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FAST Intermediate Strength Rail Test Results: 2012-2014

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Summary

In 2012, Transportation Technology Center, Inc. (TTCI) began the second test of intermediate strength (IS) rails at the Facility for Accelerated Service Testing (FAST), Pueblo, Colorado. Six rail types from five manufacturers are being evaluated. The test is being conducted in a lubricated 5-degree curve with 4 inches of superelevation. The resulting cant deficiency for the 39-ton axle load test train that is typically operated at 40 mph is 1.7 inches. The test rails installed at FAST have accumulated 360 million gross tons (MGT); this *Technology Digest* includes results and measurements for the first 348 MGT.

- Three gage-corner shell defects have been detected in the IS high rail. They were found in Type 1, TZ, and ERMS-SS rails at 280, 310, and 320 MGT of accumulated tonnage respectively. The shells in the Type 1 and TZ rails resulted in transverse defects that led to rail breaks in the track. Initial analysis of shell and transverse defect crack surfaces suggests that two transverse defects originated on the shell crack surfaces. However, the formation mechanism is still under investigation.
- Statistical two sample t-test wear analysis done at 348 MGT of accumulated tonnage indicates that ERMS-SS rail has more wear than the other rail types tested (namely, EVRAZ IH, Type 1, ArcelorMittal Steelton, SDI, and TZ). This is attributed to ERMS-SS being standard strength rail with head hardness of 320 HB, which is substantially lower than the IS rail types, which have head hardness from 330 to 360 HB.
- Rolling contact fatigue (RCF) initiated in the high rail after 100 MGT of traffic and progressed slowly over time. Light to moderate rail grinding every 60–70 MGT removed most of the surface RCF. Some deeper RCF on the top of the high rail was not removed by grinding. The low rail (which remained from the previous test that started in 2010) has accumulated 600 MGT, and it shows significant RCF on the running surface thorough the entire length of the curve.
- Nippon HEX premium rail (400 HB head hardness), which is located in the same curve as the IS rail, has accumulated 425 MGT, and it has not developed either shells or transverse defects.

TTCI will continue testing the IS rails in 2015, using visual inspection of the high rail twice a week and ultrasonic rail flaw inspection every two weeks during train operations at FAST. The track gage data and rail profiles will be analyzed to determine how the wheel/rail contact might be affecting shell development, and gage face lubrication in the test curve will be reduced to increase the wear of the high rail.

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INTRODUCTION

The second intermediate strength (IS) rail test at FAST began mid-2012. Table 1 summarizes important mechanical properties for IS rail as recommended by AREMA, along with those for standard and high-strength rail for comparison.[1] The test is comprised of six industry-leading rail types from five suppliers, focused on analyzing wear and fatigue performance in a 5-degree lubricated curve under heavy axle loads. By the end of 2014 FAST operations, the test rails had accumulated 360 MGT. Testing is scheduled to continue in 2015. Test results presented here address rail wear, RCF development, and gage-corner shelling.

Table 1. AREMA Rail Properties

Property	Standard Strength	Intermediate Strength	High Strength
Yield Strength, ksi, minimum	74.0	80.0	120.0
Tensile Strength, ksi, minimum	142.5	147.0	171.0
Elongation in 2 inches, percent, minimum	10	8	10
Minimum (Rail Head) Surface Brinell Hardness, HB	310	325	370

Test conditions are as follows:

- 40-foot 136RE IS rails were flash butt welded into an 800-foot test string. The types of rails, approximate hardness, and number of 40-foot rails of each type follow: The number of each type of rail tested was determined by rail availability and the length of the test curve.
  - EVRAZ Rocky Mountain Steel U.S. Intermediate Strength rail (ERMS-IH), ≈ 360HB head hardness, 3
  - EVRAZ Rocky Mountain Steel U.S. Standard Strength rail (ERMS-SS), ≈320HB head hardness, 4
  - Type 1 Italy, ≈360HB head hardness, 2
  - Mittal U.S., ≈350HB head hardness, 3
  - Steel Dynamics Inc. U.S. (SDI), ≈330HB head hardness, 4
  - Trinecke Zelazarny (TZ) Czech Republic, ≈330HB head hardness, 4
- Five-degree lubricated curve with 4 inches of superelevation
- 39-ton axle load environment
- 40 mph train speed (approximately 1.7-inch overbalance speed) with bidirectional traffic
- 360 MGT accumulated to date
- Rail profile grinding approximately every 60 MGT

RAIL WEAR

Figure 1 shows a typical rail profile for the high rail at 348 MGT accumulated tonnage. The area between the new rail profile (red line) and 348 MGT worn rail profile (blue line) represents total metal loss. The metal loss shown is a combination of wear and rail profile grinding.

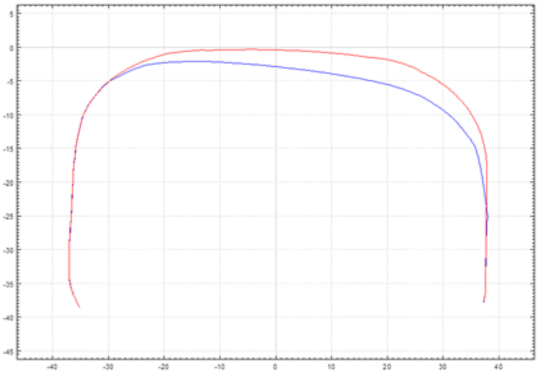


Figure 1. Comparison between new 136RE rail profile (red) and worn high rail profile (blue) at 348 MGT

Rail profiles were measured at five locations on each 40-foot rail type approximately every 60 MGT. A two sample t-test wear analysis of rail wear that compared ERMS-SS rail type to other rails in the test zone at 348 MGT indicated all of the other rail types tested (EVRAZ-IH, Type 1, ArcelorMittal Steelton, SDI, and TZ) have statistically less wear than the ERMS-SS rail. Note the ERMS-SS rail has approximately 320 HB head hardness, whereas all other rail types tested in the curve are IS rail grades ranging in hardness from 330 to 360 HB. The IS rails are being compared to the SS rail, because it is widely used and its revenue service performance is known. Area loss is shown in the box plot in Figure 2.

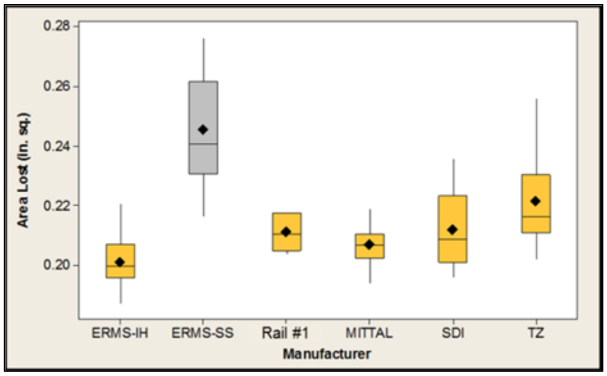


Figure 2. Two sample t-test rail wear comparison between tested rail types and ERMS-SS rail at 348 MGT. Orange color indicates less wear than ERM-SS rail.

RAIL RCF AND GRINDING

Rail RCF in the curve initiated after 100 MGT and progressed slowly. Since grinding is implemented in the curve approximately every 60 MGT, most of the surface RCF was removed from the running surface with each grinding.

However, some exceptions to this include deep RCF markings on top of the high rail (Figure 3).

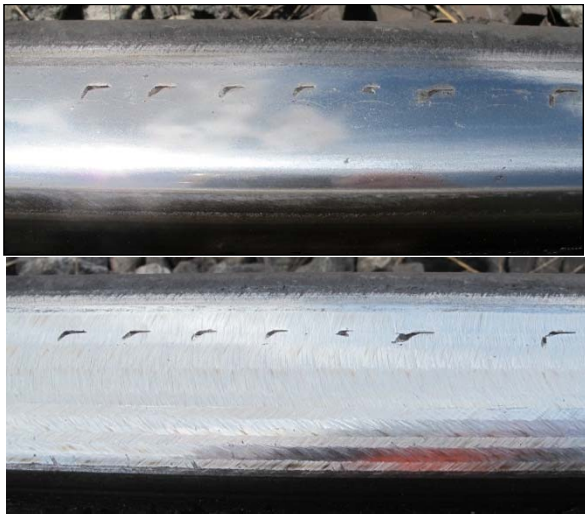


Figure 3. RCF markings on top of high rail at 300 MGT of accumulated tonnage in the IS rail curve. Top image shows rail before grinding and bottom image indicates rail after grinding.

The low rail in the curve is from the previous IS rail test (which began in 2010) and it has accumulated more than 600 MGT. All rail types have substantial RCF on the running surface. This RCF is distributed evenly thorough the entire curve length. Figure 4 indicates typical RCF condition on the low rail.

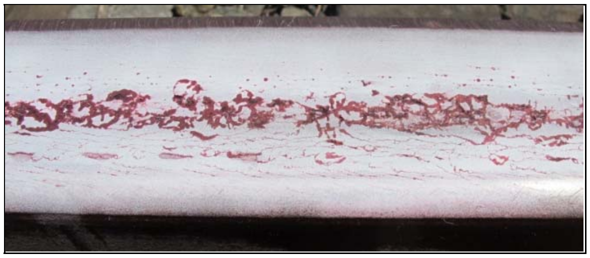


Figure 4. Low rail RCF at 600 MGT of accumulated tonnage

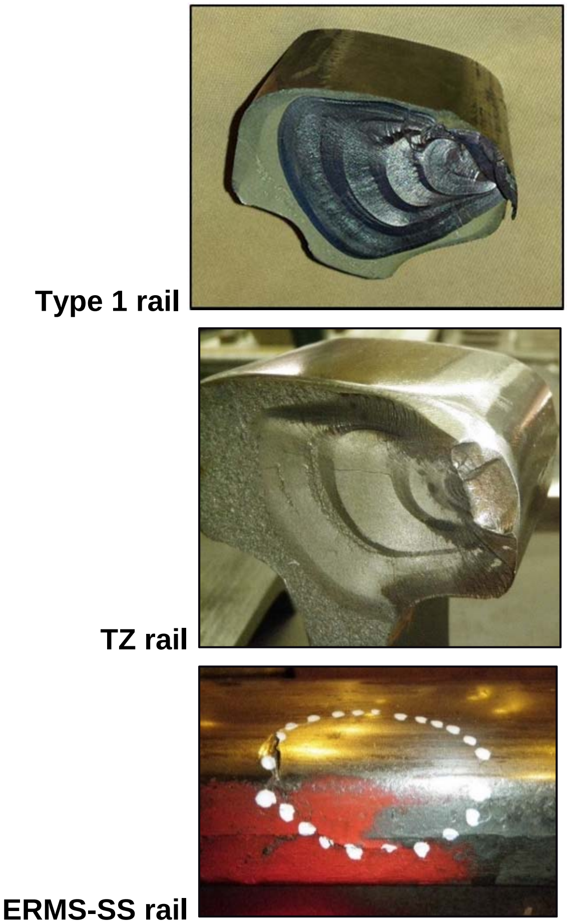
The grinding mentioned above (and shown in Figure 3) was implemented in this test for two reasons: (1) to remove RCF from the running surface while maintaining the proper rail profile, and (2) to prevent deep seated shelling (DSS) gage-corner defects from occurring. There were 18 DSS defects in the high rail during the previous IS rail test at FAST,[2] which resulted in the early termination of the test.

The 50-70 MGT grind cycle in the IS curve was implemented after consideration of a grinding study done on Canadian Pacific (CP) lines in “100 percent effective gage face lubricated” territories.[3] In that study, the proposed solution was a preventive rail grinding program to remove 0.016 inch of metal from the gage corner at the 45-degree location with a maximum grind angle of 60 degrees. However, FAST has a different operating environment than CP lines, and a rail grinder with more limited capabilities (the maximum grind angle for the grinder used at FAST is 45 degrees). The first three grind cycles in the current IS rail test zone resulted in 0.008 inch of metal removal at 45 degrees, and the last two grinds removed 0.012 inch of metal at 45 degrees.

The grinding was conducted with the aim of reducing the maximum contact stress in the railhead, moving the stress field deeper into the railhead, and maintaining a proper rail profile.

RAIL SHELLING

Shelling in the high rail began at approximately 280 MGT of accumulated tonnage during the current test. The first shell occurred in the Type 1 rail. This was the rail type to first develop shelling in the 2010–2012 IS rail test.[2] In the previous rail test, 18 total shell defects developed in all rail types between 340 and 380 MGT. None of the shells resulted in transverse defects. In the present IS rail test, the shell initiated in approximately the same location in the gage corner as the previous test, approximately 0.3 inch down from the top of the rail and 0.4 inch in from the gage face of the rail. As with most shells, there was longitudinal growth (parallel with the running surface of the rail). In addition, a transverse defect initiated from the shell surface, which then grew perpendicular to the rail running direction (see Figure 5), and it was not discovered until a service failure took place.



Type 1 rail

TZ rail

ERMS-SS rail

Figure 5. IS high rail shelling leading to transverse defect development in Type 1 and TZ rail.
ERMS-SS rail type did not indicate a developing transverse defect underneath the shell.

Another shell and transverse defect occurred at 310 MGT in the TZ rail type (Figure 5). The mechanism of this transverse defect was very similar to the previous shell and transverse defect in Type 1 rail, and it was not discovered until a service failure occurred. Shell defects can mask transverse defects that develop directly below the shell. Since the transverse defects in the Type 1 and TZ rails were directly below the formed shell, ultrasonic inspection did not detect these transverse defects.

A third shell defect was identified in the IS test curve at 320 MGT of traffic. This time the shell was found in ERMS-SS rail type (Figure 5). Since the defect was found during an ultrasonic inspection (prior to a service failure) it is not known whether a transverse defect would have developed from this shell.

The growth patterns shown in Figure 5 in both Type 1 and TZ rail appear to be in periodic step formation. This periodic reversal in growth direction is associated with reversal of FAST train operations (two nights of running clockwise followed by two nights of running counterclockwise).

Rail material strength and properties seem to be a factor in the development of high rail gage-corner shells. Nippon HEX premium rail (400 HB head hardness), which is installed adjacent to the IS test rail in the same curve at FAST, has accumulated approximately 425 MGT to date with no shells or transverse defects discovered.

SUMMARY AND CONCLUSIONS

Results presented in this *Technology Digest* address the rail performance of six industry-leading IS rail types. Analysis was concentrated on wear and RCF performance as well as rail shell defects.

To date the IS test curve has accumulated 360 MGT of tonnage. Statistical two sample t-test wear analysis done at 348 MGT indicates that the ERMS-SS rail has significantly more wear than all other rail types tested. This is attributed to the fact that ERMS-SS rail has a head hardness of approximately 320 HB, whereas the IS rail types have head hardness ranging from 340 to 360 HB.

RCF on the high IS rail initiated after 100 MGT of traffic and progressed slowly. Periodic rail profile grinding removed most of the rolling surface RCF. Exceptions include deep RCF on top of the high rail. The IS low rail in the curve has accumulated more than 600 MGT. All rail types have substantial RCF on the running surface.

Three gage-corner shell defects have been detected in the IS high rail. They were found in Type 1, TZ, and ERMS-SS rails respectively at 280, 310, and 320 MGT. Shells in Type 1 and TZ rails also resulted in transverse defects.

Nippon HEX premium rail (400 HB head hardness), which is located adjacent to the IS rail curve and to date has accumulated 425 MGT of traffic, has not developed either shells or transverse defects.

IS rails tested in a lubricated 5-degree curve under heavy axle loads at FAST have shown a greater tendency to develop high rail gage-corner shells than have premium rails being tested or utilized in the same curve. Mild, preventive grinding of the rails has not prevented the development of the shells. It may be that the amount of metal removed, and the inability of TTCI's rail grinder to grind at angles greater than 45 degrees have reduced the effectiveness of grinding at preventing gage-corner rail shells. Whether the grinding will reduce the total number of shells that develop should be known by mid-2015.

FUTURE WORK

Although there are concerns that shelling in the IS rail curve might become widespread, as it did in the previous IS rail test, testing of the IS rail at FAST will continue. Steps will be taken in 2015 that are aimed at better understanding the rail defect in question, as well as mitigating the risk of rail breaks. Since shelling can be identified through visual inspection, and the IS rail test zone is only 800 feet long, visual inspection of the high rail will be made twice a week. Ultrasonic rail flaw inspection will continue every two weeks during train operations.

The track gage data and rail profiles will be analyzed to determine how the wheel/rail contact might be affecting shell development. Also, gage face lubrication in the curve will be reduced to increase the wear of the high rail.

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