

Background and objectives

Background

- Polyethylene (PE) pipes are increasingly used in natural gas pipelines.
- Slow crack growth (SCG) induced failure is the most common failure mode. Embrittlement due to aging increases the risk of brittle failure.
- Existing NDE methods primarily focus on geometry and crack detection, lacking the ability to assess material property changes due to aging degradation for in-situ PE pipes.

Objectives:

- Perform accelerated aging tests on PE pipes using thermal cycles and UV.
- Characterize aged PE samples using FTIR, fatigue and ultrasonic NDE.
- Develop nonlinear ultrasonic NDE test using thermal modulation.
- Predict the remaining life of PE pipelines through correlation between ultrasonic NDE and fatigue testing.

Accelerated Aging Test Setup

UV Aging

- 1.55W/m²(60 °C)
No Condensation



Cyclic Thermal-Aging

- 110 °C/12h to -15 °C/12h (Manually)
- 110 °C/8h to -34 °C/8h (Automatically)



Aged PE Pipe Samples

Three aging plans for Two types of MDPE pipes

Pipe samples: E-ENDOT yellow gas pipe, D-Dura-line Polypipe,

Aging methods: U-UV, M-Manual thermal cyclic aging, A- Auto thermal cyclic aging, manual cyclic aging has a sudden temperature change

Aging Sample Numbers and aging time (Up to)

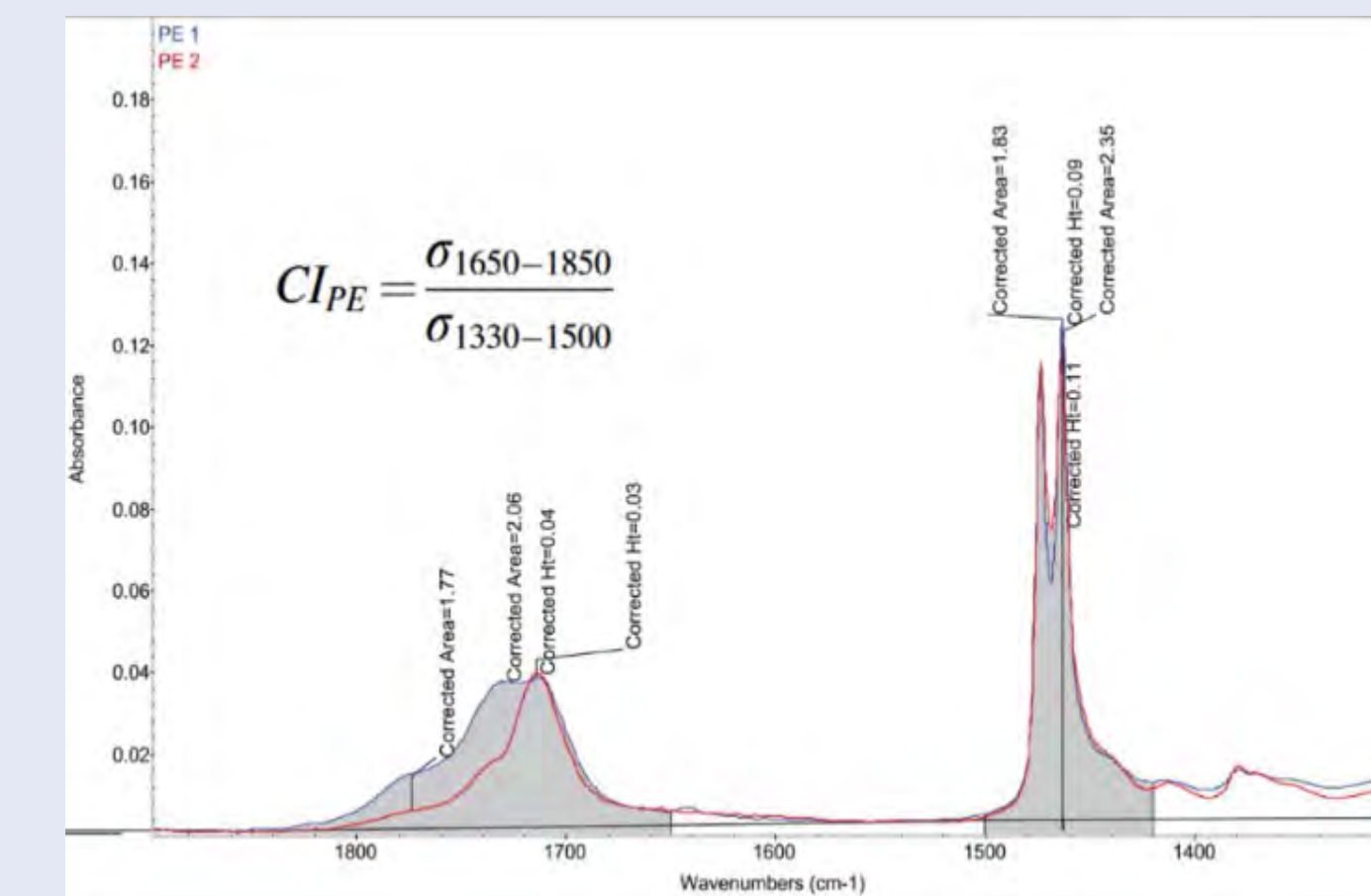
- EA : #24, 37weeks
- EU : #20, 24weeks
- EM : #9, 20weeks
- DA : #12, 43weeks
- DU : #22, 23weeks
- DM : #10, 30weeks



MDPE plastic's surface morphology vision inspection

Experimental Characterization

Fourier Transform Infrared Spectroscopy (FTIR)



➢ Carbonyl Index (CI) is defined as the peak or area ratio of the carbonyl peak relative to a reference peak

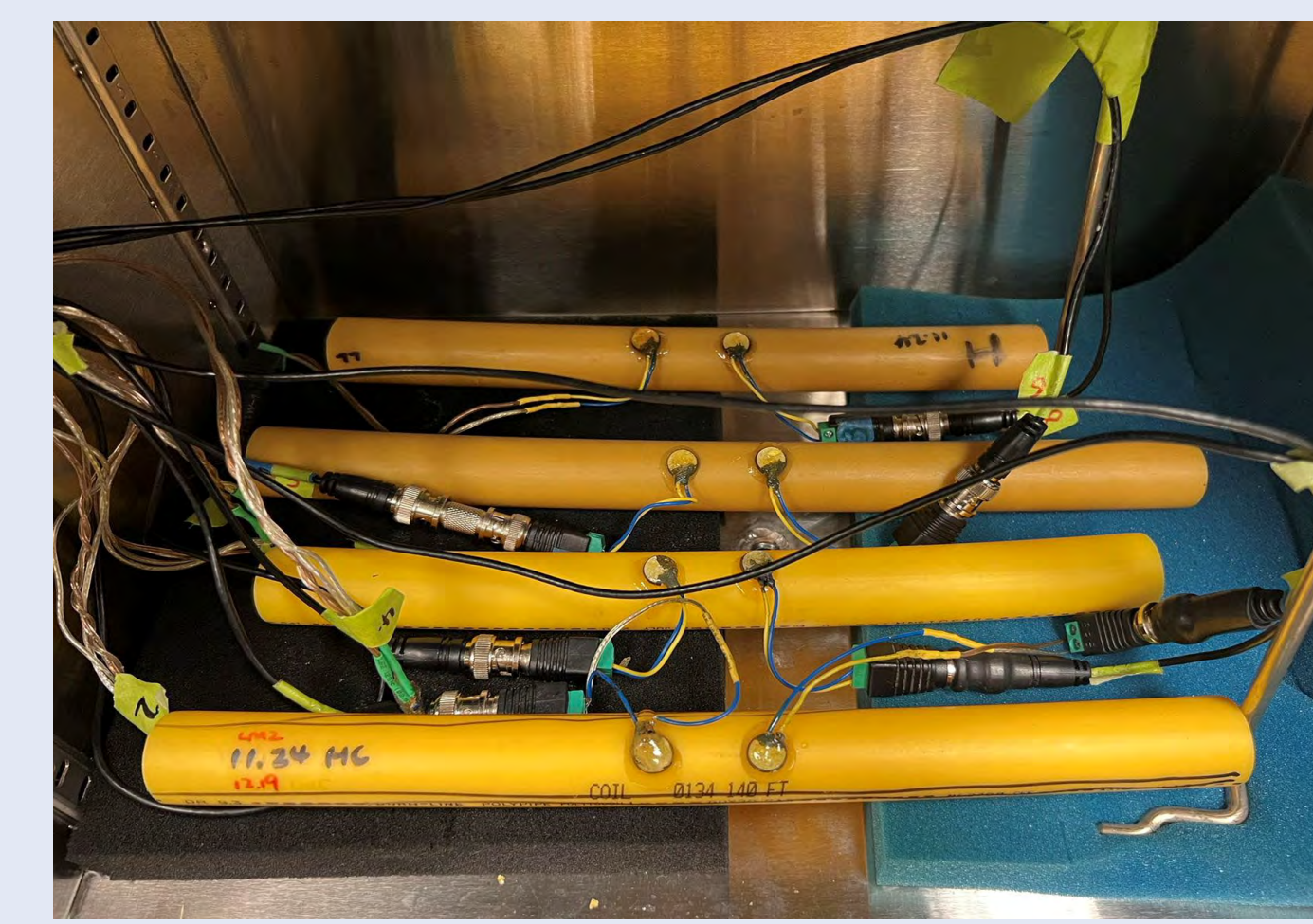
Fatigue Test

Evaluating the aging effect on the remaining service life



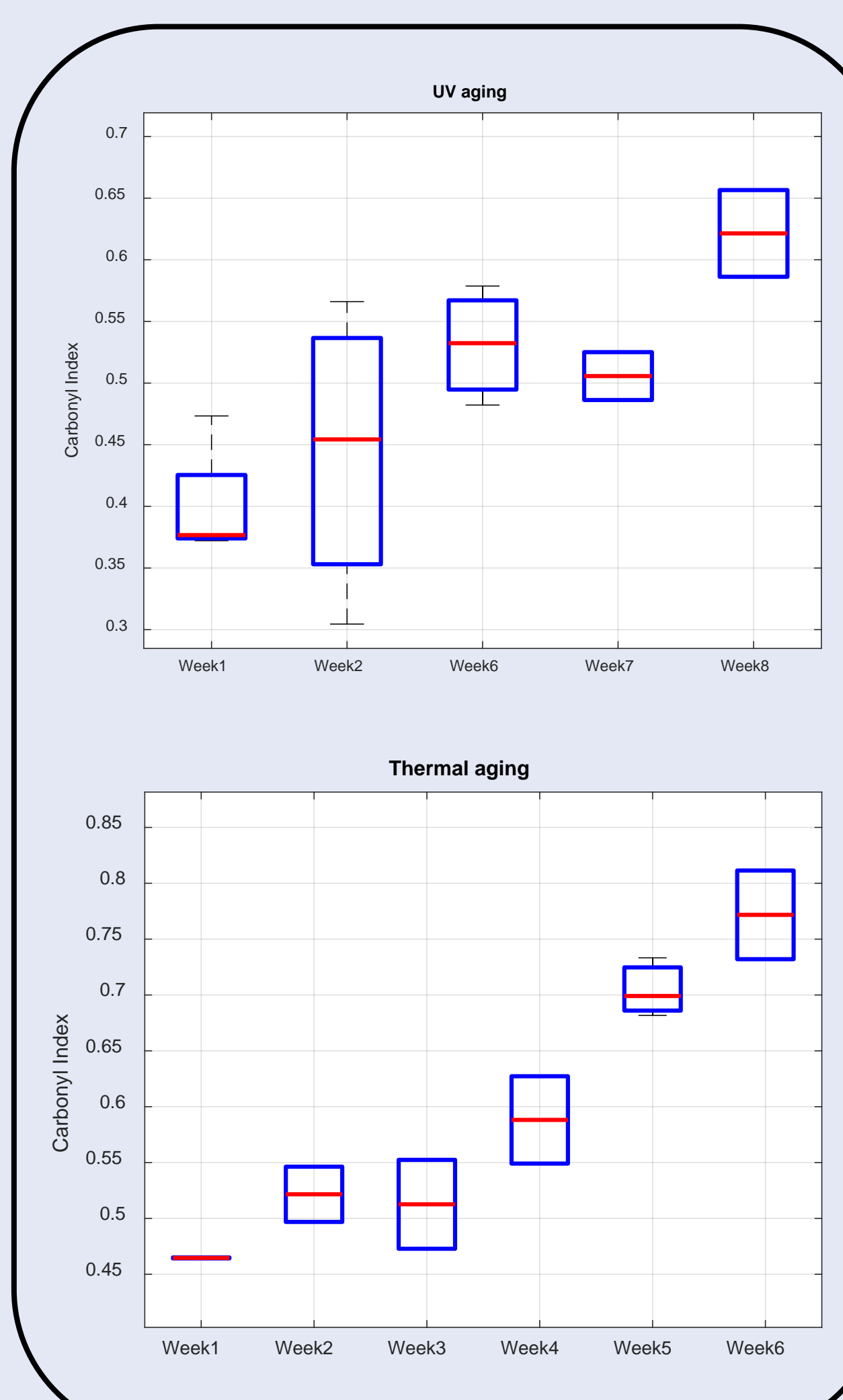
Ultrasonic NDE

Use nonlinear ultrasonic thermal modulation techniques to evaluate degree of aging in pipe samples

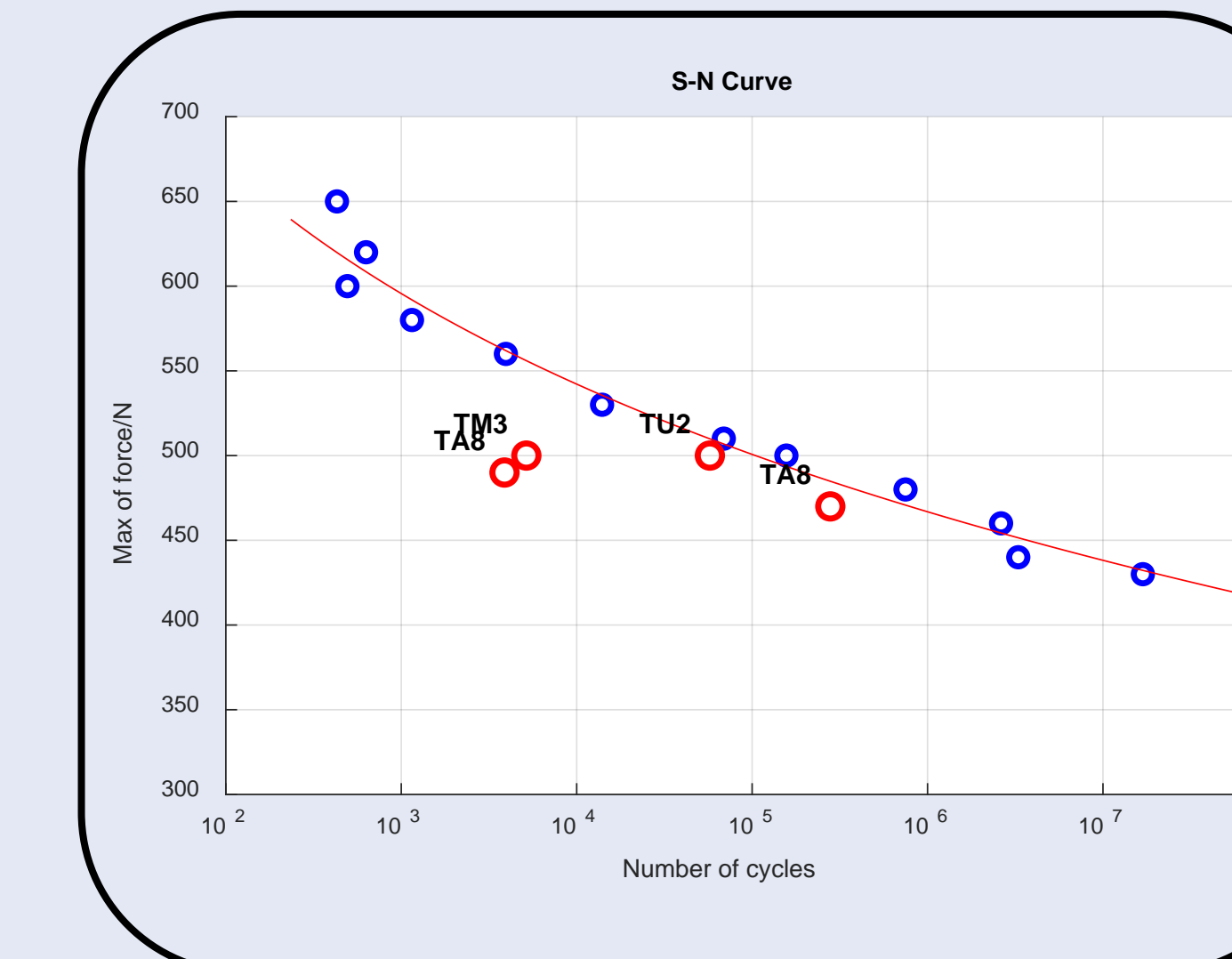


Results – FTIR and Fatigue Tests

FTIR Test



Fatigue Test

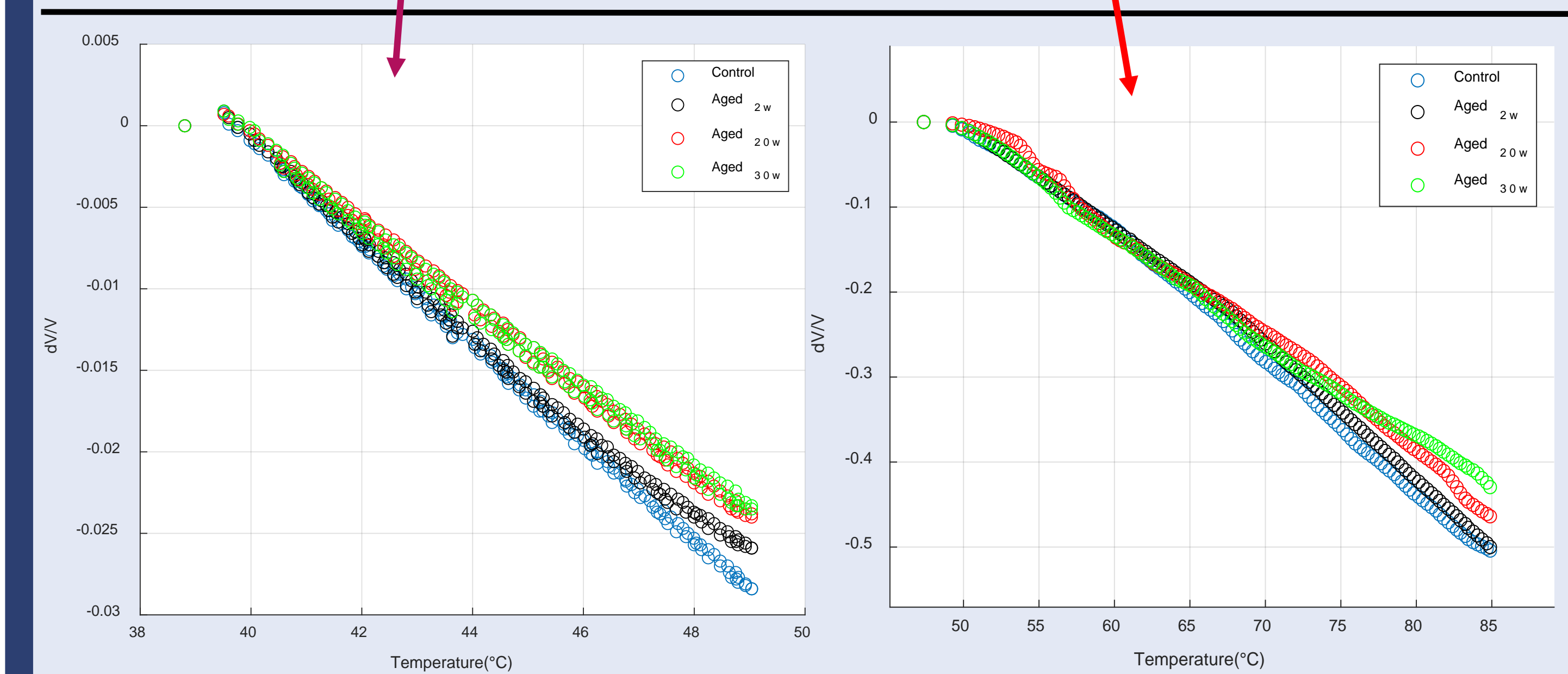
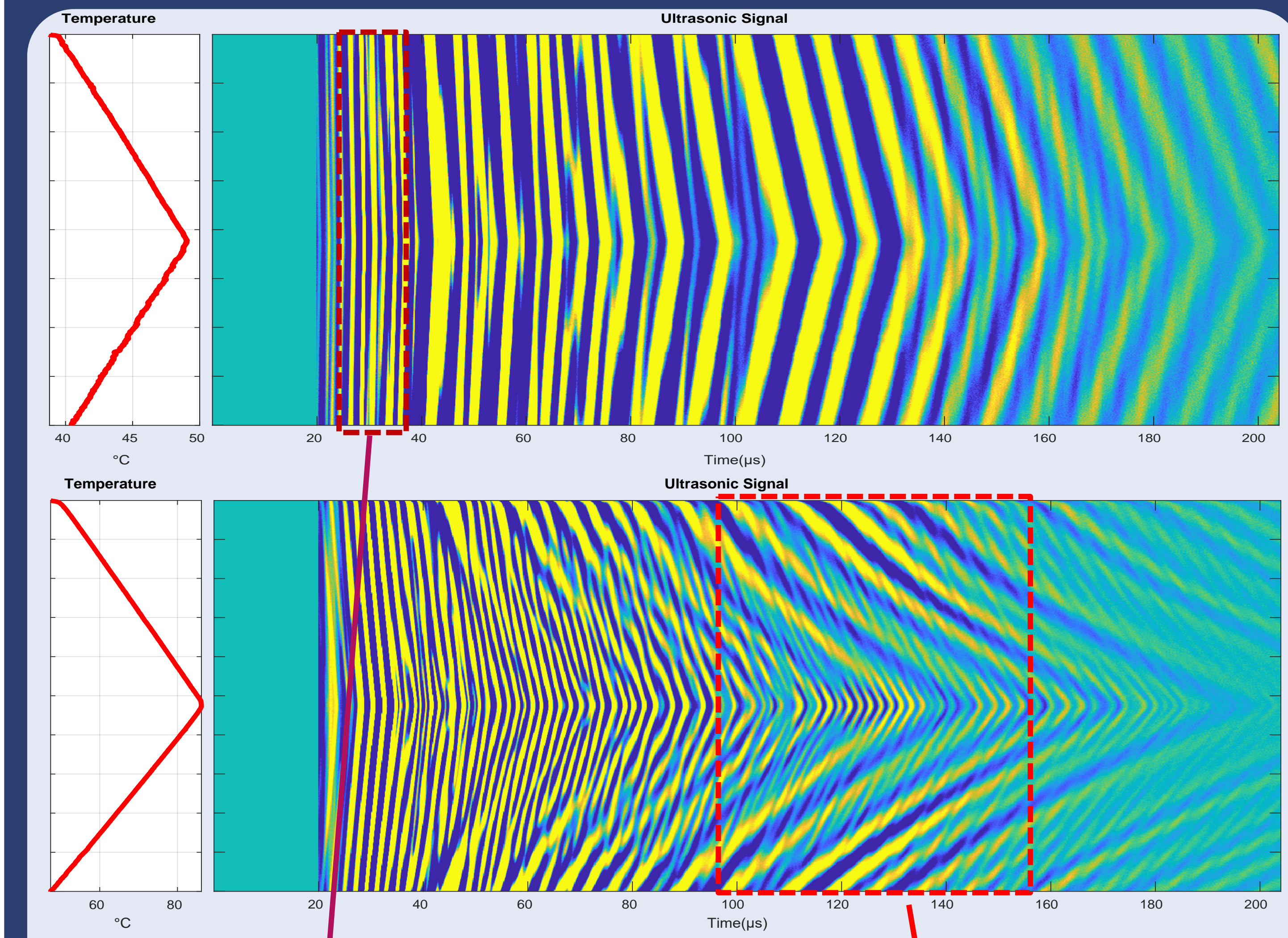


S-N curve from fatigue tests.

The aged samples showed reduced fatigue life at the same stress level

FTIR CI index analysis of different aged PE samples through UV aging and manual cyclic thermal aging.

Results - Ultrasonic



- Monitor ultrasonic wave velocity change with temperature in aged pipes.
- Multiple guided wave modes are measured in the signals.
- The early arrivals are dominated by high frequency modes – the aged samples are less sensitive to temperature than the control samples.
- The later arrived signals are dominated by low frequency modes – highly sensitive to temperature change.
- Aged samples are distinguished above 65 °C.

Conclusions and Future Work

- ✓ Aged MDPE pipes showed reduced fatigue life. FTIR tests indicate an increased Carbonyl Index.
- ✓ Thermal modulation test of ultrasonic waves shows the feasibility of evaluating aging of MDPE pipe samples.
- ✓ Future work: build a correlation between ultrasonic parameters and fatigue test results to predict the remaining life of PE pipe.

Acknowledgement

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Public Project Page

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