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PROOF-OF-CONCEPT DEMONSTRATION: CONTROLLING ROLLING CONTACT FATIGUE WITH TOP OF RAIL FRICTION CONTROL

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13. ABSTRACT

A proof of concept demonstration was conducted on two curves to demonstrate the effectiveness of wayside based top of rail (TOR) friction control in reducing occurrence and growth rate of rolling contact fatigue (RCF) on low curvature railroad track. Benefits were primarily noticed on the low rail of the test curve. Results on the high rail were less noticeable, in part due to variable gage face lubrication throughout the trial period. Vertical wear rate of the low rail was reduced by applicator of TOR friction control, while at the same time high rail vertical and gaga face wear varied by changes in gage face lubrication policy. The improvement in rail surface behavior allowed the grinding cycle in this area to be extended from the present 8 months to a 10 month interval while developing the same level of RCF. While this demonstration was limited to two curves, the low rail RCF performance suggested an improvement with the use of TOR. A more extensive test with a larger range of curvatures and rail is suggested to improve data quality and obtain statistically significant results.

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EXECUTIVE SUMMARY

A proof-of-concept demonstration to demonstrate feasibility of controlling rolling contact fatigue using top of rail (TOR) friction control was conducted on the Union Pacific railroad in Kansas. Rail performance was monitored over two curves during two consecutive periods (one without TOR and one with TOR). Results suggest:

- TOR application of a TOR friction modifier reduced RCF growth on a TOR treated single test curve under normal heavy freight operating loads.
- A statistically significant 79 percent reduction in the TOR treated test curve low rail surface RCF (spalling/shelling) has been achieved.
- High rail results were variable, potentially due to non-optimized gage face lubrication during the TOR phase. High rail surface RCF growth was significantly lower compared to low rail growth rates by a minimum factor of eight.
- Test curve rail surface condition following friction modifier (FM) application permitted a 25 percent extension of the historical area grinding cycle from 8 to 10 months.
- Practical issues were encountered in obtaining valid control curve measurements, however, simultaneous monitoring and observation of the non-TOR treated curve suggests that the TOR treated test curve RCF reductions were due to FM application.
- TOR reduced vertical head wear rates primarily on the low rail of the treated curve.
- Changes in gage face lubrication appear to dominate gage face wear rates, with measurements showing little or no measurable influence of TOR on gage face wear rates.

As intended, this was a test conducted as a proof-of-concept over a limited length of track utilizing only two curves. One major grinding cycle for baseline and TOR performance was monitored, and direct comparison between baseline and TOR curves is not viable due to differences in curvature, rail type, rail age, and train speeds. A more comprehensive evaluation with a longer test zone and additional TOR units is suggested with the following items and controls to consider.

- Implement a multi-unit trial over a larger problem RCF zone with more curves to improve data quality and statistical significance of results.
- Gage face lubrication should remain constant at each test curve or group of test curves during the monitoring process.
- Quantify the economic benefits of reduced metal removal or time extensions for existing grinding cycles using TOR technology.

- Determine FM coverage range capability (i.e., track miles) to produce effective RCF reductions.
- Further investigate the benefits of TOR FM application in reducing rail surface cracks and spalls that may inhibit ultrasonic rail inspection quality/processes.

1.0 Background

In North American freight railroads, rolling contact fatigue (RCF) is sometimes experienced on rails that are subjected to heavy axle loads. RCF is usually observed in the form of small cracks on the rail running surface. When left in place, under continued exposure to traffic, these cracks can, in some cases, grow until they interconnect and form larger cracks below the running surface. This may eventually lead to spalling or bigger fragments of metal removal. In other cases, crack growth can proceed into the rail, producing a transverse defect which can eventually result in a broken rail. Multiple, closely spaced cracks and spalling may interfere with normal ultrasonic flaw inspection including the ability to detect transverse defects. Therefore, controlling rail surface conditions to limit RCF has the potential of extending rail life and improving system safety.

The root causes of developing and growing RCF is the subject of a number of studies [References 1, 2]. Common contributing parameters stated by a number of theories include high friction levels and low metal removal rates (low rail wear rates). Generally in North America, experience under heavy axle loads has shown that RCF rarely occurs in areas where rail wear rates are high or where grinding programs are scheduled on a frequency such that RCF is removed before it can grow to a harmful size or depth.

Rail grinding frequency is usually scheduled to control average conditions over a wide territory, with grinding conducted on planned cycles. Isolated areas where RCF occurrence and growth rate may be greater than the average of adjacent rails can exhibit excessively large crack sizes and extensive spalling. If the grinding cycle were to be set based on the worst performing segments of a given area, then locations with little or no RCF would receive too much grinding (and subsequently higher than needed metal removal), thereby prematurely wearing out rail in many locations.

2.0 Demonstration Objectives

This evaluation, conducted by the Transportation Technology Center, Inc., with funding from FRA and the AAR, is intended to demonstrate the feasibility of adjusting friction to reduce occurrence and growth rate of rolling contact fatigue (RCF). By limiting RCF occurrence and growth, rail life could be extended by reducing metal removal from grinding or extending grinding cycles. Depending on performance and deployment, adjusting friction to control RCF may be on a site specific basis, or on a territory wide basis, thus improving overall cost effectiveness of rail in track.

The primary objective of this evaluation is to demonstrate the effect of controlled friction by applying top of rail (TOR) friction modifier (FM) materials at limited selected locations. As RCF generally occurs on or near the TOR running surface, simply applying traditional lubrication would not be a viable solution. Lubricant will reduce friction to below 0.2 μ, while the use of lubricant (as applied to an FM product) would also likely reduce occurrence of RCF, the lower friction level could also lead to braking and traction problems. By utilizing a FM product [Reference 3], an intermediate level of friction (at or near 0.35 μ) will be produced. This friction level, as utilized in the shakedown theory [Reference 4], would reduce the occurrence of RCF and still provide adequate friction levels for train braking and traction needs.

3.0 Approach

Due to budget constraints, this proof-of-concept test was conducted as an initial demonstration and proof-of-concept under a limited number of variables over a limited length of track. The overall approach was to select a curve that historically produces RCF between grinding cycles, treat that curve with TOR friction modification, and determine if RCF rates are reduced. If results suggested RCF could be reduced, further testing over a larger territory with a greater range of conditions would be proposed.

To provide a control, two curves were selected that exhibited a past history of high RCF occurrence and growth rates. These curves were such that RCF historically grew to nearly unacceptable size between grinding cycles. Simultaneously, other nearby sites located on the same line did not exhibit such unacceptable RCF in the same grinding interval.

By adjusting friction on one curve, while monitoring RCF performance on both curves, the effect of TOR friction control in reducing RCF could be documented. Curves were selected that would be subjected to similar train, tonnage, and operating conditions for both periods. Provided the control curve had about the same RCF performance for both periods, a difference in RCF performance for the test curve during back to back periods could be attributed to controlling TOR friction levels.

4.0 Site Details

Through cooperation with Union Pacific (UP), single test and control curve locations were established for RCF monitoring in the Main Track 2 at mile posts (MP) 39.6 and 42.7 respectively of the Kansas City Subdivision (Figure 1). Main Track 2 of this double track line is subjected to 200 million gross tons (MGT) annually of predominantly coal and mixed freight – the majority of all traffic being eastbound loaded traffic. Main Track 1 is used primarily for westbound empty traffic. The MP 39.6 test curve was selected due to historical accelerated low rail RCF growth.

In late 2004, six high and low rail measurement sites were marked in each curve, with both curves monitored during baseline (non-TOR) and TOR application phases. The control curve was used to validate consistency of area operating conditions between trial phases, and did not receive FM treatment during either the baseline or TOR FM periods. The two curves had minor differences in curvature, rail type, and fastener components.

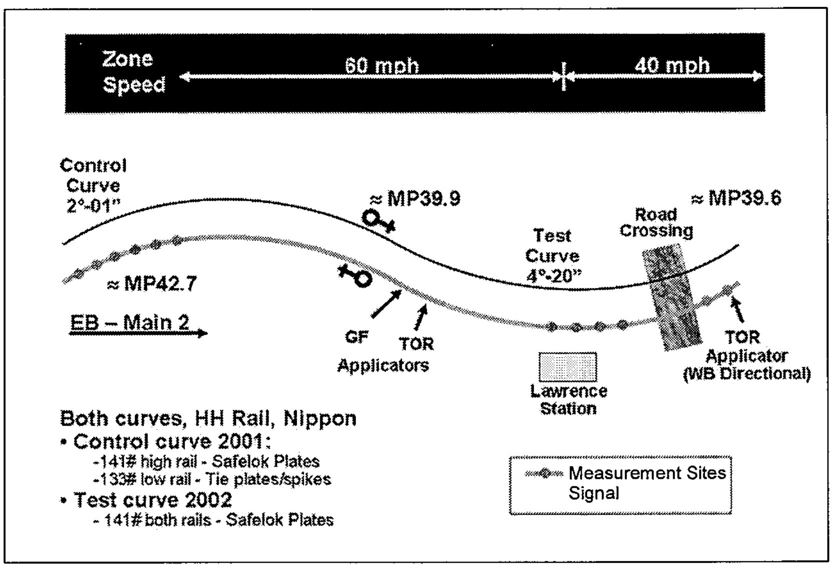


Figure 1. Site Schematic of Project Test and Control Curves

An approximate 2.5 mile buffer zone separated the two curves, mitigating the likelihood of residual FM transfer to the control curve from sporadic westbound traffic. Current area grinding cycle is every 8 months.

5.0 Measurement and Inspection History

Prior to starting the test evaluation, a rail grinder was operated over both the control and test curves. After this initial grinding, the rail was inspected and measured three times before the next grinding activity occurred. This 8 month, 122 MGT period (9/24/04 to 5/3/05) is considered the baseline/no-TOR FM application project phase. After the May 2005 rail grind, TOR FM application units, as Figure 1 shows, were installed to control TOR friction and the site monitored and measured four additional times until April 5, 2006, with an additional 157 MGT accumulated. This second period is the TOR FM period, during which time the test curve received direct TOR friction modification.

Table 1 summarizes the dates and events during this evaluation.

Table 1. Summary of Measurements and Inspections, Dates, and MGT

Date	Activity	Test (MGT)
9/24/04	Grind rail both curves, normal UP cycle	0
11/3/04	Initial inspection, establish measurement sites	21
2/8/05	Site inspection, measurements, initiate baseline period data	73
5/3/05	Site inspection, measurements, end of baseline data	122
5/27/05	Rail ground on both curves, normal UP schedule	135
6/23/05	Site inspection, measurements, initiate TOR application on test curve and TOR FM period data collection	149
7/26/05	Site inspection for rail friction only	167
9/7/05	Site inspection to confirm gage face friction adjustments	191
10/26/05	Site inspection and measurements	217
2/2/06	Site inspection to determine if RCF on test curve allows extended period before grinding	271
4/5/06	Final site inspection, measurements	306

During each of the inspection and measurement activities the following information was gathered:

- RCF – by use of dye penetrant and digital photographs
- Rail friction – manual hand push tribometer
- Rail profiles – use of MiniProf™

6.0 Inspection and Analysis Methodology

Dye penetrant (DP) inspections were performed at each of the test and control curve high and low rail measurement sites during the baseline and TOR FM monitoring periods. Digital images of the DP inspections were captured and further analyzed using imaging analysis software (SigmaScan Pro 5). The same rail surface sections at each measurement site were isolated for review during this procedure to ensure consistency of comparative analysis between inspections. Two main RCF conditions were reviewed:

- TOR Surface RCF (spalling/shelling) – Measured in percentage of RCF per MGT
- Gage Corner Cracks (length/spacing/angle)

TOR surface RCF analysis was restricted to a 1 by 5 inch portion of the main running band/wheel contact area immediately adjacent to the terminating point of gage corner cracks.

7.0 RCF Reduction Results

7.1 TOR Surface RCF – MP 39.6 Test Curve

An 8-month TOR application period was completed following baseline monitoring. Both phases were similar in length and operating tonnage (TOR = 224 days/122 MGT versus baseline = 221 days/122 MGT). Examination of RCF from the dye penetrant inspections suggested a 79 percent reduction in test curve low rail surface RCF growth was achieved during the TOR FM application period. Figure 2 shows that the average low rail growth rate was 0.051 percent RCF per MGT compared to 0.239 percent RCF per MGT for the baseline period.

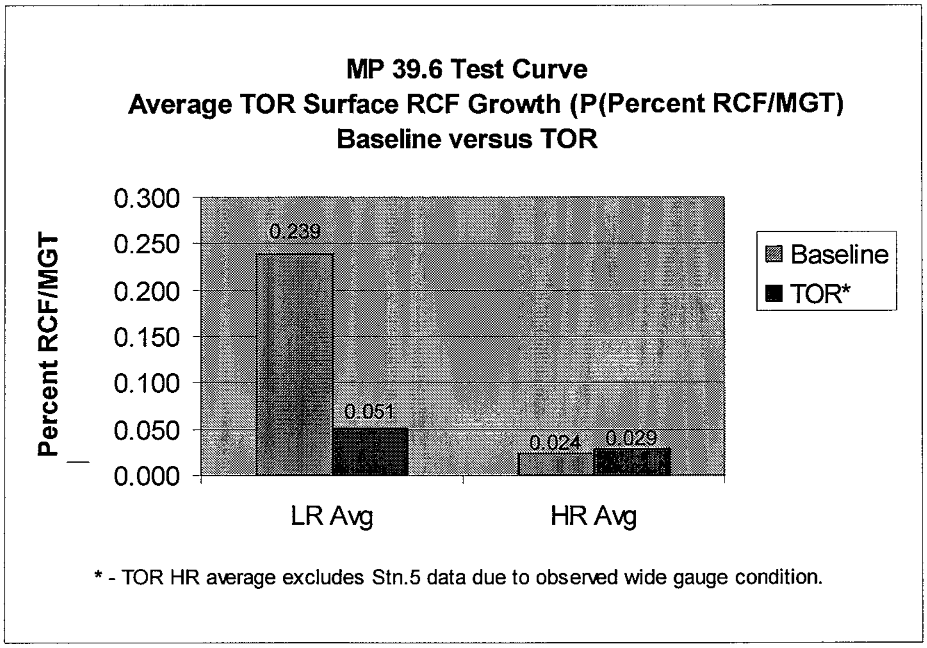


Figure 2. Test Curve Average for TOR Surface RCF Growth (Percent RCF/MGT)

The low rail growth rate difference between phases was statistically significant, as assessed using a Student's t-test with 90 percent confidence interval. Reductions were noted at all test curve low rail monitoring sites (Figures 3 through 5) and are considered representative of the general test curve low rail surface condition following TOR application.

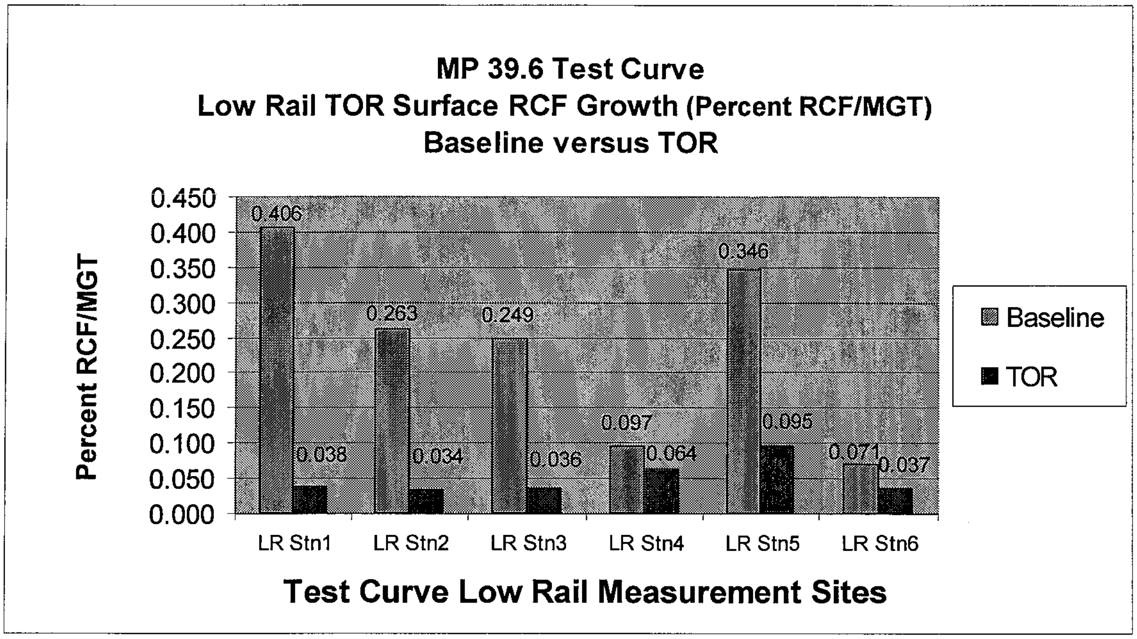
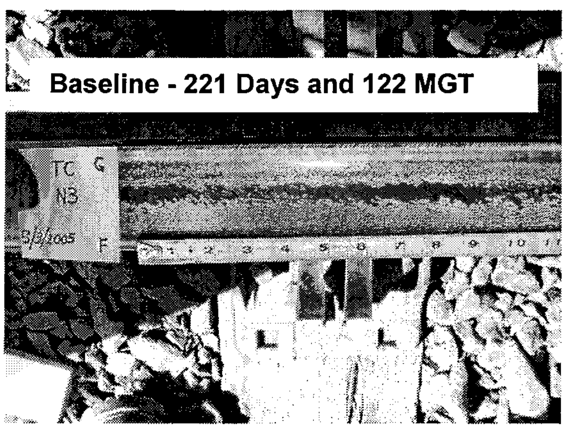
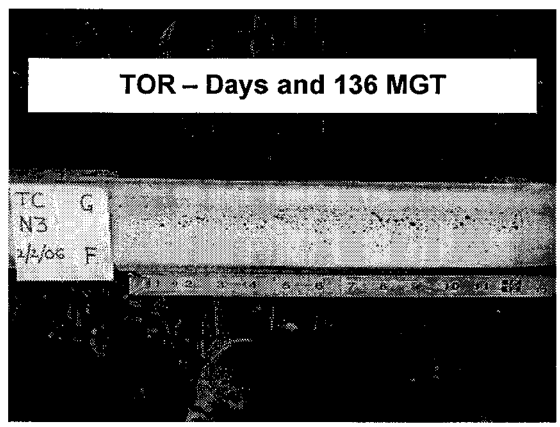


Figure 3. Test Curve Low Rail Surface RCF Growth (Percent RCF/MGT)





Figures 4 and 5. Concluding Test Curve RCF – Baseline Versus TOR FM Application – Low Rail Measurement Site No. 3

Test curve high rail results following TOR FM application were variable with limited statistical significance, indicating minimal if any change from baseline (Figures 2 and 6). Extent of high rail RCF growth was notably lower during both phases by a minimum factor of eight compared to low rail growth rates (HR = 0.001 – 0.048 Percent RCF/MGT versus LR = 0.034 – 0.406 Percent RCF/MGT).

The high rail growth range shown does not include data for Station No. 5. This measurement site demonstrated accelerated RCF growth due to dynamic wide gage greater than 1 inch, as validated by field inspection and track geometry car data, and did not accurately reflect general high rail conditions.

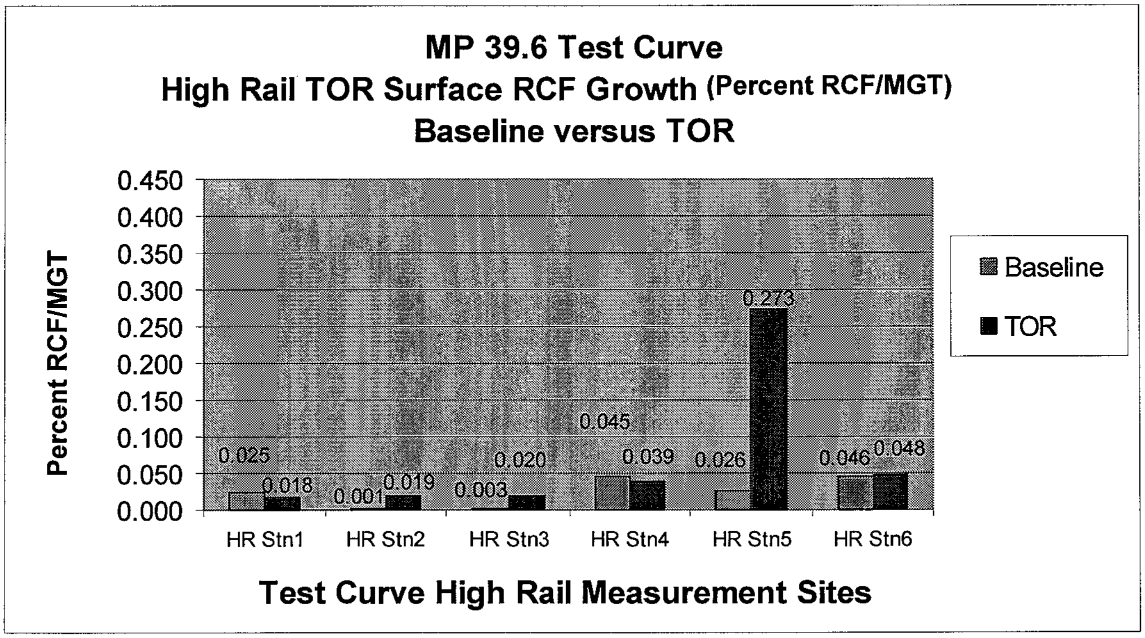


Figure 6. Test Curve High Rail Surface RCF Growth (Percent RCF/MGT)

7.2 Gage Corner Cracks – MP 39.6 Test Curve

No improvement was noted to test curve gage corner cracks following the TOR FM phase. Data involving high rail cracks only was analyzed due to the absence of low rail gage corner cracks after the baseline period. There were no statistically significant differences recorded in gage corner crack length (mm), spacing (mm), or angle (degrees) between phases. These results may be due to non-optimized gage face lubrication inhibiting the effect TOR FM may have had on crack reduction potential. Non-optimized gage face lubrication occurred while a lubricator was undergoing tests and adjustments during the TOR FM phase (refer to Section 7). The minimal differences recorded also fall within the measurement variability range of the imaging analysis process. An alternate inspection process may be required to more accurately quantify marginal changes in gage corner cracks between trial phases.

7.3 Grinding Cycle Extension

Significantly reduced test curve low rail RCF and sustained minimal high rail RCF achieved during the TOR FM phase, permitted a 25 percent extension of the historical area grinding cycle from 8 months to 10 months. RCF analysis following 2 months and 35 MGT of extended operation confirmed a still favorable and statistically significant 67 percent reduction in low rail average surface RCF growth (0.080 percent RCF/MGT compared to 0.239 percent RCF/MGT for the baseline). High rail surface RCF growth demonstrated a statistically significant increase from the baseline after the extended period, but the average growth rate remained low and similar to the improved low rail performance during TOR FM application (low rail = 0.080 percent/MGT versus high rail = 0.083 percent/MGT after 10 months of TOR friction control). The high rail value does not include data associated with the Station No. 5 measurement sitewide gage anomaly.

Test curve RCF reductions achieved through TOR FM application further suggest the possibility for reduced metal removal required to eliminate rail surface defects during grinding. This possibility should be investigated during future RCF test initiatives. Improvements to rail surface condition will also enhance ultrasonic inspection quality and potentially reduce the frequency or inconvenience of No Test designations requiring unplanned corrective grinding.

7.4 Control Curve Performance

Control curve surface RCF growth after the initial 8-month TOR FM phase indicated a 68 to 80 percent statistically significant reduction from baseline for both rails. Figure 7 shows the control curve TOR surface RCF growth average. Although this result suggests a possible change in area operating conditions positively influencing test curve TOR performance, control curve data as derived from the measurement sites was not considered representative of general curve condition. Sixteen locations containing RCF of equal or greater severity compared to baseline were noted adjacent to control curve measurement sites following the project TOR FM phase, with associated RCF growth rates up to 0.594 percent RCF per MGT. This observed consistency in control curve RCF development between trial phases, combined with uniform area operating conditions during this project (i.e., similar tonnage, no speed changes, etc.), indicates test curve RCF reductions are solely due to TOR FM application.

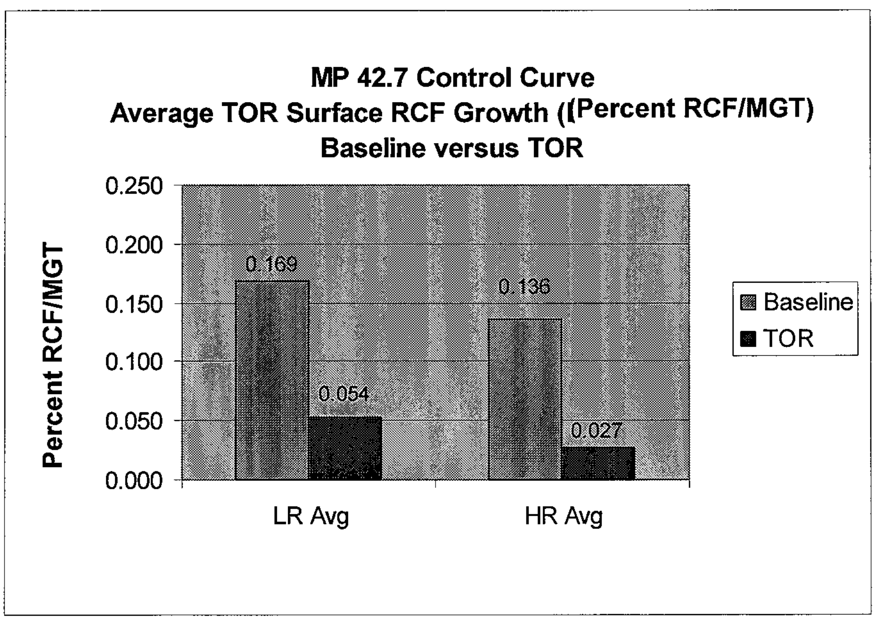


Figure 7. Control Curve Average TOR Surface RCF Growth (Percent RCF/MGT)

8.0 Application System Adjustments

8.1 Gage Face Lubrication

The control curve received no direct gage face lubrication, as the nearest wayside lubricator for eastbound trains was located over 10 miles to the west. A daily short local switcher train was the only regular westbound traffic over this curve. Any westbound train on Main track 2 would pass a gage face lubricator at MP 39.9 (about 2.8 miles away). During the test period, control curve gage face friction varied from dry (0.5 μ) to an occasional indication of lower friction in the 0.3 μ range. The source of lubrication causing these occasional low readings was not determined.

The test curve (MP 39.6) received direct gage face lubrication from all eastbound trains passing the same lubricator located at MP 39.9, less than a half mile away. Periodic inspection of the test curve indicated a more uniform and lower friction level compared to data recorded for the control curve. During early periods of the TOR FM phase, conditions of insufficient gage face lubrication as well as excess lubrication on top of both rails at the applicator site were observed. Because the gage face lubricator at this location was in process of being upgraded to a current version unit, a number of changes and modifications were implemented during the early stages of the program. These included adjustments and modifications to the lubricator system, components, and output rates, as well as relocating the applicator bars approximately 30 feet to avoid severely worn rail inhibiting optimized grease transfer.

Adjustments to the gage face lubricator were made based on friction measurements and rail inspections conducted on the test curve and on rails at and immediately next to the wayside applicator site. A summary of the gage face lubricator upgrades follows:

- 3/21/05 Upgraded sensor
- 7/08/05 Reduced pump speed by half (decreasing grease output by half) and decreased wheel count to 18
- 7/15/05 Replaced primary valve. Grease was not proportioning properly
- 7/26/05 Tribometer/rail friction data from test curve indicated improvement but revealed some ongoing contamination
- 8/01/05 Moved unit westward 30 feet to allow applicator bars to be attached to rail in better condition (less metal flow and flattened rail head)
- 8/15/05 Upgraded seals and brushes on applicator bars
- 8/26/05 Upgraded to new mounting brackets (bar lowered on the gage face)
  - Set activation wheel count to 22 wheels, pump speed adjusted to 2 seconds and half speed
- 9/7/05 Tribometer inspection of test curve – Gage face results indicated good lubrication

As the primary goal of this program was to demonstrate and monitor the effect of TOR friction control, the gage face lubricator operation was not included in the test matrix. Field observations and recommendations for adjusting lubricant contamination were provided to the appropriate railroad personnel and subsequent inspections confirmed that gage face lubrication had been properly controlled.

8.2 TOR Applicator System

The test curve was fitted with two TOR systems, one at the east end (TOR No. 1 – MP 39.42) and one at the west end (TOR No. 2 – MP 39.95) The predominate direction of traffic was eastbound. To limit wasting TOR product for eastbound trains passing the eastern TOR applicator, this unit was equipped with a directional detection sensor for application. Only westbound trains would activate the system. The other applicator, located about 300 feet east of the gage face lubricator near MP 39.9, also contained a directional sensor activating for eastbound trains only. For most of the test period the only westbound traffic was a daily local switcher train.

Adjustments to the TOR application systems were made based primarily on visual inspections conducted at the applicator sites. A summary of TOR applicator adjustments and upgrades conducted after the installation (May 3 and 4, 2005) follows:

- 6/23/05 Both TOR units activated to commence post-grind TOR application trial phase. Application rate for duration of TOR phase = 0.45 seconds every 20 axles (0.15 gals/1,000 axles).
- 9/7/05 TOR units inspected. No major concerns noted.
- 10/26/05 TOR units inspected. SW applicator bar for TOR No. 1 noted to be broken from passing equipment. No impact to KELTRACK application quality. SW bar removed from service the same day, replacement ordered. Reconfigured hose valves for three bar operation. No adverse TOR application expected due to minimal traffic flow in westward direction. No major maintenance concerns noted for TOR #2.
- Mid-Nov 05 Exact date unknown. 2 bars damaged at TOR No. 2 during surfacing and removed from service. Replacement bars shipped to repair previously reported TOR No. 1 damage (1 replacement bar + 1 spare) used to repair higher traffic TOR No. 2 site. TOR No. 1 site had been restored to 4 bar operation for a brief period (< 1 week), but was reduced to 3 bar operation following the TOR No. 2 damage.
- 1/11/06 TOR No. 1 site restored to 4 bar operation. No adverse impacts to trial noted from non-optimized TOR No. 1 hardware configuration, again as this unit is for minimal westbound traffic.
- 1/18/06 TOR units inspected. No major concerns noted.
- 2/2/06 TOR units inspected. No major concerns noted.

- 4/5/06 Trial TOR application phase terminated. Both TOR units to be run dry of product, cleaned, and placed into storage pending review of possible Phase 2 project activities.

9.0 Rail Wear Results

Although controlling rail wear was not a primary objective of this demonstration, rail profile data was collected to determine if both curves received the same grinding pattern and as backup information should a location exhibit unusual RCF or other cracking problems.

MiniProf™ profile data was analyzed by comparing initial profile shapes for each curve (test and control) with profiles collected during subsequent inspections for each monitoring period (baseline and TOR). With this information, along with knowing the applied tonnage between each measurement cycle, the change in head height (vertical wear) and gage width (gage face wear) could be used to determine wear rates. Figure 8 shows the vertical change in control curve rail height by tonnage for the entire project (in units of mm/MGT for each period).

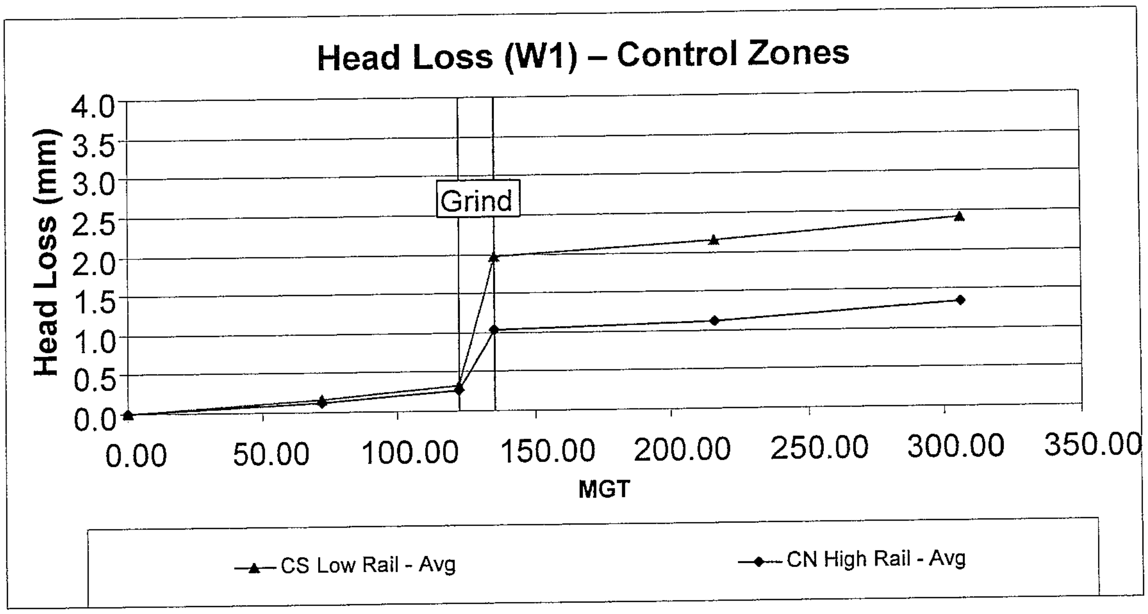


Figure 8. Vertical Head Height Change From Initial (0 MGT) Plotted Against Accumulated MGT for the Control Curve. Low and High Rails Shown Separately

The wear rate for each period can be established by determining the slope of the line for each period of measurement (in the example, as Figure 8 shows, this is: baseline 0 MGT to 101 MGT and TOR FM period is 128 MGT to 285 MGT).

9.1 Vertical Wear Rates

Figure 9 shows the head height wear rates for the baseline and TOR FM periods for the control curve. Figure 10 shows the results for the test curve.

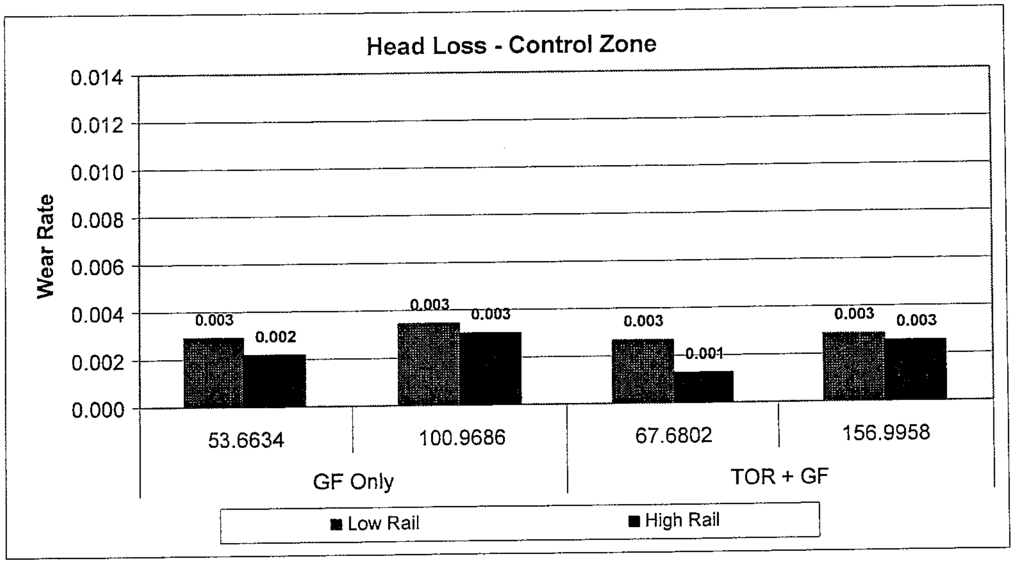


Figure 9. Vertical Head Wear Rates for the Control Curve

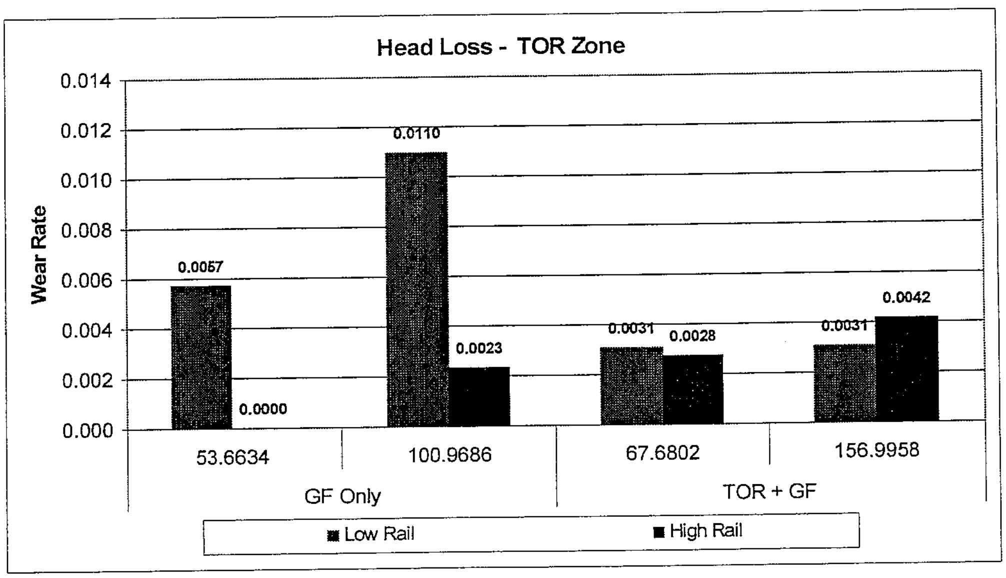


Figure 10. Vertical Head Wear Rates for the Test Curve

Examination of Figures 9 and 10 suggest the following:

- Vertical wear rate on high rail of test curve was almost zero during initial period and very low during full period
- Vertical wear rate of low rail on test curve was lower by factor 67 percent (0.0105 to 0.0035 mm/MGT) during the TOR FM period compared to the baseline period
- Vertical wear rate on high rail of test curve about the same for both periods
- No significant change in vertical wear rate of both rails on control curve between periods
- TOR had largest benefit on low rail wear rate of test curve

9.2 Gage Face Wear

Gage face wear rates were evaluated in a similar fashion as the vertical wear rates, with results summarized in Figures 11 (control curve) and 12 (test curve). W2 represents gage face wear measurement data - W3 is gage corner data. Because of variations in gage face lubrication (as described in Section 8), the gage face wear rates exhibited two distinct rates within the total TOR FM period. This difference did not show in the wear rate data for vertical wear, only the gage face wear. In order to separate the period when the gage face lubrication application system was undergoing upgrades, gage face wear rates are shown as the two measurement periods within the baseline period and the TOR FM period.

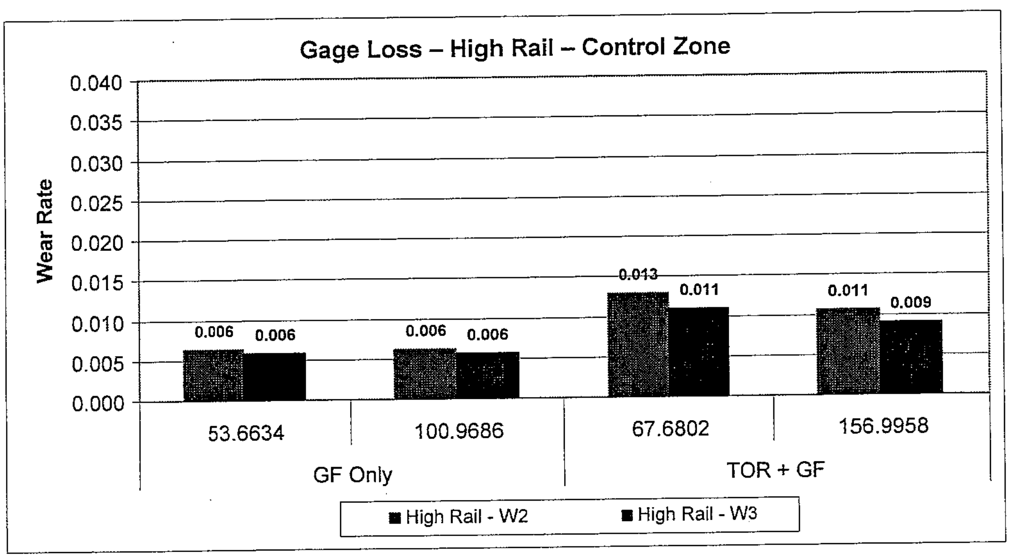


Figure 11. Gage Face Wear Rates for the Control Curve

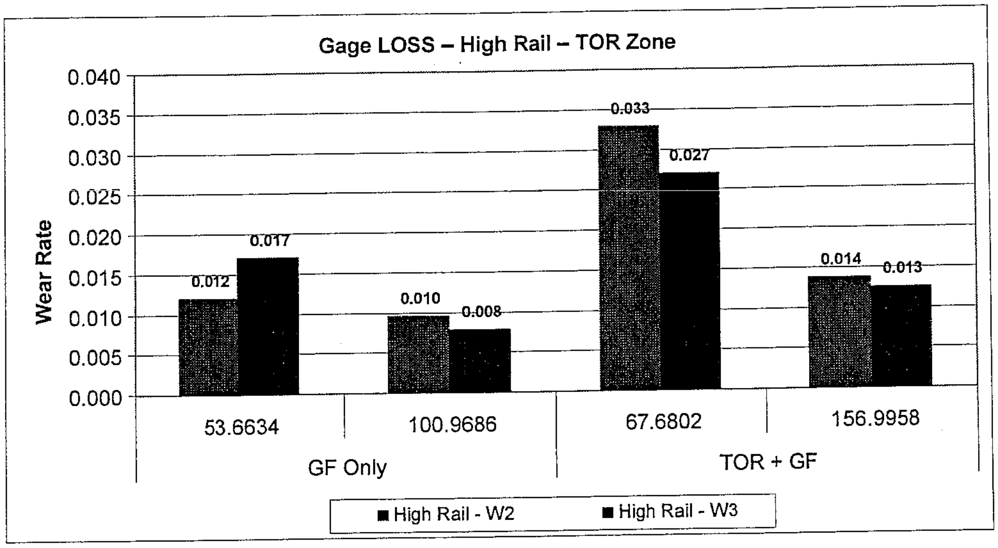


Figure 12. Gage Face Wear Rates for the Test Curve

Figures 11 and 12 show the most significant difference in wear occurred in the first TOR FM phase measurement period for the test curve. Therefore, the first 68 MGT will be higher due to variable gage face lubrication.

Results from examining Figures 11 and 12 suggest:

- Test curve wear rates are higher than the control curve, likely due to the sharper test curve geometry (4^0 20' versus 2^0 01').
- Gage face wear rates during TOR FM period were higher than during the baseline period at both curves (control and test curve)
- Gage face wear for the test curve improved during the second half of the TOR FM period
  - Suggests improvements/upgrades in gage face lubrication were successful
  - Gage face wear rate during last half of test similar to that during baseline period
- Data suggests TOR had little or no effect on gage face wear rates
  - Variations in lubrication overpower effect of TOR on gage face wear

10.0 Conclusions

- TOR FM application has successfully reduced RCF growth (Percent RCF/MGT) in a proof-of-concept single test curve operating environment.
- A statistically significant 79 percent reduction in test curve low rail surface RCF (spalling/shelling) was achieved.
- High rail results were variable. Field reports indicated non-optimized and variable gage face lubrication during the TOR FM phase. High rail surface RCF growth was significantly lower compared to low rail growth rates by a minimum factor of eight.
- Test curve rail surface condition following TOR FM application permitted a 25 percent extension of the historical area grinding cycle from 8 months to 10 months.
- While practical issues, such as localized differences in rail type, age and curvature, were encountered in obtaining valid control curve measurements, simultaneous monitoring and observation of this curve suggests that test curve RCF reductions were due to TOR FM application.
- TOR FM reduced vertical/rail head wear rates primarily on the low rail of the curve.
- Changes in gage face lubrication appear to dominate gage face wear rates, with measurements showing little or no measurable influence of TOR on gage face wear rates.

11.0 Future Investigations – Next Steps

As intended, this was a test conducted as a proof-of-concept over a limited length of track utilizing only two curves. One major grinding cycle for baseline and TOR FM performance was monitored but direct comparison between the two curves to evaluate TOR FM benefits is not viable due to differences in curvature, rail type, rail age, and train speeds. A more comprehensive evaluation with a longer test zone and additional TOR FM application units is suggested with the following items and controls to consider:

- Implement a multi-unit trial over a larger problem RCF zone with more curves to improve data quality and statistical significance of results
- Gage face lubrication should remain constant at each test curve or group of test curves during the monitoring process
- Quantify the economic benefits of reduced metal removal or time extensions for existing grinding cycles using TOR technology
- Determine TOR FM coverage range capability (i.e., track miles) to produce effective RCF reductions
- Further investigate the benefits of TOR FM application in reducing rail surface cracks and spalls that may inhibit ultrasonic rail inspection quality and processes

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Acronyms

DP	Dye penetrant
FM	Friction modifier
HR	High Rail
LR	Low Rail
MGT	Million gross tons
MP	Mile post
RCF	Rolling contact fatigue
TOR	Top of rail
UP	Union Pacific