Appendix B Nontechnical Abstract

Pipeline safety plays an important role in the transmission and distribution of energy, such as in fossil fuel and natural gas pipelines. To preserve the integrity and safety of these pipelines, a large percentage of them are coated with protective materials. However, environmental conditions, aging, and excavation accidents can compromise the effectiveness of these protective measures. Thus the inspection and monitoring become indispensable due to the high cost of replacement with new pipelines. Periodic or as necessary non-destructive evaluation (NDE) is required to tell the pipeline operator the current status of a pipe and whether remedial action is necessary. Methods exist for detecting cracks in pipelines, but they are either highly costly or with limited inspection abilities. Ultrasonic guided waves, because of their long range inspection ability, are being used more and more as a very efficient and economical pipeline inspection method.

An ultrasonic wave is a mechanical wave at frequencies (usually larger than 20 kHz) higher than the human's audible frequency range. For civilian applications, ultrasonic techniques have been used widely in medical diagnostics and NDE of material and structures for many years. These applications basically utilize ultrasonic waves in frequency ranges higher than several MHz and so the wave propagation distance is very limited due to the high attenuation at those frequency ranges. These waves are usually called bulk waves due to the small wavelength compared to the size of bulk wave propagation media. When the wavelength is equivalent to media geometry size at low frequency (kHz) range, waves are called guided waves which can propagate along a wave guide for as long as hundreds of feet. Therefore, guided wave inspection is much more efficient than the tedious point-by-point bulk wave inspection.

Guided waves in pipes are quite complicated in terms of dispersion and mode diversity. They can be categorized into axisymmetric including longitudinal and torisonal waves, and non-axisymmetric waves including flexural longitudinal and flexural torsion waves. Axisymmetric waves and phased array focusing are the two main techniques for long range pipeline inspection. Focusing techniques can increase energy impingement, locate defects, and enhance greatly inspection sensitivity and propagation distance of guided waves. A typical scenario of long range guided wave inspection is to generate guided waves from one single transducer position, which will propagate with long distance and then impinge onto any possible defects with the occurrence of wave scattering. The inspection strategy is to acquire the possible reflected waves from defects and to analyze the waves for defect detection, locating, sizing and characterization. Therefore, the inspection distance is am important parameter evaluating the guided wave inspection ability.

However, the viscoelastic nature of coating materials leads to significant attenuation consequently reducing guided wave inspection distance. Because of the variation of coating materials and the complexity of the wave mechanics in viscoelastic multilayered structure, many aspects and questions on guided wave inspection in coated pipe still remain unknown and very challenging. In this work, guided wave propagation, scattering and phased array focusing in viscoelastic coated pipes were stuided for the first time via numerical method, analytical method as well as some experimental measurements. A powerful 3-dimensional finite element tool was developed first for the modeling of any guided wave propagation and focusing in a coated pipe. Wave scattering studies were then followed on three-dimensional defects with respect to inspection and sizing potentials. Some exciting results were acquired in which phased array focusing potentials in coated pipes were proved. Some criteria on wave attenuation reduction and consequently inspection distance increment were established. A process from experimental measures to theorectical models has been established as a tool to evaluate the guided wave inspection potential of in-field coated pipes. Most of the work has never been studied before and therefore the accomplishments achieved have a high impact for the future long range guided wave inspection of coated pipe.