachined and worn rail (in light green transparent in the background) and the machined rail (in grey in the foreground) with a comparative measurement between the nominal and actual transverse profile after machining*

Obr. 2 *Neopracovaná a opotrebovaná koľajnica (svetlozelená priehľadná v pozadí) a opracovaná koľajnica (sivá v popredí) s porovnávacím meraním medzi nominálnym a skutočným priečnym profilom po opracovaní*

Another important point for optimising the contact and extending the service life of a rail is the surface quality in the longitudinal direction. The more uniform the surface finish of a rail, the longer defects resulting from dynamic forces can be avoided. ***fig. 3*** shows a roughness measurement of a worn rail (in red) and a machined rail (in green). The roughness depth Ra is reduced from 4.95 µm (worn rail) to 2.12 µm (machined rail). With milling, a Ra value of less than 5 µm can be achieved easily and continuously, which, according to the EN 13231-3 standard, corresponds to half of the permitted roughness depth Ra of 10 µm.

Not only the conformity of the transverse profiles in the wheel-rail system and the surface condition in the longitudinal direction of the rail are decisive for optimising contact and extending the service life of the rail, but also the microstructural structure of the rail is decisive and must therefore be taken into account.

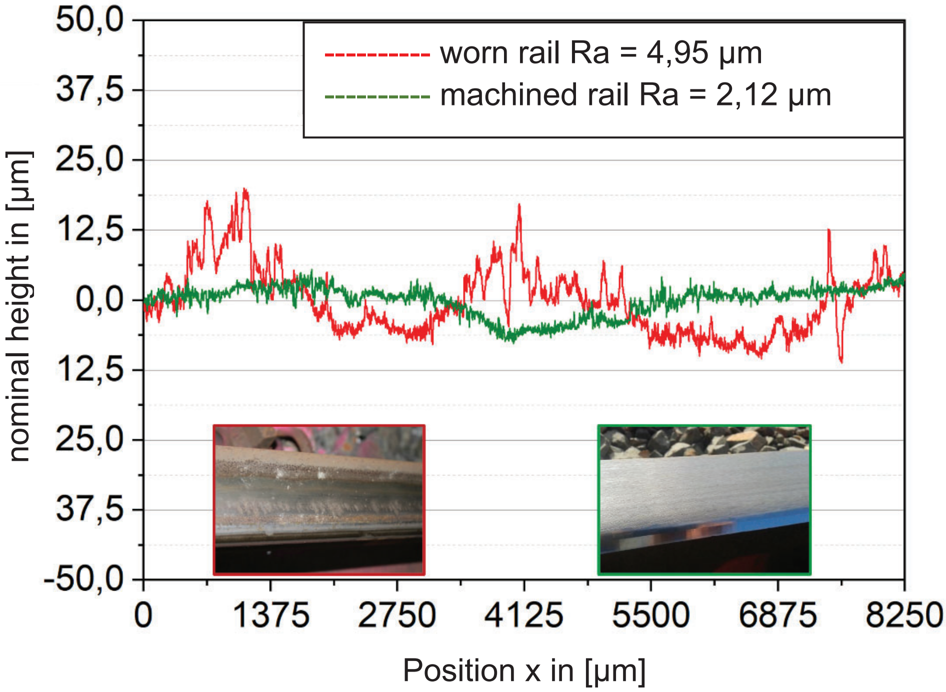

Fig. 3 *Roughness measurements of a worn rail and a rail machined by milling with the corresponding Ra values.*

Obr. 3 *Merania drsnosti opotrebovanej koľajnice a koľajnice opracovanej frézovaním so zodpovedajúcimi hodnotami Ra*

A worn rail normally has a deformed microstructure on the surface the trains are travelling on, which includes both cracks and changes in the microstructure. This damaged microstructural material must be completely removed so that the rail's service life can be extended. The infrastructure manager must be confident that after proper maintenance, an unaffected microstructural material will be left on the track. In order to know what remains on the track after milling, structured tests and precise metallographic examinations were carried out and evaluated in cooperation between the University of Leoben, the Materials Center Leoben and the company Linsinger [4]. A rail of steel grade R260 was machined, which has a purely pearlitic structure.

Fig. 4 shows a piece of rail that has been finished by milling, from which both transverse and longitudinal sections were taken and analysed. The machined rail shows an unaffected and purely pearlitic structure in the longitudinal and transverse directions, i.e., the deformed and damaged material was removed thoroughly and without residue during machining. Thus, the rail can also be considered better than new. The absence of any influence on the microstructure also proves that there is no heat input whatsoever during and after the complete milling process and thus, no structural transformation in the material. The unaffected and as good as new rail structure in combination with the conformity of the transverse profiles and the surface condition in longitudinal direction contribute to the fact that the contact pressures are optimally distributed over the contact surface and, consequently, considerably improve the contact mechanical condition of the rail lying on the track.

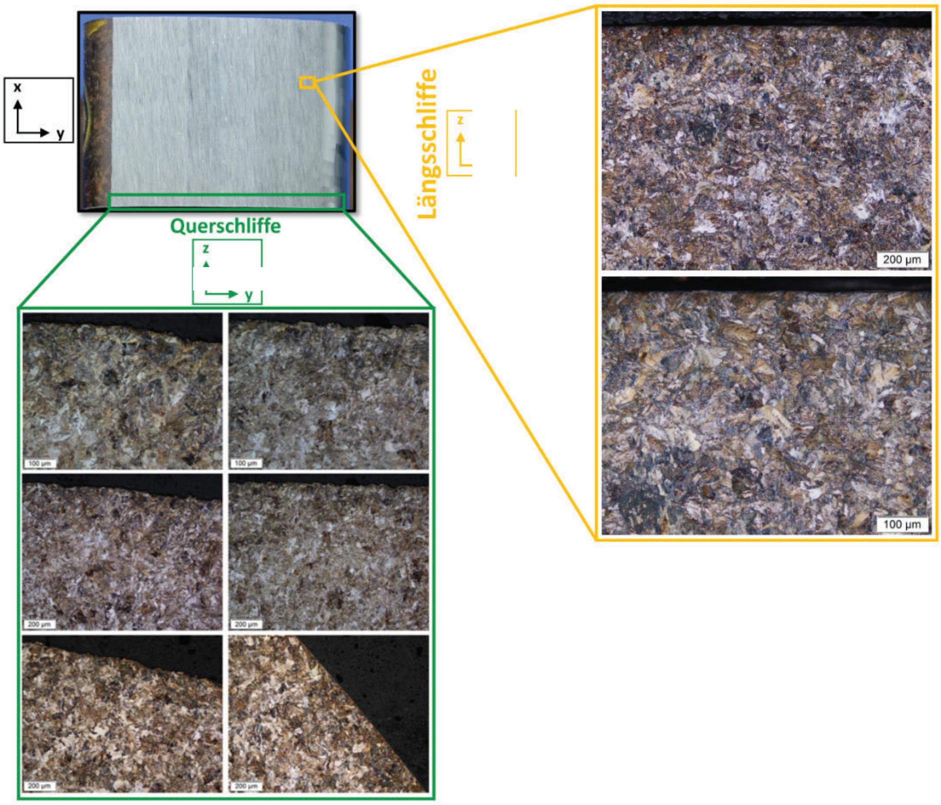

***Fig. 4** Transverse and longitudinal sections of a rail machined by milling. An unaffected pearlitic material structure is shown*

***Obr. 4** Priečne a pozdĺžne rezy koľajnice opracované frézovaním. Je zobrazená nedotknutá perlitická štruktúra materiálu*

5 CONCLUSION

Mobile rail milling is now an established maintenance technology that offers significant advantages for improving and optimising the contact mechanical condition of a rail lying on the track. Reliable and continuous reprofiling takes place based on the profile defined by the cutter head. Both the transverse profile and the roughness of the machined rails are restored very precisely and in accordance with the standards, so that the contact mechanical load is again distributed more evenly over the optimised contact surface. This also results in a reduction of the maximum contact pressure, which helps to delay various signs of wear. Due to the complete and residual removal of the deformed and damaged material from the rail surface and the introduction of compressive stresses close to the surface, the machined rail can even be considered better than new. There is no heat input into the machined rail and thus it can be guaranteed that no structural transformation takes place. Thus, rail milling leads to a significant extension of the service life of a rail on the track as well as to a massive cost saving compared to rail replacement. In addition, a fully functional and safe condition of the rail can be guaranteed after mobile milling, which is a crucial point for every infrastructure manager and network owner.

References

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Summary

Increasing freight volumes, rising passenger numbers, shorter train intervals and higher speeds in passenger traffic lead to deformations at the wheel/rail contact area. Resulting rail defects that are accompanied by the following negative aspects:

Safety risk

Unplanned reduction of line speeds – increased delays

Downtime – high failure costsg increased carbon footprint

Rail and wheel wear

Formation of fatigue rail defects, corrugations, rail breaks and other rail defects

Reduced track quality and driving comfort

These aspects require a modern, flexible and reliable technology which sustainably extend the service life of rails.

Milling technology makes it possible, with regular treatment of the rails, to extend the service life of the track and thus reduce costs and carbon footprint.

Resumé

Zvyšujúce sa objemy nákladu, rastúci počet cestujúcich, kratšie vlakové intervaly a vyššie rýchlosti osobnej dopravе vedú k deformáciám v oblasti kontaktu kolesa a koľajnice. Výsledné poruchy koľajníc, ktoré sú sprevádzané nesledujúcimi negatívnymi aspektmi:

Bezpečnostné riziko,

Neplánované zníženie traťových rýchlostí – zvýšené meškania,

Prestoje – vysoké náklady na poruchu,

Znečistenie hlukom znížená životnosť koľajníc a zvýšená uhlíkova stopa,

Opotrebenie koľajníc a kolies,

Tvorba únavových defektov koľajníc, zvlnenia, zlomov koľajníc a iných defektov koľajníc,

Znížená kvalita koľaje a jazdný komfort.

Tieto aspekty si vyžadujú modernú, flexibilnú a spoľahlivú technológiu, ktorá trvalo predlžuje životnosť koľajníc.

Technológia frézovania umožňuje pri pravidelnom ošetrovaní koľajníc predĺžiť životnosť koľaje a tým výrazne znížiť náklady a uhlíkovu stopu.