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# FAST Premium Rail Test Results: 2016-2018

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## Key Findings:

- Gage face wear, or simply gage wear, was the most dominant wear mechanism in this test compared to head wear (vertical wear) and gage corner wear. There was a 24 percent difference in high rail head loss comparing best to worst rail type.
- Eight EFB weld failures were observed in this test involving all six rail types. Most of the welds had fatigue initiation points in the region extending from the top half of the web up into the head-web radius. Four out of eight welds were examined microstructurally, and presence of martensite was not found at the defect initiation sites.
- RCF visual ratings exhibited a complex pattern for all rail types throughout the test. Grinding was implemented to reduce RCF at 255 and 429 MGT when RCF got severe throughout the test zone, but grinding did not eliminate RCF completely. At the end of the test, RCF was uniformly severe across all rail types.

In May 2018, Transportation Technology Center Inc. (TTCI) concluded testing of six premium rail types in a 5-degree reverse curve of the High Tonnage Loop (HTL) located at the Facility for Accelerated Service Testing (FAST) in Pueblo, CO. Testing ended after the rails accumulated 651 million gross tons (MGT) of service. The test started in February 2014 and TTCI monitored rail wear, rolling contact fatigue (RCF), internal defects in rails and electric flash butt (EFB) weld failures that occurred between the test rails. *Technology Digest* (TD16-001)[1] summarized the results of this test up to 343 MGT and this article summarizes the results at the conclusion of the test.

The curve has 4 inches of superelevation and is not lubricated by any gage or top-of-rail (TOR) lubrication. The FAST train operates at 40 mph resulting in 1.7 inches of overbalance for the train's operating speed. Six rail manufacturers participated and donated 40-foot rail segments. The manufacturers were Arcelor-Mittal Steelton LLC. (USA), Angang Group International Panzhihua Co. Ltd. (China), British Steel (UK, France), voestalpine Schienen GMBH (Austria), JFE Steel Co. (Japan) and Nippon Steel (Japan). Dissimilar rail types were welded to one another by an EFB welding process by an external welding company and five rail profiles per rail segment were marked for data collection. This TD summarizes the results of this test which lasted for 651 MGT. Gage wear necessitated the conclusion and subsequent removal of the rails.

### Rail Wear

Figure 1 shows the comparison of metal loss of the high rail at the end of the test in terms of head area loss and gage wear. Area loss includes vertical head wear, gage corner wear and gage wear and thus gives an overall idea of the total metal loss due to wear and grinding. The gage wear data is shown in the same plot to give an idea that it is the main contributor to the area loss data. The yellow dots in each series represent the medians of each rail type. Based on the sample sizes of the test, type E showed the highest median head area loss while type C had the least. Type E was more worn than type C with 24 percent more head area loss. The median difference was statistically significant and expected to be between 19.7 and 26.0 percent at a 95 percent confidence interval.

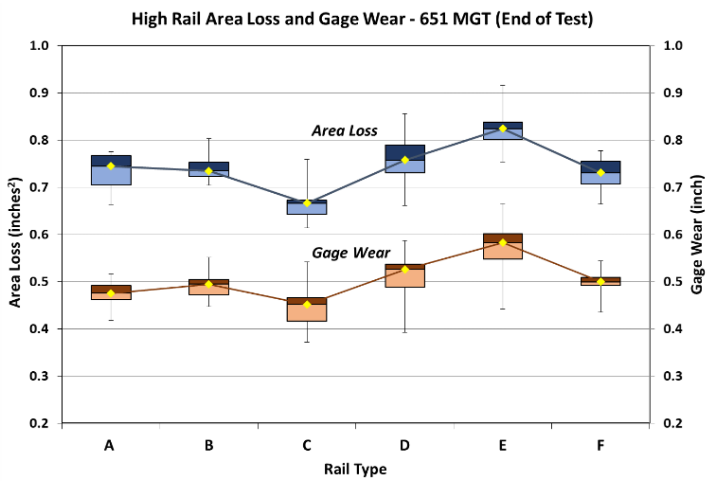


Figure 1. Area loss and gage wear of high rail at 651 MGT

The high rail was ground twice at 255 MGT and 429 MGT to remove RCF and spalls from all the rail types. Corrective grinding on the head of the rail was done with approximately equal amounts of metal removed from all rails as the grinder made continuous passes. High amounts of gage wear, along with plastic deformation of the steel at the bottom of the gage face (metal flow), caused the high rail to form a profile that may have contributed to an increase in wheel flange shelling. To correct this, the metal lip formed at the bottom of the gage face was ground using a trolley-mounted grinder as shown in Figure 2. Compared to the high rail, there was significantly lower wear of the low rail for all rail types. The average area loss of the high rail was found to be almost nine times more than the average area loss of the low rail. The low rail received an additional corrective grind at 590 MGT due to the formation of severe RCF and spalls.

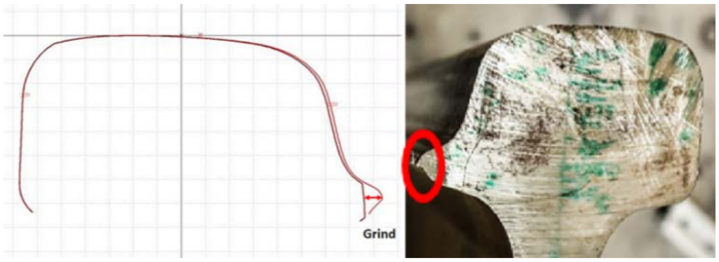


Figure 2. Grinding of metal lip formed at the bottom of gage face of high rail

## EFB Weld Failures

Eight EFB welds failed on the high rail during the course of the test. Out of the different rail types involved in EFB weld failures, type A rail was involved in five failures while type E rail was involved in four failures. Types C, D and F rails were each involved in two weld failures while type B rail was involved in one failure. Initial EFB weld failures were not considered to be an important aspect of the test and thus failed weld specimens were not collected and examined. As more EFB weld failures occurred, five out of the eight EFB weld failures were recovered and examined and all had fatigue marks with defect initiation sites in the region extending from the top half of the web up into the head-web radius. Examples of three such EFB weld failures are shown in Figure 3. Microstructural examination of the defect initiation sites showed deformed pearlitic microstructure with no presence of martensite. No microstructural difference was observed from one rail type to the connecting rail type across the longitudinal EFB weld surface and thus it was impossible to determine any influence of differences in rail metallurgy on the EFB weld failures.

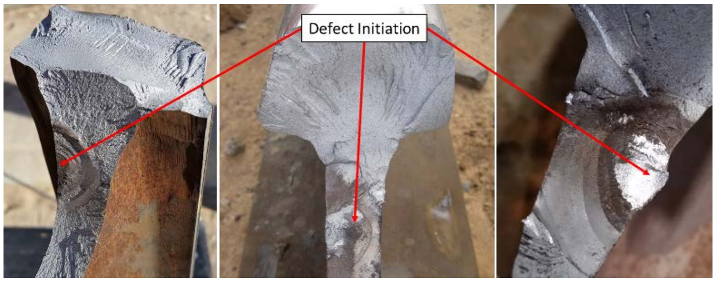


Figure 3. Defect initiation sites observed in failed EFB welds

## Internal Rail Defects

Unlike a previous premium rail wear test (2010-2013)[2,3] in which rail base breaks were observed, no rail base breaks or shells were observed in this test. Two defects were observed during the four years of this test. During a regularly scheduled ultrasonic rail scan of the entire HTL, a transverse defect of size 4 percent of the head area was detected in a type D low rail. The head of the rail was carefully sectioned, and the detected area was re-scanned using ultrasonic scanning equipment. A thin hairline crack was observed 0.2 inch below TOR surface and the transverse defect was ruled out.

The second defect was a fatigue defect observed in a type F high rail that caused a vertical split head fracture. An EFB weld failure happened seven months earlier between the type F and a type C rail and was replaced by a thermite weld. The thermite weld failed, and the type F rail was temporarily joined to a non-test rail with joint bars. The fatigue defect initiated 1.5 inches away from the cross-sectional surfaces of the two rails towards the field side as shown in Figure 4.

The failed sample was machined and the top half containing the split was cut out to get a better view of the defect initiation location. The defect initiation location was examined at higher magnifications using scanning electron microscopy (black and white image in Figure 4) and chemistry was scanned using electro-dispersive spectroscopy (EDS) at random spots at that location. No contaminants were found but some scans showed high sulfur and oxygen contents indicating the possibility of presence of sulfide and oxide inclusions.


Figure 4. Fatigue defect at various magnifications

### Rolling Contact Fatigue (RCF) analysis

A subjective, visual RCF rating scale, where 0 is no RCF, 1 is mild, 2 is heavy, and 3 is severe, was used for regular RCF estimation of the rails during the test[1]. RCF estimation was done on each rail at every tie and ratings were averaged for all six rail types.

Change in head wear over particular tonnage intervals was analyzed and compared with the change in average RCF rating for all rail types. Considerable scatter in the data yielded no conclusive correlation. RCF growth rates were different across the same rail of any rail type as well as different across the six different rail types. As shown in Figure 5, type E rail had four different ratings during the last inspection at the end of the test. All rail types had instances where sporadic ratings of 3 were observed with the rating on the adjacent tie being 1 or 0. Thus a correlation between TOR RCF and head wear or any other wear parameter could not be analyzed.

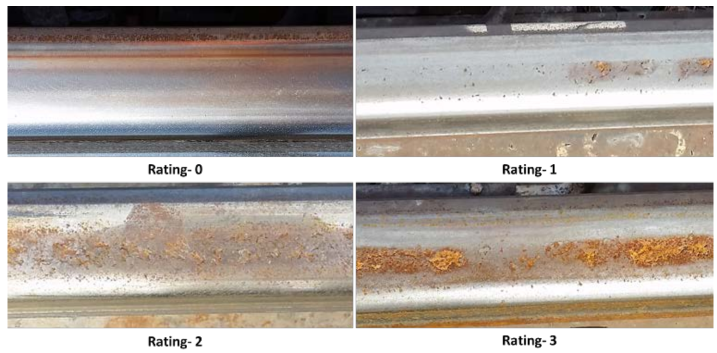


Figure 5. Four different RCF ratings observed on type E rails at the end of the test

Grinding of the test zone was done when the overall test zone showed severe RCF and spalling and majority of the ratings were 3 for all rail types. Grinding did not completely remove RCF and some of the RCF existed after grinding as shown in Figure 7. The entire test curve at the end of the test had uniformly severe RCF across all rail types.

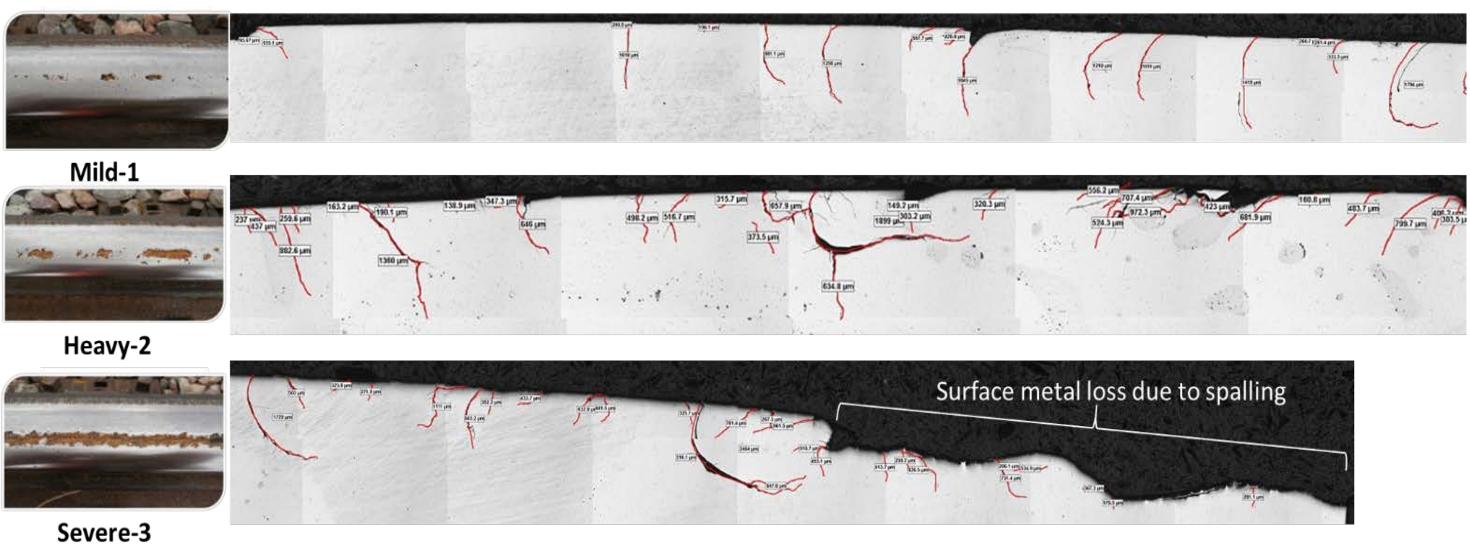


Figure 6. Comparison of RCF crack appearances along the cross-section of the rail head for different RCF ratings.

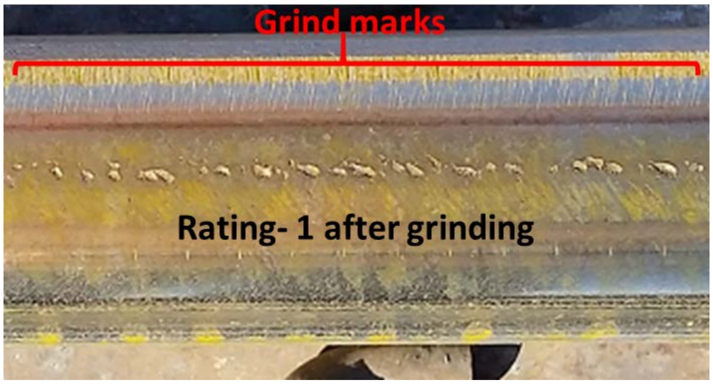


Figure 7. RCF rating of 1 on a type E rail after grinding at 429 MGT and one night of trail operations.

Samples of RCF ratings 1, 2, and 3 of types C and E were sectioned, polished and viewed under the optical microscope. Figure 6 shows the RCF ratings of 1, 2 and 3 of the visual rating scale and cross-sectional images of crack depth observed in type E samples at the end of the test. At the rating of 1, the cracks are vertical with zero or some curvature, but the surface of the rail looks free of spalls. At the rating of 2, longer cracks start changing directions while more cracks are found to initiate. The rail seems to be losing some metal due to spalling caused by multiple cracks growing in close proximity. At the rating of 3, spalling appears to be more prominent as cracks continue to grow. One arc-shaped crack left of the spalled area is a probable location for impending spalling as the crack travels upwards and joins other cracks moving towards it. It is to be noted that the images shown i are three different spots on the same rail and the TOR images shown on the left are not images of the type E rail.

## CONCLUSION

A four-year premium rail test with six rail types concluded after accumulating 651 MGT of tonnage. Gage wear was the dominant wear mechanism for all rail types. The highest wearing rail had nominally 24 percent more head area loss (statistically significant) than the rail wearing least. Eight EFB weld failures involving all six rail types occurred during the test along with two internal defects in the rails. One of the internal defects was a fatigue crack that caused a vertical split head fracture. RCF was analyzed in regular intervals and samples with varying RCF were analyzed to understand crack growth.

### References


1. Banerjee A. and Davis D., February 2016, "FAST Premium Rail Wear Test Results: 2014-2015," *Technology Digest* TD-16-001, AAR/TTCI, Pueblo, CO.
2. Szablewski D., J. LoPresti, and D. Sammon, July 2013, "Premium Rail Testing at FAST," *Technology Digest* TD-13-016. AAR/TTCI, Pueblo, CO.
3. Szablewski D. and J. LoPresti, October 2014, "FAST Premium Rail Test Results: 2010 through 2013 Test Period," *Technology Digest* TD-14-021. AAR/TTCI, Pueblo, CO.


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