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Update on U.S. Revenue Service Rail Testing

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Key Findings:

- To date, none of the HS or IS rails at the eastern and western revenue service sites have developed internal fatigue defects or shells.
- The high rail of one of the HS rail test curves (MP 348.9) at the eastern test site has shown more wear than the high rail of the second HS rail test curve (MP 349.3) and was removed at 182 MGT. Gage face wear was the biggest contributor to the head area loss for all high rails.
- In the western revenue service site, the HS rails in both test curves have accumulated 909 MGT. The differences in area loss between high and low rails for the respective rail types are more in the curve with only gage face lubrication than the curve with both gage face and top-of-rail lubrication.

Since 2014, TTCI has been conducting rail performance tests at two revenue service sites in the United States. Based on the results from previous testing efforts at the revenue service sites,[1] TTCI, in collaboration with Norfolk Southern Railway (NS) and Union Pacific Railroad (UP), installed test curves at eastern (NS) and western (UP) test sites to: 1) evaluate the latest generation of high strength (HS) rail steels, comparing their performance against that of the previous generation tested, and 2) optimize rail life extension strategies for both HS and intermediate strength (IS) rails. Preliminary results from the 2014–2016 time period were published in a previous *Technology Digest*.[2]

INTRODUCTION

The eastern revenue service site, owned and operated by NS, is located on a major heavy-haul route through the mountains of West Virginia. The track with the test curves carries 45 million gross tons (MGT) of 36-ton axle load traffic per year. Trains operate at speeds between 15 and 35 mph over grades as high as 1.4 percent. The HS test began in 2014 with the installation of rail on the high and low sides of two 11.3-degree curves having gage face (GF) and top-of-rail (TOR) lubrication. One of the curves, milepost (MP) 348.9, has corrective grinding as required (typically once a year), while the other curve, MP 349.3, has preventative grinding one to two times per year. Six manufacturers—British Steel Limited, Liberty Steel France (erstwhile British Steel France), Cleveland-Cliffs Steelton (formerly Arcelor-Mittal Steelton), EVRAZ Rocky Mountain Steel, Nippon Steel, and JFE Steel Corporation—provided rails for the HS rail test. The IS rail test was on a 9.7-degree curve with GF and TOR lubrication and receives preventative grinding twice a year. This test was conducted with rail types from five manufacturers: EVRAZ Rocky Mountain Steel, JSW Steel Italy Piombino (formerly Lucchini), Cleveland-Cliffs Steelton, Steel Dynamics Inc., and Třinecké železárny/Moravia Steel.

The western revenue service site, owned and operated by UP, is in the great plains of western Nebraska on a major heavy-haul coal route. Approximately 122-140 MGT of traffic is accumulated annually with 36-ton axle loads with operating speeds ranging between 40 and 50 mph over flat grades.

A rail test in this revenue service site started with donated HS rails from four manufactuers: Cleveland-Cliffs Steelton, EVRAZ Rocky Mountain Steel, Nippon Steel,and JFE Steel. Both curves are on a preventative grinding schedule at every 60–70 MGT. Table 1 summarizes the railroad, degree of curvature, lubrication, and grinding frequency information for the rail test curves.

Table 1. Railroad, curvature, lubrication, and grinding frequency details in rail tests

Railroad	Curvature	Lubrication	Grinding/ year	Rail Type
NS	11.3°	GF and TOR	1-2	HS
NS	11.3°	GF and TOR	As required	HS
NS	9.7°	GF and TOR	2	IS
UP	2°	Only GF	2	HS
UP	2°	GF and TOR	2	HS

WEAR ANALYSIS

All the rails in the three test curves on the eastern revenue service test site have experienced higher wear than the HS rails tested in the 2005 rail tests.[1] The 2005 rail tests were conducted on shallower curves with GF and TOR lubricators in closer proximity to the test curves. The reduced curvature and effective lubrication in the test curves due to closer proximity of lubricators might have combined to lengthen the life of the test rails in the previous tests.

Each set of rails was tested versus the control type on the corresponding high or low rail using a two-sample t-test. This test is used to determine whether the population means of two independent groups differ and are statistically more or less. Some rail types showed substantial differences from the control, but overall, the results were inconclusive due to low sample size of some types. Figure 1(a–c) indicates the latest status of the area loss of the different rail types on the high and low rails of the three test curves.

For each rail type and the control, the plots show the mean value of the collected data and the 95 percent confidence interval for the mean. Wider confidence intervals, especially seen in Figure 1a, indicate less certainty for where the mean is located due to fewer data points or wider variation in the data.

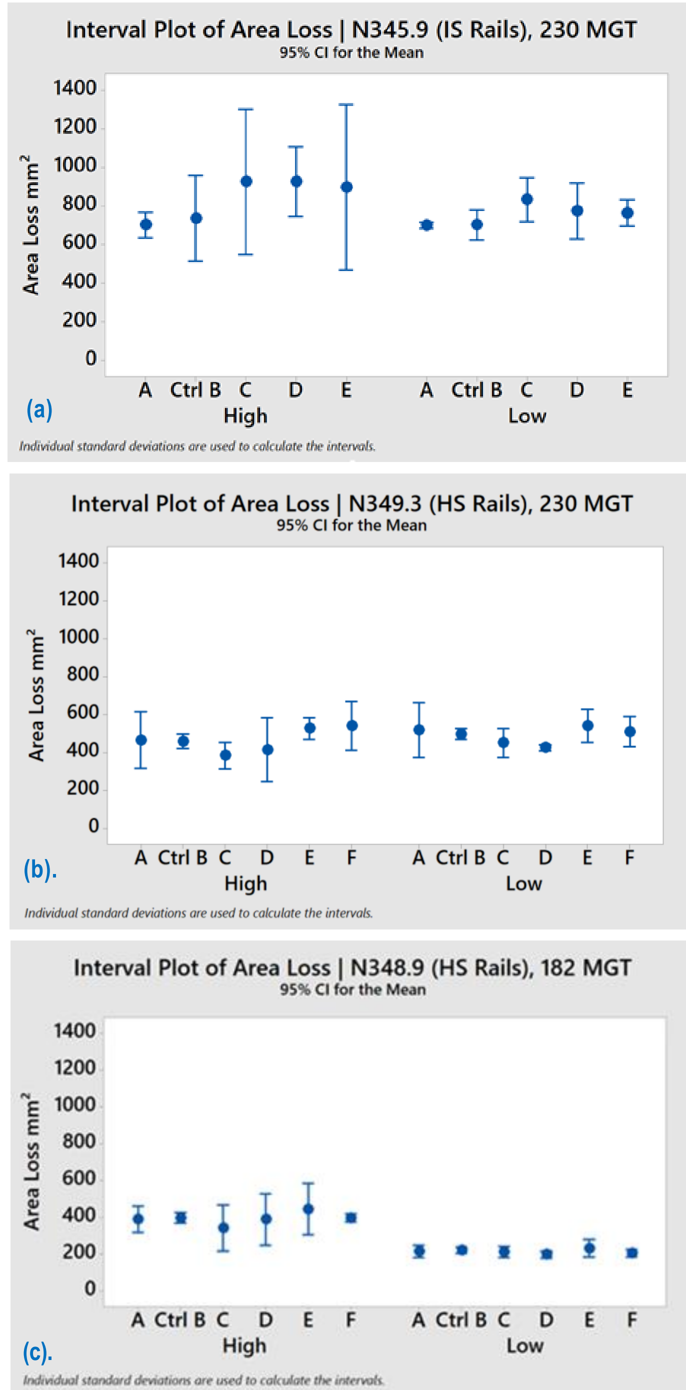

Figure 1. Area loss plots of (a) IS rails in MP 345.9 curve as of 230 MGT, (b) HS rails in MP 349.3 as of 230 MGT, and (c) HS rails at MP 348.9 as of 182 MGT

The HS rail test curves at the western revenue service site are in 2-degree curves with flat grades. The MP 18.3 and MP 19.3 curves are in opposite orientations. Since both curves started receiving preventative grinding at the same intervals every year since 277 MGT (when substantial rolling contact fatigue (RCF) was noted),[1] and both curves have GF lubrication, the difference in operating conditions is mainly the absence of TOR lubrication for the MP 19.3 curve. It should be noted that the GF lubricator is located right before the MP 19.3 curve, and the grease gets carried over to the MP 18.3 curve by the wheels, while the TOR lubricator is located in between the two curves.

A two-sample t-test was conducted for these rails with a similar result as discussed above. Figures 2a and 2b show the area loss interval plots of the MP 18.3 and MP 19.3 curves at 909 MGT. In comparison to the rails at the eastern revenue service site, these have less wear, so the test is expected to continue for a few more years.

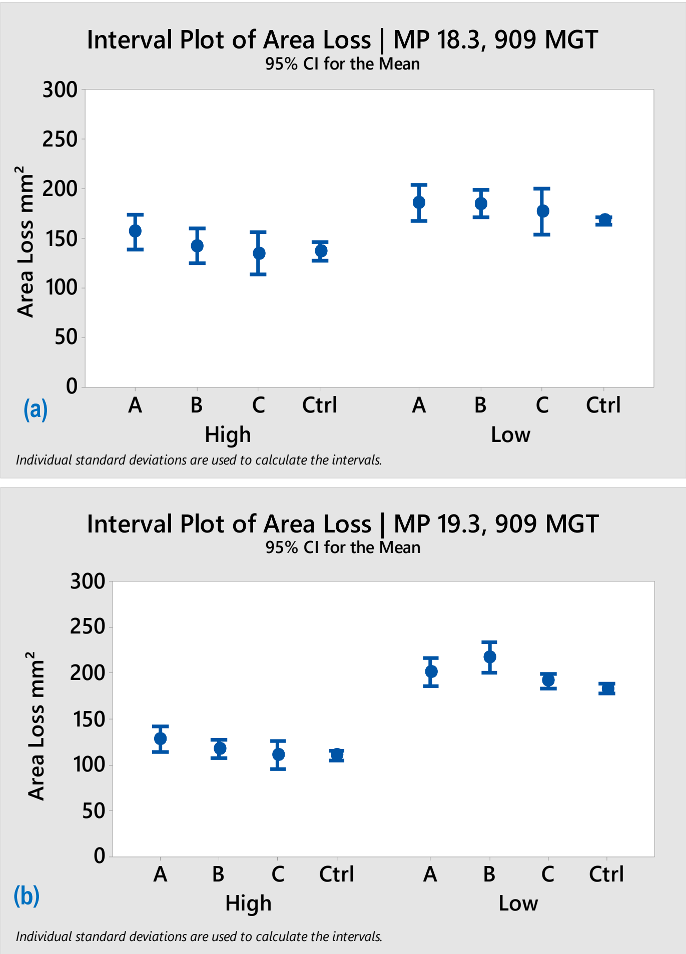

Figure 2. Area loss plots of (a) HS rails at the MP 18.3 curve and (b) HS rails at the MP 19.3 curve at 909 MGT

ROLLING CONTACT FATIGUE AND DEFECTS

To date, no rail at any test site had developed internal fatigue defects. There had been three electric flash butt (EFB) weld failures, with one in each of the 2-degree curves at the western revenue service site and the other in the HS rail curve at MP 349.3 at the eastern revenue service site. Optimized grinding has helped reduce the chances of shell formation. For all three test curves at the eastern revenue service site, grinding has played an important role in controlling rolling contact fatigue (RCF) development on the top of the rail and the gage corner. Spalling has been severe on the low rail in between grinds for all rail types, while RCF developed on gage face and gage corner on the high rails of all rail types in both curves. Figures 3a and 3b show the spalling on an IS high rail and gage face pitting and gage corner RCF on an HS high rail from the curve at MP 348.9, respectively.

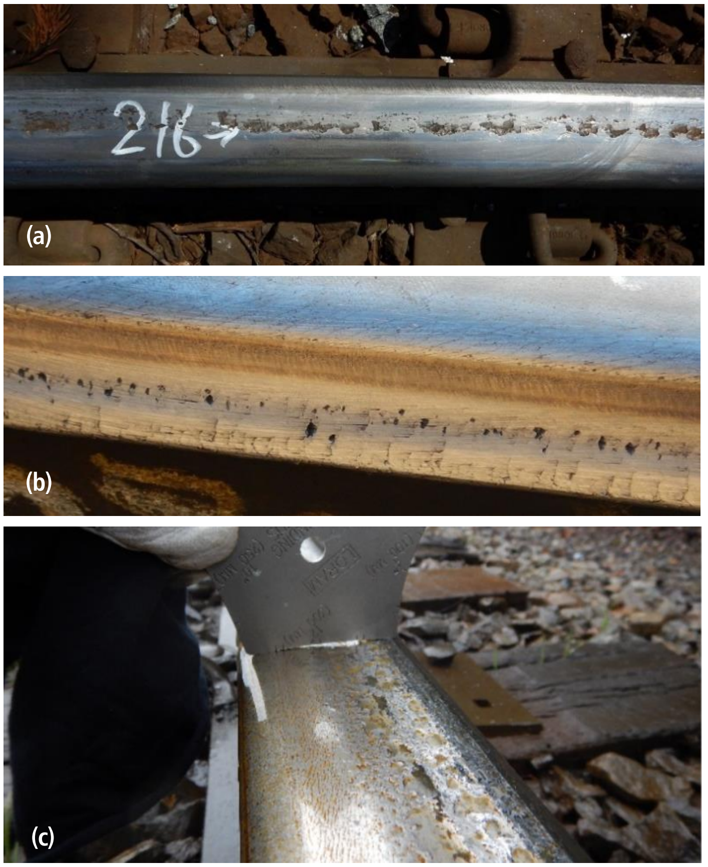

Figure 3. (a) Top of rail RCF in IS high rail, (b) gage face pitting and gage corner cracks in HS high rail in MP 348.9, and (c) RCF on HS low rail close to field corner in MP 349.3

Prior to the removal of the high rail curve at MP 348.9 (182 MGT), the MP 349.3 curve received more grinding passes than the MP 348.9 curve, as shown in Table 2.

Table 2. Grinding history of rail tests in eastern revenue service site before the removal of the high rail of the MP 348.9 curve

Year	Month	Grinding Passes High/Low		
		MP 349.3 HS	MP 348.9 HS	MP 345.9 IS
2014	Mar.	1/1	1/1	1/1
	Oct.	1/1	1/1	1/3
2015	Feb.	2/3	skip	1/1
	Sept.	skip	skip	1/3
2016	Mar.	2/3	2/3	2/5
	Nov.	skip	skip	2/3
2017	Apr.	2/3	skip	2/3
	Oct.	skip	skip	1/3

To control RCF and reduce the chances of shell formation on IS rails, the MP 345.9 curve received grinding twice a year, with a total of 11 passes on the high rail and 22 passes on the low rail until the end of 2017. Previous IS rail tests at TTCI have shown improvement in extending rail life and delaying shell initiation by implementing grinding at regular tonnage intervals.[3]

All curves in the eastern revenue service site have shown significant gage wear on the high rails. This has contributed to gage widening in all three curves. Consequently, false flange contact of worn wheels has been observed on low rails through the formation of top-of-rail RCF close to the field corner, as shown in Figure 3c.

During inspection and measurements at 277 MGT at the western revenue service site, minor RCF in the form of spalling was observed on the low rails in both curves. Grinding was initiated to address the RCF, and the test curve with TOR friction control was placed on a regular grinding schedule of once per year. Continued RCF growth on low rails led UP to introduce preventative grinding twice per year on both curves after 300 MGT. Since then, grinding efforts have reduced the RCF more on the gage corner than the top of the rail. Figure 4 shows an example of the RCF, which has been consistent in appearance on both curves regardless of rail type, observed on low rail.

Figure 4. RCF on HS low rail in western revenue service site

CONCLUSIONS

A five-year study on the performance of the latest HS rails has been conducted at two revenue service sites, along with a test of the latest IS rails at the eastern (NS) site. Substantial wear of the HS and IS rails has been observed in the sharp curves and steep grades of the eastern site, while wear of the HS rails on the shallower curves and flatter grades of the western site (UP) are comparatively lower. RCF has been observed on the top of low rails in both test sites, while high rail RCF has been prominent along the gage corner and gage face for both HS and IS rails on the eastern revenue service site.

Acknowledgments

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