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Testability and Corrective Grinding Depth of Rails with Poor Surface Condition

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Summary

Transportation Technology Center, Inc. (TTCI) provided data to support corrective grinding efforts and quantify the testability of rails with poor surface condition as part of the Association of American Railroads (AAR) Strategic Research Initiatives Program (SRI).

Analysis of five sample rails removed from service due to low confidence ultrasonic test (UT) results and installed at Transportation Technology Center (TTC), demonstrated that small internal defects in the rail heads could have been identified and acted upon despite the poor surface condition. Holes drilled in the test rails produced an average of 67 percent of the relative UT response compared to a control rail with a similar drilled hole.

Optical microscopy identified 880 rolling contact fatigue (RCF) cracks or spalls in the five sample rails. Ninety percent of the RCF cracks and spalls were found to extend no more than 0.040-inch deep below the surface of the rail. As an alternative to replacing these rails, three to five passes with a production grinder would likely have improved UT confidence.



INTRODUCTION

TTCI provided data for corrective grinding efforts and quantifying the testability of rails with poor surface condition. The analysis demonstrated that small internal defects could have been identified and acted upon despite the poor surface condition. Rather than replacing these rails, three to five passes with a production grinder would likely have improved UT confidence.

BACKGROUND

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 material removed.¹ Corrective rail grinding becomes necessary when RCF, spalling, or other near-surface conditions reduce the confidence of UT for internal defects. One way of gauging the confidence of UT results is to verify that a vertically oriented ultrasonic signal can be successfully transmitted from the head of the rail to the base of the rail and reflected back to the head of the rail. If the reflected signal strength decreases, it can be a sign that anomalies at or near the rail surface, such as RCF or spalling, may be scattering a portion of the ultrasonic signal. This is commonly referred to as “loss-of-bottom.” When this condition is encountered, rails are typically ground back to a state of acceptable UT signal strength or replaced.

Rail testing is conducted using a hi-rail detector car configured to scan the rail at multiple fixed locations and orientations. When a rail testing operator identifies a condition worthy of further investigation, he or she will disembark from the detector car and conduct a manual UT hand scan to arrive at a final decision about the internal condition of the rail. For rails with loss-of-bottom, neither the depth of the surface anomalies nor the confidence in the UT are well-defined. Figure 1 illustrates the concept of loss-of-bottom and shows a UT hand scan of a rail.

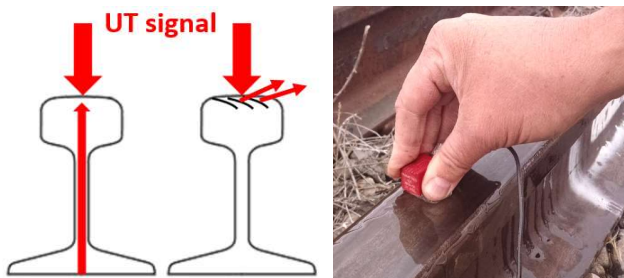


Figure 1. UT Loss-of-bottom illustration (left) and UT hand scan (right)

RAIL CONDITION AND PREPARATION

TTCI acquired four lengths of rail removed from revenue service due to surface conditions that were reducing the confidence in the UT results. In addition, a fifth rail (test rail No. 5) was removed from one of the tracks at TTC due to surface condition obscuring the UT. These rails are shown in Figure 2.

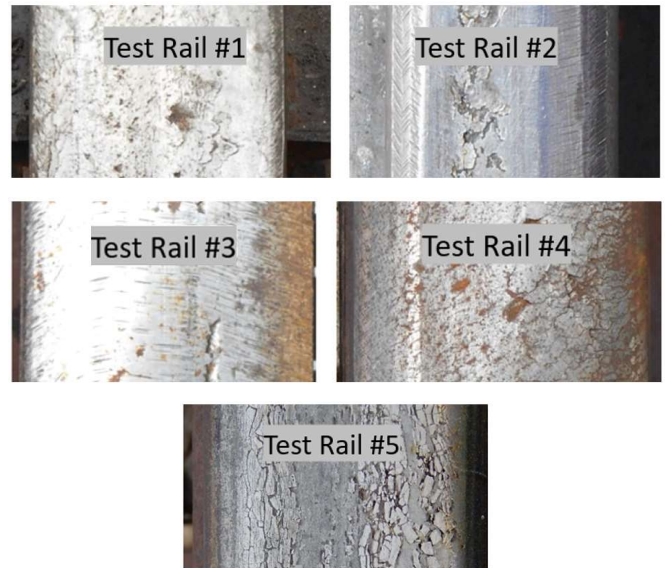


Figure 2. Surface condition of rails

Preliminary hand scan UT was used to identify specific locations along each rail where the bottom reflection signal was weakest. At these locations, multiple 1/8-inch diameter holes were drilled through the transverse cross section to ensure that the rails contained conditions that should be detectable via UT. Figure 3 shows a drilled rail. Each of the test rails was then installed on a special track at TTC accessible by a detector car. A nearby rail with good surface condition was also drilled to provide a control rail for comparison.



Figure 3. Transverse cross section and side view photo of rail with drilled hole

QUANTIFYING TESTABILITY

The test rails and the control rail were evaluated with a detector car. Figure 4 shows an image derived from the detector car results. Output from various UT transducers are shown in this image. The yellow box on the left side of the figure contains the results from transducers scanning the rail head near some drilled holes in one of the test rails. The white streaks are indications of the holes. The pink box on the right shows output from the same transducers at the control hole. The small red box in the lower left corner of the figure shows the loss-of-bottom. The detector car showed mixed results for the drilled holes at the center of the rail head and on the gage side of the rail head with indications ranging from strong to faint. For the test rails and the control rail, the field side indications were typically stronger than the center or gage side indications.

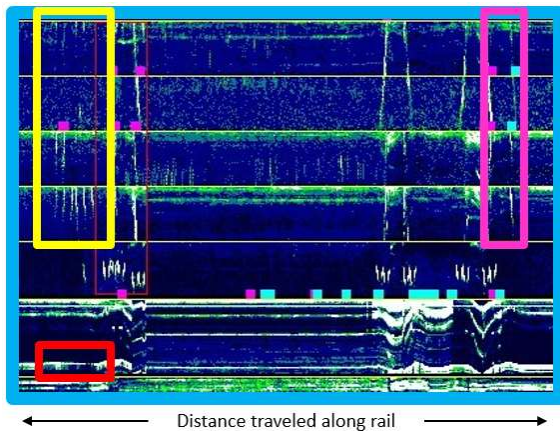


Figure 4. Detector car sample results

Hand scan UT then was conducted to replicate what a detector car operator might do in when faced with a rail exhibiting a condition worthy of further investigation. Using a 70-degree transducer, the UT hand scan operator first determined the maximum amplitude from the drilled hole in the control rail at three locations across the rail head: gage side, center, and field side. In the same way, the operator then determined the signal strength of the holes in the test rails. Table 1 and Figure 5 summarize the relative UT signal strength of the drilled holes in the test rails in relation to the drilled hole in the control rail. Similar to the height of the bars in a histogram, the area of the balls in Figure 5 is directly related to the quantity of observations.

In some cases, the test rails produced higher amplitude response than the control rail as indicated by relative response greater than 100 percent. This is thought to have occurred when the test rails presented a flatter surface over the area of the transducer compared to the control rail and therefore would have received more

ultrasonic input energy. Compared to the control rail, the test rails produced on average 67 percent (and in no case less than 15 percent) of the relative UT response.

Table 1. UT hand scan average results

Rail #	Quantity of Drilled Holes	Average Relative UT Response			
		Lateral Location			Overall
		Gage	Center	Field	
1	6	57%	41%	85%	61%
2	3	65%	39%	79%	61%
3	5	65%	50%	54%	56%
4	5	93%	76%	80%	83%
5	3	58%	53%	113%	75%
All	22	68%	52%	80%	67%

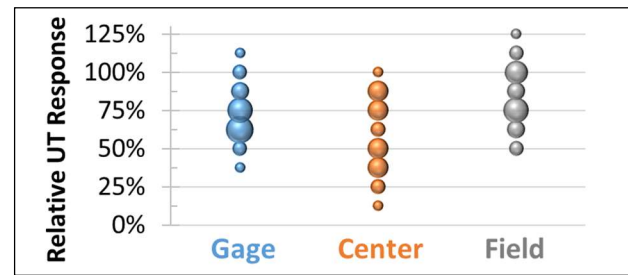


Figure 5. UT hand scan result distributions

QUANTIFYING SURFACE DAMAGE DEPTH

After determining the relative UT response from the drilled holes, the test rails were removed from track and sectioned for destructive evaluation. Transverse and longitudinal sections were removed from the area immediately surrounding each drilled hole. Dye penetrant was used on the sections to verify that no naturally occurring defects were present in the rail head below the depth of the surface damage. Figure 6 shows examples of rail sections with dye penetrant applied.

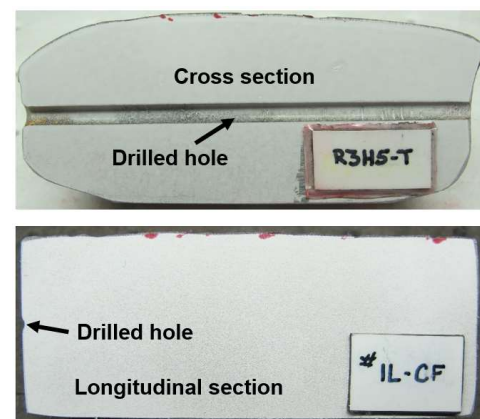


Figure 6. Transverse cross section and longitudinal section treated with dye penetrant

Each rail section was then subdivided and prepared for optical microscopy by mounting and polishing. The optical microscopy samples were reviewed in detail and the maximum depth of every visible crack and spall was measured and recorded. Figure 7 shows an example of an optical microscopy sample. It should be noted that complete elimination of all cracks is not necessary for improved UT response.

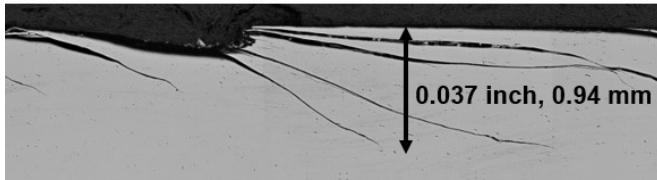


Figure 7. Optical microscopy to determine maximum depth of each crack or spall

Figure 8 contains a summary of the maximum depths of each crack and spall observed from the optical microscopy samples. A total of 880 cracks or spalls from the rails in the vicinity of the 22 drilled holes are represented. Ninety percent of the cracks and spalls were found to extend no more than 0.040-inch deep below the surface of the rail.

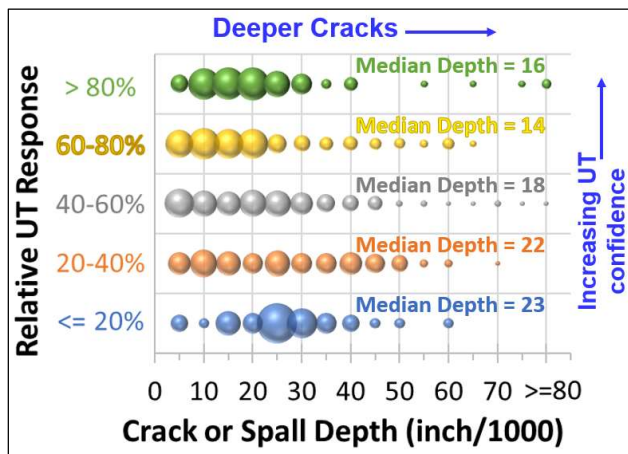


Figure 8. Distributions of crack or spall depth

This data is partitioned into five categories based on the relative UT hand scan response. Although statistical testing can identify some differences in depth of the surface damage between the different categories of

relative UT response, the practical differences between the groups are extremely small. Slightly deeper cracking and spalling is observed when relative UT response amplitude is lower.

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. Based on these values, three to five grinder passes could have completely eliminated the majority of cracks and spalls in the five test rails and substantially reduced the depth of any remaining surface damage, thus resulting in improved UT confidence.

CONCLUSION AND FUTURE WORK

A study of five rails with surface conditions sufficiently severe to reduce the confidence in the UT results provided an average of 67 percent relative UT response from reflectors in the rail head 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.

Grinding is an alternative remediation strategy for such rails and optical microscopy shows that the maximum depth of 90 percent of the 880 cracks and spalls measured from these rails did not exceed 0.040 inch. This is well within the range of corrective grinding with a large production grinder and likely would have restored high confidence UT in these rails.

TTCI is attempting to expand the sample size of this work by looking at the historical number of grinder passes applied to rails with loss-of-bottom and the subsequent detector car results.

ACKNOWLEDGEMENTS

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References

1. Roney, M. and S. Cummings, "Survey of Current Rail Grinding Best Practice in North American Freight Railways" Report R-1011, June 2015, AAR/TTCI, Pueblo, CO.

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