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Research Summary – Assessment of Alternating Current Field Measurement Non-Destructive Testing (ACFM NDT) for Use on Tank Cars

Transportation of Dangerous Goods | Scientific Research Division

SUMMARY

Non-Destructive Testing (NDT) techniques are often used to identify flaws during routine tank car inspections. One technique known as Alternating Current Field Measurement (ACFM) is being proposed for use by tank car manufacturers for inspection purposes. Additionally, an equivalency certificate [1] was temporarily approved by Transport Canada's (TC) Transportation of Dangerous Goods (TDG) Directorate to allow the use of ACFM inspection for structural integrity inspection subject to additional conditions, prior to the method's inclusion in the Association of American Railroads (AAR) Manual of Standards and Recommended Practices Specifications for Tank Cars, M-1002, Appendix T. The equivalency certificate identified the immediate need to build an understanding of ACFM as evaluated against other well-established NDT tank car surface inspection methods such as Magnetic Particle Testing (MT) and Liquid Penetrant Testing (PT).

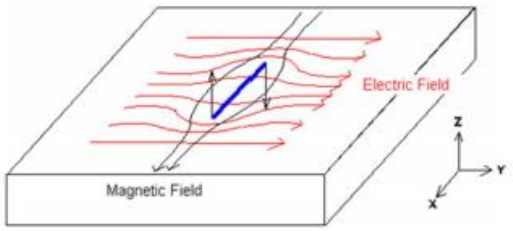

Figure 1 – ACFM – Disruption of the excitation flux line by the presence of a crack

BACKGROUND

Under a memorandum of understanding with TC in 2019, Natural Resources Canada (NRCan) CanmetMATERIALS (CMAT) completed an initial literature review for internal use, reviewing emerging NDT techniques, including ACFM, for potential use in dangerous goods tank car inspection. [2] A steering group was formed that included knowledgeable representatives from TC, U.S. Department of Transportation (DOT) Federal Railroad Administration (FRA), Transportation Technology Center Inc. (TTCI), CMAT, and the National Research Council Canada (NRC) to develop a test plan to evaluate

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the feasibility of the ACFM technique for tank car inspections.

OBJECTIVES

In this work, NRC was tasked by TC to perform an assessment of ACFM as an NDT technique for use in identifying known flaws and defects. The objective of this feasibility study was to evaluate and compare the ACFM technology against established surface inspection techniques MT and PT. Certified Canadian General Standards Board (CGSB) NDT inspectors were tasked with inspecting FRA-supplied test panels, with no prior knowledge of the number of defects or their characteristics (location, length, depth). This feasibility study was not a probability of detection study for the ACFM technique.

METHODS

This feasibility study compared the performance of ACFM against the established surface inspection techniques of PT and MT. Appendix T of the AAR Manual of Standards and Recommended Practices, Specifications for Tank Cars M-1002 specifies the requirements for all three methods of NDT used in this study. The procedures for PT and MT were based on industry standard practices, and those for ACFM were developed by certified experts for their use on tank cars.

ACFM is an electromagnetic testing technique that uses a uniform field induction and two magnetic field sensors. The magnetic and electric field lines travel around and under the crack by choosing the path of least electric resistance and magnetic reluctance.

MT is applicable for the detection of surface or near-surface flaws in ferromagnetic specimens. Indications of discontinuities are visible by an agglomeration of the magnetic particles applied to the tested surface.

PT is employed to detect surface-open cracks using the capillarity action of a liquid dye.

Four CGSB-certified NDT inspectors (Table 1) inspected master gauge test panels from the FRA defect library, and their results on detection, length of crack and location data were recorded.

Table 1 – Operator Summary

Operator and Method	Certifications	NDT Experience (years)
1 - PT	CGSB 48.9712 PT Level 2 MT Level 2 UT Level 2 ET Level 2 RT Level 2	35
2 - MT	CGSB 48.9712 PT Level 2 MT Level 2 UT Level 2 ET Level 2 RT Level 2	15
3 - ACFM	CGSB 48.9712 MT Level 2 ET Level 2 EN473 CSWIP ACFM Level 2 PA Level 2 SNT-TC-1A ET Level 2	15
4 - ACFM	BINDT PCN ACFM Level 2D&3D	12

PT: Penetrant Testing
MT: Magnetic Testing
UT: Ultrasonic Testing
ET: Eddy Current Testing
RT: Radiographic Testing
PA: Phased Array Testing

RESULTS

No NDT technique can be universally applied; each technique has specific capabilities and limitations, as well as range of applicability in terms of materials, discontinuity types, locations, and sizes.

These characteristics, as well as the experience of the inspectors, resulted in differences in the hit ratio between the methods. Hit ratio % (Table 2) is defined as the percentage of known defects detected by the NDT method versus the total number of known defects.

Table 2 – NDT Comparison – Hit Ratio (%)

Crack Length Range (mm)	<12.7	12.7-25.4	<25.4
Defect Count	2	9	2
Operator 1 (PT)	100	100	100
Operator 2 (MT)	100	100	100
Operator 3 (ACFM)	50	67	50
Operator 4 (ACFM)	100	89	100

Operators 1 and 2, using PT and MT respectively, successfully identified all the known defects in the plates, of all sizes. Operator 4, a more experienced ACFM technician, was more successful at identifying the defects using ACFM than Operator 3, with Level 2 certification.

The report found that all the techniques used in the study are appropriate for detection of surface-open cracks, and specifically of fatigue cracks in the case of ACFM. The work also found that for crack detection, MT and ACFM methods could suffer from the orientation of the excitation electromagnetic field with respect to the crack length, while PT could suffer from closed, clogged, or obstructed cracks.

CONCLUSIONS

The feasibility study shows that ACFM can detect a wide range of crack lengths. Operator level of experience will affect accuracy and the results of this research should be considered during development of any future tank car inspection requirements. Overall, it is important to make sure ACFM can detect cracks before they reach their critical size, which is often unique to an individual manufacturer.

FUTURE ACTION

A more comprehensive assessment of ACFM inspection's capability to detect surface-open cracks of a critical size in comparison to established techniques could evaluate outcomes in situations of complicated surface conditions, such as rough and non-uniform surfaces, welds next to heater coils, difficult to access surfaces, etc. Thus, it is strongly recommended that a fracture mechanics study be conducted prior to a POD design of experiments.

REFERENCES

1. Transport Canada Approvals – Search by Certificate Number (tc.gc.ca), File Number SR 13171, Expiry Date 2022-05-31 (at time of publication)

2. McKinley, Jonathan, Natural Resources Canada CanmetMATERIALS, Hamilton, ON, 2020, pp. 1-83, *Investigation into Non-Destructive Testing for Tank Car Inspection* (Internal TC Document)

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KEYWORDS

Non-destructive testing, NDT, Tank Car, Inspections, Alternating Field Current Measurement, ACFM, Magnetic Particle, MT, Liquid Penetrant, PT, Rail