



Inspection & Integrity

**MFL Data Fusion:
Enhancing Pipeline Integrity
by Reducing Conservatism
and Increasing Certainty**

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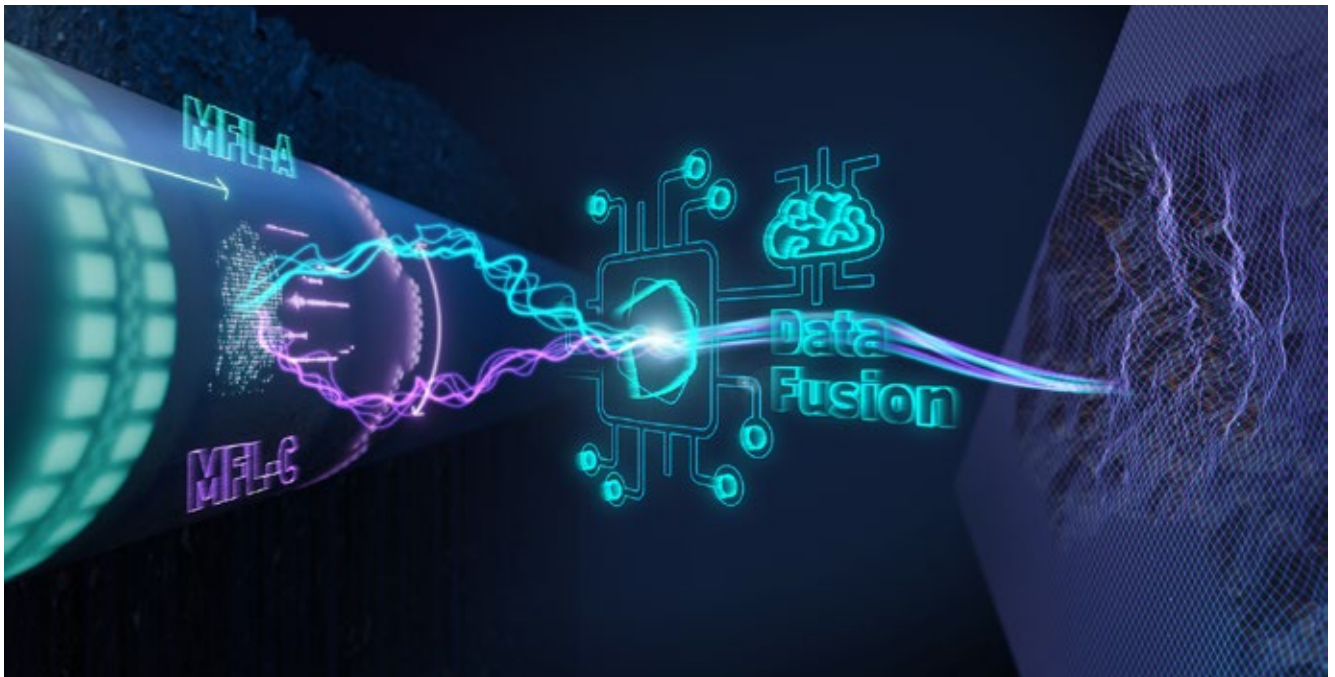
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MFL Data Fusion: Enhancing Pipeline Integrity by Reducing Conservatism and Increasing Certainty

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Abstract

Magnetic Flux Leakage (MFL) technology has been widely used for pipeline inspection due to its reliability in detecting metal loss. However, unidirectional axial (MFL-A) and circumferential (MFL-C) tools have inherent limitations in detecting and sizing complex corrosion anomalies. These limitations often result in conservative reporting, increased digging costs, and reduced confidence in inspection results.

A new approach, MFL Data Fusion, addresses these challenges by combining MFL-A and MFL-C datasets into a unified 3D depth profile. This system leverages the complementary strengths of axial and circumferential magnetic fields to improve anomaly characterization, reduce conservatism in reporting, and optimize integrity management programs. By increasing certainty and reducing unnecessary digs, the system offers significant cost-saving opportunities for pipeline operators.

1. Introduction

Pipeline operators have traditionally relied on MFL-A and MFL-C tools for corrosion detection. While these technologies are effective, their unidirectional magnetic fields limit their ability to detect anomalies aligned with the direction of the applied field. For example, MFL-A struggles to accurately identify axial metal loss, while MFL-C faces challenges in detecting circumferential anomalies. These limitations often lead to incomplete or conflicting data, complicating integrity assessments and increasing operational costs.

To address these issues, operators frequently inspect pipelines using both MFL-A and MFL-C tools. However, analyzing these datasets separately introduces subjectivity and ambiguity, often requiring additional testing to resolve conflicting results. This approach increases costs and delays decision-making.

MFL Data Fusion provides a solution by integrating MFL-A and MFL-C datasets into a unified 3D depth

profile. This approach improves anomaly characterization, reduces conservatism in reporting, and enables more informed integrity management decisions.

2. MFL Data Fusion: A Technological Breakthrough

Data fusion maximizes the value of MFL datasets by mitigating the physical and procedural limitations of traditional methods. Integrating MFL-A and MFL-C data delivers a detailed 3D depth profile of the pipeline surface, offering unprecedented insights into corrosion morphology.

2.1 The Technology

The fusion process begins with collecting and qualifying MFL-A and MFL-C datasets. These datasets are then refined to remove noise and signal aberrations, ensuring high-quality input for the fusion process. A pre-trained Convolutional Neural Network (CNN) aligns and merges the datasets using specialized U-Net architecture algorithms. The result is a high-resolution 3D depth profile that rivals the accuracy of in-ditch UT scans (e.g., laser scans).

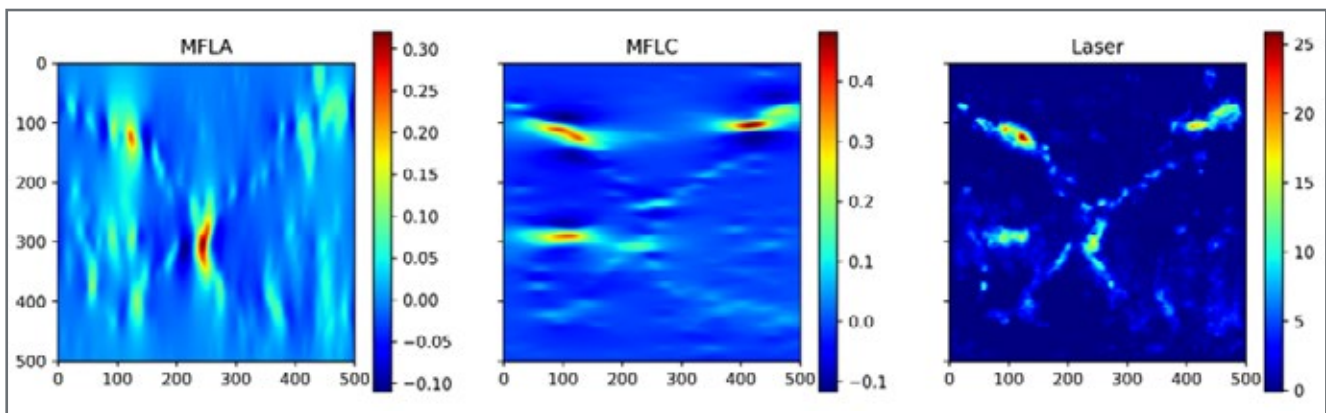


Figure 1: Training data set example – MFL-A and MFL-C signals are simulated from the laser scan

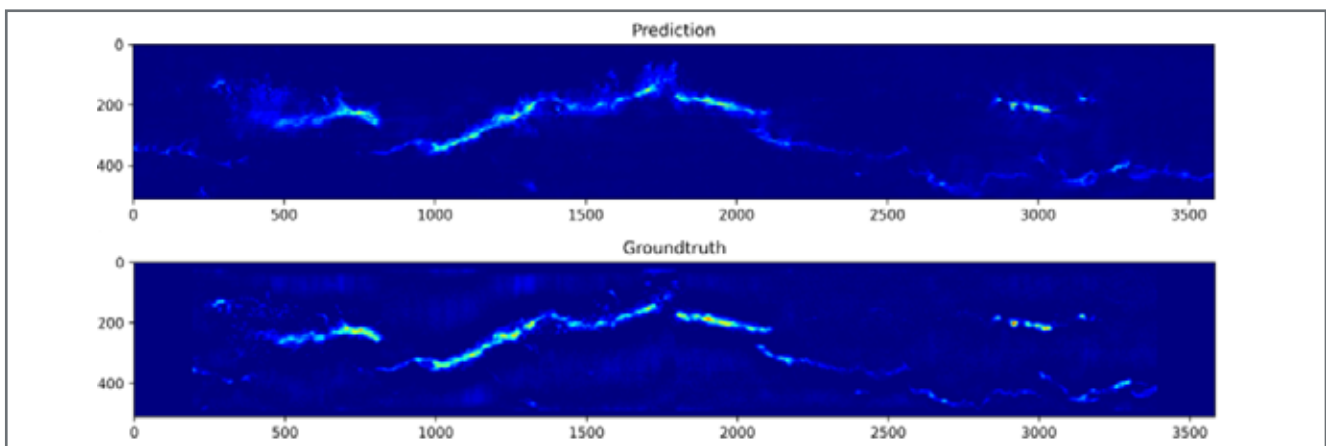


Figure 2: Example of fusion data (prediction) vs. Laser scan data

3. Training the Fusion Model

The U-Net architecture is trained using supervised learning with paired input and output data. The input consists of stacked MFL-A and MFL-C signals, while the target output is derived from laser scans. Based on extensive field data, this training process ensures the development of a robust and reliable fusion model.

4. Output: 3D Fusion Depth Profiles

The fusion process generates detailed 3D depth profiles along the entire pipeline length. These profiles are comparable to those obtained from in-ditch scans (e.g., laser or AUT scans), offering high accuracy in anomaly characterization. For example, the figure below illustrates a 3.7-metre pipeline section where the fused data closely matches the laser scan profile, demonstrating the system's reliability.

5. Capabilities and Validation

The MFL Data Fusion system has been rigorously validated using API STD 1163 Level 3 methods.

Key findings include:

- Depth Characterization: Analysis of 21,461 field laser anomaly data points from six pipeline systems revealed a depth tolerance of $\pm 5.19\%$ at 80% confidence. This represents a significant improvement over traditional MFL methods, which typically achieve $\pm 10\%$ tolerance at the same confidence level.
- Anomaly Morphology: The system provides detailed insights into the shape and orientation of corrosion features, addressing all Pipeline Operators Forum (POF) categories. This reduces the impact of corrosion morphology on reporting accuracy, enabling more precise integrity assessment.
- Burst Pressure Calculation: The high-resolution 3D depth profiles generated by the fusion system improve the accuracy of burst pressure calculations. Traditional MFL methods often produce conservative estimates due to incomplete anomaly characterization, while the fusion system provides more precise inputs for industry-standard calculation methods like RSTRENG and Psquared.

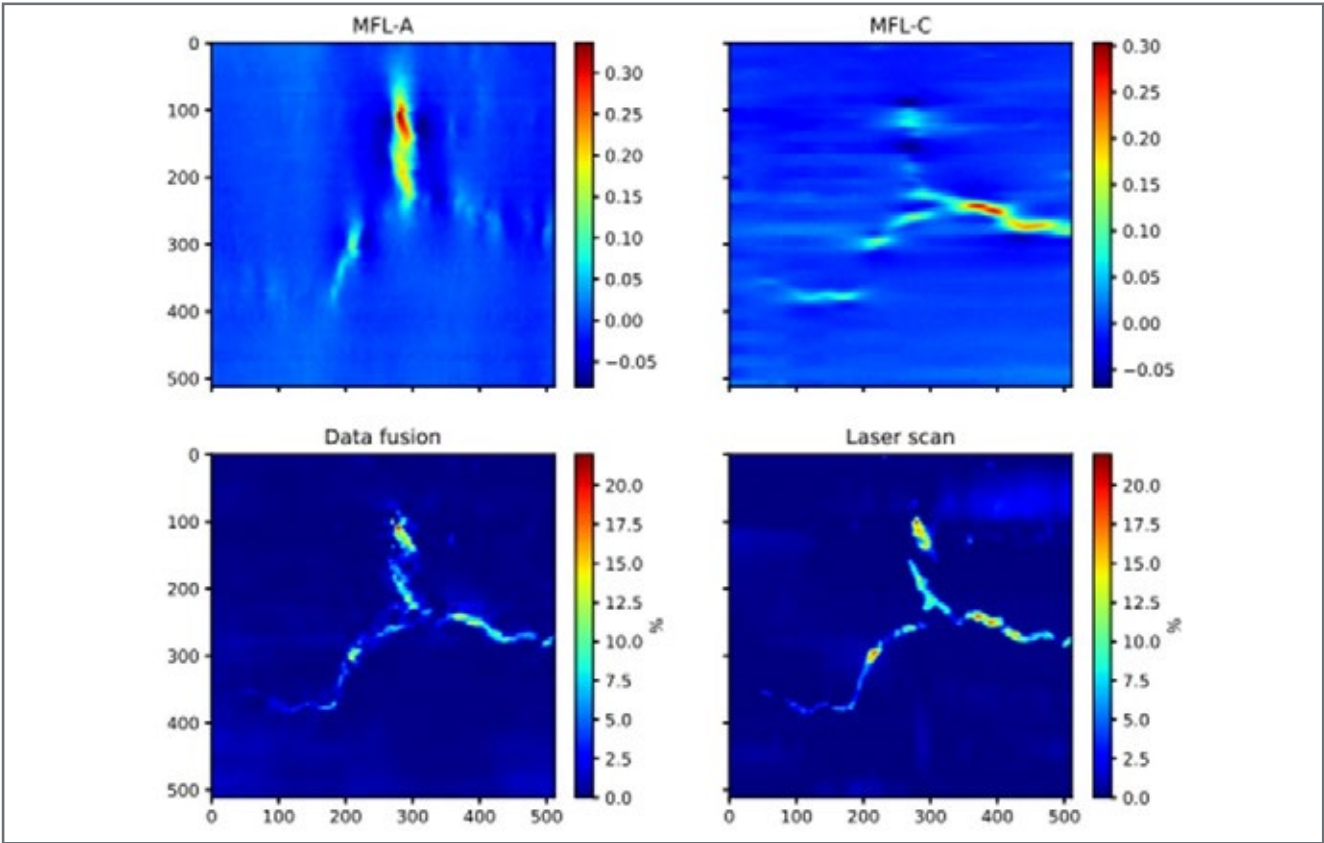


Figure 3: Input signals of MFL-A and MFL-C, with resultant Data Fusion output and Laser scansignals are simulated from the laser scan

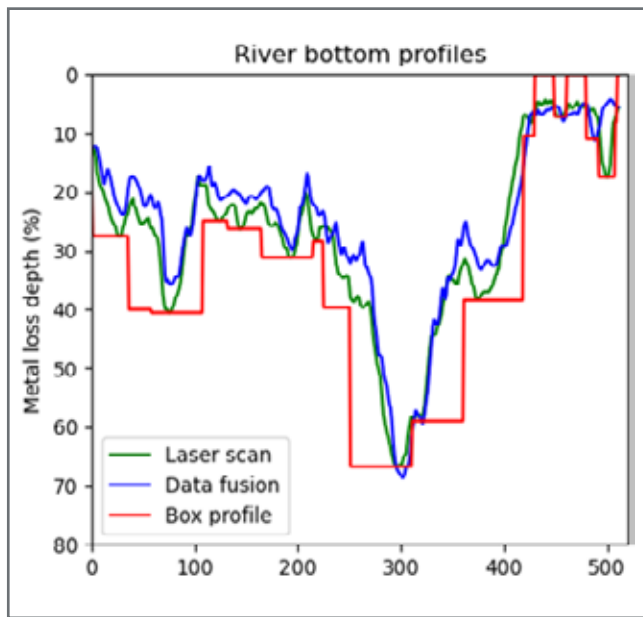


Figure 4: River bottom profiles of Laser, Data Fusion and Box data (Source: ROSEN Group)

6. Integrity Applications

The MFL Data Fusion system offers several advantages for pipeline integrity management:

- **Accuracy:** Improved depth accuracy reduces unnecessary digs and enhances safety.
- **Certainty:** The system's high confidence levels minimize the risk of mischaracterizing anomalies.
- **Consistency:** Automation reduces reliance on human judgment, ensuring objective and consistent results.
- **Reliability:** Dual data collection from MFL-A and MFL-C ensures no anomalies are missed due to orientation.

7. Operational Benefits

The primary advantage of MFL Data Fusion lies in its ability to reduce digging costs and increase the efficiency of integrity management programs. By providing more accurate and comprehensive anomaly characterization, the system enables operators to:

1. **Reduce Unnecessary Digs:** Traditional MFL methods often require conservative depth margins to account for uncertainty, leading to unnecessary

digs. The fusion system's improved depth accuracy reduces this conservatism, minimizing the number of digs while ensuring high-risk anomalies are identified.

2. **Increase First-Run Success:** The system's ability to enhance each recorded MFL-A and MFL-C data during fusing and accurately characterize anomalies reduces the likelihood of missed or misclassified features. This increases the probability of first-run success during inspections, reducing the need for repeat runs and associated costs.
3. **Optimize Dig Programs:** The fusion system provides detailed 3D depth profiles, enabling operators to prioritize digs based on accurate risk assessments. This optimizes resource allocation and reduces operational costs.
4. **Leverage Complementary Data:** Integrating MFL-A and MFL-C datasets ensures that no anomalies are missed due to their orientation or morphology. This dual-data approach provides a more comprehensive understanding of pipeline integrity, enhancing the reliability of inspection results.

8. Conclusion

MFL Data Fusion represents a significant advancement in pipeline inspection technology. By combining the strengths of MFL-A and MFL-C datasets, the system addresses the limitations of traditional unidirectional MFL tools, providing more accurate and comprehensive anomaly characterization.

The system's ability to reduce digging costs, increase first-run success, and optimize dig programs makes it a practical solution for pipeline operators. Its validation using API STD 1163 Level 3 methods ensures high reliability, while its integration of advanced neural networks and big-data management sets a new standard for pipeline integrity management.

Future developments will focus on expanding the system's capabilities to address a broader range of pipeline threats, further enhancing its value to the industry.

9. Abbreviations

- MFL: Magnetic Flux Leakage
- MFL-A: Axial Magnetic Flux Leakage
- MFL-C: Circumferential Magnetic Flux Leakage
- CNN: Convolutional Neural Network
- POF: Pipeline Operators Forum
- UT: Ultrasonic Testing

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Unlock the Power of Data

Elevate your asset integrity with unmatched data accuracy and unparalleled expertise

Our unique synergy of advanced inspection systems, cutting-edge analytics and human expertise allows us to transform data into knowledge. Knowledge enables smarter decision-making and delivers a comprehensive understanding of asset safety, lifetime, and performance.

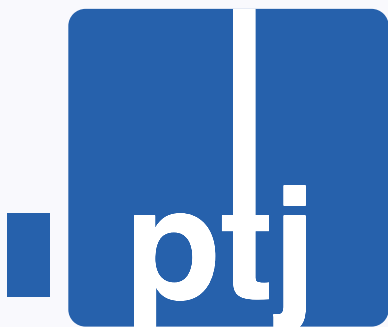


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