

## NORTH AMERICAN RAIL GRINDING ON CURVES IN TRACK

by Kevin Sawley

### Summary

Rail grinding has been found to be effective in reducing rail-surface damage and maintaining the desired rail profiles in revenue-service trials conducted by Transportation Technology Center, Inc., with the cooperation of North American railroads. The site trials (all on curves between 2 and 9 degrees) were augmented by a survey to establish current grinding practices, and by computer modeling to examine the damaging stresses input to the rail surface by wheel/rail contact.

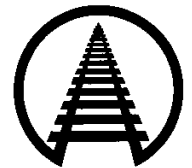
Grinding practices used by North American railroads to maintain rail, and their effectiveness in controlling surface damage and profiles on rail, have been studied in the Association of American Railroad's (AAR) Wheel/Rail Asset Life Extension Project. Principal results from this study are:

- For clean premium rail, grinding should focus more on the low rail (to reapply a crown radius of 7 to 10 inches and relieve the field side to prevent damage from hollow wheels). High-rail grinding need only give minor gage-corner relief to aid natural wear.
- For standard and ingot premium rail, there may be a need for more gage-corner relief to reduce shells and transverse fractures. However, grinding to promote strong two-point contact between wheel and rail should be avoided on curves.
- Grinding interval depends on many factors, including grinding-train logistics and curve radius. No unique value can be given, but the aimed-for minimum value should be no more than 25 million gross tons unless rail surface damage forms rapidly.

Expert local knowledge of traffic, track condition, and rail history (backed up by pregrind and post-grind surveys) is needed to plan the best use of grinding for a curve.

#### Suggested Distribution:

- Maintenance of Way
- Planning & Analysis
- Track Maintenance
- Safety



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## INTRODUCTION AND CONCLUSIONS

Grinding practices used by North American railroads to maintain rail on curves, and the effectiveness of these practices in controlling rail-surface damage and profiles, have been studied in the Association of American Railroad's Wheel/Rail Asset Life Extension Project. The study was conducted in three parts. First, railroads were surveyed for details of current grinding practices. Second, service trials were undertaken in curved track to examine how grinding interval and practice affect the production of rail-surface damage and defects such as detail fractures. Third, the NUCARS vehicle dynamics model was used to examine the effect of a number of parameters on the stresses produced in the rail by wheel/rail contact. Principal results from this study are:

- For continuous-cast premium rail, grinding should focus on the low rail – to reapply a crown radius of 7 to 10 inches and relieve the field side to prevent damage from hollow wheels. High-rail grinding should relieve the gage-corner to aid natural wear.
- For standard and ingot premium rail, there may be a need for more gage-corner relief to reduce shells and transverse fractures.
- For any type of rail, grinding to promote strong two-point contact between wheel and rail should be avoided on curves.
- Grinding interval depends on many factors, including grinding train logistics and curve radius. No unique value can be given, but, the aimed-for minimum value should be 25 million gross tons (MGT) unless special factors apply.

Local knowledge, backed up by pregrind and cost-grind surveys, is needed to plan the best use of grinding for a curve.

Two types of grinding are routinely adopted. Preventive grinding, which usually means frequent light (single-pass) grinding to prevent the initiation of rail-surface damage. Corrective grinding, which is less frequent and uses multiple pass-

es of the grinding train allows damage to initiate before removal. Preventive grinding is currently used by most railroads and gives the best rail-surface condition throughout rail life. This practice increases the total number of grinding passes the rail receives, but it is not clear that it minimizes total rail-maintenance cost.

## RAILROAD GRINDING SURVEY

North American railroads were contacted to provide information about their current grinding practices and budgets. Replies were obtained from seven separate railroads. As expected, different railroads adopt different practices, but the survey showed that consensus is emerging. Results are summarized in Exhibit 1.

Little quantitative information was obtained on the benefits of grinding, or on tangent-rail grinding. Also, the survey did not produce information about different grinding practices needed to treat standard rail, ingot premium rail, and continuous-cast premium rail. Further work needs to address these three areas.

## SERVICE GRINDING TEST SITES

With railroad cooperation the effect of different grinding regimes on the life of rail in service test sites on Canadian National (CN) and Norfolk Southern (NS) is being studied. All test sites are in curved track (from 2.4 to 8.4 degrees), and contain premium head-hardened rail of 136-lb. section laid on concrete and wood ties. The rails installed at the CN sites were made from continuous-cast steel made to CN clean-steel specifications by Nippon Steel Corporation and NKK Corporation. The rails installed at the NS sites were made by CF&I (now Rocky Mountain Steel Mills) and Rodange (France) using ingot-cast steel and continuous-cast steel respectively. Early results were reported in Technology Digests TD 97-007 (NS) and TD 97-040 (CN). The sites have so far accumulated about 164 (CN) and 330 (NS) MGT, and the most recent results are reported in TD 98-033.

Three different regimes are being studied: no-grinding, preventive (or frequent) grinding, and light (less frequent) grinding. Results are mixed, and show clearly that rail-surface damage is highly site-specific and rail-specific. General conclusions are given in Exhibit 2.

<b>1</b>	Most railroads use, or wish to use, preventive grinding. Corrective grinding is used to renovate rail with extensive surface damage, to deal with rail in problem curves, or when logistics dictate that frequent grinding cannot be carried out. Grinding speed is at least 5 mph in curves, and up to 15 mph in tangent track.
<b>2</b>	Grinding interval varies widely, with a minimum interval in the range 10 to 15 MGT. Interval is based on tonnage or time, and depends on curvature, logistics, and approach (corrective or preventive).
<b>3</b>	Curved track is ground more frequently than tangent, but ratios (tangent/curve) vary from 50/50 to 25/75.
<b>4</b>	There is consensus that the field side of low rails of curves should be relieved to prevent damage and crushing from the false flanges of hollow wheels. A common aim is to grind to produce a low-rail crown radius in the range 7 to 10 inches.
<b>5</b>	There is a general belief that the high-rail gage corner should be ground to give "two-point-contact" conditions, but most survey responses included words like "slight," and "semi-conformal" to describe the ground profile. Heavy gage-corner grinding to give extreme two-point contact in curves is not common.
<b>6</b>	The low rail is the main focus of grinding in curves. Although one response said that grinding effort was split equally between high and low rails in curves, all other responses said that more attention was given to grinding the low rail, which flattens in service, to a profile that improves steering.
<b>7</b>	Benefits of grinding included: removal of corrugation and surface damage (which may give improved ultrasonic inspection), reduced internal defects, improved vehicle steering, and less low-rail damage from hollow wheels. Grinding is seen as an essential tool of rail maintenance

**Exhibit 1. Results from Railroad Grinding Survey**

Because of surface damage, which threatened to impair ultrasonic inspection, the low rails at three of the four no-grind NS sites were ground in March 1998 (at 330 MGT). All rails at the CN no-grind sites were ground in October 1998 (at 164 MGT), to remove surface cracks, spalls and shells, and to reprofile flat low rails. In all cases, between three and five passes of the grinding train were

<b>1</b>	Grinding is beneficial in preventing or reducing damage to the rail surface.
<b>2</b>	Grinding is also beneficial in maintaining the desired low-rail transverse profile.
<b>3</b>	There is a difference between the high-rail damage on CN and NS track. Unground CN high rails (continuously cast steel) show significant shells, unlike the ingot-cast NS rails that show only minor damage.
<b>4</b>	Rodange rails in the NS sites are more prone to damage than CF&I rails.
<b>5</b>	No rails have been removed from any site for transverse, or other, head defects.

**Exhibit 2. Summary of Results from Site Trials**

applied. This grinding restored the desired high- and low-rail profiles and removed most visible damage. At first sight it seems that rail can be maintained more economically by corrective than by preventive grinding. But this may be misleading. Preventive grinding decreases surface damage, improves ultrasonic inspection efficiency, and better maintains desired curving performance. Also, corrective grinding did not remove all visible damage, and probably left surface-breaking cracks which have potential to reinitiate damage. Further monitoring of these "no-grind" sites is essential.

**MODELING OF RAIL DAMAGE**

Rails deform, crack, spall, and shell when the stresses applied by the wheel are too high for the rail to withstand. Grinding is used to rectify this surface damage. Modeling using the NUCARS vehicle dynamics program was done to study how wheel and rail profiles interact to generate damaging stresses. The study modeled a 263,000-lb. hopper car equipped with standard three-piece trucks with tapered and hollow-worn wheels, running on tangent and curved track.

Two types of rail stresses were examined. The contact stress,  $P_0$ , is the maximum stress applied normal to the plane of the contact patch. The shear stress is the average shear stress acting laterally in the plane of the contact patch. The study examined the effect on rail stress of:

- Wheel profile (from tapered to 6-mm hollow-worn).



- Rail rotation under the action of gage-spreading lateral forces (for rotations typical of elastic fasteners on concrete ties and cut spikes on wood ties).
- Running at typical under- and over-balance speeds in curves.

Exhibit 3 shows principal results.

### GRINDING BEST PRACTICES

Based on these results, it cannot be said which method of grinding — preventive or corrective — is best overall. Preventive grinding may be easiest to apply, and give the best control of the rail, but it may not be the most cost-effective way of maintaining the rail surface. More work is needed to quantify the economic difference between preventive and corrective grinding. Also, results show

that the need for grinding is highly specific to the site and rail type. In these respects, there probably is no definitive best practice in terms of type and interval of grinding for rail grinding in curves. That said, some firm guidelines can be laid down.

- The type of grinding a curve needs is best decided based on expert local knowledge of traffic, track condition and rail history.
- Pre-grind surveys should be used to plan grinding, with post-grind surveys to confirm that the desired high- and low-rail profiles have been applied by grinding. Grinding to inappropriate profiles can be worse than not grinding at all.
- For track with clean premium steel, grinding should focus more on the low rail (to apply a crown radius of 7 to 10 inches and relieve the field side). High-rail grinding should aim for minor gage-corner relief to aid the natural wear.
- There may be a need for heavier gage-corner relief of standard rail and ingot premium rail, to reduce transverse fractures.
- Strong two-point contact conditions reduce the ability of trucks to steer, and should normally be avoided in curves.
- Unless conditions are such that significant rapid rail-surface damage occurs, the minimum grinding interval should be no less than 25 MGT.

<b>1</b>	Hollow-worn wheels could be responsible for much of the surface damage seen on low rails in curves. This is a consequence of the wheel false flange riding on the field side of the low rail. Damage is predicted to increase as hollow wear rises above 2 mm (0.08 inch).
<b>2</b>	Low-rail damage is likely to be made worse by wide gage and rail rotation towards the field side (caused by lateral gage-spreading forces).
<b>3</b>	Hollow-worn wheels are predicted to have little effect on high-rail surface damage. This is because there is less chance for the false flange to ride on the high-rail top.
<b>4</b>	Rail rotation towards the field side has a minor effect on high-rail stress.
<b>5</b>	Running above or below balance speed is not predicted to have a major impact on high- or low-rail surface damage. The NUCARS model used, however, may have insufficient input data to accurately model non-balanced running.

**Exhibit 3. Principal Results from Rail-Stress Modeling**

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