TTCI TECHNOLOGY DIGEST

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Research described in this Technology Digest was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Effectiveness of Corrective Grinding

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Key Findings:

- Corrective grinding was a successful remediation strategy for 77 percent of the 88 rail exceptions analyzed. The success rate in restoring rail to a valid test condition was higher at rail exceptions that had deeper grind treatments. All grinds that removed at least 0.060 inch of metal were successful in achieving a valid rail flaw test.
- Several case study sites demonstrated that the complete elimination of all cracks is not necessary for acceptable ultrasonic testing (UT) response in rail.
- The large variation in corrective grinding efforts does not allow for a blanket recommendation for corrective grinding depth but does highlight the need for an accurate non-destructive means to quantify crack depth.

Transportation Technology Center, Inc. (TTCI) investigated the effectiveness of corrective rail grinding to restore high confidence ultrasonic test (UT) results through detailed data collection at a limited number of case study sites plus analysis of estimated metal removal depths at a larger number of sites. Although the success rate of restoring rail to a valid test condition was observed to be higher when more metal was removed, the variation in data does not allow for a blanket recommendation for metal removal depth. This work was performed under the Association of American Railroads' Strategic Research Initiatives Program.

North American freight railroads conduct preventive rail grinding at regular intervals to maintain good rail surface condition and the target profile while minimizing the amount of metal removed.[1] Corrective rail grinding becomes necessary when rolling contact fatigue (RCF), spalling, or other near-surface conditions reduce the confidence of UT for internal defects. In this *Technology Digest*, rails with poor confidence UT results will be referred to as "rail exceptions." When rail exceptions are encountered, rails typically are ground back to a state of acceptable UT signal strength or replaced. If discovered shortly before a visit from the rail grinder, rail exceptions often will receive corrective grinding in an attempt to allow a valid test during the subsequent detector car visit. Alternatively, a railroad may elect to avoid extra grinding effort if, for example, the rail head is heavily worn and it makes more sense to replace the rail. Also, if corrective grinding is attempted and UT results from the subsequent UT continue to provide insufficient confidence, the rail exception will be removed from service.

Using a sample size of five rail exceptions that were removed from service, TTCI previously quantified the depth of the surface anomalies and the confidence in the UT.[2] Identical reflectors in the railhead produced an average of 67 percent relative UT response from the five rail exceptions compared to a control rail with no visible surface damage. This implies that small internal defects could have been identified and acted upon despite the surface condition. Optical microscopy showed that the maximum depth of 90 percent of the cracks and spalls measured from these rails did not exceed 0.040 inch.

CORRECTIVE GRINDING CASE STUDIES

Detailed data was collected at a diverse group of corrective grinding case study sites to better define the effectiveness of corrective grinding and optimal amount of metal removal. The sites, provided by two railroad partners, included older rail with heavy spalling on a lower tonnage line and newer rail with shallower damage more representative of main-line conditions. At all sites, the corrective grinding successfully restored high quality rail testing.

Four of the individual sites were within a 7-mile range on a single line and ranged from tangent to 3.3-degree curvature. This line typically is ground every other year and averages 15 million gross tons (MGT) per year. The rail is relay — it was manufactured and originally installed in the early 1980s on a heavy tonnage mainline and then relocated to its current location in 1991. Before grinding, the rail surface condition at these sites included spalls of many sizes and well-developed RCF cracks. Figure 1 shows representative images of rail surface conditions at one of these rail exception sites.

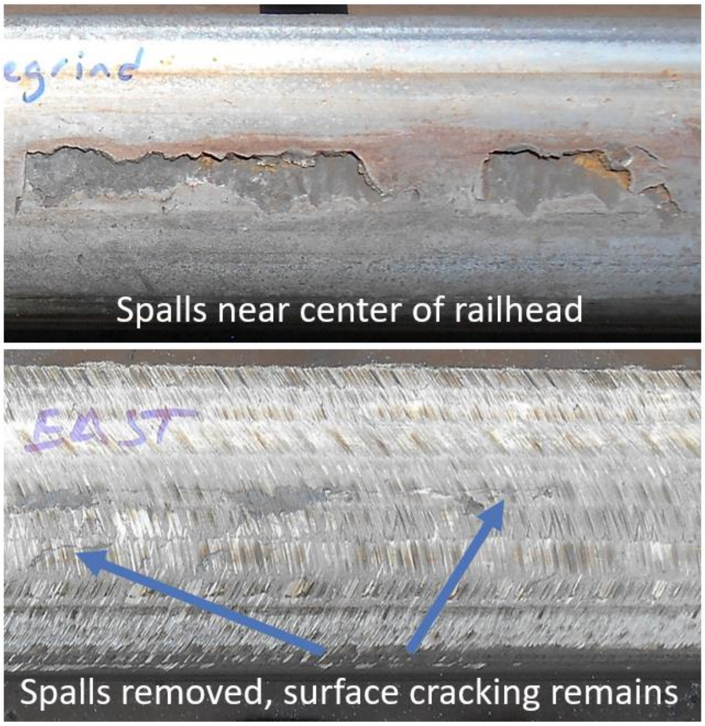

Figure 1. Representative pre-grind (top) and post-grind (bottom) rail condition at a site with older rail and annual tonnage of 15 MGT

These four sites were treated with five to 11 passes from a 96-stone production grinder resulting in 0.031 inch to 0.157 inch of metal removal from the center of the head. Inspection of the sites occurred before, during, and after grinding and included photographs of the rail surface condition and rail cross-sectional profiles. Between grind passes, observers noticed that, in some cases, as the grinder removed spalls that had been open to the surface, it was uncovering spalls that were previously hidden beneath the surface.

Another rail exception case study site, on a different line, was the low rail on a 3-degree curve that carries 43 MGT per year. Figure 2 shows representative images of the rail surface conditions at this rail exception site.

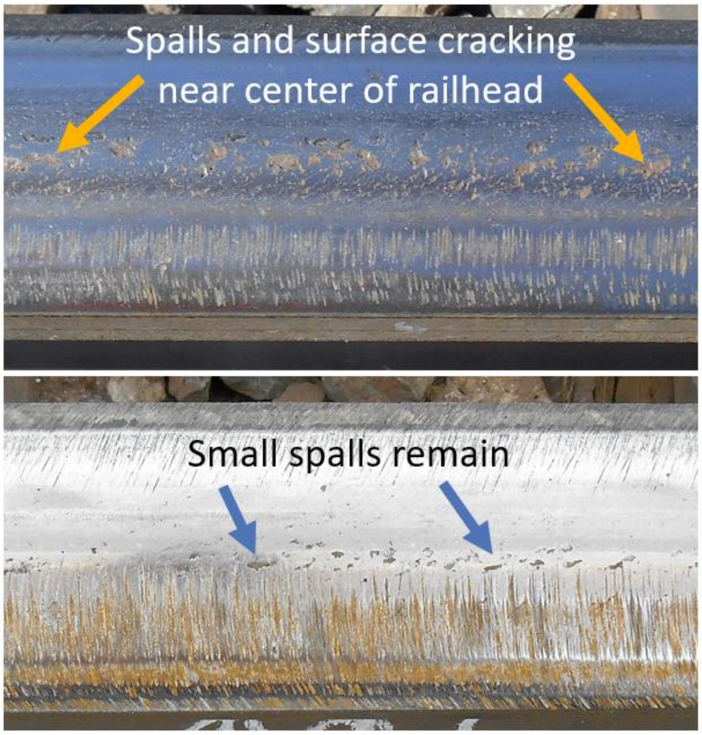

Figure 2. Representative pre-grind (top), post-grind (bottom) rail condition at a site with newer rail and annual tonnage of 43 MGT

The standard (non-premium) rail was produced in 2006. This site is at a congested area and has a permanent speed limit of 20 mph. The grinder typically visits this site semi-annually. Poor UT confidence was discovered and marked over a length of approximately 25 feet. The rail received two grind passes that improved the UT results, but not enough to remove the rail exception. No inspection data is available regarding the grinding operation. A second visit from the grinder provided high confidence UT results after three additional grind passes. Pre-grind and post-grind inspections were made for this second grinder visit. By overlaying the pre-grind and post-grind profiles, the amount of metal removed from the center of the rail head during the second grinder visit was determined to be 0.012 inch. RCF cracks and small spalls were visible on the surface before grinding. After grinding, RCF cracks were no longer visible but spalls, though reduced in size, were present and visible.

ESTIMATED GRIND DEPTH

Although the case study data provides excellent detail about the visual rail surface condition and high confidence about the depth of grind via rail profile measurements, it is difficult to collect a large quantity of data in this manner. Instead, a larger sample size can be gathered more easily using estimates (rather than measurements) of the amount of metal removed. Comparison of pre- and post-grind rail profiles shows that a large production rail grinder can remove as much as 0.014 inch per pass at slow travel speeds, and 0.006 to 0.008 inch per pass at more typical travel speeds. Scaling these values appropriately allows for relative estimates about metal removed based on grinder model, grinder speed, and number of passes.

Multiple railroads provided dates, locations, and outcomes for their rail exceptions. This data was cross-referenced with grinding data provided by a vendor to identify locations that were ground between the date they were first identified as rail exceptions and the date they were either removed from service or received a valid test. Table 1 lists pertinent information about the 88 rail exceptions that were analyzed. Most of these sites (68 of 88) received a successful corrective grinding. For the 20 rail exceptions that were removed from service shortly after grinding, it is possible that at least some had insufficient remaining head height to justify a true corrective grind effort.

Table 1. Summary of data analyzed

Post Grind Outcome	Valid Test	Removed
Rail Exceptions Analyzed	68	20
Grinder Pass Count (Min/Median/Max)	1 / 3 / 17	1 / 2 / 5
Grinder Speed (mph) (Min/Median/Max)	5 / 8 / 13	6 / 8 / 12
Rail Exception Length (feet) (Min/Median/Max)	20 / 462 / 18,480	30 / 238 / 1,750
Estimated Grind Depth (inch) (Min/Median/Max)	0.006 / 0.028 / 0.157	0.006 / 0.018 / 0.059

Whereas the previous study[2] found only 10 percent of cracks and spalls extended beyond 0.040 inch from the rail surface, this analysis shows that 40 percent of the successful corrective grinding efforts removed more than 0.040 inch of rail. Although this data shows that many rail exceptions (e.g., Figure 2) can be addressed with relatively little metal removal, some rail exceptions require significant corrective grinding effort (such as in Figure 1). Removing too little metal during corrective grinding leaves the possibility of wasted effort if the subsequent UT does not provide a high level of confidence. Of the unsuccessful corrective grinding efforts, only 10 percent removed 0.035 inch or more.

Figure 3 looks at the relationship between grind depth and outcome. For example, rail exceptions produced valid tests in 77 percent of the grinds that removed at least 0.005 inch of metal, 88 percent of the grinds that removed at least 0.020 inch of metal, and 100 percent of the grinds that removed at least 0.060 inch of metal.

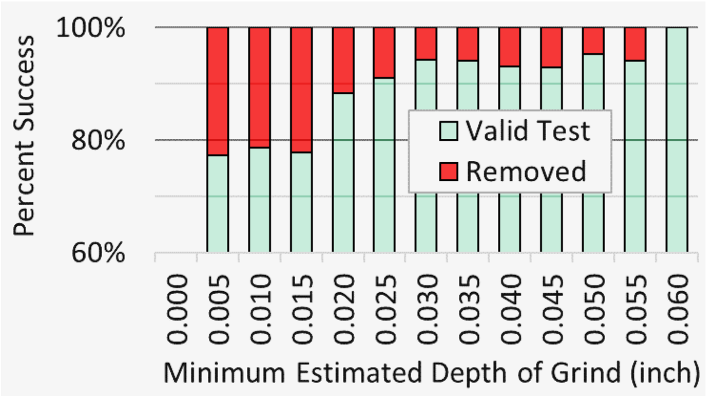

Figure 3. Success rates by grind depth

Figure 4 shows the relationships between rail exception length, estimated grind depth, and post-grind results for four different railroads. One successfully ground rail exception is omitted from Figure 4 due to its length of 3.5 miles (18,480 feet).

Railroad A attempted corrective grinding on six rail exceptions of more than 1,400 feet in length, and five were successful. Deep grinds were successfully executed on each of the four railroads with 0.060 inch to 0.157 inch of rail removal. This type of deep corrective grinding opens the possibility that alternative supplemental technologies, such as rail milling, may have potential application for North American freight railroads.

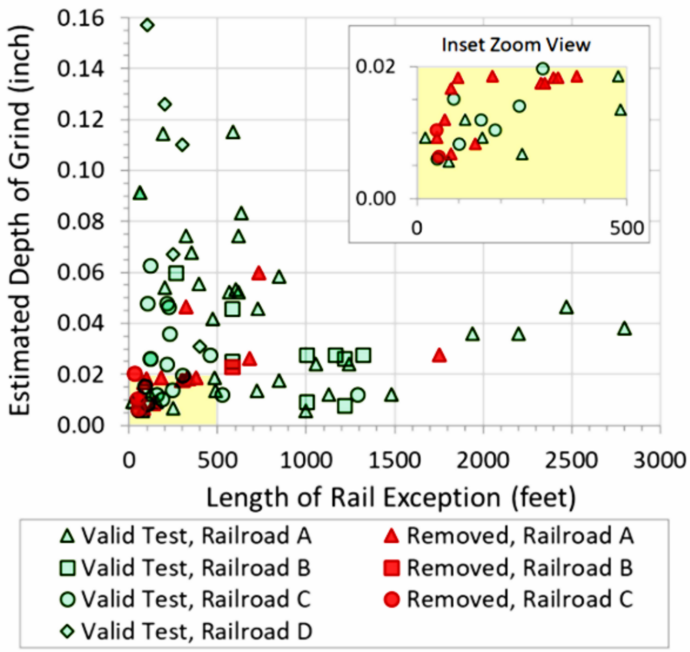

Figure 4. Grind depth and outcome as a function of rail exception length

CONCLUSION AND FUTURE WORK

Corrective grinding was a successful remediation strategy for 77 percent of the 88 rail exceptions analyzed. The grinding effort ranged from one pass to 17 passes of a production grinder resulting in estimated metal removal of 0.006 inch to 0.157 inch at the center of the head. Rail exceptions remediated through grinding ranged in length from 20 feet to 3.5 miles. All grinds that removed at least 0.060 inch of metal were successful in achieving a valid rail flaw test.

The large variation in corrective grinding efforts does not allow for a blanket recommendation for corrective grinding depth. Each rail exception likely will have its own optimal metal removal depth. This highlights the need for an accurate non-destructive method to assess rail surface crack depth before the grinder arrives. TTCI is actively exploring existing technologies to fill this need.

As shown previously under controlled conditions[2] and demonstrated at several case study sites, complete elimination of all cracks is not necessary for acceptable UT response in rail.

ACKNOWLEDGEMENTS

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References

1. Roney, M. and S. Cummings. June 2015. "Survey of Current Rail Grinding Best Practice in North American Freight Railways." Report R-1011. AAR/TTCI. Pueblo, CO.
2. Cummings, S. November 2018. "Testability and Corrective Grinding Depth of Rails with Poor Surface Condition." *Technology Digest* TD18-027. AAR/TTCI. Pueblo, CO.

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