

The research described was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

## Key Findings:

- One EFB weld failure occurred at 210 MGT but no internal defects have been detected in any of the rails to date.
- Similar to earlier HS rail tests in the same curve at FAST, gage wear is the dominating wear mechanism.
- The RCF assessment was done visually both before and after the rails were ground, and seven out of the eight rail types showed a decrease in the RCF ratings after grinding.
- The maximum sub-surface crack depth of the rail head was measured using the EMFI NDE method. All eight of the rail types experienced a decrease in the average maximum crack depth after grinding although the differences in crack depths before and after grinding did not correlate with the differences in visual RCF ratings.

# FAST High Strength Rail Test: Results through 325 MGT

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Since 2018, [TTCI](#) has been testing eight premium rail types (also known as high strength, or HS rail) without any direct lubrication on a 5-degree reverse curve on the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST), Pueblo, CO. To date, the rails have accumulated 511 million gross tons (MGT) of service. This *Technology Digest* describes testing during the first 325 MGT, which occurred from the time of the rails' installation in September 2018 through May 2020.

During that period of testing, TTCI monitored rail wear, rolling contact fatigue (RCF), internal defects in the rails, and electric flash butt (EFB) weld failures. One EFB weld failure occurred at 210 MGT but no internal defects or other weld defects were observed in any of the rails through 325 MGT. A previously published *Technology Digest*<sup>1</sup> summarized the results of the testing to determine the mechanical and metallurgical properties of the rail steels included in this test.

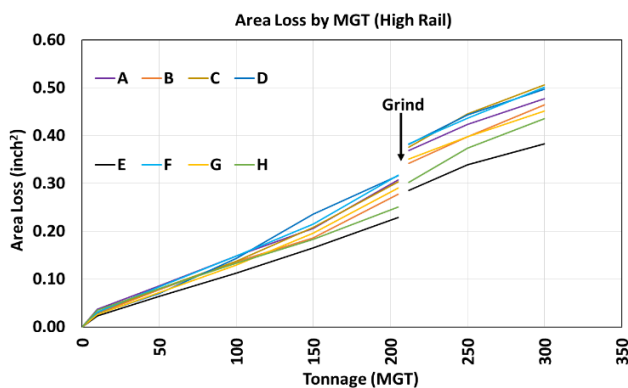
The test layout consisted of six 40-foot-long rails of each rail type (three high rails and three low rails).<sup>1</sup> The six rails from each manufacturer were dispersed over the entire high and low rails of the curve per the test layout described in *Technology Digest* TD19-004.<sup>1</sup> Five locations on each rail were selected for a total of 15 rail wear measurement locations on both the high rail and the low rail per rail type (manufacturer). The test team visually estimated RCF above each tie on each rail for the different rail types for a total of more than 600 locations. On a visual rating scale of 0 to 3 (with 0 being no RCF and 3 being severe RCF with spalling), most of the rails exhibited average ratings close to 3 before being ground. In order to reduce RCF, at 209 MGT the entire length of the high rail was ground using the same grinding speed and patterns. The low rail has received fewer grinding passes because the RCF was minimal on this rail. Crack depth was also measured using the electro-magnetic field imaging (EMFI) technique—an emerging non-destructive evaluation (NDE) method used to measure surface crack depths. The results of the wear analysis, the RCF visual assessment, and

crack depth analysis using the EMFI technique are discussed here. The eight participating rail types in test at FAST along with their manufacturers are as follows:

- Cleveland-Cliffs Steelton (formerly Arcelor-Mittal Steelton) (USA) – AHH grade.
- EVRAZ Rocky Mountain Steel (USA) – OCP grade.
- Steel Dynamics Inc. (USA) – HC/HP grade.
- Angang Group International Panzhihua Co. Ltd. (China) – PG5 grade.
- Liberty Steel France (erstwhile British Steel France Rail) – MHH400 grade.
- voestalpine Rail Technology GMBH (Austria) – UHC grade.
- Nippon Steel Corporation (Japan) – HE-X grade.
- JFE Steel Corporation (Japan) – JFE-D grade.

## WEAR ANALYSIS

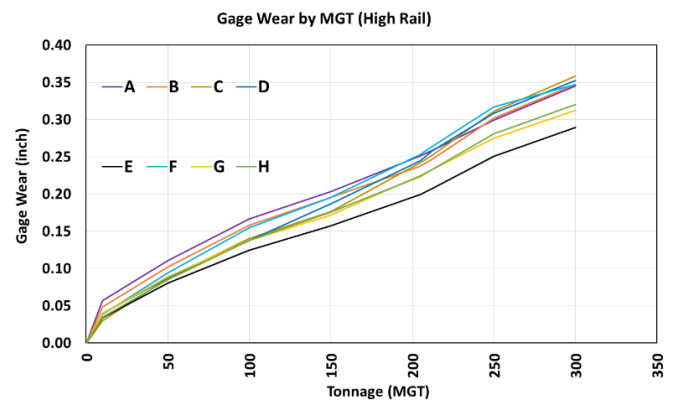
Rail profile measurements were collected at 0, 10, 100, 205, 212, and 300 MGT using a MiniProf profilometer. The rail profile measurements at 205 MGT were considered pre-grind profiles while the 212 MGT measurements were considered post-grind profiles. Gage face wear or simply gage wear was the main wear pattern contributing to the overall high rail head wear. This observation consistently aligned well with what was indicated by the primary wear type in previous HS rail tests conducted in the same 5-degree reverse curve on the HTL.<sup>2</sup> Figure 1 shows the overall head area loss of the different rails in the current test.



**Figure 1. Median head area loss of eight rail types A–H in the current 2018 HS rail test**

Though gage wear contributed to head area loss, the MiniProf calculates area loss, vertical wear, and gage wear

based on the measured profiles. Figure 2 shows gage wear on the eight rail types — the rapid wear in the data shown near the origin of the plot after 0 MGT is believed to have been caused by the removal of the soft decarburized layer on the surface of the rail heads for all types. No initial grinding was done during this test to remove the mill scale and decarburized layer. The same rapid wear can be seen in area loss in Figure 1, but it is less pronounced than what can be seen in Figure 2. Rail type E has the least wear in the test. Rail types G and H show higher wear than type E, but comparatively less wear than types A through D and F. Weak correlations were observed between vertical wear, head area loss, and the surface hardness of the eight rail types through 300 MGT in the current test.



**Figure 2. Median gage wear of rail types A–H in the HS rail test initiated in 2018**

## Visual RCF Assessment

A visual RCF assessment was done using a visual RCF rating scale at 100, 205 (pre-grind), 212 (post-grind), and 300 MGT. The visual rating scale of 0 to 3 in increments of 0.5 was the same as the scale that was used in the previous test.<sup>2,3</sup> In the current test, an interesting trend was observed in the visual RCF assessment from 100 to 300 MGT with pre-grind and post-grind ratings in between. Figure 3 shows the mean RCF ratings for the eight participating rail types. At 100 MGT, rail type D showed a higher RCF rating than the other rail types did. All the rail types, except type H, had mean RCF ratings between 2 and 3 at 205 MGT. Type H had the lowest RCF rating at both 100 and 205 MGT. After grinding, all rail types except H saw a substantial decrease in the mean RCF rating at 212 MGT. At 300 MGT, rail type H had the highest mean RCF rating of close to 2 while the remaining seven rail types had ratings between 0 and 1.

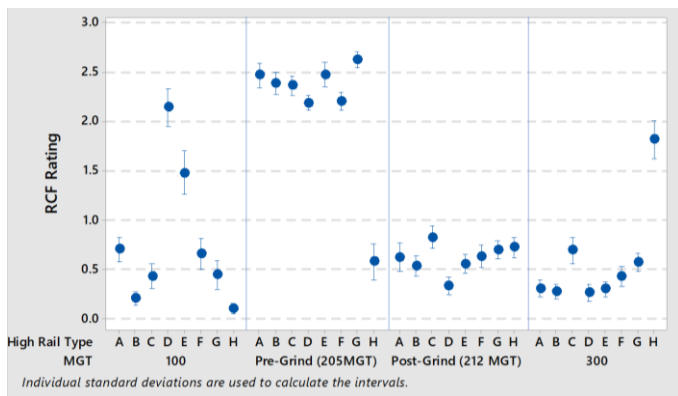


Figure 3. Mean RCF ratings of eight rail types at 100, 205, 212, 300 MGT

### RCF Assessment using EMFI Technology

TTCI has been facilitating the development of EMFI technology for measuring and quantifying rolling contact damage crack depth under the Association of American Railroads’ Strategic Research Initiatives Rail Inspection Technology project. Two previous *Technology Digests* provide background on the technology.<sup>4,5</sup>

For this test, the Athena Industrial Services, Ltd. ECHO-Rail G2 sensor was used to scan the test rails during the pre-grind (205 MGT) and post-grind (212 MGT) processes. This EMFI-based system is still undergoing development and was used under agreement with the vendor in order to evaluate the EMFI technology relative to current visual-based RCF evaluation techniques. The final analytical approach selected for the evaluation of the EMFI data relied on statistical methods and is sensitive to various inspection parameters such as data sample rate and encoder steps (sample interval length). The results shown represent one set of results that may not reflect the absolute precision attainable with the technology (see Figure 4).

A calibrated ECHO-Rail G2 sensor was attached to the TTCI prototype C5500 rail inspection high rail vehicle. The analysis shown here was based on a single pass of the entire Section 7 test rails. TTCI used its MULTIVU™ analytics software package to postprocess the data by rail segment. Figure 4 shows the pre- and post-grind maximum crack depth averages for each of the rail types. The numbers represent the average deepest crack depth measured on each 4-mm sample interval for each rail segment. These crack depth values were then averaged over all of the segments of each rail type. The mean maximum crack depth for each rail type

was averaged over all three 40-foot segments of each type except for rail type C where the average was over only two 40-foot rail segments due to an error during the post-grind measurement run. The EMFI data was collected only at pre- and post-grind (205 and 212 MGT, respectively) in contrast to the RCF visual ratings that were conducted at four tonnage intervals, so it was not possible to trend the development of crack depth with the EMFI data.

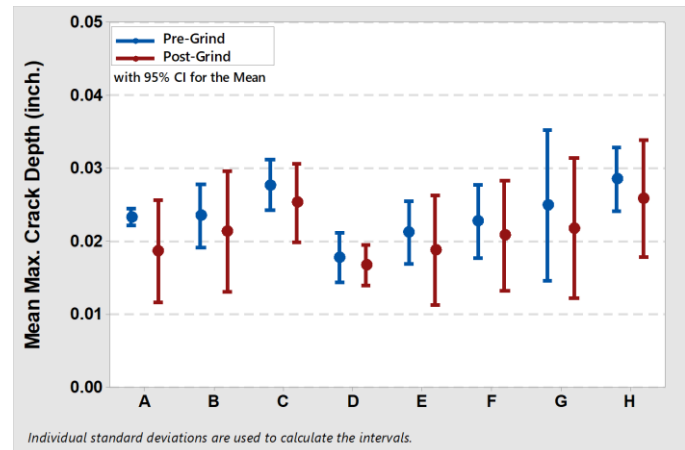


Figure 4. Pre-grind and post-grind mean maximum crack depths per rail type as measured by EMFI technology

The decrease in crack depth after grinding as measured by EMFI does not correlate directly to the decrease in the RCF visual rating. For rail type E, the mean RCF visual rating decreased from 2.48 at pre-grind to 0.56 at post-grind, while the mean EMFI maximum crack depth decreased by 0.003 inch. For rail type A, the mean RCF visual rating decreased from 2.47 to 0.62 while the mean maximum crack depth decreased by 0.005 inch. In contrast, rail type H had a low pre-grind RCF visual rating of 0.58 which increased slightly to 0.72 after grinding, but it had the highest mean maximum crack depth among all rail types as measured by the EMFI technique. This indicates that the extent of surface RCF and spalling can be different than the measured crack depths existing below the top of rail surface. Since visual evaluation is based primarily on surface coverage, no correlation was found between the difference in the visual RCF ratings and the difference in the maximum crack depth as measured by EMFI before and after grinding. This lack of correlation highlights the importance of a visual assessment of the extent of the existing RCF on a rail surface and an NDE inspection of the sub-surface crack depths before deciding on the extent of grinding, especially when the track consists of different rail types.

## Weld Failure

In this HS rail test that ran through 325 MGT and is still continuing, one EFB weld failure occurred at 210 MGT. The source of the failure was a fracture found along the weld fusion line. This failure appeared to be similar to most of the EFB weld failures in the previous HS rail test that had a total of eight EFB weld failures with four failures happening before 312 MGT. Figure 5 shows the fracture as detected in track with the location of defect initiation highlighted.



Figure 5. EFB weld failure between test rails

## CONCLUSIONS

A HS rail test started in 2018 on the FAST HTL accumulated 325 MGT of traffic through May 2020. Similar to the findings of previous tests conducted in the same test curve at FAST<sup>3</sup>, gage wear due to the lack of direct lubrication on the high rail is the dominating wear mechanism. The rails were ground once between 205 and 212 MGT with multiple passes on the high rail to reduce RCF. Fewer passes were needed on the low rail. RCF was evaluated using a visual assessment (rating scale of 0 to 3) and interesting trends were observed at various tonnage intervals including pre-grind and post-grind intervals. Sub-surface crack depths were measured using an EMFI NDE-based approach, and

maximum crack depths were analyzed before and after grinding. No correlation was found between the decrease of crack depth and the change in RCF visual rating for the eight rail types. Through 325 MGT, no internal defects were detected in any of the rails. One weld fractured at 210 MGT on the high rail, and the defect initiation was found to be on the weld fusion line. Further investigations into wear, RCF, and weld failures will continue as the test progresses and will be reported in future publications.

## References

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