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RESEARCH RESULTS
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RAIL FLAW SIZING USING CONVENTIONAL AND PHASED ARRAY ULTRASONIC TESTING

SUMMARY

An approach to detecting and characterizing internal defects in rail through the use of phased array ultrasonic testing has shown the potential to reduce the risk of missed defects and improve transverse defect characterization.

Transportation Technology Center, Inc. (TTCI) conducted research and data collection on rail flaw sizing and master gauge development using conventional and phased array ultrasonic testing techniques. This Federal Railroad Administration (FRA) research effort addresses both safety and reliability through the development of the Rail Flaw Library of Associated Defects (RF-LOAD) (Figure 1), which provides a test bed for performing probability of detection (POD) studies on commercially available nondestructive evaluation (NDE) systems, as well as NDE systems that are under development.

The continued development of the RF-LOAD has also provided the means to quantify the performance of NDE inspection methods and techniques for rail flaw detection and characterization.

Faced with the challenge of improving rail inspection methods and techniques, TTCI invited railroads, rail inspection suppliers, and phased array manufacturers to participate in ultrasonic defect detection and sizing evaluations. The evaluations used both conventional and phased array ultrasonic testing techniques.

The RF-LOAD consists of known defects and flaw orientation that can be used for ultrasonic characterization. Phased array applications allow for multiple phase angles to be implemented during a single scan using one transducer, thereby providing the inspector with more information regarding size and orientation of defects.

This research focused on the development of rail segments with manufactured, artificial defects (herein referred to as master gauges), collecting field defects, and baseline quantification of rail flaw sizing using conventional and phased array ultrasonic testing approaches. Future phases will involve expansion of the RF-LOAD to include different orientation of defects and data analysis utilizing new developments in ultrasonic testing techniques.

Figure 1-Scanning of RF-LOAD

The performance of improved rail inspection techniques, such as the phased array method, can be quantified and documented using the information gathered thus far through RF-LOAD master gauge development. Over time, implementation of these improved field inspection techniques will increase safety and decrease rail flaw service failures by reducing missed defects and limiting the number of false alarms.

BACKGROUND

FRA safety statistics show that service failures from internal rail defects are the highest cause of track related derailments. Thus, the FRA and Association of American Railroads (AAR) rail integrity research aims to increase rail transportation safety through improved rail inspection methods.

TTCI researchers, under sponsorship of FRA's Office of Research and Development, have performed evaluations of manual rail scanning techniques that use either conventional or phased array ultrasonic test methods.

Research efforts under this project focus on rail safety enhancement through the following:

- Master gauge development
- Rail sample collection
- Ultrasonic phased array evaluation

The RF-LOAD has been established to accomplish this research effort. The RF-LOAD is comprised of rail samples containing a variety of flaws that can be used to develop and/or quantify the performance of inspection methods and techniques for detecting, categorizing, and sizing flaws in rail. The RF-LOAD will ultimately be made up of a variety of rail samples with both artificially and service induced flaws.

Rail samples containing artificially induced flaws are used as master gauges with known types, sizes, and locations of flaws. Samples containing service induced flaws have also been assessed to determine flaw type, size, and location, and are included in the library as representative rail flaws introduced during field service.

OBJECTIVES

The objective of this research effort is to identify and evaluate ultrasonic phased array technology and determine its effectiveness in accurately sizing rail flaws.

The anticipated industry impact includes the following:

- Increasing safety through nondestructive testing (NDT) technology development
  - Reducing rail flaw related derailments, accidents, and service failures
  - Increasing reliability through reduction in service failures and train delays
- Addressing industry needs in key areas:
  - Maintenance
  - Inspection
  - Risk analysis
  - Damage tolerance

RF-LOAD Samples

Through industry collaboration, TTCI has obtained rail samples with service induced rail flaws to establish the RF-LOAD. AAR member railroads have supplied rail samples with varying amounts of wear, surface damage, and flaw sizes.

The rail samples containing service flaws were characterized, and rail attributes such as profile, length, surface condition, internal flaw size, and orientation were documented.

Rail with no service induced flaws were similarly characterized and the rail attributes were documented. Manufactured, artificial defects were introduced in several of these rails. For example, some samples had end flat bottom holes drilled into them. The holes were drilled in various sizes, depths, and angles.

The holes were drilled into the railhead at locations that would be representative of transverse defects. These holes were then plugged and the rail ends machined to mask the hole locations.

Ultrasonic Scanning Evaluations

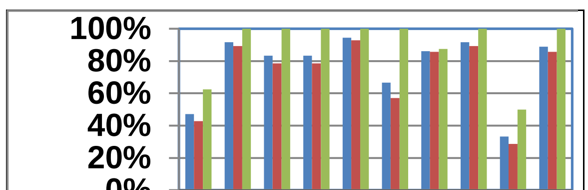
The initial ultrasonic scanning evaluations discussed in this report were performed on 136 pound/yard rail sections. The samples scanned included rail with and without flaws. The flaws in the rails were either service induced or artificially machined into the railhead (Figure 2).

Figure 2-Phased Array Analysis

RESULTS

The achievements of the project to date include the generation of master gauge samples for the RF-LOAD. The RF-LOAD has been developed to serve as a master reference for quantification of rail defects using ultrasonic testing techniques. All of the defects in the samples, artificial and service induced, have been characterized and documented for future research and ultrasonic capabilites.

The final report will include a detailed summary of findings from TTCI research and industry participation in rail flaw sizing and detection using both conventional and phased array ultrasonics (Figure 3). Nine members of the railroad industry, including railroads, nondestructive evaluation (NDE) service providers, and NDE equipment manufacturers, took part in the evaluations, and the information obtained through the studies has helped outline a strategy for future development of additional samples to be added to the RF-LOAD.



	5%-0	5%-20	5%-S	10%-0	10%-20	10%-S	20%-0	20%-20	20%-S	30%-S
Hit% (All)	47	92	83	83	94	67	86	92	33	89
Hit% (C)	43	89	79	79	93	57	86	89	29	86
Hit% (PA)	63	100	100	100	100	100	88	100	50	100

Figure 3-Conventional versus Phased Array Comparison

CONCLUSIONS

The conclusion of the efforts in the development of the master gauges and RF-LOAD is to use the data collected as a reference or standard against which future systems can be compared. The master-gauge samples will be used to measure future advances in rail inspection methods and technology. As technology evolves, additional studies and samples will be added to the library with the goal of staying ahead of industry standards and increasing rail reliability through the reduction of in-service failures. Signal detection theory may be used to put forth a minimum detection standard using, for example, a receiver operating characteristic (ROC) curve.

FUTURE TASKS

With the fast developing ultrasonic phased array equipment in the rail inspection field, and the results obtained through the RF-LOAD, it is now possible to quantify probability of detection (POD) of traditional inspection systems as well as phased array inspection systems, and, as the technology advances, quantifying the POD of new systems will also be feasible.

The RF-LOAD will continue to be used to quantify performance of NDE systems and monitor and assess advances in software as well as hardware algorithms—including transducer/wedge design—when implementing ultrasonic testing for rail flaw inspection.

A full report on this research is in preparation and will include a matrix of defects and profile analysis blueprints of each sample that has been created for the RF-LOAD (Figure 4).

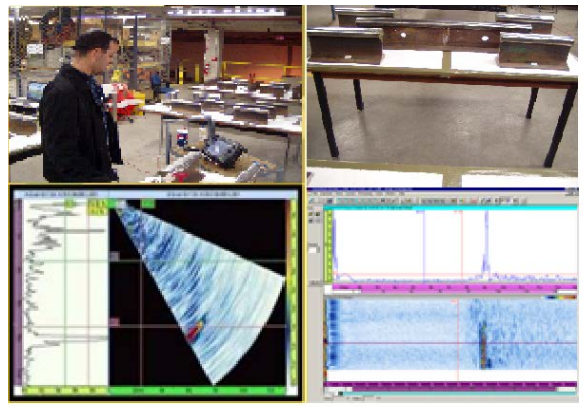


Figure 4-Phased Array using A, S, and C Scans

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KEYWORDS

Rail Flaw Library of Associated Defects, transverse defect, ultrasonic testing