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# Enhanced Structural Damage Detection Under Thermal Variations Using Finite Element-Based EMI Modeling

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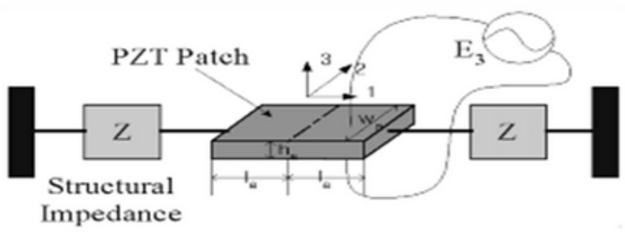
## INTRODUCTION

- EMI-based SHM with bonded PZT sensors is highly sensitive to local stiffness changes (incipient damage).
- In practice, temperature changes material properties and causes frequency and amplitude shifts, generating false alarms.

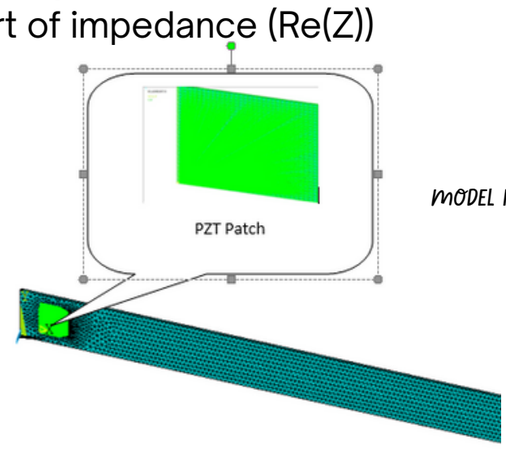



## OBJECTIVES

- Build a 3D FEM EMI model (ANSYS Multiphysics) with temperature-dependent properties.
- Quantify how temperature (25–85°C) and crack depth affect impedance signatures.
- Demonstrate a cross-correlation temperature compensation method to separate temperature effects from true damage.

## METHOD

1. Model setup :
   - Aluminum beam 500 × 30 × 2 mm
   - PZT patch (PSI-5H4E) 15 × 15 × 0.267 mm, bonded 20 mm from beam end
   - Epoxy layer 0.03 mm
   - Harmonic analysis, high-frequency band around resonance peaks (≈ 18.5–21 kHz)
   - Temperature-dependent properties for beam and PZT
2. Damage scenarios : Crack modeled as a 2 mm wide notch, depth varied (2–7 mm), located 125 mm from beam edge.
3. Damage metrics : RMSD and CCDM computed using real part of impedance (Re(Z))




MODEL FOR SQUARE PATCH ON HEALTHY BEAM

## RÉSULTATS

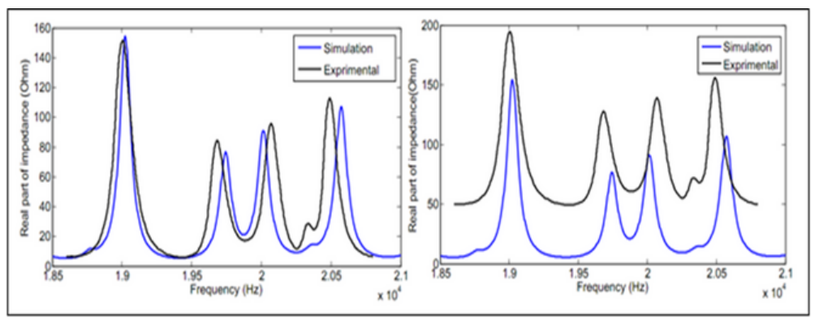
Temperature Effect

- Increase in temperature produces leftward frequency shifts
- Both frequency (horizontal) and amplitude (vertical) changes observed
- Temperature effects may resemble damage signatures

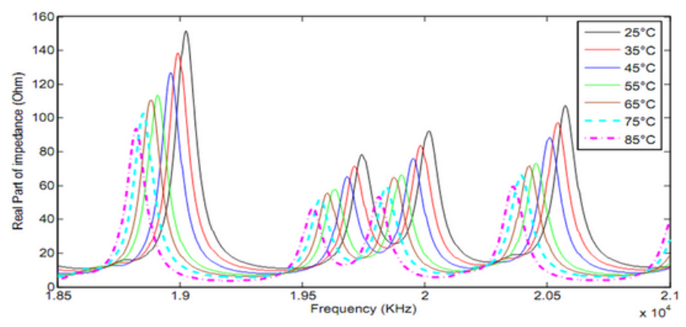
Damage Detection

- Crack growth leads to:
  - Resonance peak shifts
  - Appearance of new peaks
  - Increasing RMSD and CCDM values
  -

EMI technique shows high sensitivity to incipient damage.




COMPARISON BETWEEN SIMULATION AND EXPERIMENTAL RESULT FOR AN ALUMINIUM BEAM (25 ).

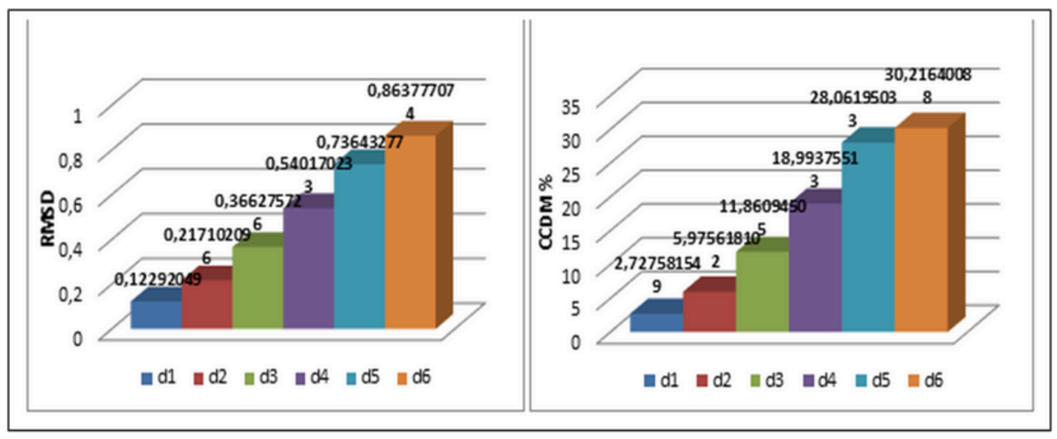



REAL PART OF THE ELECTROMECHANICAL IMPEDANCES RESULTING FROM TEMPERATURE CHANGES

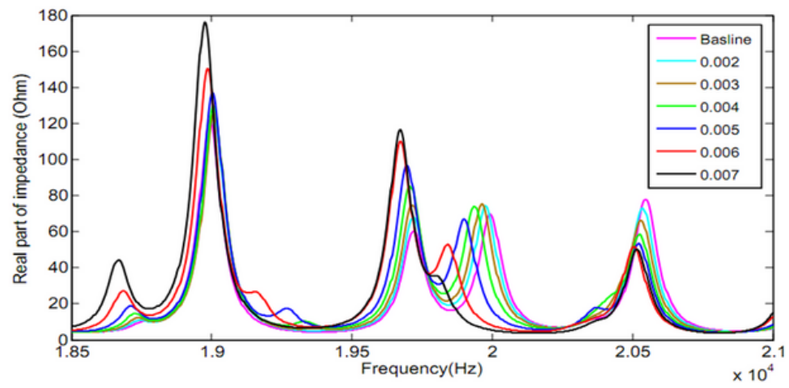
## CONCLUSION

- Temperature is a critical environmental factor in EMI-based SHM
- Uncompensated impedance data may lead to misinterpretation
- Proposed approach enables robust, real-time structural monitoring

EMI remains a powerful SHM tool when temperature effects are properly addressed.




HISTOGRAM OF THE (A) RMSD AND (B) CCDM OF DAMAGE




REAL PART IMPEDANCE FOR DIFFERENT SIZES OF DAMAGE

## RÉFÉRENCES

Liang et al., JIMSS, 1997
Park et al., Shock and Vibration Digest, 2003
Koo et al., JIMSS, 2009

TEMPERATURE SHIFTS EMI SIGNATURES AND CAN HIDE REAL DAMAGE. BUT A CROSS-CORRELATION COMPENSATION ALIGNS THE SIGNATURES AND RESTORES RELIABLE DAMAGE DETECTION.