TECHOLOGY DIGEST

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GRINDING-TRIAL RESULTS ON CANADIAN NATIONAL AND NORFOLK SOUTHERN RAILROADS

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Summary

Trials on two North American railroads indicate that rail grinding is effective in reducing or preventing rail-surface damage in curved track. While grinding can beneficially reduce cracks and shells on the high rail, indications are that low rails benefit most from grinding. The trials have been undertaken by the Association of American Railroads, with the close cooperation of the Canadian National (CN) and Norfolk Southern (NS) railroads. Tests began in 1993 (NS) and 1995 (CN), using newly installed, clean, premium rail made from both continuously cast and ingot steel. Total tonnage to date is 164 (CN) and 330 (NS) million gross tons. Results from the sites are mixed, but the following conclusions can be drawn:

- Grinding is beneficial in preventing or reducing rail-surface damage such as cracks, flakes, and spalls, especially on the low rail. Frequent light grinding essentially eliminates surface damage, but infrequent heavy grinding largely renovates damaged rail.
- The high-rail damage on CN and NS track is different. Unground CN high rails (continuously cast steel) show significant shells, unlike NS high rails (ingot cast) that show only minor damage.
- The reduction in damage due to frequent grinding comes at the cost of increased rail-metal loss.
- Rodange rails in the NS sites are much more prone to damage than CF&I rails.
- No rails have yet been removed from any site for transverse, or other, head defects. It is not known if this is because the sites have not seen sufficient tonnage to cause defects, or because clean, premium rail suppresses internal defects in the railhead.

The study is examining the effects of three different grinding regimes on rail life: no-grinding, light (or infrequent) grinding, and preventive (or frequent) grinding. Since no rails have been removed for defects, it is not yet possible to quantify the benefits on rail life conferred by grinding. Because of surface damage, the low rails at two of the three CF&I no-grind sites on NS were ground in March 1998 (330 MGT). All rails at the CN no-grind sites were ground in October 1998 (164 MGT). This application of heavy grinding (three to five grinding passes in one visit) successfully re-applied the desired low-rail profile, and removed most of the visible damage. Further monitoring is needed to establish the rate at which damage returns at these "no-grind" sites, and to determine the effect of grinding on transverse fractures at higher tonnage.

Suggested Distribution:

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

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INTRODUCTION AND CONCLUSIONS

The Association of American Railroads, with cooperating railroads, is studying the effect of different grinding regimes on the life of premium rail at test sites on Canadian National (CN) and Norfolk Southern (NS) track. The sites have so far accumulated about 164 (CN) and 330 (NS) million gross tons (MGT). Three different regimes are being studied: no-grinding, light (or infrequent) grinding, and preventive (or frequent) grinding. Results are mixed, but general conclusions are:

- Grinding is beneficial in preventing or reducing damage to the rail surface.
- 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 NS rails (ingot cast) that have minor damage.
- Rodange rails in the NS sites are more prone to damage than CF&I rails.
- No rails have been removed from any site for transverse, or other, head defects.

Because of surface damage on NS, the low rails at two of the three CF&I no-grind sites, and the Rodange no-grind site, were ground in March 1998 (330 MGT). All rails at the CN no-grind sites were ground in October 1998 (164 MGT). At all these sites, multi-pass grinding successfully reapplied the desired profiles, and removed most of the visible surface damage. Since no rails have yet been removed for defects, it is not possible to quantify the benefits of grinding on rail fatigue life.

TEST SITES

Test site details are given in Exhibit 1. NS sites had new premium 136-pound (10-inch crown radius) rail, made from ingot steel by CF&I (now Rocky Mountain Steel Mills) and continuously cast steel by Rodange (France). CN sites had new premium 136-pound (4-inch crown radius) rail, made from continuously cast steel made to CN clean-steel specifications by Nippon Steel Corporation and Nippon Kokan.

On NS, five sites were ground aggressively, using multipass grinding to give high-rail gage-corner relief of between 0.025 and 0.035 inch. Four sites were lightly ground, at the same interval, but with fewer passes and less metal removal each visit (0.01- to 0.015-inch relief). Grinding was done on average at 41 MGT intervals. Four control sites

NORFOLK SOUTHERN	CANADIAN NATIONAL
Sites near Roanoke, VA, established 1993	Sites near Kamloops, B.C., established 1995
Thirteen test sites in curved track*	Six test sites in curved track
Curve range: 2.4° to 8.4°	Curve range: 3.2° to 7.1°
Sites carry mainly unit coal trains, loaded one way	Sites carry unit trains and mixed freight
Annual tonnage about 65 MGT	Annual tonnage about 45 MGT
350 MGT to date	164 MGT to date
With one exception (elastic fasteners), all sites have wood ties with cut spikes	All sites have concrete ties with elastic fasteners
All sites have premium ingot steel rail	All sites have premium continuously cast rail
*One site was lost after 103 MGT because of a non rail-related derailment.	

Exhibit 1. Details of Test Sites

were left unground. Sites were split into mild (2.4- to 2.9-degree), medium (4.4- to 6.2-degree), and severe (7- to 8.4-degree) curves. Each type of curve included control sites, and lightly and aggressively ground sites.

The CN sites included three mild (3.2- to 4-degree), and three severe (6- to 7.1-degree), curves. One of each was ground to normal CN practices for this route. This was intended to produce a 7- to 8-inch radius on the low rail and a 6- to 7-inch radius on the high rail, and to give slight high-rail gage-corner relief, and low-rail field-corner relief. Grinding was done at average intervals of 12.5 MGT. Two curves (medium and severe) were ground the same way but at less-frequent intervals (21 MGT). One medium and one severe curve were left unground as control sites.

At all sites, visual observations (with photographic records) and profile measurements were made before and after each grinding visit. At the CN sites, transverse profiles were taken using the Miniprof® system. Profiles were analyzed to give the cross-sectional area lost with accumulated tonnage, and height and gage-face loss. Most measurements at the NS sites were taken using a manual gage which gave rail-height loss, and gage-face wear ⅝ inch below the actual top of the rail center. At all sites measurements were analyzed to give metal lost by grinding and metal lost by natural wear.

CANADIAN NATIONAL SITE RESULTS

Visual Observations

The CN-grind schedule was very effective at keeping the high and low rails in good surface condition, with the desired profiles. Very light cracks and pits developed, but were insignificant in terms of rail damage.

Light grinding at 21 MGT was less effective at controlling surface damage. Both high and low rails showed light cracks and moderate pits and spalls.

The no-grind sites showed extensive rail-surface damage. The 6.5-degree curve showed heavy checks and shells on the high-rail gage corner, and light spalls on the rail top. The low rail was flat, with extensive cracks, spalls, and flakes. The 3.9-degree curve showed shells on the high-rail gage corner, and cracks and spalls on the low-rail top.

After 164 MGT, low rails at all sites showed fine cracks on the rail top, aligned mainly along the rail. Such cracks were seen but less pronounced on some high rails. They indicate the likely presence of high lateral wheel/rail forces.

Rail Metal Loss

As expected, ground rails showed more metal loss than unground rails. This is shown in Exhibit 2, which shows, for the CN sites after 154 MGT, the total area of cross section lost (A_t), and the amounts removed by grinding (A_g) and natural wear (A_W). For comparison, 136-pound rail has a head area of 3,200 square millimeters (4.98 square inches), and rails are typically replaced after 35 percent wear loss. The amount of metal removed each grinding visit decreased throughout the trial period, reaching about 15 square millimeters for both the high and low rails, and for the light-grind and CN-grind sites. (This equates to 0.2 to 0.25 millimeter height loss.) The only practical difference in grinding between the light- and CN-grind sites was the grinding interval.

Site, curve	High rail*			Low rail*		
	A_W	A_g	A_t	A_W	A_g	A_t
No-grind, severe	117	0	117	167	0	167
Light-grind, severe	71	131	202	74	179	253
CN-grind, severe	60	273	333	21	328	349
No-grind, mild	37	0	37	54	0	54
Light-grind, mild	77	105	182	38	150	188
CN-grind, mild	79	187	266	49	294	343

* All values in square millimeters
A_W = area removed by wear; A_g = area removed by grinding; $A_t = A_W + A_g$

Exhibit 2. Rail-Metal Loss at CN Sites

Latest Grinding Visit, October 1998

Because of cracks and shells on the high rails, and cracks, spalls, and a flat top on the low rails, the CN no-grind sites were ground in Oct. 1998 (164 MGT). Exhibit 3 details the grinding, and compares it to the total grinding applied to the CN-grind rails. This grinding was sufficient to reapply the desired low-rail profile, remove the visible low-rail damage, and remove most (but not all) of the high-rail visible damage.

Site, curve	High Rail visits/passes	Low Rail visits/passes
No-grind, severe	1 / 5	1 / 5
CN-grind, severe	14 / 14	14 / 16
No-grind, mild	1 / 3	1 / 4
CN-grind, mild	13 / 14	13 / 21

Exhibit 3. Comparison of Grinding Applied to CN-Grind and No-Grind Curves

NORFOLK SOUTHERN SITE RESULTS

Visual Observations

CF&I rails behaved much differently from Rodange rails. The Rodange low rails cracked and shelled early in the test, and grinding did not control the damage. Rodange high rails also showed more gage-face wear than the CF&I rails. Rodange rails are no longer manufactured, and their performance will not be discussed further.

The CF&I high rails, ground and unground, were in good condition after 330 MGT traffic. The mild-curve, no-grind rails had two spalls, but these were associated with a rolling seam formed in the rail during manufacture. The severe-curve no-grind rails had a little worse surface damage than the mild-curve rails, and showed one or two patches of small spalls. The light-grind rails were mostly in good surface condition, but some rails showed areas of light spalls on the rail top. The aggressively ground high rails were substantially free of damage.

The CF&I low-rail surface damage showed clear differences between the three treatment practices. Aggressively ground rails were mostly free of defects, although minor spalls were present at the medium-curve site. Light-ground rails showed few spalls, although they were present at the mild-curve site, appearing in two distinct parallel bands. The mild-curve, no-grind rails showed no spalls, but did show metal flow towards the field and gage sides. The medium- and severe-curve, no-grind rails showed cracks, spalls, and flakes, especially towards the field side of the rail top, and were much flatter than the ground rails.

Rail Metal Loss

Grinding increased rail-metal loss at the NS sites. Exhibit 4 details the metal lost on the CF&I high and low rails. After early heavy grinding the metal removed by grinding at the NS CF&I rail sites changed little with time. High rails were ground about 0.1 to 0.2 millimeter per visit, the low rails about 0.1 millimeter per visit. More metal was removed at the aggressive-grind sites than at the light-grind sites.

Latest Grinding Visit, March 1998

Because of cracks, flakes, and spalls on the no-grind medium- and severe-curve low rails, the rails were ground in March 1998 (330 MGT). The severe-curve low rails had five grinding passes, the medium-curve rails had three passes. This grinding removed most of the visible damage, but left some small pits and spalls on the rail top.

Site, curve	High rail		Low rail
	Height	Gage face*	Height
No-grind, severe	1.75	2.21	1.94
Light-grind, severe	3.73	4.01	3.67
No-grind, medium	1.12	2.21	1.28
Light-grind, medium	2.69	2.46	2.86
Aggr.-grind medium	4.55	3.63	3.52
No-grind, mild	0.79	0.20	0.91
Light-grind, mild	3.23	5.97	3.11
Aggr.-grind, mild	2.72	4.24	3.58

* Measured 5/8 inch below worn rail top.

Exhibit 4. Metal Lost (in millimeters) from CF&I High and Low Rails at NS Sites

OVERALL CONCLUSIONS

At these test sites, grinding has been clearly beneficial in preventing surface damage and maintaining desired profiles. The no-grind CN rails (high and low) showed cracks, flakes, spalls, and shells, and the low rails were flat. Results at the NS sites were more complex. Rodange rails were much more prone to damage than CF&I rails. While the unground CF&I high rails were in reasonable condition, little worse than the ground rails after 330 MGT, the unground CF&I low rails had much more damage than the ground rails, especially in the high-curvature sites.

Heavy grinding after 164 MGT (CN) and 330 MGT (NS) appeared to restore the desired high- and low-rail profiles and remove most visible damage. Initially it appears that rail can be maintained more economically by infrequent heavy grinding than by frequent light grinding. This may be misleading. Frequent light grinding decreases surface damage, improving ultrasonic inspection efficiency. It also maintains desired curving performance. Also, heavy grinding did not remove all visible damage, and probably left surface-breaking cracks in the rail which have potential to rapidly reinitiate damage. Further monitoring of these "no-grind' sites is needed.

Finally, no rails (ground or unground) have been removed from any site because of transverse fractures. Perhaps the sites have seen insufficient traffic to nucleate and grow defects, but it may be that clean premium steels are highly resistant to internal defects (which nucleate at inclusions). Grinding clean premium steels to inhibit high-rail transverse fractures may not be necessary.

Note: Contact Kevin Sawley at (719) 584-0636, with questions or comments about this document.

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