The Fifth International Conference on Railway Technology
RAILWAYS 2022
22–25 August 2022
Montpellier, France

Proceedings of the Fifth International Conference on
Railway Technology:
Research, Development and Maintenance
Edited by J. Pombo
Civil-Comp Conferences, Volume 1, Paper 21.15
Civil-Comp Press, Edinburgh, United Kingdom, 2022, doi: 10.4203/ccc.1.21.15

New Methodology for Assessing Preventive Grinding in Rails

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Abstract

Rail grinding is the main maintenance process for rails to keep the rail track in a safe and operational state. The most commonly used technique is the preventive maintenance where rails are reprofiled on a regular basis to remove any potential defects and maintain a desirable rail profile. A study to analyse the effect of preventive maintenance on the different rail grades took place to investigate the technique. This paper reports the findings of preventive grinding experiments performed on a laboratory environment. Various rail grades were utilised to assess the effectiveness of the preventive grinding process and study its effect on their surface quality. Results with regards to the mass loss, and the grinding induced roughness were collected. WEL was detected on the contact surface indicating a phase transformation due to the grinding process. Measurements with regards to the WEL thickness were collected and a comparison between the various rail grades was done. Consequently, rolling/sliding experiments were performed on the ground samples to evaluate their post-grinding performance and study the development of the friction coefficient as well as roughness. Correlations were done with regards to the roughness development and the coefficient of friction. The initial low friction values were associated with the high grinding-induces roughness values. After the smoothing of the asperities the coefficient of friction was stabilised.

Keywords: Post-grinding performance, Post-grinding roughness, Rail grinding, WEL, Preventive rail grinding, Martensite, Small-scale rail grinding.

1 Introduction

Rail grinding was introduced to eliminate defects such as head checks and to extend the life cycle of rails [1]. The process of reprofiling the rails can occur several times until a rail needs to be replaced. Preventive maintenance is where grinding occurs on a regular basis to remove any possible defects and maintain the desired profile of the rail. According to Grassie et al. [2] the appropriate preventive maintenance schedule can achieve a 40% reduction on the total cost of grinding while the quality of the track and the rail can be improved significantly. A failure to predict the correct maintenance schedule will lead into more drastic measures of a corrective maintenance process being required, where larger volumes of material need to be removed to restore the rail into its previous state. This more destructive process will result in a higher energy input into the rail surface that can lead in an unwanted material transformation of the surface material and formation of brittle white etching layer (WEL) which can cause the initiation of cracks and lead to squat/stud formation [3]. Thus, it can be said that applied pressure and speed between the train and the rails can be the deciding factors on the post-grinding material properties.

The aims of this study were to examine the grinding process thoroughly and understand its effectiveness on various rail grades. This will allow further knowledge to be acquired with regards to the effect of grinding on various rail grades’ life cycle. Twin disc testing was carried out after a representative grinding process using a bespoke scaled grinding rig to evaluate the run-in performance of each rail grade. A particular focus was placed on surface roughness evolution and the presence of WEL. Both WEL and roughness are outputs of the grinding process, which can affect the performance of the rail differently. WEL can alter the life-cycle of the rail by introducing new defects and roughness can be interlinked with derailment incidents. Furthermore, the grinding induced roughness can create stress concentration points which along with the coexistence of a brittle martensite layer can increase the likelihood of crack initiation and defect formation.

2 Methods

The rig utilised for the grinding experiments was designed and manufactured by the Grupo de Tribologia y Superficies at the Universidad Nacional de Colombia [4]. The specimen’s geometry is that of those also used in a twin disc machine to allow grinding followed by a simulation of service conditions. The rail specimens used in the grinding experiments, were machined from rail grades of R260, R350HT, MHH 375, R400HT, and Laser Clad R260 (LC 260). The rail samples were extracted from actual rails. The clad specimens (R260) were treated after machining to apply a 1mm thick layer of martensitic stainless steel The wheel specimens were machined from a BS5892-3 grade R8 wheel

A summary of the grinding parameters employed is shown in **Table 1**. A similar methodology to a previous study was followed [4]. In each grinding pass a load of 5kg was maintained for 30 seconds. Then the experiment was terminated. The rail specimens were then removed for measurements to be taken on the material removed in terms of mass and diameter. This procedure indicated the completion of one pass. Multiple passes were done to reach a 0.25mm depth of cut on the radius of the disc. This replicates the preventive grinding process occurring in the field with a multiple passes pattern. Furthermore, the depth of cut performed during the laboratory testing is comparable to what is currently utilised in the field as indicated by other studies [1].

Maintenance type	Grinding Wheel Speed (V_s -rpm)	Specimen Speed (V_w -rpm)	Applied Load per pass (N)	Depth of Cut (mm)	Overall Grinding Time per pass(s)	Number of passes
Preventive	3600	700	49.05	0.25	30	>5

Table 1: Grinding Testing parameters for preventive maintenance scenario

For all the specimens a rolling/sliding experiment was performed after the grinding process to generate wear on the discs imitating the field conditions present for wheels passing over the ground rail. For this experiment, SUROS, an already existing test rig was used. This method has been used in other studies as well [5]. The parameters employed for the twin disc testing involved 8000 dry cycles under a 1% slip ratio and a maximum contact pressure of 1300MPa to generate normal usage wear.

Contact Pressure (MPa)	Slippage (%)	Cycles
1300	1	8000 dry

Table 2: Twin-testing parameters.

3 Results

3.1 Grinding Results

The material loss over the distance required for each disc to remove 0.5mm from the diameter are presented for all the discs in **Figure 1**. This parameter differs on the various grades due to the dissimilar resistance to the material removal process of each grade. As expected, the R260 grade which has the lowest hardness, exhibits the highest material loss (mg)/distance (m) parameter. On the other hand, the LC260 which exhibits significantly higher levels of hardness demonstrates the lowest material loss/distance. **Figure 1** also presents the roughness data including values of Ra, Rq and Rz; the roughness values are comparable between them. The only variation from the trend is observed on LC260 discs which illustrate lower roughness.

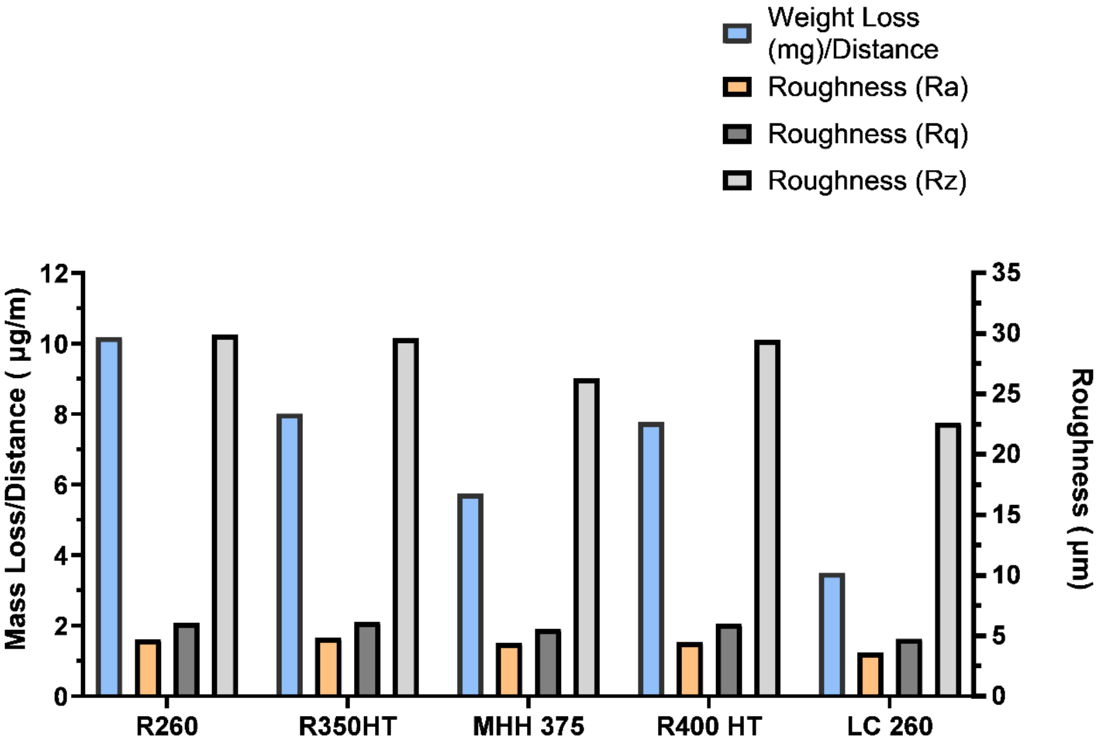

Figure 1: Mass and roughness loss ground with the preventive maintenance configuration.

Figure 2 exhibits the WEL thickness detected on the various rail grades. The thickness of the WEL observed in the discs' microstructure are between 1-8µm. The maximum thickness is similar in all grades however the mean value is different indicating that the frequency the maximum thickness appeared is different in each sample.

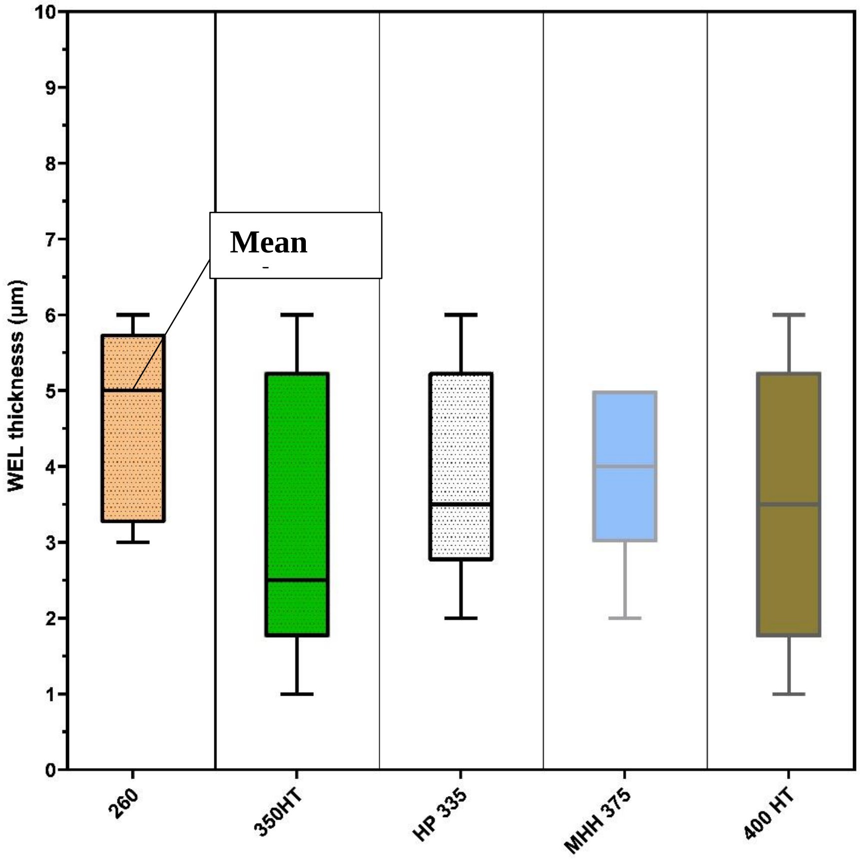

Figure 2: WEL thickness comparison across the rail grades for the preventive maintenance grinding.

3.2 Post-Grinding Performance

The friction data obtained from the post-grinding twin-disc testing are presented in **Figure 3** a). The specimens underwent a run-in stage where the coefficient of friction between the rolling surfaces experienced a sudden raise. This stage took place between the 0-2000 cycles with some specimens going through this phase much sooner, such as R260, and other specimens taking a bit more time, such as MHH375. This occurs as on a micro-level during the initial run-in the asperities formed due to grinding are smoothed out from the shear forces and normal load applied on the discs. As the experiment continued the coefficient of friction was slowly stabilised around 0.4 at 8000 cycles. The smoothing of the asperities is visually represented in **Figure 3** b). Others such as the LC260 demonstrated a constant decrease of the roughness without reaching a stable value. Analysing the microstructure of the tested discs showed partly delaminated WEL as well as WEL penetrated into the pearlitic matrix. As shown in other studies [6] the latter observation could yield extensive crack formation and result in the decrease of rail’s service life.

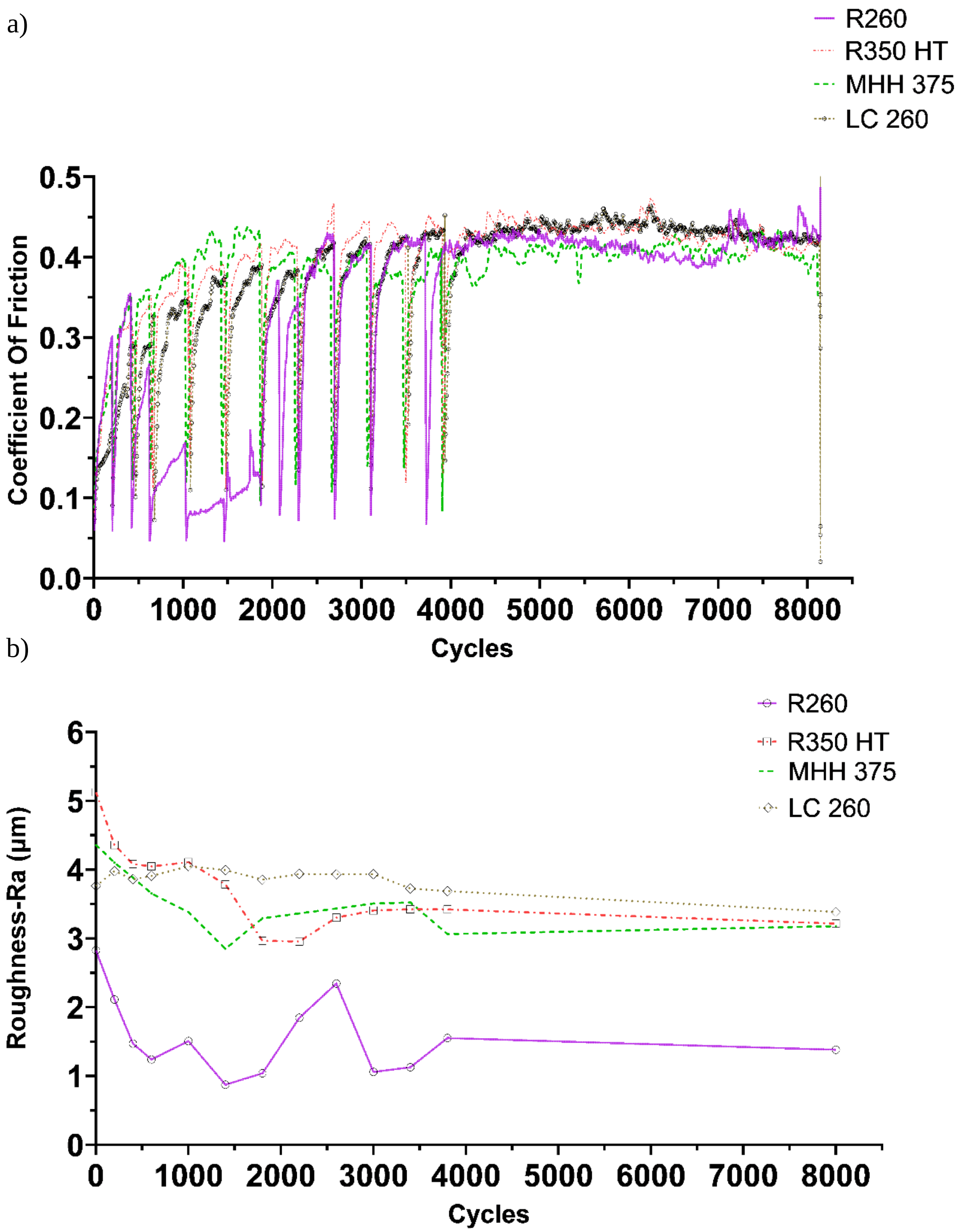

Figure 3: Data from the post-grinding twin-disc testing representing the development of a) the friction coefficient b) roughness.

4 Conclusions and Contributions

Taking into account the data obtained from this set of experiments it can be said that a new experimental methodology was successfully employed to simulate grinding existing in the field. The interaction between two bodies, the ground rail discs, and the fresh surface wheel disc was studied to understand the effect of grinding in the performance of the rails. During the interaction between the two discs, friction varies based on the surface topography and material properties. The transitions the discs undergo, occur in an attempt for the tribo-system to reach a steady state condition [7]. Observing Figure 2 b) it can be said that during the smoothing process of the ground surfaces' asperities the friction values are possibly affected as the run-in stage does not comprises a usual response. This can be clearly identified by comparing the results from Figure 2 a) to the response of a twin-disc testing with freshly machined surface discs carried out by another study [7] presented in **Figure 4**. Similar parameters were used for that study with 1% slip and a maximum contact pressure of 1300MPa.The run-in period of the discs lasts for approximately 1000 cycles where the coefficient of friction reaches its maximum value and then settles for a lower value and remains stable. In contrast the response from all ground rail discs apart from the R260 follows a constant increase of the friction coefficient until the smoothing of the asperities is done.

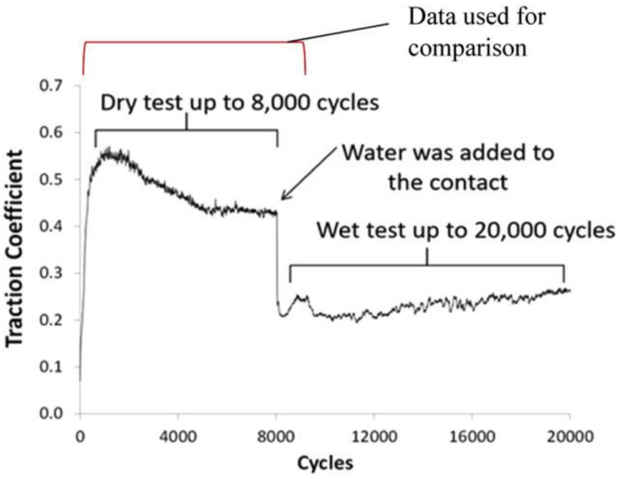

Figure 4: Response of friction in dry and wet conditions produced in [7].

The rate of the friction coefficient being increased is different on each grade and it is potentially determined by the hardness of the material. Harder rail material such as the LC260 take more time to reach its maximum values (around 5000 cycles); on the other hand, softer rail grades like the R260 reach the maximum coefficient of friction at around 2800 cycles. This comes in agreement with the roughness values and the rate of change observed in the different rail grades. In general, in all the experiments there is a slight increase in the roughness values after a number of cycles. This is due to the surfaces entering the wear region where the material loss increases [8]. Similar behaviour has been presented by Blau et al. [9] on previous studies as one of the common behaviours which can be observed in sliding surfaces.

Acknowledgements

The authors are grateful to the Royal Academy of Engineering for financial support through the Industry Academia Partnership Programme, project n. IAPP\1516\91, and to the Metro de Medellín for providing rails and wheels for study.

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