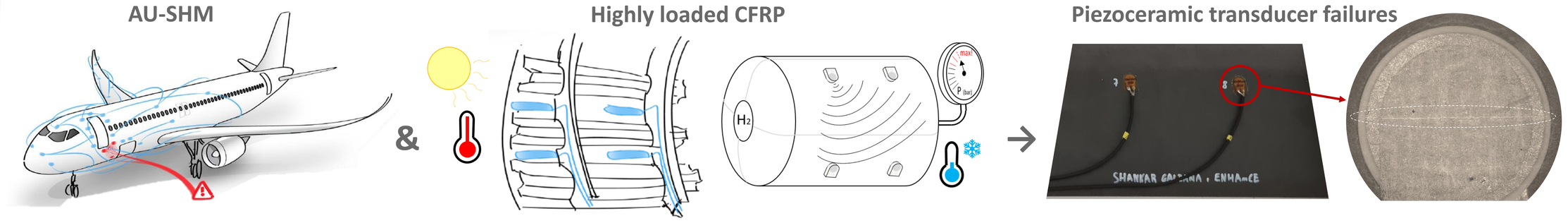
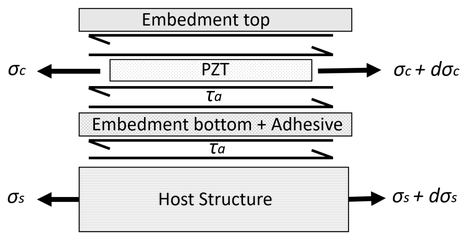
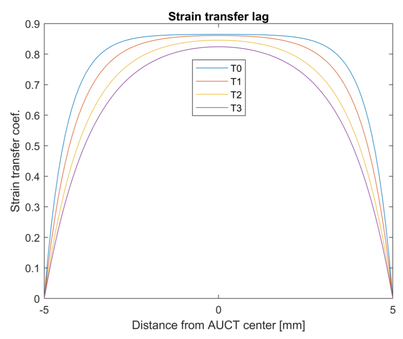
Effect of the Piezoceramic Embedment on the Robustness and Lamb Waves Transmission of Acoustic-Ultrasonic Composite Transducer (AUCT)



Shear-Lag Load transfer tuning

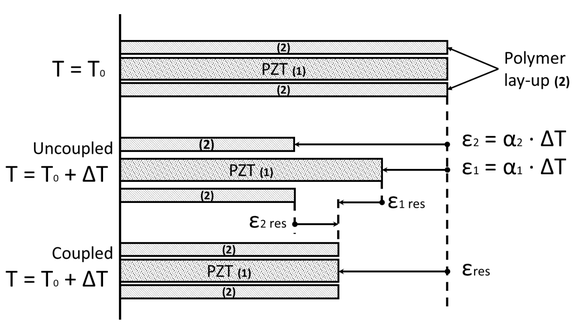


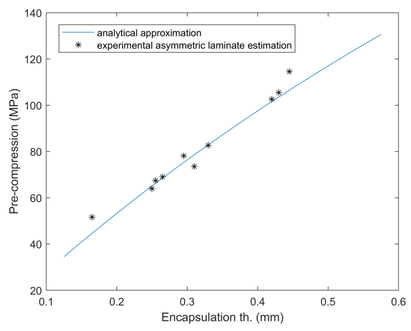


$$\Gamma^2 = \frac{G_{int}}{E_c h_c \boldsymbol{h_{int}}}\left(1+\frac{\alpha}{\Psi}\right) \qquad T_\varepsilon = \frac{\Psi}{\Psi+\alpha}\left[1-\frac{cosh\,\Gamma x}{cosh\,\Gamma l}\right]$$

Embedment material thickness and the adhesive layer bond between the host structure and the piezoceramic cause incomplete transmission of strain from the structure to the piezoceramic, known as the shear lag effect. This effect is governed by the thickness and mechanical properties of the materials between the structure and the piezoceramic (interface).

Piezoceramic pre-compression





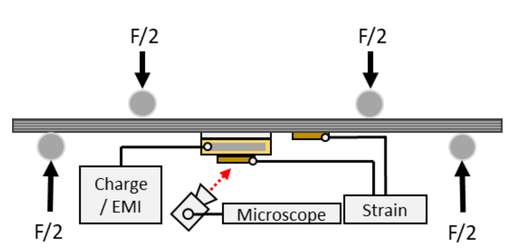
$$\sigma_p = \Delta T\left[\frac{2E_c\,(E_m \boldsymbol{t_m} \alpha_m - \alpha_c)}{2E_m \boldsymbol{t_m} + E_c t_c}\right]$$

In AUCT's, ceramic pre-compression occurs when cooling during production curing, which causes more contraction of the encapsulating material than the piezoceramic material. This is owing to the different heat coefficients of the two materials and chemical shrinkage.

Results resume

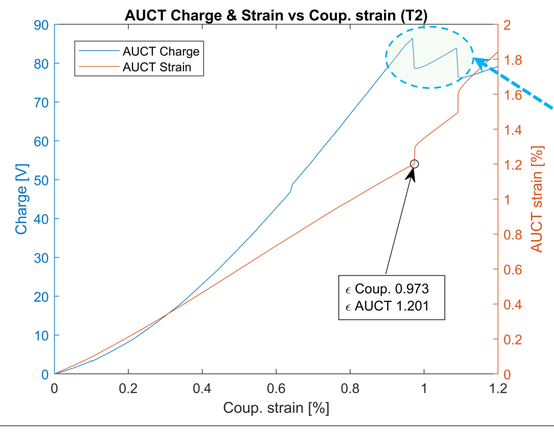
T_n	Transducer th. (mm)	Ultimate strain (%)	Max. amp. (mV)
T_0 (ref.)	0.45	0.66	64
T_1	0.65	0.88	42
T_2	1	1.0	26
T_3	1.35	1.2	15

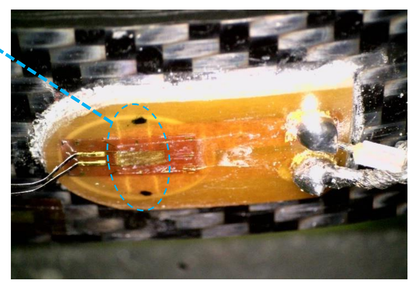
Ultimate strain determination



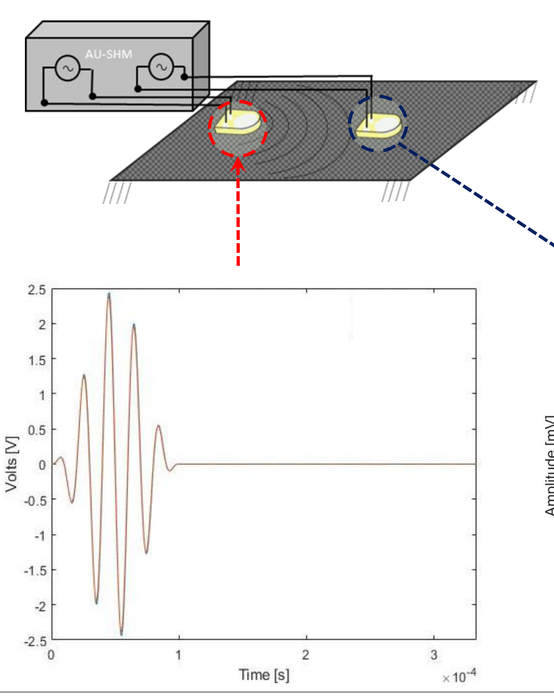
The ultimate strain of the secondary-bonded AUCT is determined using a 4-point bending coupon test by measuring:

- Coupon tension surface strain.
- Top AUCT surface strain.
- Piezoceramic charge.
- Top AUCT surface microscope.





Lamb wave performance characterization



Characterization of the lamb wave performance of the secondary bonded AUCT is done by using a flat panel with:

- 50KHz sine 5p Hanning window burst signal 400mm span.
- Maximum amplitude of the Hilbert transformation for A_0 mode.

Motivation

Fiber-reinforced composites are becoming more widely used with new materials and in new applications that require them to operate in highly loaded structures and at extreme temperatures. Acousto-ultrasonic composite transducers (AUCT) based on piezoceramic materials show great potential for monitoring damage in them. However, when they are integrated into highly loaded composite structures, their mechanical properties are challenging, particularly because they face brittleness and vulnerability to tensile loads. Therefore, increasing their tensile load tolerance and decreasing transferred stresses while attached into structures surfaces would allow them to be used in a wide range of composite applications.

Research hypothesis

- Thicker AUCT embedment results in a greater distance between the structure surface and the piezoceramic, which increases shear lag. Higher shear-lag causes less load transfer from the structure to the piezoceramic, allowing the AUCT to operate in higher loaded structures, increasing the robustness of the system
- Thicker AUCT embedment results in a greater pre-compression of the piezoceramic during the manufacturing process. Higher pre-compression allows the ceramic to survive to higher tensile loads, increasing the robustness of the system
- Thicker AUCT embedment can be used without compromising Lamb wave transmission performance

Results and discussion

- Ultimate strain survivability increases proportionally to the loss of performance on Lamb wave transmission.
- Despite significant signal decay, the Lamb wave's signal-to-noise ratio remains high, allowing the SHM analysis to be performed on all the proposed transducers
- Based on the findings, it is possible to identify optimal thickness configurations for specific applications where robustness is critical.

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