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Wheel/Rail Contact Inspection on a Norfolk Southern Route

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Summary

Transportation Technology Center, Inc. (TTCI) has further developed the automated wheel/rail contact inspection (WRCI) system under the Association of American Railroads' Strategic Research Initiatives Program in 2007. Three new functions have been added into the WRCI system in 2007: wheel/rail contact defect priority reports, grinding analyses, and wear analyses.

The system has been successfully used for WRCIs on revenue service lines on a Norfolk Southern (NS) route from Louisville, Kentucky, to Chattanooga, Tennessee, in 2007.

Exception reports and wheel and rail contact defect priority reports for all inspected tracks were provided to NS after the inspection. The reports indicated that the rail profiles are compatible with the wheels measured on the NS cars in most track sections. The WRCI system did, however, identify a few sections that showed high contact stress between rails and wheels on nonflanging wheelsets, higher conicity (above 0.25) and severe two-point contact. TTCI recommended grinding patterns for worn rails in some track sections, using the new grinding analysis tool. Rails in several sections have been worn to the level close to or exceeding the wear limit. Rail replacement in those sections may be needed.



INTRODUCTION AND OBJECTIVES

TTCI has developed an automated WRCI system under the Association of American Railroads’ Strategic Research Initiatives Program. This system performs real-time assessments of wheel/rail contact conditions using rail profiles measured by the system and pre-collected wheel profiles taken from cars operating on the lines being inspected. Track curvature, wheel loads, and track gage are taken into account in the assessment. Likely effects of wheel/rail contact on vehicle performance are then predicted based on the assessment results.

The WRCI system has proved to be a useful tool to assist railroads in monitoring rail profiles and rail wear, assessing wheel/rail contact conditions, inspecting rail grinding quality, and identifying potential problems. Inspection results can be the basis to determine the need and/or priority of rail maintenance.

Three new functions were added into the WRCI system in 2007. They are wheel/rail contact (WRC) defect priority reports, grinding analysis, and wear analysis, as Figure 1 shows.

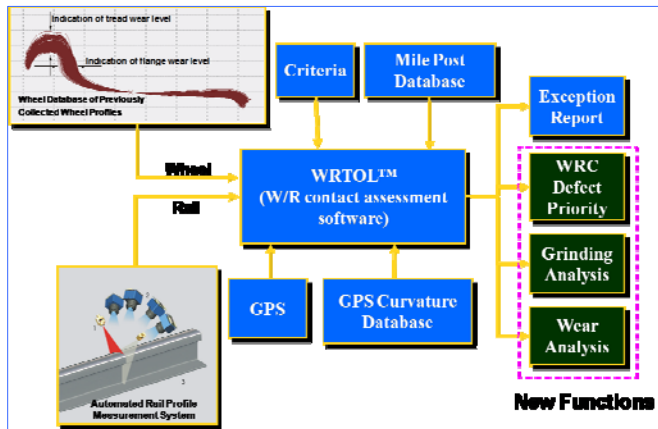


Figure 1. WRCI System

TTCI conducted tests on revenue service lines to further test the WRCI system and its new functions in 2007. The inspection described here was on a NS route from Louisville, Kentucky, to Chattanooga, Tennessee (about 400 miles, Figure 2).

These tests not only evaluated the WRCI system, but also provided a track condition inspection for NS. After the inspection, exception reports and WRC defect priority reports for all inspected tracks were provided to NS. TTCI recommended grinding patterns for worn rails in some track sections, using the new grinding analysis tool.



Figure 2. Inspection Route

The inspection was made to study wheel/rail contact conditions on the route, to determine if the rail shapes contributed to the rail defects that were reported by the railroad’s rail defect inspection car, and to recommend rail grinding patterns.

Rail inspection results are reported using exception reports and the new WRC defect priority reports generated by the WRCI system. The exception reports identify the rail sections where more than 30 percent of wheels in the wheel database, when contacting with the measured rail profiles, exceed pre-defined contact criteria for a distance of at least 100 feet. The WRC defect priority reports further emphasize the rail sections that require maintenance, as Table 1 shows. The contact conditions that have larger effects on vehicle performance or wear/RCF are given a higher WRC defect priority.

Table 1. WRC Defect Priorities

Parameter	WRC Defect Priority
Low rail contact position	1
Effective conicity	2
Max high rail contact angle	3
Conformality – high rail	4
Contact stress index	5
Distance exceeding = 0.1 mile/mile	

Assessment of Contact Parameters

The assessment of wheel and rail contact conditions is performed using the rail profiles measured on the route and a wheel database. The wheel database used on this inspection consisted of 212 wheel profiles previously measured on NS cars that frequently travel along this route.

The assessment of contact parameters includes:

- Maximum wheel/rail contact angle (CA),
- Contact positions on the low rail of curves (CP),
- High wheel/rail contact conformity on curves (CC),
- Rolling radius difference of leading (Frrd) and trailing axles (Nrrd) on curves,
- Effective conicity (Cnct) on tangent tracks
- Contact stress indices on left/right wheels on leading and nonflanging wheelsets (HR, LR, RN and LN)

The definitions of these parameters are discussed in detail in AAR research report R-981.¹

Summary of Exception Report

Table 2 provides an overview of the rail profile conditions. It summarizes the track length on which parameters exceeded the given criterion, 100 feet, on the three routes. L, D and O represent Louisville, Danville and Oakdale, and 1 and 2 main lines 1 and 2, respectively, in the table.

Table 2. Summary of Exception Reports

Section	CA	CP	CC	Frrd	Nrrd	Cnct	HR	LR	RN	LN
L-D (1)	0.10	0.58	0.67	0.04	0.04	4.08	3.81	0.19	8.29	6.12
D-O (2)	0.04	0.17	2.23	0.00	0.00	1.38	2.63	0.03	11.32	7.99
O-D (1)	0.04	0.10	0.66	0.00	0.05	3.72	2.12	0.00	7.63	5.49

In summary, the exception reports indicate that there are a small percentage of tracks that continually exceed the given criteria in the three assessed track sections. Relatively higher percentages of exceptions were noted for contact stress for the nonflanging wheels (RN and LN). These were possibly caused by contact toward the rail gage or shoulder. Also some sections of tangent track produced higher conicity values.

WRC Defect Priority Report

WRC defect priority reports for severity indices 1 to 4 is provided for the inspections on the three routes. These defect levels have a direct influence on vehicle performance and safety. Note that the defect reporting distance applied in this report is 0.1 mile/mile — 0.1 mile is about five times longer than the 100-foot criterion used in the exception reports. However, no continuing conditions of exceptions are required as is the case with the exception report. Table 3 summarizes the defect priority reports on the three routes between Louisville to Oakdale. Note that a length of the tracks under any one of the severity levels indicates that there was at least 0.1 mile (or higher) that exceeded the specified criterion in every mile of the length of track.

Table 3. Summary of the Severity Reports

Section	1	2	3	4
L-D (1)	2.83	26.48	0	2.41
D-O (2)	0.30	6.20	0.90	11.65
O-D (1)	2.77	33.92	0.72	3.98

In summary, rails in many tangent sections from Louisville to Danville (Track 1: MP 272–MP 360) and from Oakdale to Danville (Track 1: MP 253–MP 116) produced higher conicity (above 0.25) when contacting with the wheels in the database (refer to Appendix B in reference 1). Due to the limiting speed of 50 mph in these zones, vehicle hunting may not be a concern. Rails on some curves from Danville to Oakdale (Track 2: MP 119–MP 255) may produce severe two-point contact as indicated by the gap between high rail gage corner and the wheel flange throat exceeding 0.5 millimeter.

Recommended Rail Grinding Patterns

The WCRI system also provides recommended rail grinding patterns, which are based on the average deviation of rail profiles measured in a curve or tangent section from the grinding templates.

For a track segment, the total metal removal of all measured rail profiles is computed. An average metal removal of the track segment is then calculated and expressed in Figure 3. A table of average metal cuts of all rails at different angles is

shown under the plots. The angles are user definable. (The table is the basis to determine grinding patterns.)

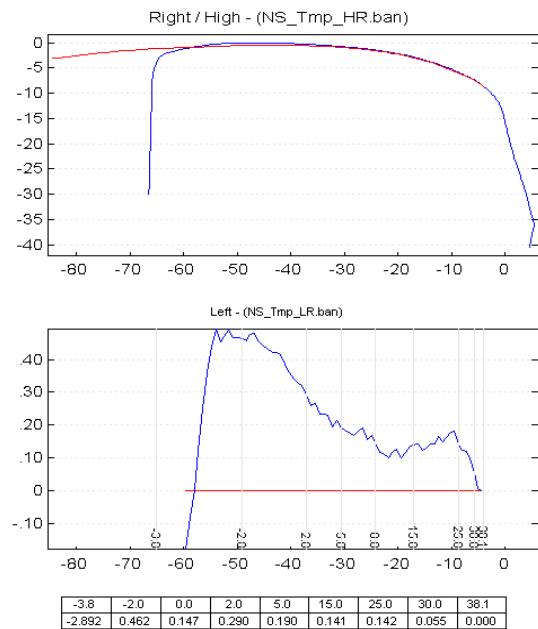


Figure 3. Average Metal Removal for the Segment

Based on grinding analysis on two sections from MP 167.5 to MP 177.5 and from MP 226.5 to MP 234.3 between Danville to Oakdale, the grinding patterns are recommended by the WCRI system for these tangents and curves. Grinding pattern 31 is recommended for the high rails in most curves.

NS provided their planned grinding patterns for the same sections of track. These two groups of grinding patterns proposed by NS and TTCI were independently determined based on different inspection techniques. Although the pattern numbers are different for some track sections between these two groups, the patterns proposed by NS and TTCI have similar features when the pattern shapes are carefully compared. The patterns proposed by TTCI are more detailed in the grinding ranges (denoted by the angles) and the metal removal positions.

Rail Wear

The WCRI's laser rail profile measurement system now provides the difference between a measured rail profile and an unworn rail profile. The data can be used to perform wear analysis.

The NS rail wear limit is 7/16 inch when measured from rail top and 8/16 inch when measured from gage side for 132-pound/yard rail. The inspected lines are primarily 132-pound/yard rail. Some short sections are 136- and 141-pound/yard rail; however, they are relatively new and present no concern relative to exceeding the wear limits.

Figure 4 shows an example of wear data output from the WCRI system. In the plot for the right rail (relative to the moving direction), both rail top and gage wear relative to the new rail shape are displayed. Depending on the curve direction, the right rail can be either the high rail or the low rail

of the curve. For example, on the 5-degree curve at MP 251, the right rail is the high rail of the curve with about 0.4 inch gage loss and 0.2 inch head loss.

This type of plot can provide the railroad with a quick view of rail wear along their routes. It can also be used over time to develop a rail replacement maintenance plan.

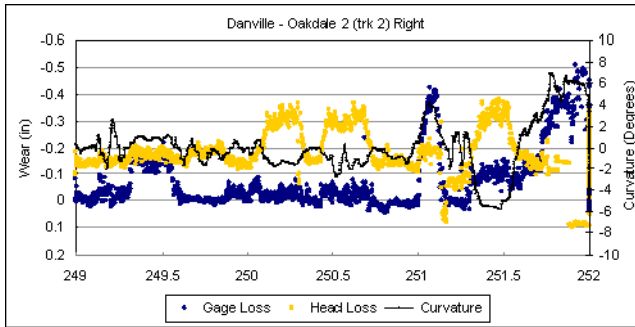


Figure 4. Example of Rail Wear Results Output from the WRCI System

Summary of Wheel/Rail Contact Inspection

- The WRCI system has been successfully used for wheel/rail contact condition inspections on revenue service lines.
- Reports producing defect priorities, grinding and wear analyses have been developed for the WRCI system.
- In the inspection on NS track, the rail profiles inspected are compatible with the wheels measured on the NS cars with some sections of rail indicating higher conicity and severe two-point contact that can be corrected by controlling grinding quality.
- The rails in several sections have been worn to the level close to or exceeding the wear limit. Rail replacement in those sections may be needed.
- TTCI recommended grinding patterns have similar features with the NS planned patterns with more detail in the grinding range (denoted by the angles) and the metal removal positions. A new Pattern 31 is suggested.

COMPARISON OF LASER SYSTEMS FOR FUTURE IMPLEMENTATION OF THE WRCI SYSTEM

As part of the strategy for implementing automated wheel/rail contact assessment techniques on the track geometry cars, data from other rail measurement systems are being investigated. A few pairs of rail profiles collected by NS’s track geometry vehicle were analyzed. NS and other railroads currently use a different rail profile measurement system than the WRCI system. A comparison was performed to assess measurement range, profile smoothness, and measurement accuracy:

Measurement range: The NS laser data produced the whole rail image. The railhead shape is formed by about 300–350 data points. This is comparable to the output of the WRCI laser system.

Profile smoothness: It has been noticed that the rail profiles measured by the NS laser system show some surface roughness on the railhead. The profile fitting function in the WRCI program can smooth out some of the roughness. TTCI is still in the process of determining if this will be a problem.

Measurement accuracy: Figure 5 compares the rail profiles measured with the WRCI laser system and the NS laser system. The profiles were tracked by GPS and mile post data. They may not be the rail profiles at the exact same position on the track, but they should be within a few feet of each other. In general, the profiles measured by the NS laser system (shown with rougher surface conditions in the figure) are similar in shape to those measured by the WRCI laser system.

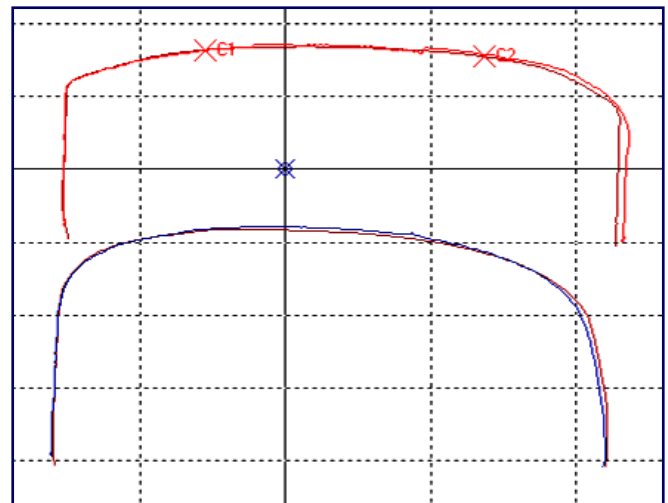


Figure 5. Comparison of Rail Profiles Measured by the WRCI and NS Laser Systems

Summary of the NS Laser Measurement Analysis

- The railhead profile measurement range of the NS and WRCI systems are similar.
- There are sufficient points to form the railhead.
- The profiles generally agree to those measured by the WRCI laser system but with some discrepancy.
- It is likely that the WRCI system can be implemented using the NS laser system. Therefore, TTCI is continuing to analyze data from NS to ensure the systems produce reliable wheel/rail contact information.

REFERENCE

1. Hou, Keping et al. November 2006. “Wheel/Rail Contact Inspection System Development and Validation,” Research Report R-981, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colo.