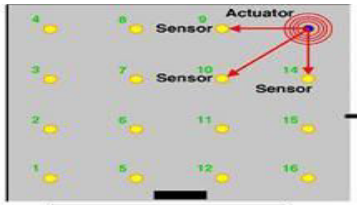
Integrative Multiscale Engineering of Materials and Systems Lab

Department of Aerospace Engineering, Indian Institute of Science

Structural Health Monitoring using Lamb Wave, Piezoelectric Sensor/Actuator array and Computational Technique



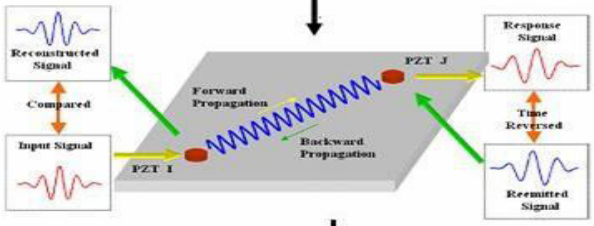
Sensor Network

$$A(t)_i = S(t)_{ij}\ ,\ i,j = 1,2,3 \ldots\ldots n$$

$$\begin{bmatrix} S(t)_{11} & S(t)_{12} & S(t)_{13} & \cdots\cdots & S(t)_{1j} \\ S(t)_{21} & S(t)_{22} & S(t)_{23} & \cdots\cdots & S(t)_{2j} \\ S(t)_{31} & S(t)_{32} & S(t)_{33} & \cdots\cdots & S(t)_{3j} \\ \vdots & & & & \\ S(t)_{i1} & S(t)_{i2} & S(t)_{i3} & \cdots\cdots & S(t)_{ij} \end{bmatrix}$$

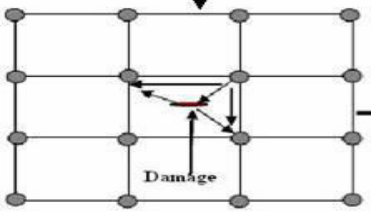
Data stored in Matrix form

Time Reversal of the Sensor Signal

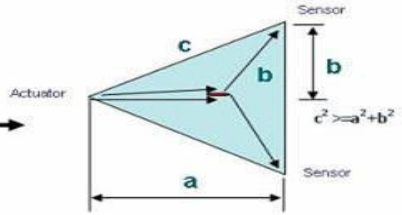


Data stored in matrix form after time reversal

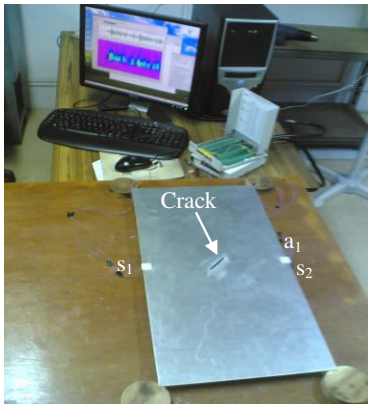
$$\begin{bmatrix} S(t)_{11}=A(t)_1 & S(t)_{12} & S(t)_{13} & \cdots\cdots & S(t)_{1n} \\ S(t)_{21}=A(t)_1 & S(t)_{22}=A(t)_2 & S(t)_{23} & \cdots\cdots & S(t)_{2n} \\ S(t)_{31}=A(t)_1 & S(t)_{32}=A(t)_2 & S(t)_{33}=A(t)_3 & \cdots\cdots & S(t)_{3n} \\ \vdots & & & & \\ S(t)_{n1}=A(t)_1 & S(t)_{n2}=A(t)_2 & S(t)_{n3}=A(t)_3 & \cdots\cdots & S(t)_{nn}=A(t)_n \end{bmatrix}$$

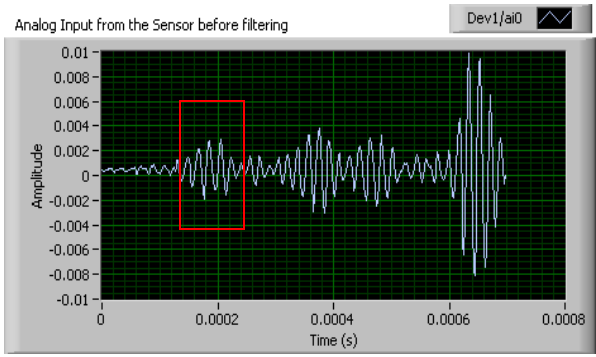


Affected Sensor Cluster for Damage Localization



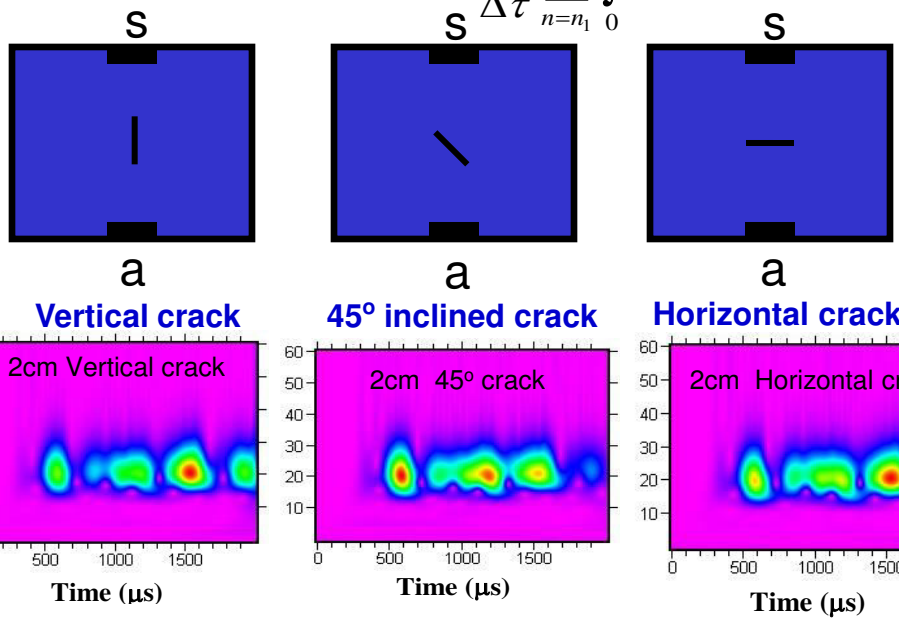
Triangulation for estimation of size and shape of damage





$$\bar{V}(t) = \frac{\mathrm{FIR}[V(t)_{\mathrm{crack}}]}{V_0} - \frac{\mathrm{FIR}[V(t)_{\mathrm{uncrack}}]}{V_0}$$

$$J = \frac{1}{\Delta\tau} \sum_{n=n_1}^{n_2} \int_0^{\Delta\tau} |\psi(\omega_n, t)|^2 \, dt$$



Wavelet energy based damage parameter correlation

Laser Doppler Vibrometry (LDV) – 3D scanning

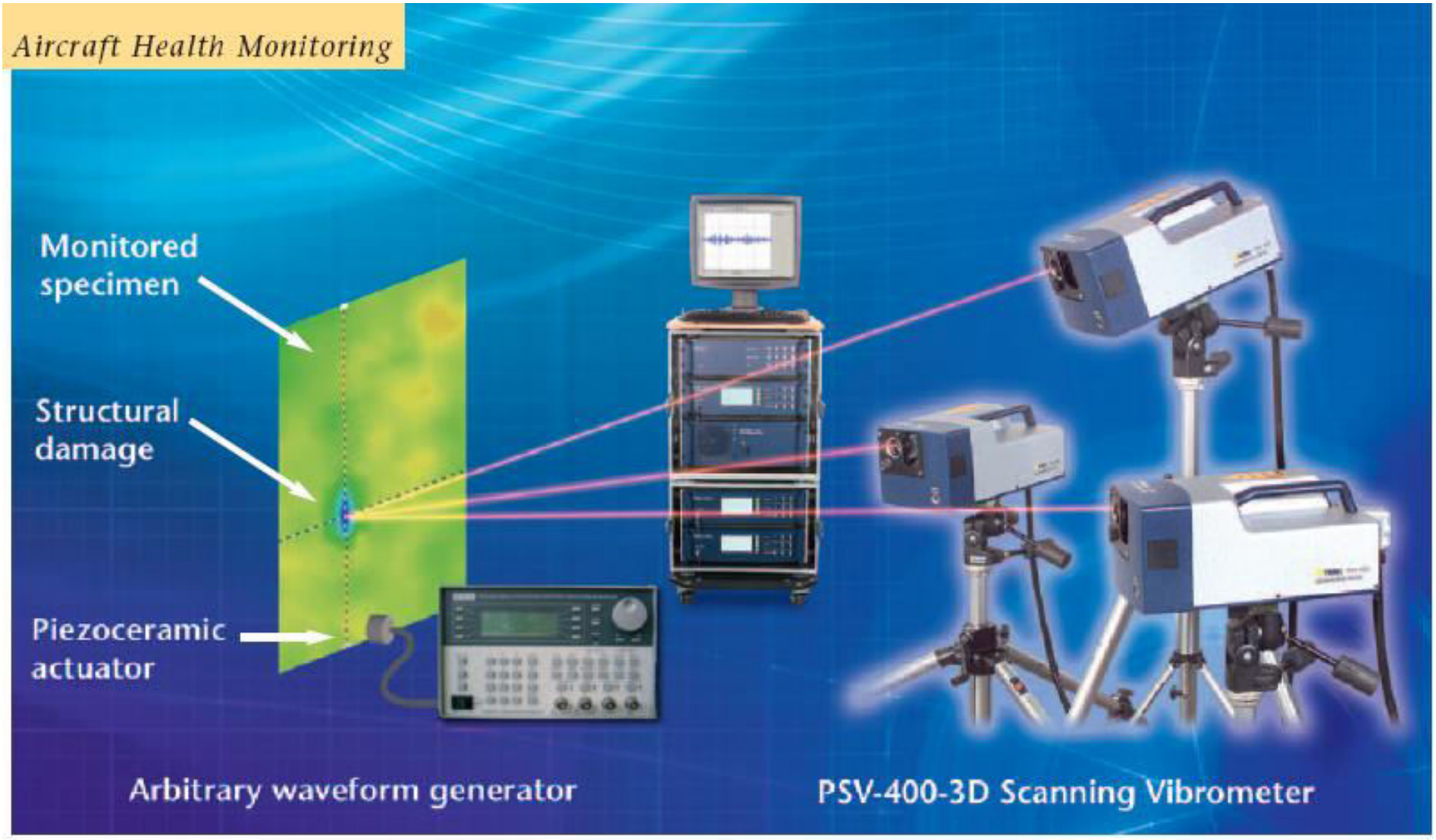
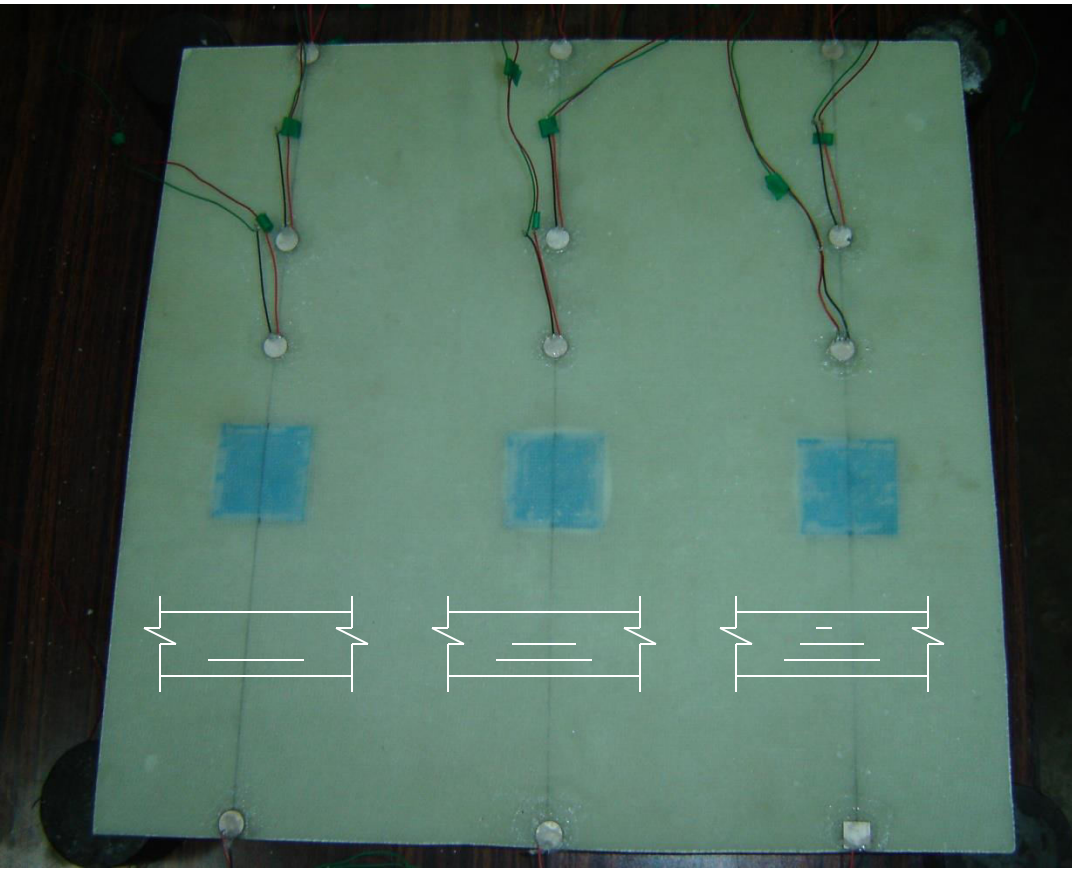
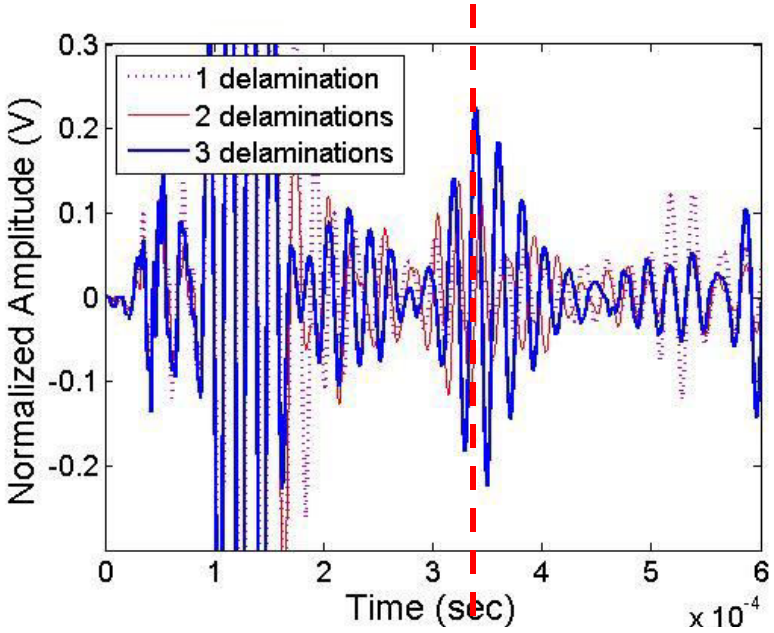
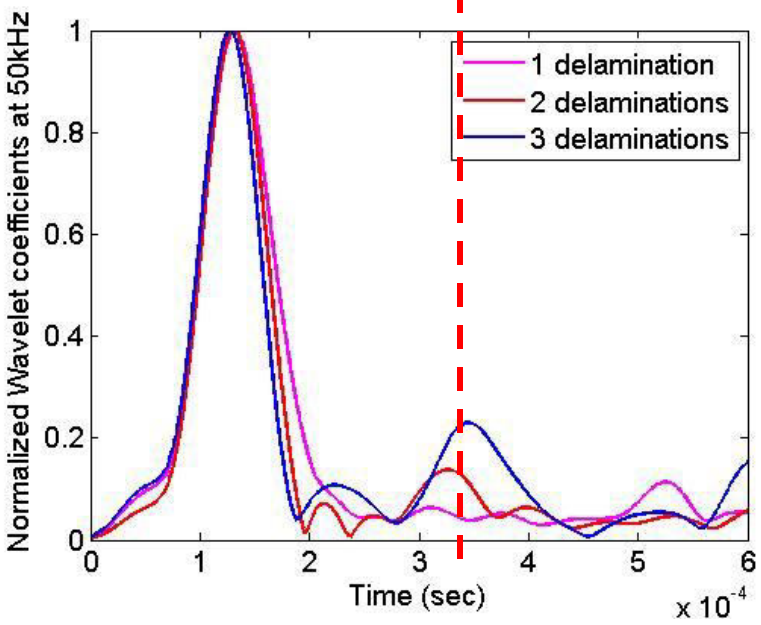


Figure 1: Experimental arrangements for Lamb-wave damage detection using 3-D laser vibrometry as a receiver.

Damage Detection in Composite using PWAS

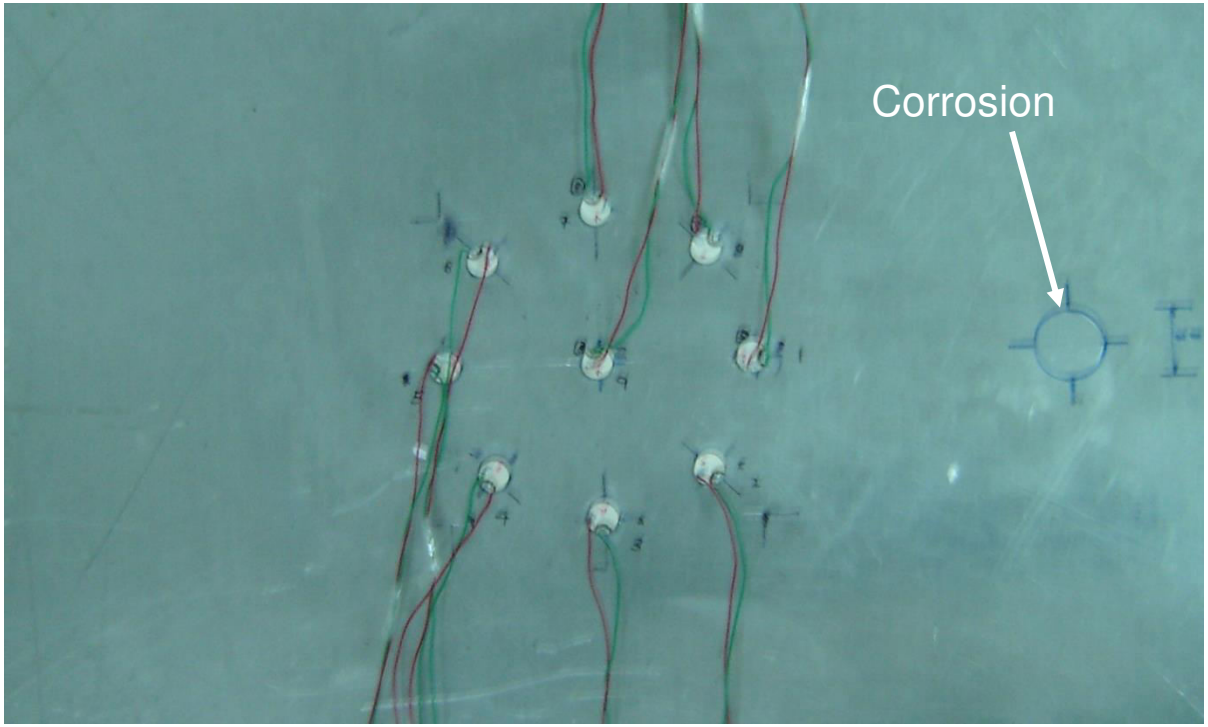






2.25mm thick quasi-isotropic Glass-Epoxy Laminate
Total number of layers: 12
Delamination sizes: 40mm, 30mm, 20mm
Layer locations: 5-6, 4-5, 3-4
Actuation: 60V peak, 80kHz, modulated sine

Use of Piezoelectric Active Sensor (PWAS) Network



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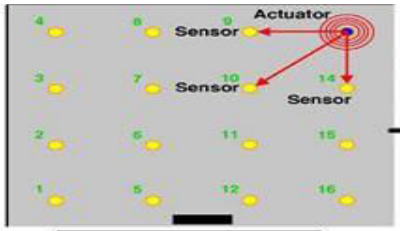

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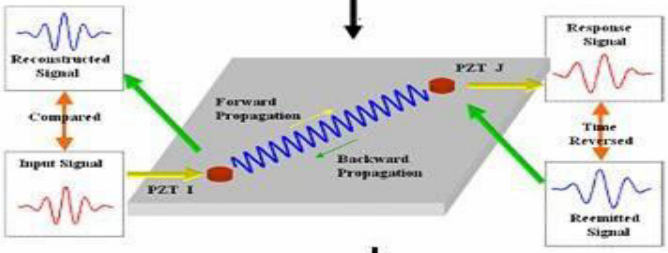

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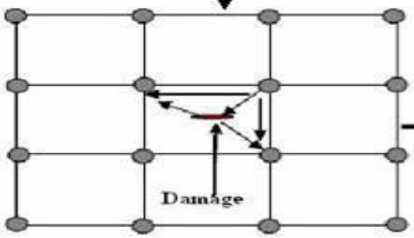

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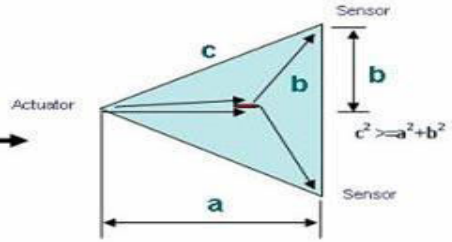

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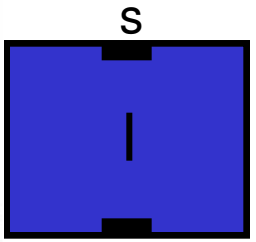
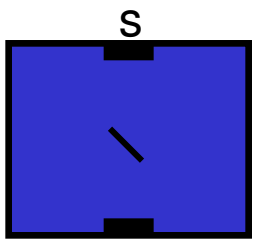
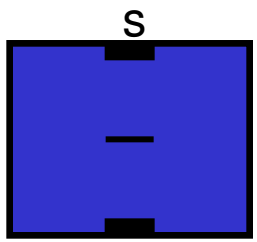


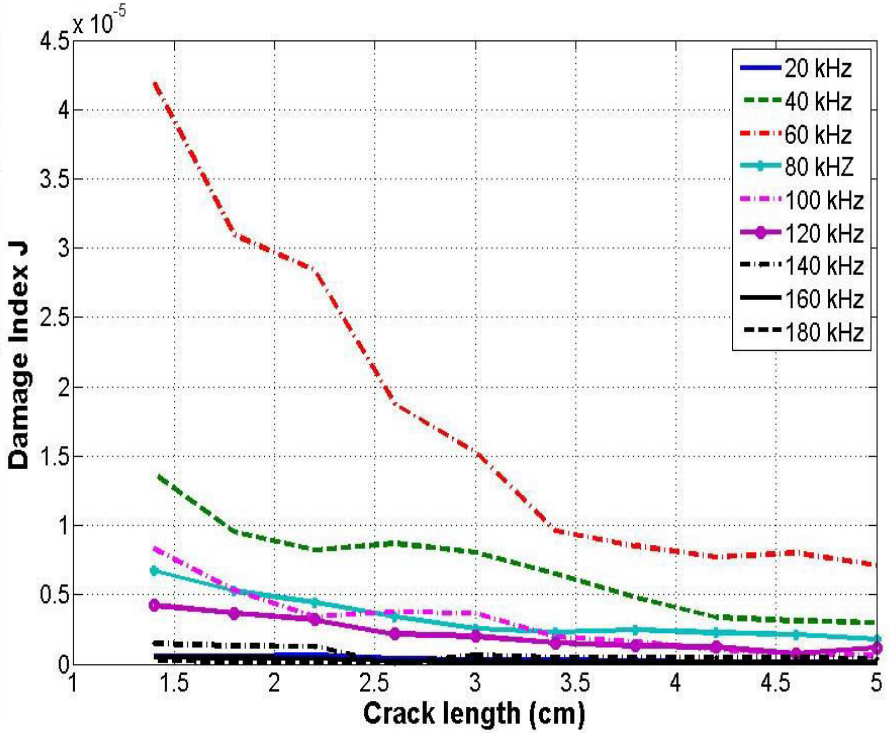
Vertical crack



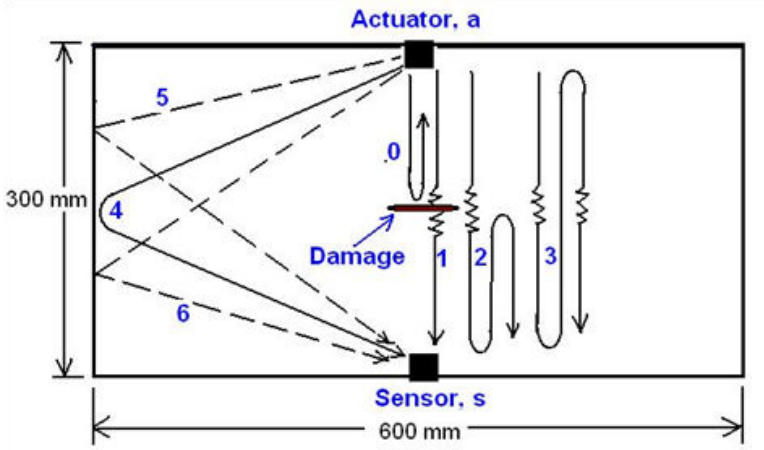
45° inclined crack

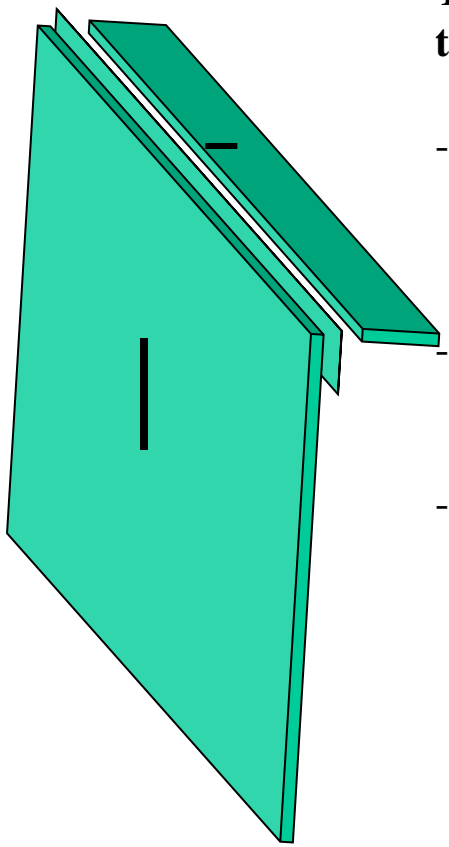


Horizontal crack



Amplification of Transmitted Waves Through Hidden Damages





Tasks to be performed by the Software

- Take boundary type data and main panel thickness data as input

- Perform frequency sweep and obtain A0/S0 curves

- Perform damage index specific to A0/S0 frequencies for main panel.
  If above tolerance then damage is in main panel. If it is at some other frequencies then the damage is in the substructure.