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# Comparison of Rail Grinding Template Alignment Methods

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## Summary

Transportation Technology Center, Inc. (TTCI) has conducted a numerical study involving three grinding template alignment methods commonly used or proposed for use on North American freight railroads, including centerline alignment method, Euronorm alignment method, and range alignment method. The study quantified the results of these methods with regard to the quantity of material removed and the resulting shape of the ground rail. This work was conducted as part of the Association of American Railroads' Strategic Research Initiative on wheel and rail profile design and maintenance.

The results of simulated rail grinding using a range of measured rail profiles and templates have shown that the variations in unground rail profile and variations in grinding template tend to overshadow the differences between the centerline and Euronorm template alignment methods. In general, the range alignment method leads to larger railhead loss than the other two methods, while showing higher conformance of ground rail profile to the grinding template.

None of the three examined methods is consistently best at both evaluation categories: quantity of material removed and resulting shape of the ground rail. Selection of template alignment method should take into account such factors as grinding regime, grinding depth required to remove rolling contact fatigue (RCF) damage, acceptable number of grinding passes, and grinding templates used by the particular railroad.

Rail grinding removes material near the railhead surface for two primary reasons: to introduce or restore a desired rail cross-sectional profile shape and to remove incipient or fully present RCF damage or other surface anomalies. This analysis focuses on restoration of the desired profile with a minimum amount of material removal, which would represent the grinding objective in the rail profile grinding or preventive grinding regimes involving rail with little or no surface condition issues. When more material removal is desired, oftentimes requiring multiple passes with the grinder, the method used for rail profile template alignment becomes far less critical. This is the case on rails with significant RCF in the corrective grinding or maintenance grinding regimes.



**INTRODUCTION**

Currently, a number of rail grinding template alignment methods are being used by railroads and maintenance of way providers. While in some countries these methods are standardized, there is no such explicit consensus in North America. TTCI performed this work to quantify the results of these methods in terms of railhead material loss and adherence to the shape of the target grind template.

**SURVEY OF ALIGNMENT METHODS**

**Description of Grinding Template Alignment**

Grinding template alignment may refer to one of two procedures: (1) aligning an unground or ground rail profile with a reference profile to determine if the two are within tolerance or if additional grinding is required, or (2) aligning the unground rail profile with the grinding template to determine the amount and location of metal to be removed. In this study, the grinding process is simulated by a computer script (see Section “Approach Taken”), which allows combining the two procedures into one step.

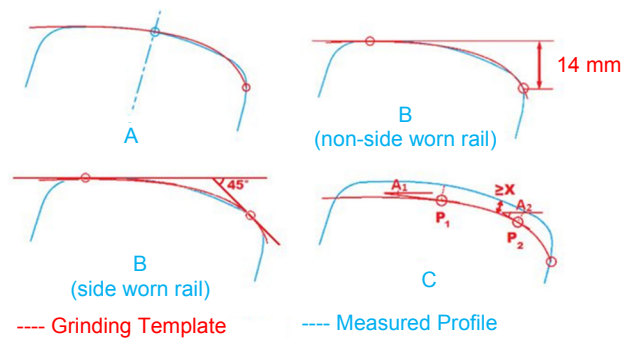
**Description of Alignment Methods**

A number of methods for aligning measured rail profile and grinding template are currently used in the industry. Figure 1 shows a schematic of the three methods evaluated in this study. All of the methods described here assume, either implicitly or explicitly, that both left and right rail profile are in a coordinate system in which the horizontal axis is parallel to the line tangent to the top of both left and right rail. Once this condition is achieved, methods involve horizontal and vertical shifting (but not rotation) of the grinding template with respect to the measured profile.

**Method A (Centerline)** consists of these constraints:

1. Farthest point on gage side of the template must coincide with any point on the measured rail profile.
2. Centerline point on the measured rail profile must coincide with any point on the grinding template.

Centerline of the measured rail is determined automatically by the laser measurement system aboard a rail grinder, which measures not only railhead profile, but also base and web of the rail. If the measurement system does not have this capability, centerline can be estimated from the railhead profile alone, which can be challenging for rail profiles with significant gage side wear.



**Figure 1. Common alignment methods**

**Method B (Euronorm)**<sup>1</sup> recognizes two cases: non-side-worn rail (i.e., rail on a tangent track or low rail in a curve), and side-worn rail (i.e., high rail in a curve). For non-side-worn rail, two reference points are defined on the grinding template. These two points must coincide with any points on the measured rail profile.

1. The point where railhead is coincident with a reference line. The latter is defined as a line that is tangent to the top of both left and right rail.
2. The point located at the gage side of the rail 14 mm below the reference line.

For a side-worn rail, the first point is defined similarly, but the second point is defined as a point on the gage side where contact angle equals 45 degrees.

**Method C (Range)** ensures that the ground rail profile is identical to the template throughout a specified range of contact angles through use of the following constraints:

1. Farthest point on gage side of template must coincide with any point on the measured profile.
2. Grinding template is positioned such that a minimum of X material is removed above all points on the template between points P<sub>1</sub> and P<sub>2</sub>, which have contact angles A<sub>1</sub> and A<sub>2</sub>, specified by the user.

Note that method C is meant to determine the amount and location of metal removal during grinding, but not to determine whether a ground profile is acceptable (see “Definition of Alignment”).

**Acceptance Criteria**

When an alignment method is used to determine if a measured profile and a reference profile are within tolerance, acceptance criteria are needed.

One such criterion is the range of deviation (the difference between maximum positive and maximum negative deviation of measured profile from reference

profile).<sup>1</sup> Acceptable ranges are specified for different classes of rail reprofiling.

Another approach is to calculate grinding quality index (GQI), defined as the percentage of the difference curve between ground profile and a template that falls within the user-defined acceptance envelope. GQI was first proposed to be used in conjunction with a proprietary alignment method using two-variable optimization with constraint.<sup>2</sup> GQI can be modified to account for RCF condition and MGT intervals between grinding, producing an equivalent grinding index (EGI).<sup>3</sup>

Recommendation on acceptance criteria is beyond the scope of this study. Readers can choose one of the existing methods described in literature or derive their own in accordance with the goals of the grinding process and capabilities of their grinding equipment.

## APPROACH TAKEN

### Inputs

A North American maintenance of way provider and three Class I railroads (RR 1, 2, and 3) have provided sets of measured profiles of unground rails in a variety of curves and on tangent track. Each railroad provided about 30 sets of left and right profiles, measured with a laser system aboard a rail grinder.

In addition, each railroad provided a set of grinding templates it normally used in conjunction with alignment method A. RR 1 provided three templates (high rail, low rail, and tangent track), RR 2 provided five templates (one for low rail, two for high rail, and two for tangent track), and RR 3 provided two templates (high rail and low rail/tangent track). Templates from each railroad were only used in combination with measured rail profiles from the same railroad. Some of the templates had to be extended on the field side for compatibility with all alignment methods.

The combination of 90 pairs of measured rail profiles, 10 grinding templates, and 3 alignment methods resulted in a total of 666 test cases.

### Alignment Process

A MATLAB® script was written to batch-process the test cases by applying the alignment methods described earlier. The methods used include method A as described, modified method B (for non-side-worn rail, farthest gage side point of the template was used for alignment, since none of the provided templates extended to 14 mm below the top of the rail), and method C with a minimum of 0 mm of metal removal over the range of contact angles between 0 and 30 degrees.

Since this study simulated the grinding process, the same alignment method was used for aligning the unground rail profile with the grinding template and for aligning the ground rail profile with the grinding template to determine residual discrepancy (Figure 2). The program found the points of intersection between measured rail profile and grinding template, identified the areas that were “trimmed” during the grinding process, and created a difference curve plot.

### Outputs

The outputs for each test case included an overlay plot of measured rail and grinding template (Figure 2), a metal removal plot, and a resultant ground profile.

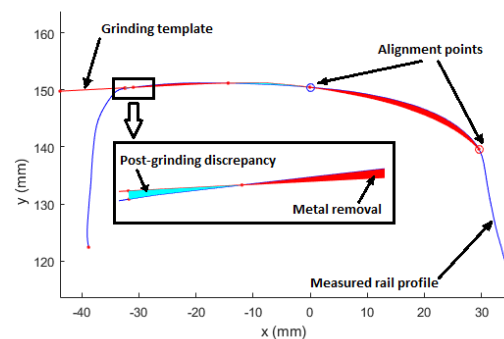


Figure 2. An example of simulated grinding process using alignment method A

In addition, a number of performance metrics were calculated, including:

1. Head loss area, defined as the cross-sectional area difference between unground and ground rail profile. This corresponds to the sum of red areas in Figure 2. For comparison, a state-of-the-art 120-stone production grinder can remove up to 0.04 in<sup>2</sup> per pass.
2. Maximum post-grind discrepancy, defined as the maximum distance between grinding template and ground rail profile in the range from the farthest intersection point on the gage side to the farthest point on the field side of the measured rail with contact angle of  $-10$  degrees, and measured perpendicular to the grinding template. This corresponds to the maximum width of the cyan areas in Figure 2. It is recognized that a real grinding operation would be unlikely to leave any unground surface on the portions of the railhead that contact the wheel; however, this metric can be considered a proxy for adherence of the ground rail profile to the target profile defined by the template.

**RESULTS**

Figures 3 and 4 demonstrate the results of simulated grinding using various template alignment methods, grinding templates, and measured rail profiles. These box plots display information about the distributions of results. Each box shows the 25<sup>th</sup>-, 50<sup>th</sup>-, and 75<sup>th</sup>-percentiles. The whiskers show the range of the data points within 1.5 times the interquartile range from the edges of the box. Stars indicate outlier data.

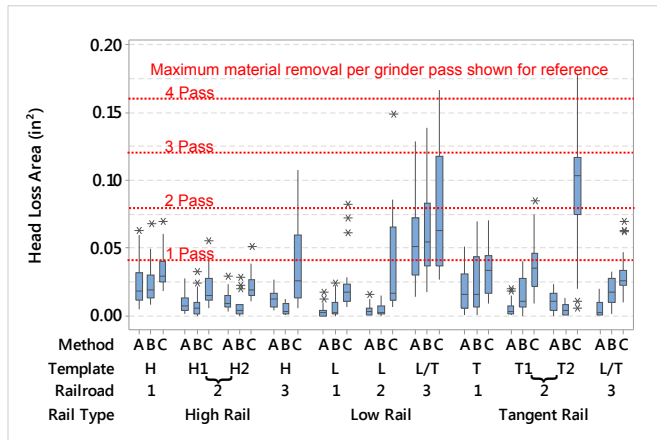


Figure 3. Box plot of railhead loss area

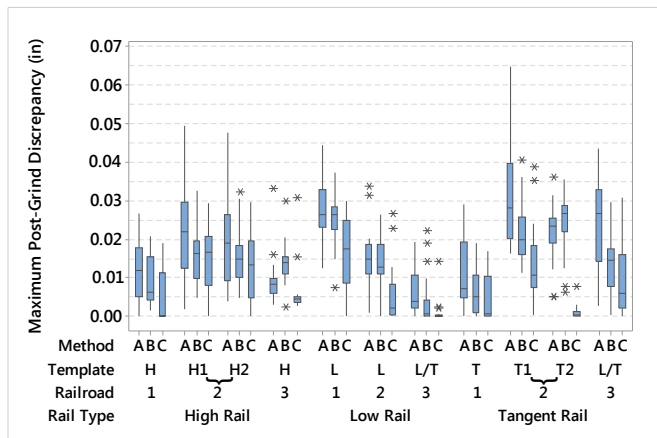


Figure 4. Box plot of maximum post-grind discrepancy

None of the three examined methods is consistently best at both evaluation criteria. The variation in unground rail profiles and grinding templates overshadows the difference between template alignment methods A and B. There is a trade-off between minimizing material removal and adherence to the grinding template. Method C tends to require more material removal than methods A and B, while showing maximum adherence between post-ground rail and grinding template, as evident from its higher head loss

area and lower post-grind discrepancy values. The difference is especially noticeable on low rail and tangent track profiles from RR 2. This is due to the fact that the templates for low and tangent rails on this railroad tended to have tighter radii than measured rails in the region between rail centerline and gage corner.

The head loss area results for RR 3 on low rails were notably higher than most of the other conditions evaluated, regardless of alignment method. This is due to a tight head radius on the template requiring grinding of the field-side and gage-side corners.

**CONCLUSION**

TTCI has conducted a study involving three grinding template alignment methods commonly used or proposed for use on North American freight railroads, including centerline alignment method, Euronorm alignment method, and range alignment method.

The results of simulated rail grinding using a variety of measured rail profiles and templates show that the variations in unground rail profile and grinding template tend to overshadow the differences due to the centerline and Euronorm template alignment methods. The range alignment method leads to larger railhead loss than the other two methods, while showing higher adherence between post-ground rail and grinding template.

None of the three examined methods is consistently best at both evaluation categories: quantity of material removed and resulting shape of the ground rail. Choice of template alignment method should take into account such factors as grinding regime, acceptable number of grinding passes, and grinding templates used by the particular railroad.

**ACKNOWLEDGEMENT**

Robert Harris of Loram Maintenance of Way, Inc. was instrumental in providing worn rail profiles, grinding templates, and description of alignment methods.

**REFERENCES**

1. European Committee for Standardization. "Acceptance of Reprofiled Rails in Track." EN 13231-3:2012. Brussels.
2. Palese, P., T. Euston, and A. Zaremski. "Use of Profile Indices for Quality Control of Grinding." In *Annual Conference and Exposition, AREMA*. 2004.
3. Devadoss, R., G. Chattopadhyay, N. Mandal, P. Sroba, M. Turner, and G. Creese. "Rail Grinding Quality Assurance Based on Profile Correction and RCF Control." In *Conference on Railway Engineering*, Wellington. 2010.

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