**Objectives:**

- Study wave propagation behaviour in complex metallic and composite structures
- Evaluate the dispersion curves and attenuation trends for different layups and material properties
- Investigate wave interaction with damages for development of SHM methodology for structural damage detection and quantification

**Guided Waves**

- Mode conversion analysis
  - Thickness change caused by damage acts as source of mode conversion
  - Detecting mode converted waves → damage detection
  - TOF information of mode converted waves → damage localization

**Directional Attenuation in Unidirectional Composites**

- S0 mode propagation: Layup: [0º/45º/90º], Plate dimension: 1000 mm x 1000 mm x 16 mm
- Sensor distance: 50 mm, Sensing frequency: 500 kHz
- Angle: 0º-45º
- Propagation time: 100 µs
- Excitation signal: 500 kHz

**Directional Attenuation in Cross-ply and Quasi-isotropic Composites**

- S0 mode propagation: Excitation signal: 500 kHz
- Plate dimension: 1000 mm x 1000 mm x 16 mm

**Dispersion Curve for Carbon/Glass Fiber Reinforced Polymer Composites**

- A0 and S0 modes propagation: Layup: [0º/45º/90º], Plate dimension: 1500mm x 300 mm x 2 mm
- Sensing distance: 50 mm, Frequency: 50 kHz to 1000 kHz
- Composite materials: IM6/SCI081 and glass fiber composite
- Results are plotted along with published experiment data

**Composite Material Property Dependence on Attenuation**

- Layup: [0º/45º/90º], Plate dimension: 400 mm x 400 mm x 16 mm
- Sensor distance varied between 50 mm and 200 mm
- Polymer materials: Epoxy 3001-4, Epoxy HY6910 and polymer/mixes
- Fiber materials: AS-4-carbon fiber, E-glass fiber and Kevlar 49
- Case 1: same fiber (AS-4) with different polymer materials
- Case 2: same polymer (Epoxy 3001-4) with different fiber materials
- Propagation time: 45 ms

**Interaction With Delamination and Through Hole**

- Layup: [0º/45º/90º], Sensor distance 600 mm
- Plate dimensions: 1200 mm x 300 mm x 16 mm
- Defect dimension: 20 mm x 20 mm
- Defect location: at the mid point between actuator and sensor

- S0 mode changes significantly due to different material components and layups. A0 is not sensitive to these changes
- Significant change in wave amplitude due to through hole
- Wave reflection due to damages

**Lamb waves have ability to travel long distances in plate-like structures & are sensitive to multiple damage types**

**Matching Pursuit Decomposition (MPD)**

- Decomposes signal into weighted linear expansion of elementary basis function (atoms)

\[
x(t) = \sum_{i=1}^{N} \alpha_i g_i(t) + r_f(t)
\]

- Iterative algorithm sorts decomposition by magnitude of \(q\) (highest energy)
- Basis function chosen to resemble signal and reduce computational complexity
- Number of peaks in Hilbert transform estimates number of modes in signal

**Dispersion Curve and Attenuation**

- Attenuation in Unidirectional Composites
  - Layup: [0º]
  - Collected actuators are used to generate S0 and A0 modes
  - Frequency: 500 kHz
  - Plate dimensions: 1200 mm x 300 mm x 16 mm
  - Actuation signal: 5 cycle cosine tone burst

- Amplitude decreases with increasing distance away from actuator
- A0 mode has higher amplitude attenuation than S0 mode

**Time of Flight Analysis Using Supervised Learning Based MPD Algorithm**

- For signal collected from each sensor, multiple modes found by MPD methodology
- Found the time of arrival (TOA) of each mode
- Calculated the group velocity for each mode
- Expected mode found by comparing the group velocities from all the sensors

**Composite Material Property Dependence on Attenuation**

- Changes in fiber property lead to significant change in wave propagation behavior
- Changing matrix properties do not cause significant change in wave propagation behavior

**Effect of Stiffness Components on Wave Propagation**

- A0 and S0 modes propagation
- Layup: Quasi-isotropic: IM6/SCI081, [45, -45], (0/45), and unidirectional AS-4/3001-4, [0º], and unidirectional AS-4/3001-4 plates, [0º], 45 degrees
- Sensing distance: 50 mm, Frequency: 50 kHz to 1000 kHz
- Small perturbations are introduced in the stiffness components

**Modeling of Ultrasonic Guided Waves in Metal and Composite Materials**

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