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Comparison of Reverse Rail Cant Measurements

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Summary

Transportation Technology Center, Inc. measured the reverse rail cant under revenue service trains at three curves to provide comparisons between maximum values in-service and values reported by track geometry (TG) cars.

Reverse rail cant is managed by different railroads using different techniques. Each railroad configures its TG car differently to measure and report reverse rail cant. One TG car that is configured to measure and report the rail cant at 1-foot intervals produced the closest match with the associated maximum values recorded during the test. This test was conducted on a curve with elastic fasteners and resulted in a maximum test value 0.1 degrees greater than the TG car value.

Another TG car measures and reports the rail cant every 10 feet. In this case, the maximum test value from a curve with 8- by 18-inch tie plates and cut spikes was 1.1 degrees greater than the TG car value. A third TG car measures the rail cant every foot and reports the average value over a moving 19-foot window. This test was conducted on track using curve blocks for the rail restraint and produced a maximum test value of 1.8 degrees greater than the TG car value. Review of the foot-by-foot nonaveraged TG car data for this site reduced the difference between the test value and the TG car value to 1.1 degrees.

Some of the rail profiles at the test sites showed indication of repetitive wear and grinding in a reverse canted position. If the nominal cant is restored, heavy grinding is advisable to relieve the field side of the profile and avoid severe two-point contact that can cause poor curving performance and reduce the margin of safety for rail rollover.

This work was conducted as part of the Association of American Railroads Strategic Research Initiatives Programs with direction from an industry Technical Advisory Group. Test sites and TG car data were provided by BNSF Railway, CSX Transportation, and Norfolk Southern Railway.

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INTRODUCTION

Transportation Technology Center, Inc. (TTCI) conducted reverse rail cant field tests at three revenue service curve sites to investigate the relationship between the maximum reverse rail cant at a given location when subject to loading conditions of typical trains compared to reverse rail cant values reported by TG cars. Host railroads for this testing were BNSF Railway, CSX Transportation, and Norfolk Southern Railway.

BACKGROUND

Tie plates are typically designed to hold rails at an inward 1:40 cant (1.4 degrees). All references to rail cant angle are relative to this nominal new condition. Rail is considered to have reverse cant if it is rotated toward the field side. The position of the rail in the absence of a train is the static cant and rotation that occurs in the presence of a train is the dynamic cant. Figure 1 shows rail in the nominal cant position.

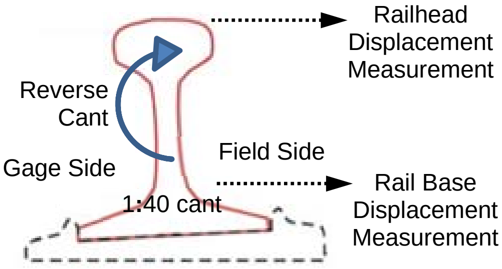

Figure 1: Rail Cant

Reverse rail cant is an issue for several reasons. Extreme amounts of reverse rail cant can lead to a rail rollover derailment or a gage spread derailment. If track maintenance activities, such as regaging or new tie installation, re-establish the nominal rail cant on a curve that previously had reverse rail cant for an extended period of time, undesirable rail profiles can result. The natural wear and rail grinding processes on a rail with reverse cant remove material from the gage corner. When the reverse rail cant is corrected, wheels can contact the field side of the railhead and severe two-point contact occurs on the high rail. This type of wheel-rail contact can cause poor curving performance and low base divided by height values that are indicative of a reduced safety margin for rail rollover.[1]

Railroads have taken precautions to minimize problems with reverse rail cant including better rail restraint methods and measurement of reverse rail cant by TG cars. Railroads measure, analyze, and report reverse rail cant in different ways. Some measure the cant every foot along the track and take a running average over some distance. Others measure the cant at larger intervals and report the individual readings. Some convert the cant into an equivalent track gage increase, and others report the readings in rotational units of degrees. The tests described here were designed to help the railroads understand how the measurements of reverse rail cant reported by their TG cars compare to the maximum reverse rail cant that can occur because of train traffic. Examples of train characteristics that could increase dynamic reverse rail cant include long wheelbase 3-axle locomotive trucks, warped freight trucks, asymmetrically worn wheels, and train speeds above or below the curve balance speed.

Reverse rail cant can be due to a number of reasons including wear at the interfaces between the rail and tie plate, tie plate cutting, tie degradation, and pivoting of the rail out of the tie plate rail seat. To address these causes, railroads have installed a number of different products including curve blocks, tie plates with a larger footprint, and elastic fasteners. Each of the three test sites made use of one of these rail restraint methods. Figure 2 shows rail restraints at the test sites. This test was not designed to evaluate the effectiveness of the rail restraint.

Figure 2: Rail Restraint Methods, Left to Right: Curve Blocks, Cut Spikes in 8- by 18-inch Tie Plates, and Elastic Fasteners

TTCI captured Miniprof™ rail profile measurements at each test site and installed a total of eight displacement transducers per test site at the railhead and base on the high and low rails on two crossties spaced approximately 13 feet apart. Static rail cant was estimated from the nonwearing surfaces of the transverse rail profiles. Dynamic rail cant was derived as the inverse tangent of the difference of each railhead and base lateral displacement divided by the vertical distance between each pair of displacement transducers. Figure 1 depicts the railhead and base displacement measurements.

TEST SITES AND RESULTS

Table 1 describes relevant details of the different test sites. All three sites were constructed with timber crossties. The spike pattern at Site A was two diagonal plate spikes and two diagonal rail spikes. Curve blocks were installed on both rails on the gage side at every third tie. For Site B with 8- by 18-inch tie plates, the high rail spike pattern consisted of two diagonal plate spikes, one rail spike on the gage side, and two rail spikes on the field side. The low rail spike pattern consisted of two diagonal plate spikes, two rail spikes on the gage side, and one rail spike on the field side. At Site C, with elastic fasteners, each tie plate was secured with two cut spikes and four screw spikes. The rail grinder visited Site C just days prior to the test and the rail grinder was scheduled to work Site B during the week following the test.

Figure 3 shows an example of the dynamic rail cant measurements at one of the sites. Many of the wheelsets passing the test site produced a peak in the dynamic rail cant due to gage spreading forces. In the example shown, the two peaks in close proximity were caused by the leading and trailing wheelsets from a single freight car truck. This truck was likely warped, resulting in a large angle of attack and high lateral forces for each of the wheelsets. Many of the other notable dynamic rail cant peaks found in the test data occurred under 3-axle locomotive trucks.

Table 1: Test Site Details

Site	Rail Cant Restraint	Curve (degrees)	Superelevation (inches)	Speed Limit (mph)	Balance Speed (mph)	Grade (percent) and Descending Direction	Rail Size (pounds/yard)	Rail Age (years)	Annual Tonnage (MGT)	Lubrication / Top of Rail Friction Modifier (TORFM)	Unloaded Track Gage (inches)	Years Since Last Tie Job	Months Since TG Car	TG Reverse Cant Degrees (High Rail / Low Rail)
A	Curve Blocks	4.0	2.5	40	30	0.1, north	141	5 high 9 low	*	Gage face lube no TORFM	56 7/8	6	3	1 / 3.5
B	Cut Spikes	5.0	3.5	40	32	0.4, east	136	17	60	Gage face lube no TORFM	57 1/8	2.5	3	3 / 1
C	Elastic Fasteners	4.0	1	30	19	1.0, north	141	15	40	Dry	57 1/4	3	4	3.3 / *

*Value not measured or not reported

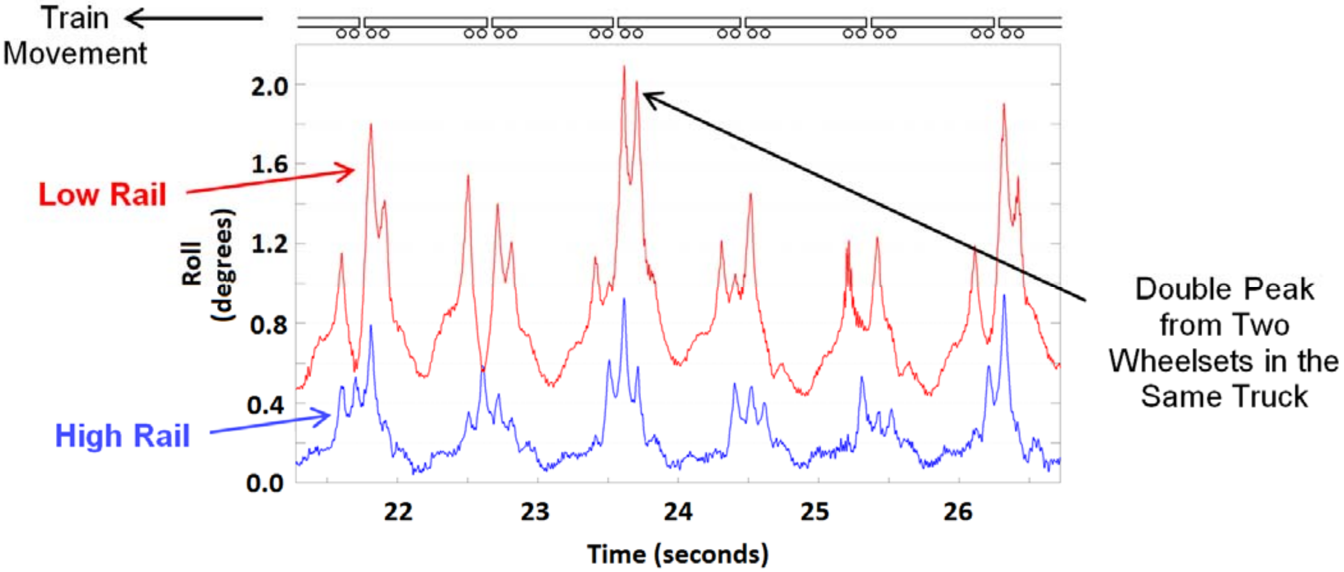

Figure 3: Example Time History of Dynamic Rail Cant Measurements

Table 2 shows the maximum reverse rail cant values recorded per train at each test site. Poor crosstie condition, particularly on the low rail side of the curve, was the primary cause of reverse rail cant at Site A with curve blocks. The curve blocks limited the rail roll relative to the tie plate resulting in more tie plate cutting. The maximum reverse rail cant at this site was generated by a freight car near the head end of a loaded coal train. Maximum values per train on the low rail were consistently near 5 degrees for three of the four trains measured at this site. However, for the first train recorded, the maximum reverse cant was only 1.3 degrees. This apparent discrepancy is most likely due to changes in the rail temperature over the course of the test day. On the low rail of a curve, thermal expansion of the rail acts to roll the rail inward, thus resisting the reverse cant effects of a passing train. The rail temperature was 117°F following the first train in the middle of a summer afternoon. The last three trains passed the site much later in the evening when the rail temperature was between 92°F and 86°F.

The maximum reverse rail cant test values on the low rail at Site A were as much as 1.8 degrees larger than reported by the TG car (5.3 degrees compared to 3.5 degrees). This is not unreasonable when considering some of the differences in how the measurements are made. First, the TG car is a single, well-maintained vehicle that may not produce as much lateral wheel/rail force as the worst-acting vehicles in a freight train. Second, all of the test trains were pulled through the curve far below the balance speed (a condition that can increase lateral wheel-rail forces especially on the low rail), while the TG car may have been traveling at a higher speed. Third, this railroad has configured their TG car to report the average reverse rail cant value over a moving 19-foot window while the test measurements were made at a specific location in the curve that appeared to have the weakest reverse rail cant restraint. Review of the foot-by-foot nonaveraged TG data showed several locations in the curve with as much as 4.2 degrees reverse rail cant, which would be within 1.1 degrees of the maximum value recorded during the test.

The reverse rail cant at Site B (cut spikes restraining the rail on 8- by 18-inch tie plates) was attributed to a combination of several minor factors including tie plate cutting, spike lift, and wear at the rail and tie plate interface. The maximum reverse rail cant per train ranged from 3.5 degrees to 4.1 degrees compared to a reported TG car value of 3 degrees. Train speeds at Site B were consistently above the curve balance speed, and, interestingly, the largest reverse rail cant value was attributed to a locomotive at the head end of an empty coal train. The railroad that hosted this test site has its TG car configured to measure and report the reverse rail cant every 10 feet along the track.

Tie plate cutting was the primary cause for reverse rail cant at Site C with elastic fasteners. The rail appeared to be well seated in the tie plates and held firmly by the elastic fasteners. The maximum reverse rail cant values for 16 trains ranged from 2.8 to 3.4 degrees compared to the TG reported value of 3.3 degrees. Trains were operated over the test site at a range of speeds including underbalance and overbalance conditions. The largest reverse rail cant value was attributed to a locomotive at the head end of manifest train pulling up the grade. At Site C, the TG car for the host railroad measures and reports rail cant at 1 foot intervals along the track.

Table 2: Maximum Reverse Rail Cant per Train

Site	Train Details			Maximum Static + Dynamic Reverse Rail Cant (Degrees)	
	Speed (mph)	Travel Direction	Type	High Rail	Low Rail
A	9	S	Loaded Coal	3.3	1.3
A	15	S	Manifest	2.5	5.1
A	15	S	Loaded Coal	3.2	5.3
A	18	S	Loaded Coal	2.8	4.7
B	37	E	Loaded Coal	3.7	2.6
B	34	E	Loaded Coal	3.7	2.5
B	40	E	Manifest	3.5	2.5
B	40	E	Loaded Coal	3.6	2.4
B	40	W	Manifest	3.8	2.1
B	40	W	Empty Coal	4.1	2.1
B	39	E	Loaded Coal	3.5	2.4
C	15	S	Manifest	3.4	2.1
C	11	S	Loaded Coal	3.3	2.5
C	17	N	Manifest	3.2	2.2
C	22	N	Automotive	3.1	1.9
C	11	S	Loaded Coal	3.0	2.1
C	16	S	Intermodal	3.0	2.2
C	17	S	Intermodal	2.9	2.1
C	17	S	Intermodal	2.9	2.3
C	18	N	Manifest	2.9	1.8
C	21	N	Manifest	3.1	1.8
C	12	N	Manifest	3.1	2.1
C	14	S	Manifest	3.1	2.1
C	17	N	Manifest	2.9	1.9
C	23	S	Intermodal	2.8	1.9
C	26	N	Automotive	2.8	2.0
C	15	S	Automotive	2.9	1.9

Although the railroads involved in this testing use different methods to monitor and report reverse rail cant, each one clearly recognizes the importance of this issue. As expected, the TG car that is configured to measure and report the rail cant at short distance intervals produced the closest match with the test values. In no way does this indicate that rail cant cannot be successfully managed using other measurement and reporting techniques. The data collected during this test allows the railroads to understand how their particular reverse rail cant measurement and reporting method compares to the maximum reverse rail cant generated by typical traffic.

Rail subjected to normal traffic and grinding while in a reverse cant position can develop a transverse profile that produces heavy field side contact when a 1:40 cant is re-established. Figure 4 shows high rail profiles at the three test sites in their static position and with a 1:40 cant re-established. Although these rails differ substantially in head and gage face wear, the shapes of the wearing surfaces overlay quite well in the "as measured" position. However, if the nominal cant is restored, heavy grinding would be advisable to relieve the field side of the profile and avoid severe two-point contact.

Figure 4: High Rail Profiles at the Test Sites

CONCLUSIONS

- The measurement distance intervals and reporting methods of reverse rail cant by TG cars can influence how closely the values reflect the maximum reverse cant produced by typical traffic. The maximum reverse rail cant value recorded under traffic was greater than the TG value by:
  - 1.8 degrees for a TG car that records a measurement every foot and reports the average over a 19-foot window
  - 1.1 degrees for a TG car that records and reports one measurement every 10 feet
  - 0.1 degrees for a TG car that records and reports one measurement every foot
- Some of the rail profiles at the test sites showed indication of repetitive wear and grinding in a reverse canted position that would require attention if a 1:40 cant was re-established.

ACKNOWLEDGEMENT

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