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Evaluation of an Eddy Current System for RCF Measurements

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Summary

As part of the Association of American Railroads' Strategic Research Initiatives Program, Transportation Technology Center, Inc. (TTCI) is working to encourage the development of systems capable of measuring rolling contact fatigue (RCF). As part of this initiative, TTCI and Norfolk Southern (NS) Railway have conducted an initial evaluation of an RCF crack detection and measurement system that utilizes eddy current technology.

The EloRail WPG D340 Draisine, developed by Rohmann GmbH of Germany, was tested on the High Tonnage Loop at the Transportation Technology Center in Pueblo, Colorado, and on NS revenue service lines. Preliminary steps have also been taken towards validating the results against the actual measured depths from cross sections of the rail. Results from this initial evaluation suggest that the device appears to be capable of detecting the surface cracks associated with RCF on rails and providing an estimated quantitative measure of both the crack density as well as depth based on an assumed crack angle. The results show the variation of Draisine measurements from the true value of crack depth to be between 5 percent and 33 percent across these samples, assuming a crack angle of 25 degrees, resulting in an estimated error less than 0.003 inch per 1 degree. This suggests the accuracy is heavily dependent upon the assumed crack angle entered by the user. Additional samples will need to be gathered and analyzed in a similar fashion to more accurately define the percent error associated with the Draisine.

RCF results in wear, material flow, and crack formation on both wheels and rail, all of which adversely affect life of both components. Being able to identify and measure RCF will allow railroads to better manage their rail maintenance and, in turn, extend the service life of their rails. As such, TTCI continues to support the development and validation of systems for use in measuring RCF. Further results will be presented in future publications as part of an ongoing search for innovative technologies to detect and quantify RCF-related defects.

A supplementary *Technology Digest*, TD-14-008, reports on the methods available for RCF detection and addresses the limitations associated with current measurement technology.



INTRODUCTION

RCF reduces wheel and rail service life and places a significant burden on track maintenance. The Centre for Surface Technology in Ontario, Canada, reports that more than US\$300 million is spent annually by North American railways in rail replacement, and at least US\$30 million is dedicated to grinding, both as a direct result of RCF.¹

RCF is a term that encompasses surface and near-surface cracks as well as wear and material flow, all of which are detrimental to service life.² While extensive development of profilometers have provided an accurate means of documenting wear and material flow, the primary means of evaluating the extent of surface and near-surface cracks resulting from wheel/rail contact has been visual inspection. This inspection method is time and labor consuming and is unreliable for determining the depth of surface defects. The industry would greatly benefit from a technology that could perform an accurate and efficient assessment of rail surface cracks.

MOBILE EDDY CURRENT TECHNOLOGY

TTCI has investigated the effectiveness of one eddy current system currently available in markets worldwide, including North America. Rohmann GmbH, a company based in Frankenthal, Germany, has developed the EloRail WPG D340 Draisine (shown in Figure 1) for measuring surface cracks along the top and gage corner of the railhead.

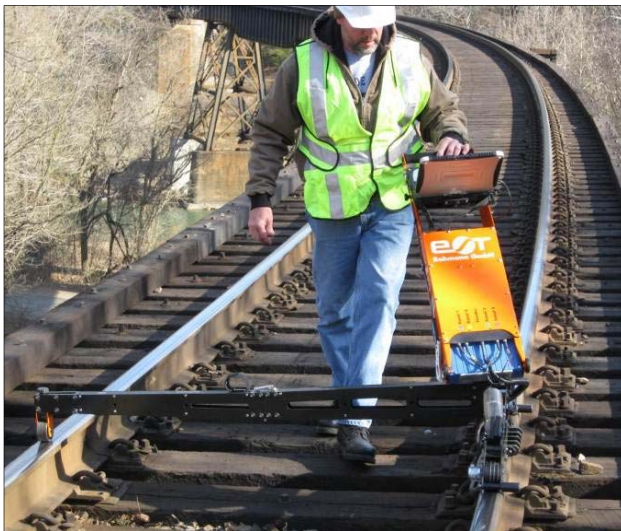


Figure 1. On-track Operation of Rohmann's WPG D340 Draisine

The device incorporates four probes housed in ceramic casings that adapt to the profile of the rail and cover specific areas along the gage corner and top. The casings prevent the probes from making direct contact with the rail while providing protection to the probes. This setup allows the device to record multiple channels of crack depth data, pinpoint the location of the cracks among the four longitudinal fields, and determine the severity of the cracks.

Electromagnetic testing (i.e., eddy current) generates a magnetic field in a conductive material using various types of coils. The signal generated by one set of coil windings is compared to the signal received by another set of coil windings, and a change in signal indicates a flaw in the material. Flaws are detected when they are open to the surface, making eddy current well suited for rail surface testing.

The Draisine relies on the user to enter an assumed crack angle, as the actual angle cannot be determined through nondestructive testing. Figure 2 presents a typical crack with angle α .

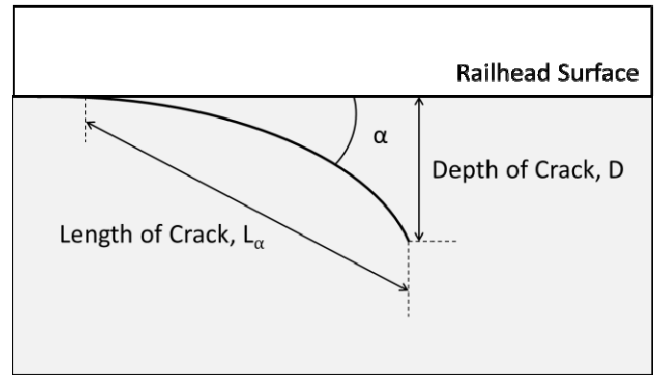


Figure 2. Orientation and Layout of a Typical RCF Crack

Examination of rail cross-sections removed from the high side of a North American heavy-haul line showed the crack angle α to vary between 18 and 28 degrees. The selectable default setting for α within the Draisine is typically set at 25 degrees.

The Draisine has been used in European markets since receiving approval in March 2011 by DB Netz AG, but it has not been tested in the North American heavy-haul environment until recently. Over the past year, the Draisine was tested to determine the capabilities and limitations of this device to measure rail cracks at Transportation Technology Center's (TTC) Facility for Accelerated Testing (FAST) and on a revenue service line in the eastern United States.

TESTING AT TTC

Section 7 of the High Tonnage Loop (HTL) at FAST is located within a 1,000-foot 5-degree curve with 4 inches of superelevation. The normal operating speed of the FAST train is 40 mph, although the balance speed for the curve is 34 mph. Rails within this curve are not lubricated. This section currently hosts the AAR's premium rail test, which is evaluating 10 different rail grades from 7 manufacturers with respect to wear and RCF growth. During train operations, this section of the HTL accumulates an average daily tonnage of approximately 1.6 MGT.

Each premium test rail, from the seven manufacturers, was installed in 40-foot segments within the curve and was measured for pre- and post-grind assessment of crack depth using the Draisine. Pre-grind measurements were conducted at approximately 340 MGT and post-grind measurements at

410 MGT. The results for one 40-foot segment (i.e., one specific grade of rail) are provided in Figure 3.

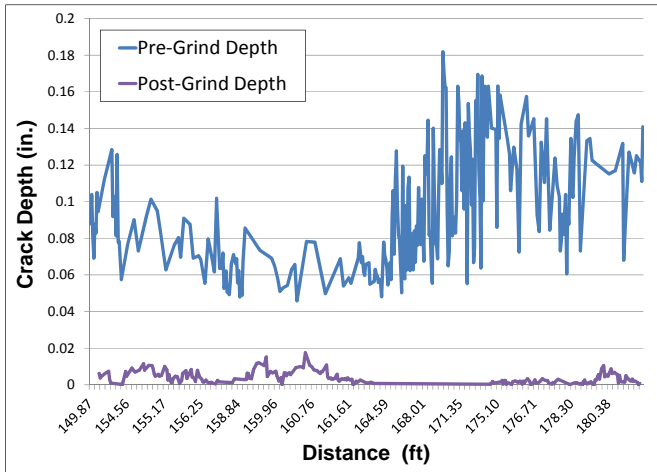


Figure 3. Results for Individual Depth Readings ($\alpha = 25^\circ$)

TESTING IN REVENUE SERVICE

To supplement the results observed at FAST, the Draisine was tested on a NS heavy haul coal line running through Virginia.

NS conducted initial testing on a 6-degree curve at Wabun, Virginia, which coincided with work of a production rail grinder. Railhead cracks along a 100-foot segment of a low rail were measured before grinding as well as after each of five consecutive grinding passes. Figure 4 shows the typical pre-grind condition of the rail. The Draisine’s results, shown in processed graphical form in Figure 5, reflect a reduction in crack depth with each grinding pass, from 0.14 inch pre-grind to less than 0.04 inch post-grind. Figure 6 shows the typical post-grind condition, with cracks still visible among the grinding stone marks. Noteworthy is the fact that the grinding stone abrasive marks did not appear to interfere with the Draisine’s measurement of the cracks associated with the RCF.



Figure 4. Low Rail at Wabun, Virginia, prior to Grinding

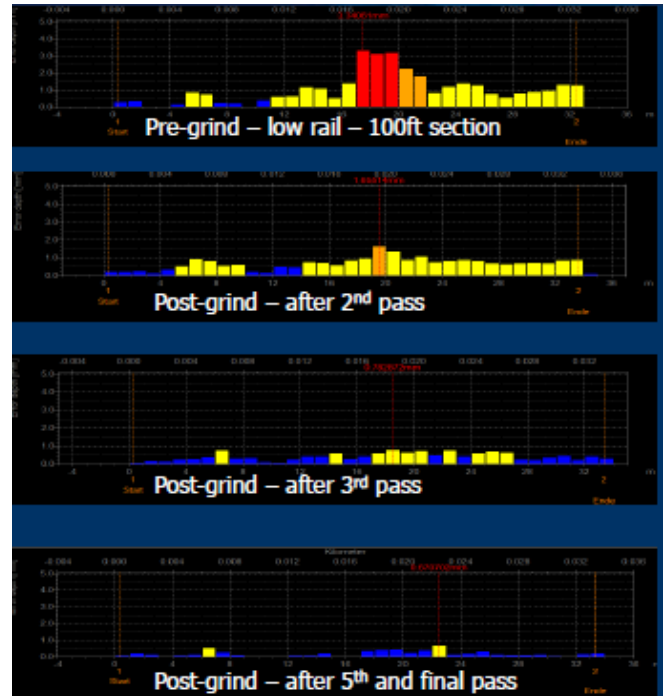


Figure 5. Draisine Output on the Same 100-ft Segment Pre-Grind and Post-Grind following 2nd, 3rd, and 5th Passes ($\alpha = 25^\circ$) (Figure courtesy of NS.)



Figure 6. Low Rail at Wabun, Virginia, after Five Grinding Passes

VALIDATION OF DRAISINE DATA

In an effort to validate the technology developed by Rohmann GmbH, NS conducted additional testing on a heavy-haul coal line near Glen Lyn, Virginia. Draisine data from a 1-degree curve was compared to actual crack measurements taken from rail cross sections. Using microscopy, the maximum depth of the cracks was measured and compared directly against the processed output from the Draisine. Figures 7 and 8 display one such cross section from Glen Lyn and the corresponding Draisine output, respectively.

The depth of the crack in the red box in Figure 8 measured 0.071 inch. The Draisine, assuming a crack angle α of 25 degrees, reported a maximum depth within this area to be

approximately 0.083 inch, a difference of 16.7 percent from the actual value. Multiple cross sections had their actual and Draisine depth measurements compared, and the results show the variation from the true value to be between 5 percent and 33 percent across these samples assuming $\alpha = 25$ degrees (see Table 1).

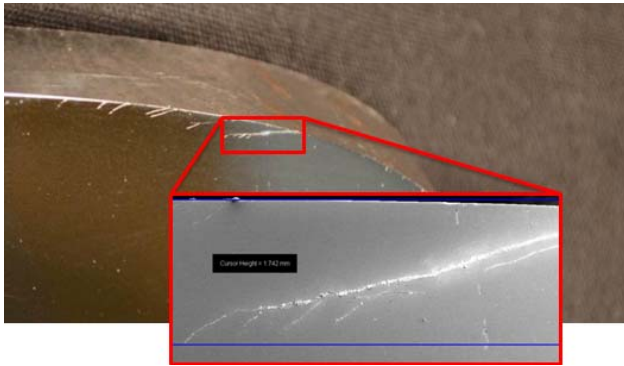


Figure 7. Cross Section of the High Rail at Glen Lyn, Virginia

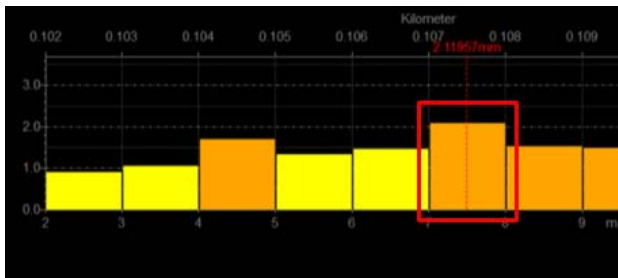


Figure 8. On-site Results Output by the Draisine's EloRail Software ($\alpha = 21$ degrees)

Table 1. Summary of Validation Results from Glen Lyn ($\alpha = 25$ degrees)

Actual Depth (in)	Actual Crack Angle	EC Measured Depth (in)	Percent Difference
0.071	21°	0.083	16.7%
0.067	18°	0.083	23.5%
0.079	25°	0.075	5.0%
0.012	28°	0.016	33.3%

Post-processing of the data included adjusting the values collected by the Draisine given the actual crack angle from the lab results of the cross sections. This greatly reduced the majority of percent differences observed between the results obtained in the lab and those from the Draisine (see Table 2).

As shown in Table 2, the fourth sample actually resulted in an increase in the percent difference under the actual crack angle than under the assumed $\alpha = 25$ degrees. As the crack depth associated with this sample was very small, the relatively small change in the actual depth resulted in a large percentage error.

Table 2. Summary of Validation Results from Glen Lyn (Actual)

Actual Depth (in)	Actual Crack Angle	EC Measured Depth (in)	Percent Difference
0.071	21°	0.069	2.8%
0.067	18°	0.063	5.9%
0.079	25°	0.075	5.0%
0.012	28°	0.019	60.0%

CONCLUSION

Preliminary results from the initial testing at FAST and on the revenue service line are very promising.

The results from the testing at FAST show a definite decrease in the depth of surface defects through the pre- and post-grind sequences. Initial studies aimed at validating the Draisine device have shown that the eddy current readings are highly dependent upon the assumed crack angle α entered by the user. Assuming the default value of α equal to 25 degrees, an error up to 0.003 inch per 1 degree is in the measurements taken at Glen Lyn. Post-processing of the data using the measured crack angle α collected from each of the samples greatly improved these estimates in most cases, although there was a residual error up to 0.0071 inch.

The amount of error for such a device would dictate how accurately railroads can optimize their grinding schedules based on regular eddy current testing. Based on the results obtained from Glen Lyn, the Draisine has the possibility of either under or overestimating the depth of the RCF present in the rails up to 0.003 inch per 1 degree of error in the estimate of the crack angle α . Additional samples will need to be gathered and analyzed in a similar fashion to more accurately define the percent error associated with the Draisine.

FUTURE WORK

TTCI and NS will continue to evaluate the performance of the Draisine, both at FAST and in revenue service to better quantify the error associated with its measurements. At present, rails selected for removal at FAST have already been analyzed using Rohmann's WPG D340 and multiple sections have been designated for laboratory analysis to verify the readings taken and further validate the eddy current system.

REFERENCES

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