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Wheel/Rail Contact Inspection of a Revenue Service Line

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Summary

Transportation Technology Center, Inc. has developed a wheel/rail contact inspection (WRCI) system under the auspices of the Association of American Railroads' Strategic Research Initiatives Program. This system performs real-time assessment of wheel/rail contact conditions using rail profiles measured by the system and pre-collected wheel profiles from trains that normally travel over the same route. This system will be used to improve wheel/rail contact conditions, reduce wheel/rail wear and rolling contact fatigue, extend wheel/rail lives through controlling and managing wheel and rail profiles, and improve vehicle performances.

Track curvature, wheel loads, and track gage are all taken into account in the assessment. Likely effects of wheel/rail contact on vehicle performance are predicted based on the assessment results. The WRCI system will 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 and solutions.

The WRCI system has undergone static and dynamic (in-motion) testing at the Transportation Technology Center, Pueblo, Colorado. The first revenue service track tests were performed in March and April, 2006, on the BNSF and Union Pacific lines from Pueblo to Denver. The test successfully detected the undesired wheel/rail contact conditions due to poor wheel/rail contact conditions.

An exception report is produced by the WRCI system after an inspection. This digest lists all track sections where the wheel/rail contact condition exceeds predetermined threshold levels continually over a specified distance along the track. Recommendations for track maintenance are provided based on conditions detected.

All designed functions of the WRCI system have been achieved. Future work includes improvement of the software and hardware to increase the speed of inspection while performing real-time data analysis and refinement of the criteria to predict contact conditions. The final stage is to implement this technology on existing track geometry cars.

INTRODUCTION

Transportation Technology Center, Inc. (TTCI) has developed a WRCI system under the Association of American Railroads' Strategic Research Initiatives Program. This system performs a real-time assessment of wheel/rail contact conditions using rail profiles measured by the system and pre-collected wheel profiles. This system will be used to improve vehicle performance and to reduce wheel/rail wear contact. Likely effects of wheel/rail contact on vehicle performance are predicted based on the assessment results. This system can currently produce real-time assessment at speeds up to 40 mph with a 10-foot measurement interval. If higher speeds are necessary, data can be collected at speeds exceeding 70 mph by bypassing the real-time processing. The data can then be processed later. Faster computers and processors would also help increase the speed of real-time inspection.

The WRCI system will 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.

The first revenue service tests of the WRCI system were performed on the line between Pueblo and Denver, Colorado, in March and April, 2006. Rail grinding was performed on this line between the two tests.

Wheel/Rail Contact Inspection System

Figure 1 shows the structure of the WRCI system, consisting of two lasers and four cameras, to measure rail profiles and the wheel/rail contact analysis process to evaluate the wheel/rail contact conditions. The rail profile measurement system can also measure track gage and vertical rail wear at the railhead.

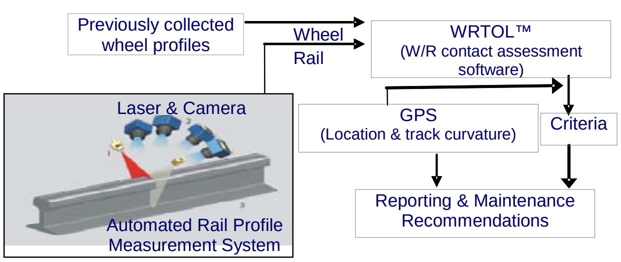


Figure 1. WRCI System

The wheel/rail contact assessment is performed with WRTOL™ software developed by TTCI. Each measured pair of rail profiles is analyzed against a large group of pre-collected wheel profiles stored in a database. The wheel database is structured with a number of wheel profiles, which were randomly collected on trains passing the line being inspected. The randomly selected wheel profiles represent common wheel shape distributions.

The WRTOL™ program computes the following contact parameters:[1]

- measurement number
- GPS coordinates
- track curvature
- milepost
- track gage
- speed of the train
- maximum contact angle
- rolling radius difference/slope/conicity
- contact position

An exceedance threshold level (ETL) and a contact intensity threshold (CIT) are designed for assessing the contact parameters. Both ETL and CIT are user defined thresholds (see AAR research report R-981 for more details).

TEST RESULTS

The wheelset database used in the test contains 360 wheel profiles. These wheel profiles were measured, using MiniProf™ at the UP yard in Pueblo, Colorado, on randomly selected cars in three trains that operate on the BNSF/UP line between Denver and Pueblo, Colorado.

Test results collected in the two test trips were saved in databases. In this section, the results from the post-grinding trip in April are displayed. Figure 2 shows the results for the track between MP 52 and MP 60.

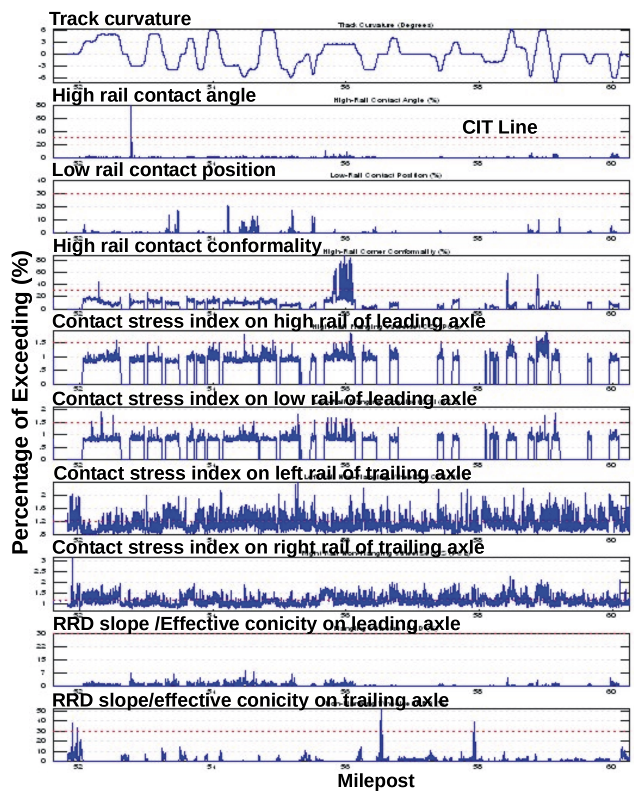
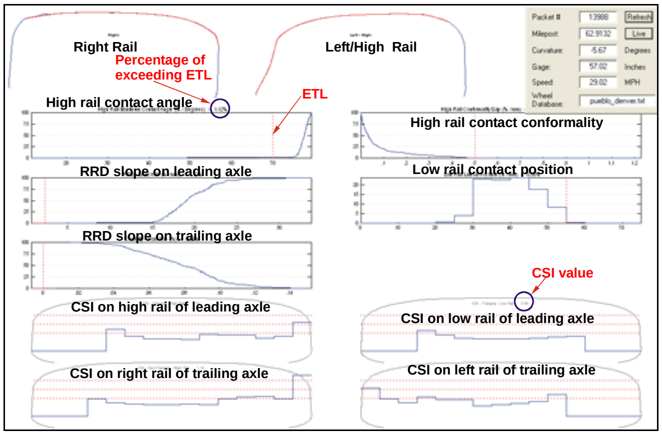


Figure 2. Historical Parameter Display from MP 52 to MP 60

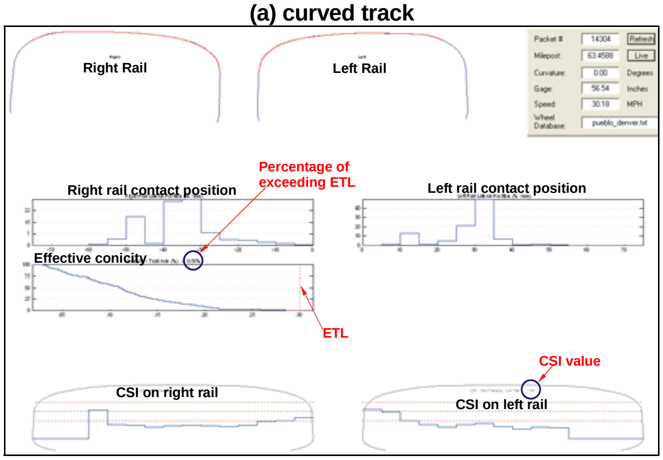
Figure 3 shows examples of assessment results for measured rail profiles on both curved and tangent track. The measured rail profiles and the track location are shown at the top of the display window. The contact conditions are displayed in terms of percentage exceedances — the percentages of wheels in the wheel database that exceed the ETL of those specific parameters when they contact with the measured rail profiles.

The exception reporting thresholds of ETL and CIT are marked with dashed lines and are shown for each assessed parameter in the display windows (in reference to Figure 3, see page 4 for an explanation of CSI).

Table 1 lists values of the ETL and the CIT with two severity levels that were used in this test. Additional severity levels can be designated by the user. Different recommended remedies are provided for different severity levels.



(a) curved track



(b) tangent track

Figure 3. Display Windows of Assessment Results for Single Pair of Measured Rail Profile on Curved and Tangent Tracks

Table 1. Test Criteria of ETL and CIT

Parameter	ETL	CIT	
		Sev. 1	Sev. 2
Maximum contact angle	<70 deg.	30%	15%
Contact position – low rail	>55 mm	30%	15%
Conformality – high rail	>0.5 mm	30%	15%
RRD – flanging wheelset	Ref [1]	30%	15%
RRD slope – non-flanging	< 0	30%	15%
Effective Conicity–Tangent	> 0.30	30%	15%
CSI– flanging wheel		>1.5	>1.5
CSI– non-flanging wheel		>1.2	>1.2
Minimum reportable track length >100 feet			

Maximum Contact Angle

The maximum contact angle is the angle of the tangent line to the horizontal line at the flange contact position. There is an increased risk of flange climb derailment if the contact angle is less than the ETL. Figure 2 shows that almost all of the pre-collected wheelsets have maximum contact angles higher than 70 degrees on the track between MP 52 and MP 60.

Conformality

Wheel/rail contact conformality is defined as the maximum gap between the wheel flange root and the rail gage, and it is a measure of steering performance of the wheelset in curves. Conformality below the ETL can improve the steering performance. Figure 2 shows the contact conformality measured on the track from MP 52 to MP 60. Most of the percentages of exceedances of conformality are below 30 percent, except the track around MP 55.8.

Rail and wheel wear eventually reshapes wheel and rail profiles to conform to each other. Rail profiles are modified with rail grinding. Conformality may become worse if the grinding template is inappropriately designed. Figure 4 shows rail profiles measured before and after rail grinding at a selected truck location. The percentage of gaps in the measured rail profiles increases from 17 percent (before grinding) to 20 percent (after grinding).

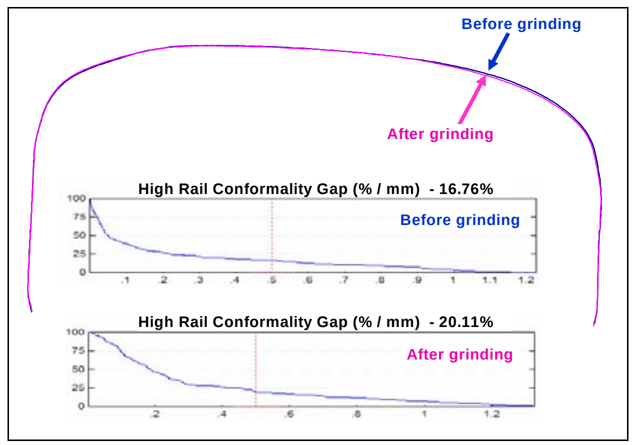


Figure 4. Profiles and Conformality Distributions Measured by Before and After Grinding

Contact Position

The wheel/rail contact position is the distance from the contact point to the rail gage and can be used to predict the risk of rail rollover. The closer the contact point is to the field side of the rail, the higher the risk of rail rollover. Figure 2 shows that exceedance percentages of contact positions on the track segment between MP 52 and MP 60 are lower than 30 percent. The measurement was conducted after the rail grinding. However, the contact position distributions on the same track before grinding were different from those after grinding. Figure 5 shows that the low-rail profile was worn to a flat top. This resulted in movement of contact towards the field side of the rail. About 35 percent of contact positions was beyond the ETL. Rail grinding corrected the low rail contact position problem by removing metal on the field side of the low rail and moving the contact positions back to the crown of the rail. The percentage of the exceedance in contact positions is reduced from 35 percent before grinding to below 1 percent after grinding. The WRCI system provided the assessment, which indicated the risk before grinding and then showed the improvement after grinding.

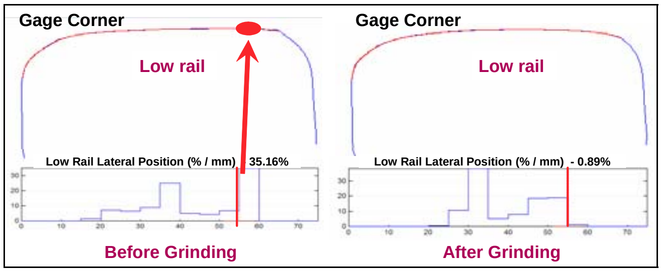


Figure 5. Low Rail Profiles and Contact Positions Measured Before and After Grinding

Rolling Radius Difference

Rolling radius difference (RRD) is an important factor affecting steering of the wheelsets and is the major influence in creating the lateral cracks of rolling contact fatigue (RCF). Figure 2 displays the percentage exceedance of RRD for the leading axles and trailing axles in curves, and the effective conicity of wheels measured on tangent track. The exceedances of RRD, RRD slopes, and conicities are generally less than the CIT (30%) for measured rail profiles on the track from MP 52 to MP 60. Only a few locations on tangent tracks reached over 30 percent of exceedance.

Contact Stress Index

Contact Stress Index (CSI) is a measure of the likelihood of RCF. Figure 2 shows a history display of the CSI for the wheels of the leading and trailing axles. The contact stress indices are generally lower than the criterion of 1.5 for the leading wheels on curves. However, many trailing wheels on curves have CSI higher than the criterion of 1.2. This means that the contact is more likely toward the gage or shoulder side. Rail grinding should move the contact back to the crown center and alleviate this situation.

Exception Report

An exception of an assessed parameter indicates that there are continuous undesired rail shapes in that section of track. Table 2 shows examples of the exception reports produced from the tests on March 24 and April 12, 2006, from Denver to Pueblo.

Comparing parameters measured before and after grinding, in Table 2, the exceedances of the contact positions on low rails observed before grinding were all corrected by the grinding operation. High rail contact conformality exceeding the CIT was reported after grinding, indicating the grinding increased the gap at the rail gage corner.

APPLICATIONS OF THE SYSTEM

This WRCI system is expected to assist railroads in monitoring their wheel/rail contact conditions, rail profiles, and rail wear by inspecting the wheel/rail contact conditions. It has the capability to identify potential problems before grinding and to monitor the rail grinding quality. Based on the inspection results, the need and/or priority of rail maintenance can be determined.

CONCLUSIONS

- The automated WRCI system has been developed for the measurement of rail profiles and real-time wheel/rail contact assessment to predict the likely performance of vehicles as influenced by wheel/rail profiles.
- Many contact parameters can be assessed by the WRCI system.
- Applying this system can increase the assessment effectiveness and improve the efficiency of wheel/rail contact conditions.
- At this stage, all designed functions of the WRCI system have been achieved.
- The operating speed is proportional to the measurement interval.
- The first service line test conducted successfully detected the undesired wheel/rail contact conditions due to poor rail shapes

FUTURE WORK

- Further increase the speed of inspection by improving software and increasing the number of processors
- Include tractive force into the system, based on the contact conditions inspected, to more accurately predict the formation of RCF
- Include the RCF risk prediction index into the assessment and exception report
- Further refine the recommended assessment criteria of ETL and CIT through more service line tests

REFERENCES

1. Hou, Keping, et al. November 2006. “Wheel/Rail Contact Inspection System Development and Validation.” Research Report R-981, AAR, TTCI, Pueblo, CO.

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Table 2. Exception Report Example Before and After Rail Grinding

TRACK				PARAMETERS								
From MP	To MP	Curvature Deg.	Gage inch	Contact Angle	Contact Position	HR Conformity	NF RRD	Flanging RRD Slope	HR-LA CSI	LR-LA CSI	RR-LA CSI	LR-TA CSI
Before rail grinding												
53.428	53.502	-4.07	56.9		×							
53.788	53.887	-2.63	56.8		×							
After rail grinding												
53.346	53.519	-4.02	56.9									×
53.624	53.648	2.07	56.8			×						