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DOT-117 TANK CAR FLAW LIBRARY DEVELOPMENT FOR NONDESTRUCTIVE EVALUATION (NDE) STUDY

SUMMARY

Tank car nondestructive evaluation (NDE) research efforts by the Federal Railroad Administration (FRA) and the Association of American Railroads (AAR) are focused on increasing the safety and reliability of fusion welded tank cars for rail transportation. In a FRA-funded study started in October 2019, researchers at Transportation Technogy Center, Inc. (TTCI) created a new set of master gauge test panels for DOT-117 tank cars and expanded the tank car flaw library at FRA's Transportation Technology Center (TTC) near Pueblo, CO. Standardized tank car defect samples are essential for qualifying the NDE methods used for tank car inspection.

For this phase, six sets of new butt welds, fillet welds, and corrosion master gage (MG) test panels were created from one of the DOT-117 tank cars. These panels included Electrical Discharge Machined (EDM) notches of various shapes, sizes, and orientations created at the toe of the welds to simulate corrosion on the tank car shells. Several NDE methods were used to characterize the notches and corrosion on these MG test panels.

BACKGROUND

Past research sponsored by FRA focused on using the probability of detection (POD) approach to evaluate the reliability of Code of Federal Regulation (CFR)-approved NDE methods. Researchers worked with railroad tank car industry stakeholders to evaluate the industry's capabilities regarding CFR-approved NDE methods, including visual (VT), liquid penetrant (PT), magnetic particle (MT), ultrasonic (UT), and radiographic testing (RT).

The team's analysis and re-characterization of the DOT-111 POD test panels fabricated in the mid-1990s showed several issues. During the DOT-111 test panel crack validation process, the MT-contrast findings demonstrated the cracks in the test panels that were used repetitively for NDE assessments in prior studies were no longer detectable. The researchers' hypothesis for this change includes two possible reasons: a) contamination of the test panels due to repeated PT/MT NDE assessments, and b) corrosion in the shallow crack face that may have caused crack closure. The detectability of the original cracks must be re-evaluated before these test panels can be reintroduced into a test set for future POD studies. The team tried to refurbish one of the POD test panels by reloading and fatiguing it to open the cracks, then rigorously cleaning the panel to remove debris from the crack face. In doing so, researchers recovered some cracks; however, other existing cracks also grew more prominent.

It should be noted that most of these POD test panels were made from a retired legacy railroad tank car (DOT-111A). Welding, manufacturing processes, and tank car specifications have improved over the past two decades to improve safety. For example, the DOT-111 car tank shell had a minimum plate thickness of 7/16 inch, unlike the DOT-117 car that requires a minimum plate thickness of 9/16 inch. DOT-117 tank cars use TC-128, Grade B normalized steel (high-strength carbon-manganese steel) instead of the ASTM A516, Grade 70 carbon steel used for DOT-111.

OBJECTIVES

The major objectives of this research were to create a new set of master gauge test panels for DOT-117 tank cars and expanding the tank car flaw library at FRA's TTC.

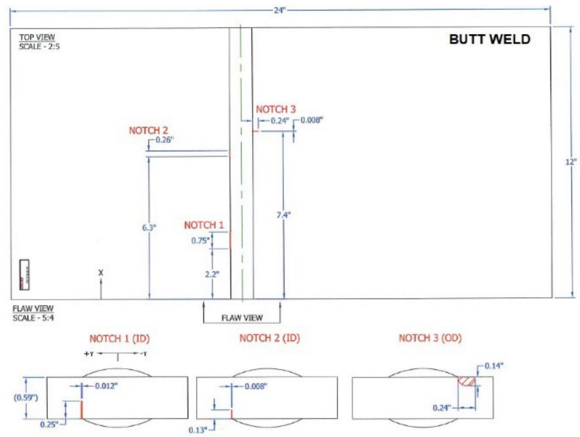
In addition, recent investigations and interactions with industry stakeholders have determined that the existing fillet welds in POD panels are somewhat obsolete and do not reflect the actual fillet welds seen in the newer fleets today. Most of the newer tank car fleet does not contain weld terminations on attachments. Therefore, to address industry needs, researchers began developing newer tank car test panels using the newer tank car fleet, DOT-117, for future POD studies and the validation of new, advanced NDE methods and corrosion studies.

METHODS

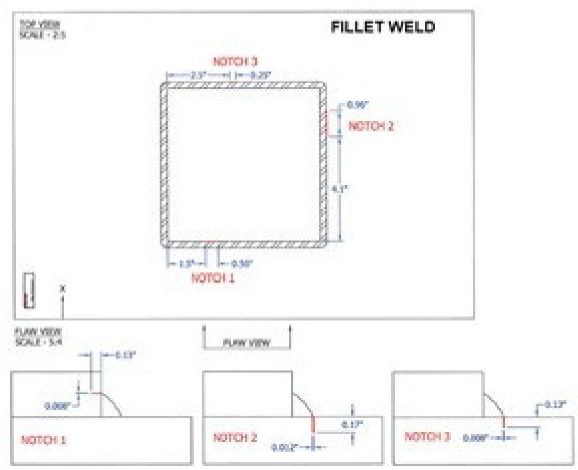
DOT-117 MG PLATE DEVELOPMENT

The MG plates were cut from the actual DOT-117 car. Fillet weld panels were later created by attaching carbon steel blocks to the cut out pieces. Butt weld and fillet weld MG test panels included several EDM notches of various shapes, sizes, and orientations created at the toe of the welds (inside and outside diameters). Similarly, corrosion MG test panels consisted of several tank car shells with simulated corrosion on the inside and outside diameter. Figure 1 shows an example of the engineering drawings produced for these MG plates.

These MG plates will serve as baselines for the inspection sensitivity verification performed during the actual POD evaluations of the industry NDE operators. The primary measure of reliability in NDE is repeatability and reproducibility. These MG plates should be used 1) as tools to perform a response comparison for calibration artifacts used in the field and also 2) periodically to validate the response linearity of the calibration artifacts.



(a)



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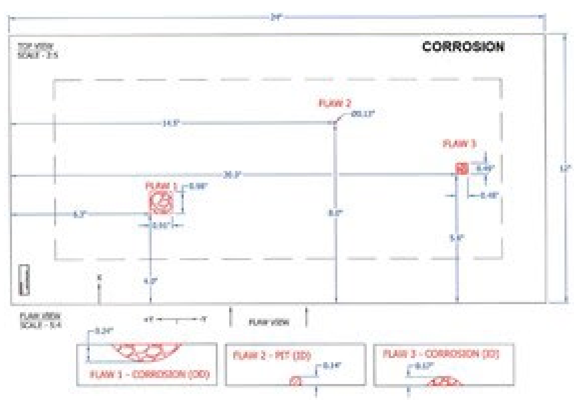

(c)

Figure 1. DOT-117 MG plate drawings: (a) butt weld, (b) fillet weld, and (c) corrosion

NDE CHARACTERIZATION

Several NDE methods were used to characterize the notches and corrosion in these test panels. These methods included VT, PT, MT, UT, phased array UT (PAUT), eddy current (ET), and eddy current array (ECA) techniques. Figure 2 and Figure 3 show the inspection and test result for one of the butt weld and fillet weld plates using PAUT, respectively.

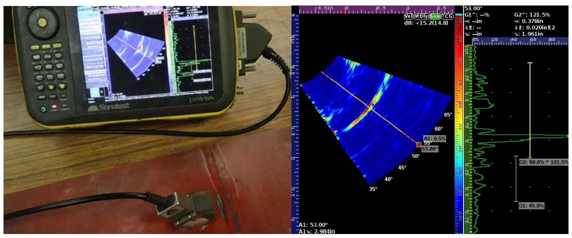

Figure 2. PAUT inspection and result for one of the butt weld MG plates

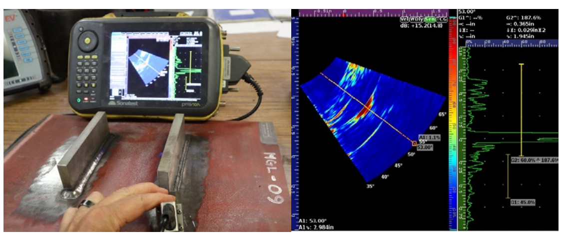

Figure 3. PAUT inspection and result for one of the fillet weld MG plates

Figure 4 shows the sizing results for each notch displayed as the difference from the notch design length for each weld type and NDE method. Positive differences indicate the measured crack was longer than the design drawing of the notch, while negative differences indicate the measured crack was shorter than the design length. The VT, PT, and MT methods showed most of their measurements and medians very close to zero difference. In comparison, the UT and ET methods had more variations, and the PAUT and ET pencil probes had more consistent higher positive medians and longer measured notches. In contrast, the ECA was more consistent in the most negative median and measured notches shorter in butt welds.

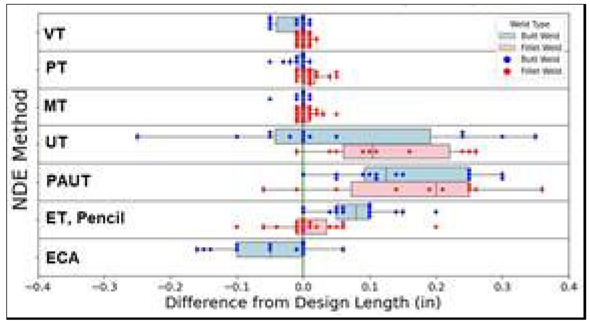

Figure 4. Boxplots showing sizing differences for each NDE methods in butt weld and fillet weld MG plates

Overall, 90 percent of the 189 length measurements that were able to detect the EDM notch were within 0.21 inch of the design length of the notch, and 75 percent of the measurements were within 0.06 inch of the design length. The test results demonstrated the success and challenges of applying individual NDE methods for accurate notch sizing.

The UT thickness, PAUT, and ECA NDE methods were applied to inspect the corrosion MG plates for material loss. Figure 5 shows the setup and test results obtained using the ECA approach for the corrosion MG plates. Most of the simulated corrosions were shallower than what could be seen with the ECA probe used for this study. However, the ECA approach could indicate a few corrosion areas with more significant and deeper material loss. Future research will need to investigate advanced NDE methods for corrosion in the tank car shells.

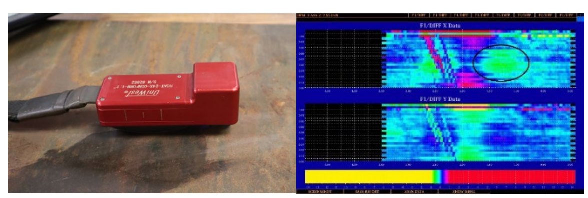

Figure 5. Eddy current array (ECA) inspection result for one corrosion plate

CONCLUSIONS

FRA and AAR are developing a new DOT-117 tank car flaw library. The MG plates were characterized by a high level of accuracy using available NDE measurement techniques. This study's test results demonstrated the successes and challenges of applying various NDE methods for sizing notches and quantifying corrosion in tank car plates.

In addition, the new library will help meet current industry inspection challenges by providing flaw library access to the tank car industry and NDE service providers to help optimize their inspection systems for better flaw detection and characterization.

FUTURE ACTION

Future efforts will focus on continuing to develop a wide array of DOT-117 tank car flaw samples. This tank car flaw library aims to meet future development needs by providing researchers with open access to different kinds of tank car defects. FRA expects the new library will be used for operator training and POD capability demonstrations for emerging NDE methods.

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KEYWORDS

DOT 117, Tank Car, Weld Defect, Tank Car Flaw Library, Nondestructive Evaluation, VT, PT, MT, UT, PAUT, ET, ECA