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Pulsed Eddy Current signal processing using wavelet scattering and Gaussian process regression for fast and accurate ferromagnetic material thickness measurement

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Abstract
Testing the structural integrity of pipelines is a crucial maintenance task in the oil and gas industry. This structural integrity could be compromised by corrosions that occur in the pipeline wall. They could cause catastrophic accidents and are very hard to detect due to the presence of insulation and cladding around the pipeline. This corrosion manifests as a reduction in the pipe wall thickness, which can be detected and quantified by using Pulsed Eddy Current (PEC) as a state-of-the-art Non-Destructive Evaluation technique. The method exploits the relationship between the natural log transform of the PEC signal with the material thickness. Unfortunately, measurement noise reduces the accuracy of the technique particularly due to its amplified effect in the log-transform domain, the inherent noise characteristics of the sensing device, and the non-homogenous property of the pipe material. As a result, the technique requires signal averaging to reduce the effect of the noise to improve the prediction accuracy. Undesirably, this increases the inspection time significantly, as more measurements are needed. Our proposed method can predict pipe wall thickness without PEC signal averaging. The method applies Wavelet Scattering transform to the log-transformed PEC signal to generate a suitable discriminating feature and then applies Neighborhood Component Feature Selection method to reduce the feature dimension before using it to train a Gaussian Process regression model. Through experimentation using ferromagnetic samples, we have shown that our method can produce a more accurate estimation of the samples' thickness than other methods over different types of cladding materials and insulation layer thicknesses. Quantitative proof of this conclusion is provided by statistically analyzing and comparing the root mean square errors of our model with those from the inverse time derivative approach as well as other machine learning models.

Author Keywords
Gaussian Process Regression; Machine Learning; Non-Destructive Testing; Pulsed Eddy Current; Thickness Measurement; Wavelet Scattering

Index Keywords
Eddy current testing, Ferromagnetic materials, Fiber optic sensors, Gas industry, Gaussian distribution, Gaussian noise (electronic), Inverse problems, Machine learning, Mean square error, Monte Carlo methods, Regression analysis, Signal processing, Thickness measurement; Eddy current signals, Gaussian process regression, Log transform, Machine-learning, Material thickness, Pipe wall thickness, Pulsed eddy current, Signal averaging, Thickness measurement, Wavelet scattering; Pipelines

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