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Fracture Toughness, defined as the amount of stress required to propagate an existing flaw, is a fundamental material property. Appropriate fracture toughness data is critical to support remediation per the American Petroleum Institute Recommended Practice 579 on fitness-for-service, which aims to increase the service life of a pipeline through maintenance. However, available fracture toughness characterization techniques present a series of limitations including but not limited to; laboratory tests that require pipeline material removal and taking the pipeline out of service. Quasi-non-destructive techniques require surface preparation (coating removal and polishing) and are only useful to rank fracture toughness but not to determine magnitudes, according to ASTM 11th national symposium. While there are nondestructive solutions for flaw detection or measuring remaining wall thickness, there is no current NDT solution to obtain accurate measurements of fracture toughness and similar material properties.

During Phase I, Innerspec introduced the idea of using Coercivity as an NDT technique to measure fracture toughness. The results during this phase were promising but inconclusive due to the inability to prepare enough samples. During Phase II, the objectives were to obtain a valid set of samples and re-test the Coercivity technique and to develop a prototype scanner that could be used to measure coercivity dynamically.

The results of the first objective were very positive, and we have been able to obtain a correlation ranging between 80-95% between Coercivity and fracture toughness. Moreover, this correlation was not limited to fracture toughness, as we were also able to find a great correlation with other mechanical parameters such as Yield Strength, Ultimate Tensile Strength, Hardness, and Charpy Impact Energy on the samples examined. These parameters are associated with changes in microstructure via phase distribution, dislocation density and location, and fatigue & stress due to work hardening, cyclic loading, temperature variations and other service conditions. Having an NDT technique that can relate to all these parameters greatly increases the potential value of this test method for the evaluation of pipelines and other ferromagnetic structures while in service.

For the scanning instrument, Innerspec designed and built a prototype system using a pulsed eddy current technique to measure magnetic decay as a proxy for Coercivity. Innerspec developed machine learning algorithms that allowed testing of over a hundred different magnetic features on the samples. While the development was successful and the instrument performed as expected, none of these features was able to replicate the results obtained from the static Coercivity measurements.

In summary, the accomplishments of Phase II are a clear and robust linear or near-linear correlation of Coercivity to not just fracture toughness, but a wide variety of mechanical properties widening the applicable scope of coercive force measurement as an NDT method of analyzing in-service structures.

While the scanning instrument developed during this work didn’t provide the results expected, we are very confident that with further refining it would be possible to develop a scanning instrument that can replicate the results from the static Coercivity tests.