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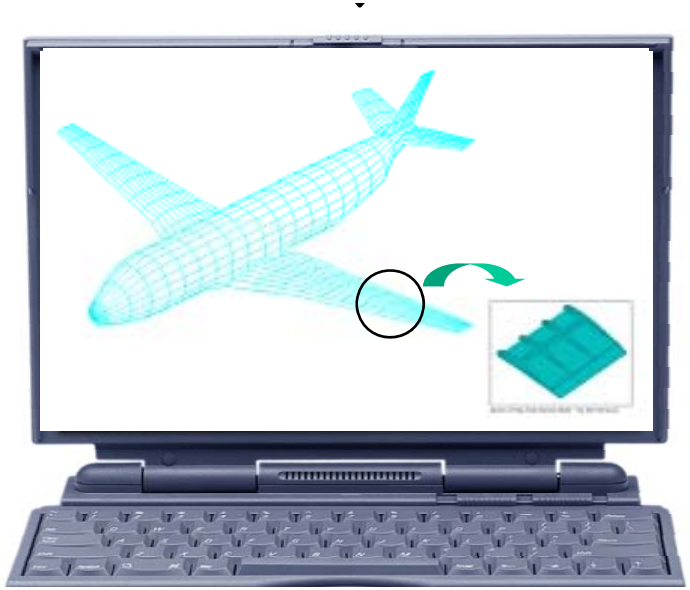
Development of an Efficient Computational Tool for Analyzing Lamb Wave Propagation in Thin Structures Generated by Built-in Piezoelectric Actuators

Sungwon Ha

Advisor: Prof. F K Chang



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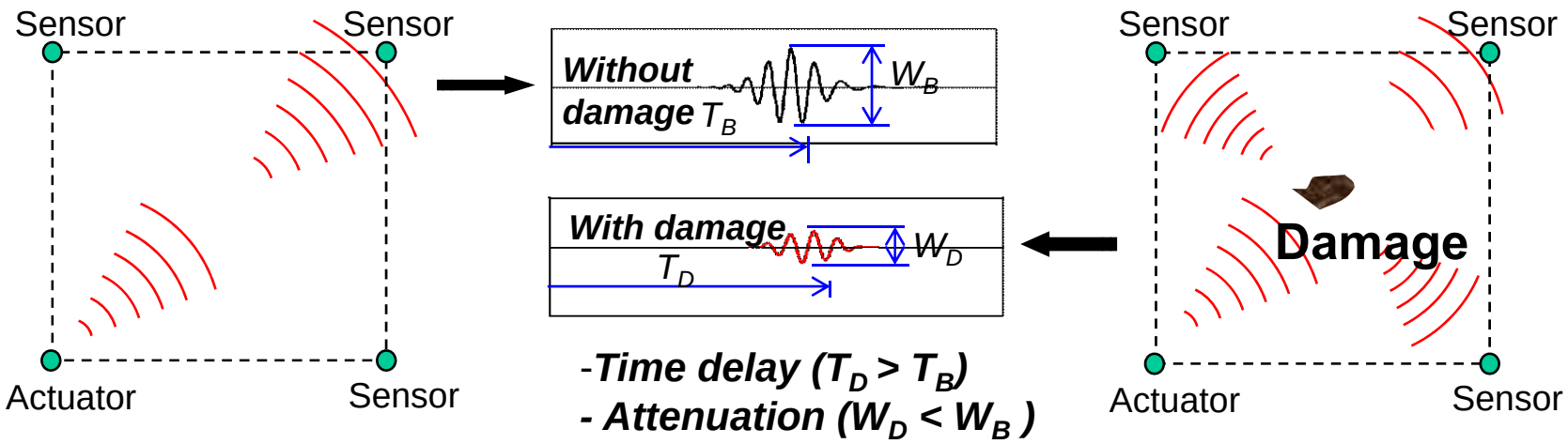
Introduction



Problem Statement

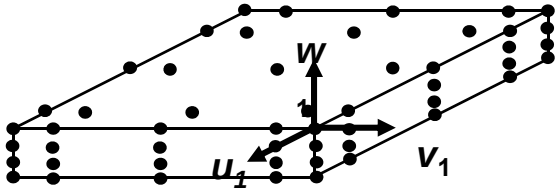
Develop a new technique to model

- **PZT-induced wave propagation fast and accurately in thin plates**
- **3-D thin interface adhesive layer effects efficiently**

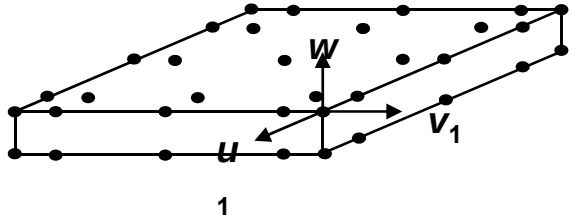
Hybrid Spectral Element

Existing solid spectral element

Source : Y. Kim, S. Ha, FK. Chang AIAA journal, 2008

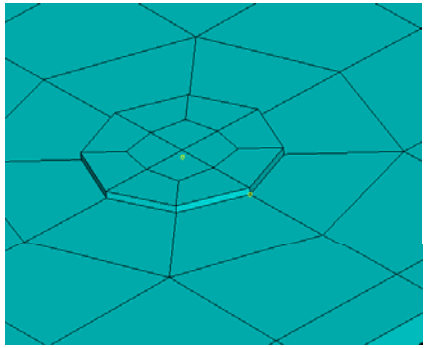


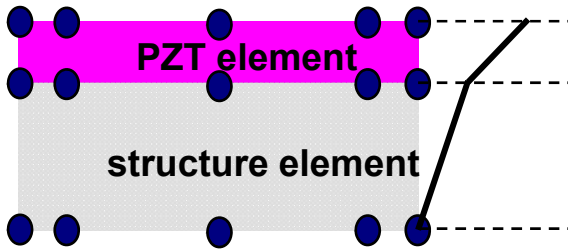
Hybrid spectral element



- **Thin structures → wave propagation in thickness direction is ignorable**
  - **Linear shape functions are good enough**
- **Linear shape function in thickness → Removes computational redundancy saving a lot of computational time**
- **Hybrid spectral element is based on**
  - Nodal quadrature in in-plane direction (Spectral element)
  - Gauss quadrature in thickness direction (Finite element)

Surface Mounted PZT Modeling for Hybrid





Equation of motion for mechanical behavior

$$M_{ij}\ddot{u}_j = F_i^{ext}(V) - K_{ij}u_j$$

Gauss' law for electrical behavior

$$K_{ij}^e V_j = P_i(\varepsilon_p)$$

separate dynamic behavior of PZT element from structure element

Validation with Experiment

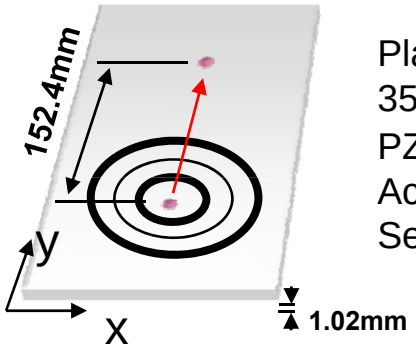
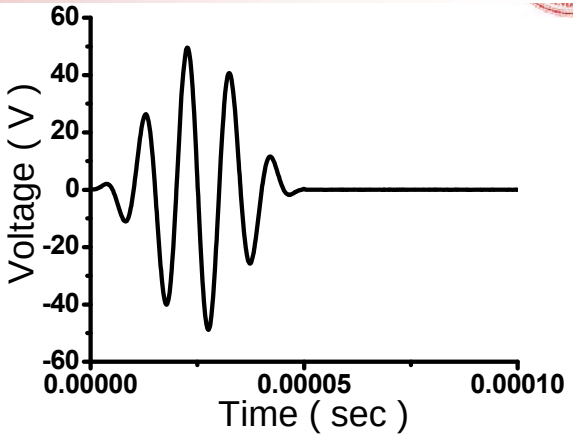
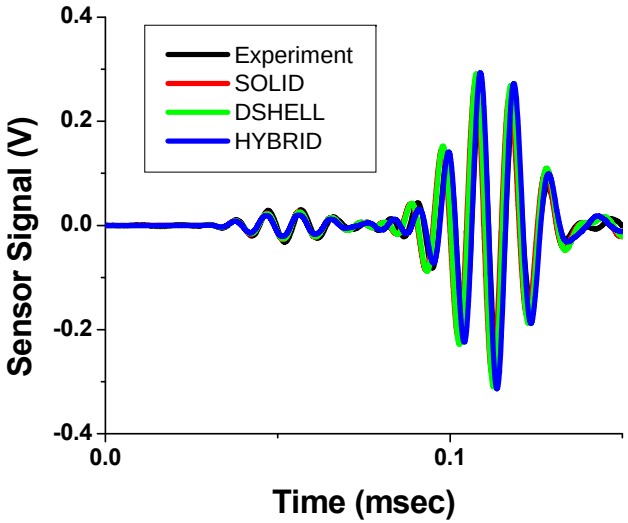


Plate dimension :
355.6 mm x 508 mm
PZT location
Actuator : (177.8 mm, 177.8mm)
Sensor : (177.8 mm, 330.2mm)



- PZT ceramic disks with 6.35mm diameter and 0.25mm thickness
- Perfect bonding condition (zero thickness adhesive layer) is assumed

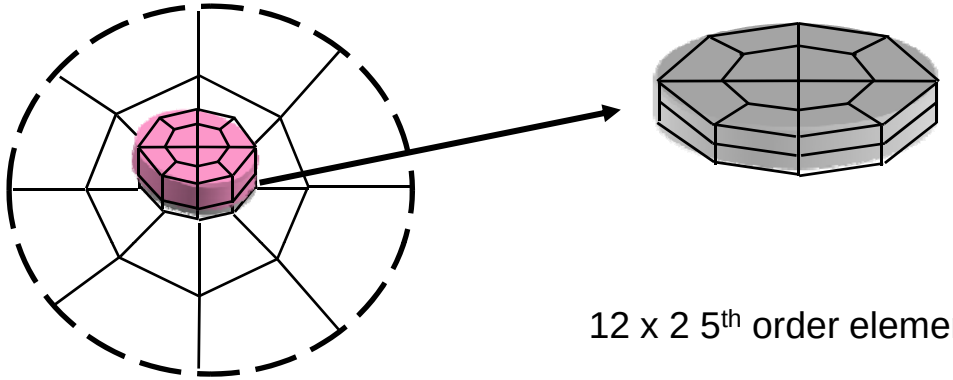


	FEM	Solid	Hybrid
Total DOF	5,458,626	716,280	252,780
Mesh size: PZT Other	0.4 mm 0.4 mm	1.6 mm 5.0 mm	1.6 mm 6.0 mm
Interpolation order	1	4	4
Time step (nsec)	28	20	26
Computational time	452 min	283 min.	**17 min**

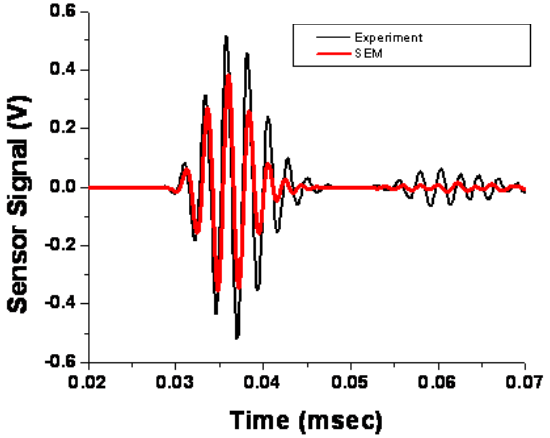
Adhesive Layer under Thin PZT

Hybrid spectral element can model thin adhesive layer directly without extreme mesh refinement

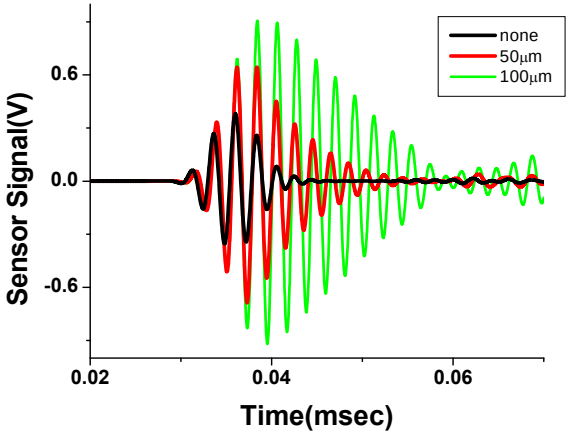
Sensor response around resonant frequency with 20 μm adhesive layer model; 400kHz excitation

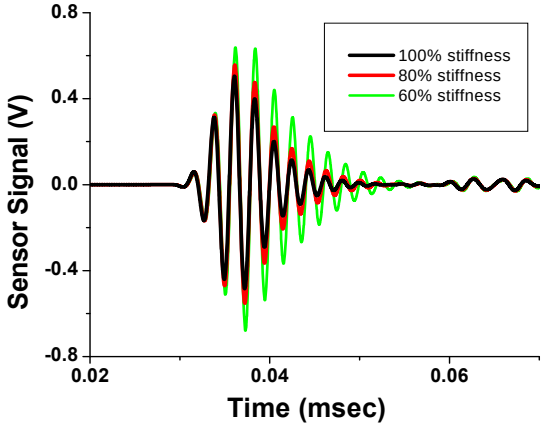


12 x 2 5th order elements

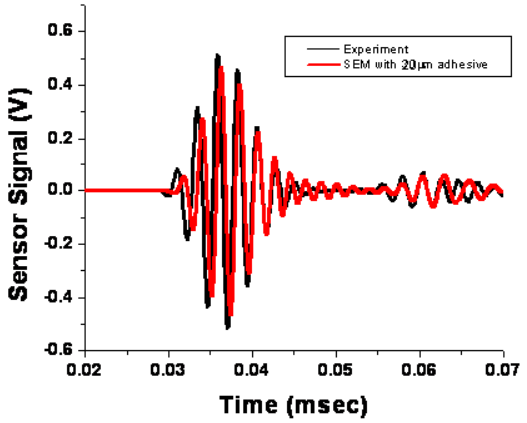


Thickness & Stiffness Effect Simulation





As the thickness or stiffness of adhesive layer increases, the resonance effect of PZT becomes more dominant



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Bio

Name : Sungwon Ha

PoB : Seoul, South Korea

Degrees:

B.S.	Aerospace	1997
M.S.	Aero/Astro	1999
M.S.	Electrical	2004
Ph.D.	Aero/Astro	2008

Hobbies: Golf