U.S. Department of Transportation
Federal Railroad Administration

RESEARCH RESULTS
FRA OFFICE OF RESEARCH, DEVELOPMENT & TECHNOLOGY

RR 22-36 | **November** 2022

EXPANSION OF RAIL FLAW LIBRARY AT THE TRANSPORTATION TECHNOLOGY CENTER

SUMMARY

In 2017, Transportation Technology Center, Inc. (TTCI) began adding naturally occurring rail flaws to the Rail Flaw Library of Associated Defects (RF-LOAD) by acquiring defective rails from the field with funding by the Federal Railroad Administration (FRA). Rail samples containing service induced flaws have varying rail profiles, such as different rail head profile wear, and different surface conditions. Since only so many of these natural/field defects can be collected every year, the goal is to continue this work and collect more rail flaw samples for the RF-LOAD every year.

TTCI characterized RF-LOAD and naturally occurring rail flaw samples collected with a high level of accuracy using available physical and non-destructive evaluation (NDE) measurement techniques. Physical measurements included dimensional and MiniProf profile measurements and analysis. This allowed researchers to calculate rail wear, align rails with the template profiles, and generate two- and three-dimensional (2D/3D) Solidworks® models of the defective rails and calculate the cross-sectional head areas for different rail head profiles. Embedded reflectors and internal flaw characterization was done by using hand-held ultrasonic testing (UT) NDE methods, which include conventional UT and phased array UT (PAUT).

These rail flaw samples and 2D/3D Solidworks® models of the rails with internal flaws are available to other rail researchers and industry service providers in the United States to support rail inspection research. Also, these rail flaw samples are useful to investigate how well particular NDE techniques can characterize rail flaws under different rail head situations.

BACKGROUND

Ultrasonic NDE methods for rail flaw detection are the primary techniques employed by the railroads to monitor, detect and characterize rail defects. Although conventional ultrasonic inspection systems have proven effective at finding most of the critical rail flaws, inherent limitations leave some flaws undetected during periodic inspection [1]. Overall, ultrasonic detection greatly depends on the magnitude of the received/recorded ultrasonic reflection from the flaw. The physical shape, size, location, and orientation of flaws, and poor ultrasonic coupling can result in a low-amplitude reflection signal. Two limitations of existing conventional ultrasonic systems lie with the fixed-angled inspection approach and not automatically compensating the ultrasonic beam path in worn rail head profiles. Another inherent limitation with ultrasonic inspection is acoustic coupling. The detection of internal defects in the presence of surface flaws as a result of rolling contact damage (RCD)/subsurface shelling can be a challenge.

The rail integrity research efforts by FRA and the Association of American Railroads (AAR) aim to increase safety and reliability of rail transportation. One of the continued FRA-funded initiatives led by the research team involves expanding the RF-LOAD and characterizing it using UT NDE methods at the Transportation Technology Center (TTC), near Pueblo, CO [2–3]. Standardized rail defect samples are important for qualifying NDE techniques used for rail inspection.

The RF-LOAD initially consisted of master gauge samples containing a variety of artificial reflectors, mostly flat bottom holes (FBHs) of differing cross-sectional area. FBHs were drilled at different orientations and locations relative to the rail head center point and then were press-fitted with dowel pins/rods (of similar material properties) to mask the holes. These reflectors represent 1 to 30 percent cross-sectional head area (CSHA) discontinuity at various orientations and depths. Master gauge rail samples include 136-RE rails with the normal head profiles (light head wear), surface damaged (rolling contact damage) profiles, and curve worn (gage face wear) profiles. Worn sections came from the high tonnage loop at the Facility for Accelerated Service Testing (FAST) at the TTC.

RF-LOAD helps to meet these challenges by providing flaw library access to rail researchers and other industry service providers so that they can optimize their inspection systems for better flaw detection and characterization.

OBJECTIVES

The primary objective of this work is to expand the RF-LOAD at the TTC. The anticipated industry impacts include the following:

- Increased safety by developing and deploying efficient and reliable advanced NDE methods
  - Improve defect detection sensitivity using any particular NDE technique
  - Characterize rail flaws under different rail profiles/geometries, and surface conditions
  - Increase inspection reliability
- Addressing industry needs in key areas, such as:
  - Operator training
  - Rigorous calibration
  - Improved inspection
  - Improved maintenance
  - Risk reduction via probability of detection (POD) demonstration

RF-LOAD

TTCI has completed fabrication of the master gauge samples in RF-LOAD. The focus now is to collect naturally occurring rail flaw samples with varying degrees of profile wear and surface damage. Master gauges and naturally occurring rail flaw samples collected are characterized with a high level of accuracy using available physical and NDE measurement techniques including dimensional and MiniProf profile measurements. This allowed the calculation of the rail wear (i.e., W1, W2, W3, gained and lost area) for each rail, alignment of rails with the template profiles, and the generation of 3D Solidworks® models of the rails. The cross-sectional head areas for different rail head profiles were calculated from SolidWorks® models using AREMA Chapter 4 guidelines. Figure 1 shows the schematic of an overlay of measured MiniProf profiles for some of the master gauge rail samples over 136 lbs./yd. template rail profile.

Embedded reflectors and internal flaws characterization were done using hand-held UT NDE methods. These methods include conventional UT and PAUT. Sizing of TD was done by approximating the size of the internal flaw as a percentage of the cross-sectional area of the rail head. This approximation is given by Equation 1 [4].

$$TD = \frac{\pi l w}{4A} \times 100\% \qquad (1)$$

where, l and w are the length and width of the internal flaw (TD) and A is the cross-sectional head area (CSHA) of the rail.

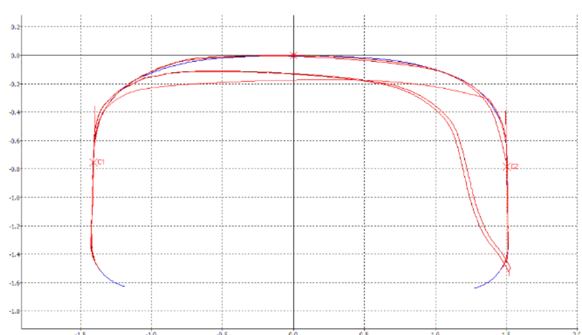

Figure 1. Overlaid measured MiniProf profiles over 136 lbs./yd. template rail profile (blue solid line)

While performing UT, the height of the TD type defect can be measured by scanning the TD along the length of the rail (i.e., longitudinal direction). Similarly, by scanning across the head of the rail (i.e., transverse direction), the width of the TD type defect can be measured.

Table 1 shows some of the wear measurements (i.e., W1, W2, and W3) and area (gained/loss) measurements for some of the master gauge samples.

Table 1. Rail profile measurement results

*Master gauge rail sample	High/low rail	Wear measurements			Measured rail head area (in.^{2})
		W1 (in.)	W2 (in.)	W2 (in.)	
N5a	H	-0.001	0.034	0.025	4.76
S5a	L	0.171	-0.008	-0.008	4.46
W1a	H	0.133	0.376	0.340	4.18

* Master gauge rail sample nomenclature - N: normal rail profile, S: surface damaged rai profile, W: Curve worn rail profile

Figure 2 shows the SolidWorks® drawing for one of the RF-LOAD master gauge samples.

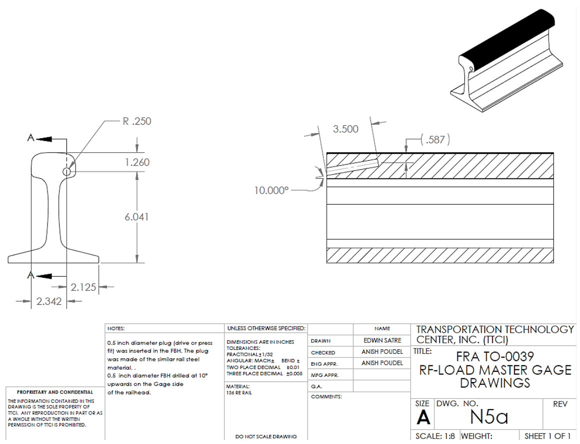

Figure 2. SolidWorks® drawing of RF-LOAD sample

Figure 3 shows the hand-held PAUT rail flaw characterization. From the UT characterizations of rail flaws, researchers demonstrated that hand-held PAUT was more accurate than the conventional UT measurements for sizing reflectors (i.e., 16–30 percent CSHA) in the gage and field faces that were oriented 5 degrees and 10 degrees relative to the base. Table 2 shows results obtained from this exercise. In some cases, it was extremely difficult to observe signals for reflectors in the gage and field faces using conventional UT for the curve worn rails. Zero-degree oriented FBHs (0.25 and 0.50 inch diameter) on the gage and field faces as shown in Figure 4 were almost impossible to find using both PAUT/UT methods. However, the detectability for PAUT increased when the FBHs were about 1 inch in diameter.

Figure 3. Hand-held PAUT rail flaw characterization

Table 2. PAUT and UT characterization the RF-LOAD master gauge samples

Rail ID		Physical measurements			PAUT measurements	% Difference	Conventional UT measurements	% Difference
		Defect orientation (deg.)	Actual TD sizing (%.)	TD location	Measured TD (%)		Measured TD (%)	
Minimal head wear	N1	5°	16.4%	Center	17.5%	1%	2.8%	14%
	N2	10°	16.4%	Center	19.0%	3%	4.0%	12%
Surface damage	S1	5°	25.7%	Gage	26.7%	1%	8.8%	17%
	S2	10°	27.6%	Gage	27.0%	1%	8.2%	19%
Gage face wear	W1	5°	29.3%	Gage	26.5%	3%	13.8%	16%
	W2	10°	29.7%	Gage	30.5%	1%	13.0%	17%

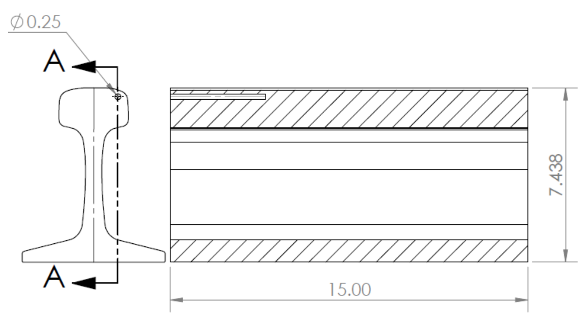

Figure 4. Zero-degree oriented FBH on gage side the rail head

The current status of the RF-LOAD is as follows:

- Artificial reflectors: 54
- Service induced flaws: 53
- No flaws: 32
- Broken weld samples: 8

CONCLUSIONS

FRA and TTCI developed an extensive rail flaw library. The rail flaw samples collected so far are characterized with a high level of accuracy using available physical and NDE measurement techniques. RF-LOAD helps to meet current industry rail inspection challenges by providing flaw library access to rail researchers and other industry service providers so that they can optimize their inspection systems for better flaw detection and characterization.

FUTURE ACTION

Efforts will continue to collect and fully characterize a wide array of naturally occurring rail flaw samples from FAST, the TTC, and revenue service. This rail flaw library aims to meet future development needs by providing researchers open access to different kinds of rail flaw defects. FRA and TTCI expect that RF-LOAD will be used for operator training and POD capability demonstrations for emerging NDE methods.

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ACKNOWLEDGEMENTS

The authors would like to acknowledge the hard work of the TTCI project team: Brian Lindeman, Greg Giebel, Joseph Paseka, Bryan Morgan, Brandon Zane and his track crews.

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KEYWORDS

Rail, rail wear, rail defect, rail flaw library, ultrasonic testing, UT, phased array ultrasonic testing, PAUT, Miniprof, Rail Flaw Library of Associated Defects, RF-LOAD, non-destructive evaluation, NDE, track

CONTRACT NUMBER

DTFR5311D00008L