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Initial Fitness for Service Evaluation of an Automated Cracked Wheel Detector

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Summary

Transportation Technology Center, Inc. (TTCI), in cooperation with Federal Railroad Administration (FRA), performed a rigorous testing program to evaluate the suitability of the gage widened special trackwork for an automated cracked wheel detector (ACWD) system from China. TTCI assessed the trackwork for derailment risk considering wheel drop and back-of-flange climb derailments. TTCI measured the lateral and vertical stiffness of the track and ran trains over the track to demonstrate fitness for service performance. TTCI also performed a tolerance analysis to verify acceptability of the special trackwork for all AAR freight car wheels. Testing in all cases showed satisfactory vehicle performance and no undue derailment risk.

- Dynamic tests up to 23 mph demonstrated the stability of the train and of the track. The dynamic test indicated no performance issues with the special trackwork.
- The risk of wheel drop derailment due to gage spreading was very low for the nominal condition tested. NUCARS®* will analyze additional configurations, such as narrow wheels and chamfered wheels.
- The special trackwork has a vertical stiffness on the order of 1 million pounds per inch and a lateral stiffness near one half million pounds per inch.
- Instrumented wheelset testing indicated safe dynamic vehicle performance and no excessive loads.

Static load testing was performed with the Track Loading Vehicle. TTCI measured dynamic loads with an instrumented wheelset (IWS). The IWS data will be used later for validating a NUCARS model. The NUCARS model will be used to predict vehicle and track interaction in regimes that were not practical for testing in track. The NUCARS analysis will determine the maintenance and tolerance limits required to assure ongoing safety of the special trackwork and will be reported separately.

*NUCARS® is a registered trademark of Transportation Technology Center, Inc., Pueblo, CO

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INTRODUCTION

In the early 2000s, ultrasonic automated cracked wheel detection was developed for the North American railroad network. This technology has since seen very limited application in revenue service. Mechanical complexity with high maintenance, remote in-yard location, and the resulting low throughput capacity have limited the application of this technology, and thus limited the availability of its benefit. Railroads are demanding higher capacity systems that can be placed on or near mainline service so they can economically monitor a greater percentage of wheels. The Chinese ACWD system is currently used in China for inspecting locomotive wheels at speeds of approximately 5 mph. The system installed at the Transportation Technology Center (TTC) has upgraded special trackwork that is intended for inspection speeds up to 20 mph. This testing program is to validate the safety of this special trackwork.

BACKGROUND

Special trackwork is required on any ultrasonic wheel inspection system designed for use on a moving train. The special trackwork exposes the tread so the ultrasonic probes can contact the wheel. Common trackwork designs are flange bearing or wide gage.

The ACWD system from China contrasts with the North American cracked wheel detector in that the wheel tracks an array of ultrasonic probes rather than having the probes robotically track the wheels. It is used in China for inspecting locomotive wheels at low speeds, approximately 5 mph. The speed limitation is largely due to the track design. In order for the sensors to contact the wheel tread, the rail gage spacing is opened beyond allowable FRA Track Safety standards limits. The wheels ride on the outer edge of the tread while rigid guardrails keep the axles centered to prevent wheel drop derailment. Before installation of the Chinese system, TTCI and Progress Rail updated the track design using North American components.

The new ACWD system uses a track gage of 61.50 inches. This will require a waiver from the FRA Track Safety Standards. Figure 1 shows the gage widened section. Guardrails are used to prevent wheel drop and derailment. The guardrails butt up to the backs of the wheels and keep the axles centered on the track while the wheels ride on the outer edge of the tread.

Figure 1. Gage Widened Section with Guardrail and Expanded Flangeway Clearance for Holding Ultrasonic Probes

Derailment concerns arise from the potential for wheel drop, gage spreading derailment, and from back-of-wheel climb on the guardrails. Testing and analysis were performed to assure that typical variations in wheels, including tread width, profile, and back-to-back spacing will not lead to a potential derailment. In addition, the lateral stiffness of the track must be great enough to keep the rails and guardrails from spreading when under load. Finally, the dynamic response of train cars on the gage widened segment must be acceptable.

METHODOLOGY

The special trackwork validation is approached using both testing and modeling/analysis. Testing demonstrates the adequacy of the special trackwork in the nominal condition. It also provides measurements for use in validating numerical models. The forthcoming numerical modeling will include NUCARS® analysis. NUCARS analysis is useful for verifying configurations that are not practical for testing in track. This approach should assure safety in all wheel and track conditions that fall within Association of American Railroads (AAR) specifications.[1]

The testing began with a static load test and culminated with dynamic running at speeds 15 percent above the intended inspection speed. The static load test measured deflections. The Track Loading Vehicle (TLV) was used to provide lateral load inputs. Test measurements included stiffness and displacements at critical locations. The TLV was not capable of loading the track at the midsection of the test segment, because the guardrails were in the way.

Dynamic test runs were made at increasing speeds to demonstrate the stability of the track. An instrumented wheelset car was also used to measure dynamic loads and to provide a baseline for validating the NUCARS models.

RESULTS

Wheel Spacing, Tread Width, and Flangeway Clearance

This first step assures that the design of the special trackwork is suitable for all train cars within AAR specifications. For interchange service, wheel back-to-back spacing and tread width range are set according to AAR standards for wheels and axles.[1] The gage and flangeway clearance limits of the special trackwork must be set to accommodate the entire range of expected wheels. In the as-new wear condition and with a standard railhead profile, the wheels engage the top of rail squarely. Figure 2 shows how a nominal wheel gage fits the test segment track.

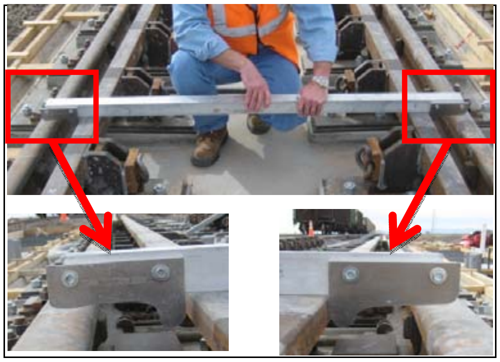
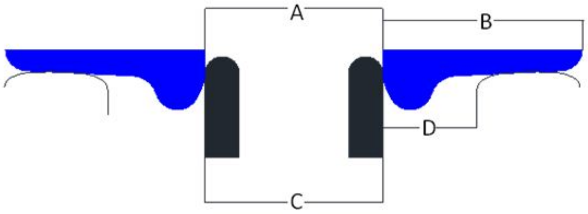


Figure 2. Wheel Gage Fit to the Test Segment

Tolerance variations for wheel width and spacing will change the amount of engagement between the wheel tread and the rail. The entire range of spacing was tabulated in a spreadsheet to determine the extremes. Figure 3 depicts the dimensions of concern for the tolerance study.



A = Wheel back-to-back spacing
B = Wheel width
C = Guard Face Gage
D = Flangeway

Figure 3. Wheel and Rail Parameters for the Tolerance Study

The worst-case combination can occur with AAR standard wheel of cylindrical tread contour for narrow flange wheels – minimum with chamfer, at maximum back-to-back spacing, minimum gage rail spacing, and maximum flangeway clearance. The engagement value in this case, amount that D is less than B, is 0.375 inch. This minimal engagement occurs only with the chamfered narrow flange wheel. It is the amount of tread on the rail before the start of the chamfer when the back of the wheel is against the guardrail. Moving the guardrails to maximum spacing results in 0.437-inch engagement, which is the second worst condition. All other combinations have at least 0.625-inch engagement of the tread. Most have more than 1 inch and range up to 3.8 inches. The adequacy of this minimal value will be determined with NUCARS analysis.

Wheel Profile

Wear will affect the engagement of the wheel. Figure 4 shows how a wheel of the TLV engages the special trackwork.

Figure 4. TLV Wheel on the Track: Back-of-flange Spacing is the Same on the Other Side

In this nominal condition, the wheel engages near the edge of the rail, but is still on a nearly horizontal plane. No substantial gage spreading forces are expected in this condition. Worn wheel profiles will be analyzed using NUCARS modeling and will be reported separately.

Rail Profile

The testing done here is with new rail profile. As the railhead wears, the engagement between the wheel and rail will change. A worn rail profile could have a more profound effect on gage spreading forces. These effects will be studied in the NUCARS analysis of the special trackwork and will be reported separately. Additionally, NUCARS analysis can help determine if it is beneficial to prescribe a unique railhead profile to increase engagement or improve tracking.

Chamfered Locomotive Wheels

Locomotive wheels in North America have a chamfer on the edge of the tread. This chamfer reduces the effective width of the wheelset and increases the risk of a gage widening derailment. Locomotive wheels are generally wider than freight car wheels, so the worst case for locomotive wheels in good condition should be better than the chamfered narrow freight car wheel. To ensure safety of the initial test train consist, the wheels for each test locomotive were measured. All three locomotives measured very close to nominal and performed safely on the ACWD special trackwork.

Track Stiffness

Rail lateral and vertical stiffness measurements are needed for modeling. Standard measurements with the TLV revealed the stiffness at the points of interest. Both vertical and lateral stiffness are very high, as would be expected. Figure 5 shows the stiffness measurements in kilopounds per inch (kip/in) at each location. Due to guardrail interference with the TLV loading mechanism, no measurements were taken at the test midsection. Because of construction similarities, vertical and lateral stiffness at the midsection should be similar to the values measured before and after the transition.

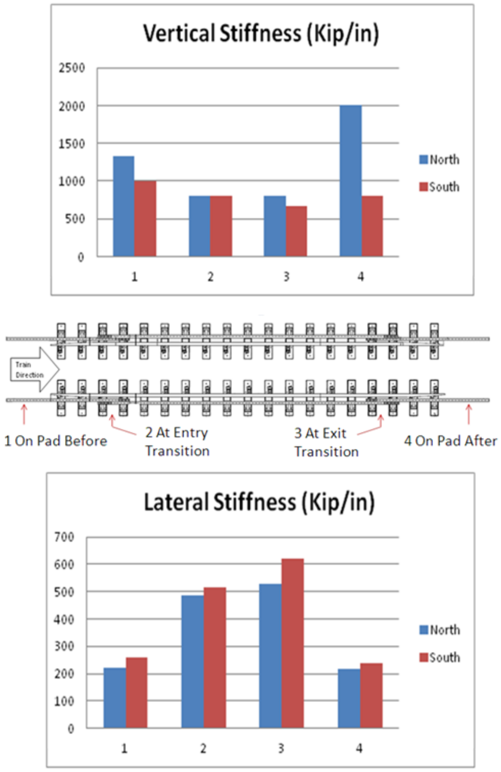


Figure 5. Lateral and Vertical Stiffness Measurements at Various Locations

Track Displacements

The lateral stiffness of the special trackwork is very high. Lateral deflection at the top of the rail measured just over 1/16 inch under an 18-kip load from the TLV. Consequently, the risk of wheel drop derailment due to gage spreading is very low unless there are abnormal lateral loads. All lateral loads observed during the testing were less than 7 kips. The NUCARS modeling will be used to predict lateral loads and gage spreading with alternate wheel and rail profiles.

The vertical stiffness values are on the order of 1 million pounds per inch where the rail is continuous and around ¾ million pounds per inch at the bolted transitions. This track will provide a stable platform for the ultrasonic sensors.

Instrumented Wheelset Testing

TTCI ran a loaded test car with instrumented wheelsets through the special trackwork at 5–23 mph. Vertical and lateral loads were monitored and used to compute the L/V ratio, which is an indicator of potential wheel climb derailment. Table 1 shows a summary of these runs. The loads from the gage widened trackwork are not substantially different than those from a turnout.

Table 1. Instrumented Wheelset Results

Speed (mph)	Minimum Vertical Load (kips)	Maximum Lateral Load (kips)	Maximum L/V Ratio
5	28.48	6.20	0.17
5	27.72	5.56	0.15
5	27.69	5.66	0.15
10	27.83	5.78	0.16
10	27.94	5.53	0.16
10	27.80	5.38	0.15
15	26.52	5.89	0.15
15	26.97	5.40	0.14
15	28.25	6.54	0.16
21	27.71	5.34	0.15
21	27.08	6.74	0.17
21	27.14	6.35	0.16
23	27.51	5.67	0.14
23	27.43	5.28	0.14

Minimum vertical load represents the dynamic unloading. A minimum vertical load of zero indicates wheel lift and suggests imminent derailment. For safety, this value should always be above 10 percent of the static axle load. The minimum vertical load values trend downward slightly as speed increases, but all vertical loads stay well above the threshold even at the maximum test speed. There is no unusual vertical unloading in the track segment.

Depending on car type and load state, a critical state may be reached. A critical state is a speed where a vehicle resonant mode (such as vertical bounce) is excited, which could cause wheel unloading. Although vertical resonance is unlikely at the intended test speeds, NUCARS analysis can be used to investigate this possibility.

The L/V ratio is another indicator of potential derailment. When the lateral load exceeds the vertical load on a given wheel, which is when the L/V ratio is above 1.0, then wheel climb is a concern. In all cases, the maximum L/V ratio is very low, thus wheel climb is not suggested.

Overall, the instrumented wheelset testing indicates safe dynamic vehicle performance in the configuration tested. NUCARS analysis will be used to verify safe operation in other scenarios.

CONCLUSION

TTCI performed a rigorous testing program to evaluate the suitability of the gage widened special trackwork for the Chinese ACWD system. On the basis of the nominal guardrail spacing and flangeway clearance, the worst-case combination of wheel width and wheel back-to-back spacing results in a 0.375-inch engagement of the tread. This was for wheels meeting AAR specifications.[1] The test train tested up to 23 mph and saw no performance issues with the special trackwork. This testing validated the performance of the special trackwork at speeds exceeding the maximum test speed of 20 mph. Both vertical unloading and lateral loading were minimal. There was no indication of flange climb derailment. With high track stiffness and low lateral loads, there was no indication of wheel drop derailment for wheels meeting AAR specifications.

FUTURE WORK

A NUCARS modeling effort is ongoing to validate scenarios outside of nominal conditions that were not practical for testing in track. The NUCARS analysis will address the wheel contact stresses and establish acceptable wear limits.

ACKNOWLEDGEMENT

Progress Rail Services of Albertville, AL, provided invaluable assistance with the design of the special trackwork.

References

1. Association of American Railroads. 2013. *Manual of Standards and Recommended Practices.* Section G “Wheels and Axles.” Washington, DC.