

The work described in this document was performed by Transportation Technology Center, Inc.,
a wholly owned subsidiary of the Association of American Railroads.

Improvement of Effectiveness and Efficiency of Rail Grinding

- A Rail Grinding Trial on a Norfolk Southern Railroad Line

By Huimin Wu, Stephen Woody,* Robert Blank,* and Benjamin Madrill

Summary

Transportation Technology Center, Inc. (TTCI), Pueblo, Colorado, a wholly owned subsidiary of the Association of American Railroads and Norfolk Southern (NS) conducted a rail grinding trial on the curves of a NS heavy haul line in 2004. Through the grinding trial, TTCI and NS demonstrated that rail grinding can be more effectively and efficiently performed by using wheel/rail profile contact assessment tools and pre-grinding inspections.

Rail grinding has been commonly accepted as an important rail maintenance procedure. It can be used as a method to reduce the growth of fatigue cracks and the number of broken rails, which in turn improves operational safety and extends rail life. Effectiveness and efficiency are two key aspects in rail grinding. Effectiveness is the measure of how well the ground profile balances wheel and rail contact conditions with vehicle performance and surface defect removal. Efficiency is measured by the grinding cost of reaching grinding goals, which relates to grinding frequency, the number of grinding passes, and amount of metal removal.

The rail grinding trial was conducted on curves with radius of 873 to 249 meters (2 to 7 degrees) on the NS TC line, close to Kingsport, Tennessee. This rail grinding trial used the wheel/rail contact assessment tool WRTOL™ developed by TTCI. A representative population of wheelset profiles measured on the vehicles operated on the trial line contacting with both designed ground templates and measured rail profiles. The results from WRTOL™ revealed that the existing low rail contact pattern caused concentrated contact at the rail shoulder for both leading and trailing wheels resulting in rolling contact fatigue (RCF) and plastic flow of the rail steels. TTCI designed a low rail grinding template that intends to distribute the contact around rail crown region to reduce contact stress and RCF.

The trial has demonstrated that conducting pre-grinding inspections can reduce the cost of grinding by reducing the number of passes required and can improve grinding accuracy by properly setting the stone patterns. This trial has also shown the need for an automated on-board wheel/rail contact assessment system to assist the pre-grinding inspection and in the prioritization of grinding needs. TTCI is now developing such a system.

The NS rail grinding trial is ongoing. Optimum solutions are being continually investigated.

*Norfolk Southern



Please contact **Huimin Wu (719) 584-0533** with questions or concerns regarding this *Technology Digest*. E-mail: Huimin_Wu@tci.aar.com.



INTRODUCTION

Rail grinding is commonly accepted as an important maintenance procedure for rails. Studies and practices have confirmed that rail grinding can reduce the growth of fatigue cracks and the number of broken rails, which in turn improves operational safety and extends rail life.

Rail grinding is generally performed to:

- Remove rail corrugations along the track in the longitudinal direction to reduce dynamic impact on the vehicle/track system
- Remove surface defects, such as head checks and spalls, and to reduce the likelihood of rail catastrophic failure, while improving the accuracy of ultrasonic inspection for rail flaws
- Restore transverse rail shape to improve wheel/rail interaction

Effectiveness and efficiency are two key aspects in grinding. Effectiveness is the measure of how well the ground profiles balance wheel and rail contact and contact stresses with vehicle curving performance and high-speed lateral stability. It is also the measure of how effectively the surface defects are removed. Efficiency is measured by the grinding cost related to grinding frequency and amount of metal removed. Optimum rail grinding should reach grinding objectives with a minimum of metal removal, grinding passes, and grinding cycles.

Three indicators of the cost of rail grinding are the grinding interval, the metal removal rate, and the number of grinding passes. However the total cost of rail life and rail grinding is ultimately related to wheel/rail interaction. Reducing rolling contact fatigue (RCF) and wheel/rail wear though improved wheel/rail interaction will increase the grinding interval and reduce the metal removal amount, which in turn extends rail life and reduces maintenance cost.

A grinding trial was conducted on curves with radius between 873 to 249 meters (2 to 7 degrees) on a Norfolk Southern (NS) line in 2004¹. This trial demonstrated that improved effectiveness and efficiency of rail grinding can be achieved by:

- Properly designing ground rail profiles based on the shapes of passing wheels
- Conducting pre-grinding inspections to determine the stone patterns and number of passes
- Monitoring the changes in wheel/rail contact position and surface condition to determine the need for grinding

RAIL GRINDING TRIAL

This grinding trial emphasized curve grinding to improve vehicle curving performance and reduce rail wear and rail surface RCF. Six curves on a heavy haul service line (TC line) of NS close to Kingsport, Tennessee, were selected as the grinding trial observation sites.

Three curves had newly-laid high rails (132 RE, installed in 2003) and worn low rails (installed between 1985 and 1998). The other three curves had worn rails that were installed between 1985 and 1986 on both high and low rails. The traffic on this line is between 40 to 45 MGT per year and consists primarily of 100-ton cars with some merchandise traffic consisting of tank cars and covered hopper cars.

Design of Ground Rail Profiles

When designing rail profiles, consideration has been given to the contact conditions of a representative population of wheels from service. One hundred and twenty two wheelsets were measured on vehicles operated on the trial line. A wheel/rail contact assessment tool, named WRTOL™ developed by TTCI, was used to assess wheel/rail contact conditions at the grinding sites. It has the ability to analyze contact situations of many wheelsets against a pair of rails. Therefore, the target ground rails could be designed to have the optimum compatibility with those wheels.

The WRTOL™ results (Figure 1) provide the distributions of both contact positions and contact stress of measured wheels contacting with the recommended ground rail profile pair. The wheelset lateral shift range used for the leading wheels was 0 to 22 mm (0 to 0.197 inches, which accounts for the possible contact conditions from the beginning of the spiral to the body of the curve. The contact positions on the high rail gradually move from the rail crown region to the gage corner region as wheels on the high rail begin flanging, while contact is generally around the rail's crown section on the low rail.

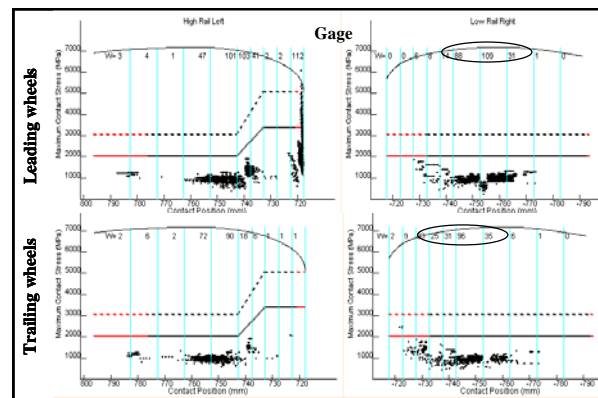


Figure 1. WRTOL™ Leading and Trailing Wheels Results

Trailing wheels generally have less lateral shift than leading wheels. Under ideal conditions, trailing wheelsets will yaw to match the radii of the curves. Therefore, the lateral shift range used in Figure 1 for the trailing wheels was from -5 to +5 mm (-0.016 to 0.016 inches) to show the likely contact conditions of trailing wheels with some lateral movement. Contacts for the trailing wheels on both high and low rails were around the crown area. The contact patterns shown in Figure 1 should lead to distributed wear and lower local contact stress concentrations.

Rail Grinding Observations and Issues High Rails after Grinding

Because the high rail grinding template selected was close to the natural worn shapes of passing wheels that give desirable contact features, grinding of the high rail was mainly for surface defect removal. Only a thin layer of metal was removed and the shape was basically maintained – about 85 percent of the gaps between the wheel and rail formed after grinding were less than 0.45 mm (Figure 2). Conformal contact would be soon reached as wheels and rails wear.

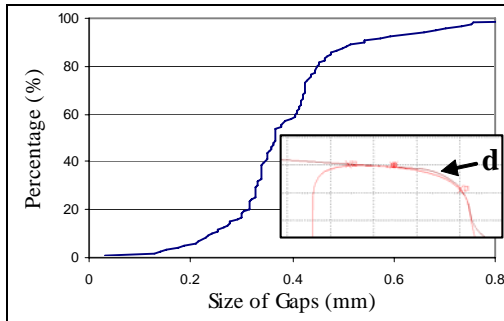


Figure 2. Gap (d) Distribution after Rail Grinding

Low Rails after Grinding

Most of the concerns in the trial were related to grinding of the low rail. Figure 3 shows the contact condition on the low rail measured on a curve of 249 meters in radius (7 degrees). Due to a flat rail head the majority of wheels contact the low rail significantly toward the field side. This increases the risk of rollover and produces high contact stresses.

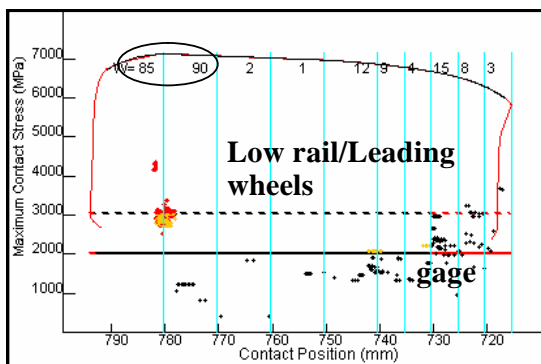


Figure 3. Low Rail Contact Positions before First Grinding

This curve was ground using an existing low rail template in October 2003. Figure 4 compares the TTCI designed ground low rail and the existing low rail grinding pattern. A high gage shoulder on the low rail can lead to contact concentration on the shoulder of the rail from both leading and trailing wheels. The TTCI designed ground low rail shape intends to distribute the contact positions of the wheels around the low rail crown area.

Figure 5 displays the contact conditions for a low rail with a high gage shoulder in a curve of 546 meters in radius (3.2 degrees). Both leading and trailing wheels had concentrating contacts on the gage shoulder region indicated by the large number of wheels contacting in that region.

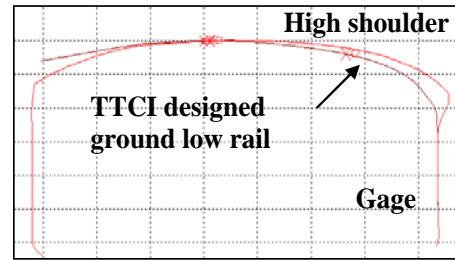


Figure 4. TTCI Designed Ground Low Rail with a Lower Rail Shoulder

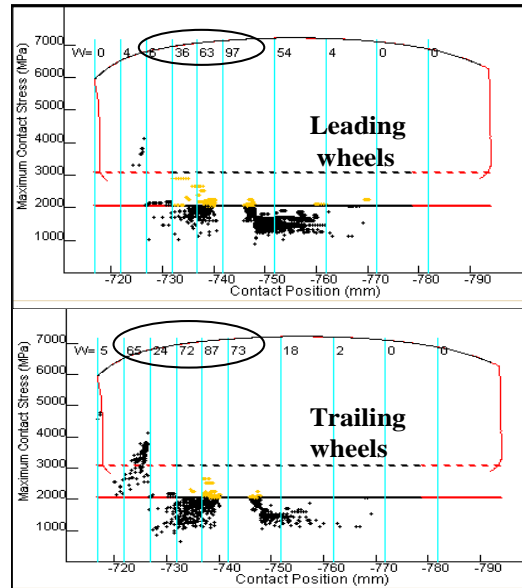


Figure 5. Contact Positions were Concentrated in Rail Shoulder Region of Low Rail (gage at left)

Figure 6 is a photo taken at this section of rail 6 months after grinding (using original template). Visual inspection showed that the contact pattern was concentrated on the gage shoulder as predicted by WRTOL™ analysis. Severe rolling contact fatigue was observed. Also a lip was formed at the gage corner indicating considerable plastic flow of the rail material.

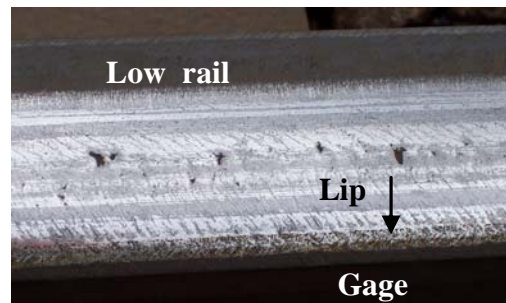


Figure 6. RCF due to Concentrated Contact in Rail Shoulder Region

Figure 7 and Figure 8 show the low rail wear and a photo taken on a curve of 249 meters in radius (7 degrees) after 6 months of grinding using the TTCI designed template. Instead of having concentrated contact to induce RCF at the rail shoulder and to form a plastic flow lip at gage corner (as

occurred 6 months ago before grinding), the contact and wear was relatively even on the rail crown region.

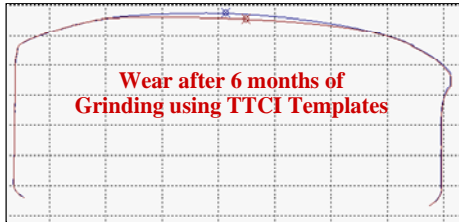


Figure 7. Low Rail Wear after 6 Months of Grinding



Figure 8. Low Rail Contact Region Shifted from Rail Shoulder to Crown Region

Grinding the field side of the low rail has become a common practice to reduce the risk of rail roll over and high contact stresses caused by hollow worn wheels. However, over-cutting the field side of the low rail can lead to unnecessary metal loss and more plastic flow on the rail crown due to the weakened support. In addition, the contact location on the low rail shifts further toward the gage shoulder, leading to fatigue damage.

PRE-GRINDING INSPECTION

Rail grinding can be expensive if it is not properly planned or the grinding patterns are not chosen properly. Large rail grinders (like the Loram 88 stone grinder used in this grinding trial) are generally used for rail grinding in North American heavy haul service. The cost can reach \$20,000 daily. Therefore, the grinding capacity of grinder should be fully utilized. In current practice, the first pass of grinding on curves is often used mainly to inspect the current rail shape. A test performed on one curve proved that better accuracy of grinding with one pass could be achieved by performing pre-grinding inspection and pre-design of the stone patterns. Note that one-pass grinding can only be achieved under the condition of no significant shape alternation.

This grinding trial has shown the need for an automated on-board wheel/rail contact assessment system to perform wheel/rail contact monitoring and to assist pre-grinding inspection. This system should have the functions of 1) high accuracy rail profile measurement, 2) contact conditions assessment, and 3) decision making capability to determine grinding needs.

Based on the assessment results and the observations of the surface conditions, recommendations can be made for the ground rail shapes, the stone patterns, and number of passes. TTCI is now developing such a system (Figure 9). In the system that TTCI is developing, the main assessment criteria include:

- Low rail contact position
- High rail/wheel maximum contact angle
- Contact stress index
- Conformality of high rail/wheel profiles
- Effective conicity on tangent track
- Rolling radius difference on curves

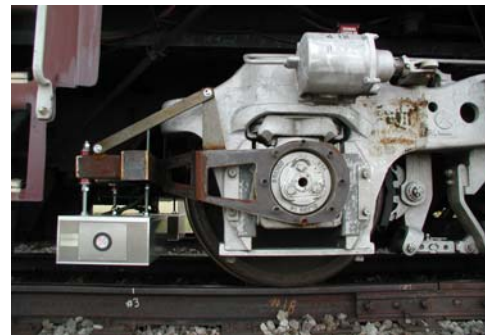


Figure 9. TTCI Wheel/Rail Contact Assessment System

CONCLUSIONS

- Effectiveness and efficiency are two key aspects in rail grinding.
- The ground rail profile for curves should consider the contact conditions of both leading and trailing wheels to control wheel/rail contact patterns with less potential for RCF.
- Analysis of rail profiles contacting a large population of representative wheels can give a comprehensive insight into wheel/rail contact conditions.
- The test conducted in this grinding trial demonstrated that better accuracy of grinding and fewer passes could be achieved by performing pre-grinding inspection.
- There is a need for a machine vision inspection system that can assess wheel/rail contact condition in a real-time fashion and assist in decisions related to grinding need and desired ground rail profiles.

FUTURE WORK

The NS trial is ongoing. The next stage of the rail grinding trial will emphasize improving grinding efficiency. A rail grinding cost assessment will be studied by combining the grinding frequency, amount of metal removed, and number of grinding passes for optimal cost benefit.

REFERENCE

1. H. Wu, S. Woody, and R. Blank, "Optimization of Rail Grinding on a North American Heavy Haul Railroad Line," Proceedings of the 8th International Heavy Haul Railway Conference, Rio, Brazil, June 2005.

Visit our website at <http://www.ttc1.aar.com>