# Lamb Wave Based Baseline-Free Active Damage Detection: Modeling and Experiments

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## ABSTRACT

Structural health monitoring (SHM) of critical structures such as aircrafts, ships, nuclear reactors, pressure vessels and pipelines for preventing catastrophic failure is a prime concern amongst the engineering community. Ultrasonic Lamb waves excited and sensed by surface-bonded thin piezoelectric wafer patches have shown great potential in detecting small localized damage in such thin-walled structures. However, the need to compare the sensor signals to a prerecorded baseline of the healthy structure in the conventional methods present several complications. This study focuses on the development of a damage detection technique without involving comparison with baseline data, based on the time reversal process (TRP) of Lamb waves. It is shown that the sensitivity of the TRP based method can be enhanced very significantly by conducting the probe at the *best reconstruction frequency* at which the similarity or correlation between the reconstructed and original input signals in the undamaged state would be the maximum over a given range of frequency, for the given structure-transducer-adhesive system. A new method of computing the damage indices (DIs) with extended signal length is proposed capturing the extra bands around the main wave packet, which are generated due to interactions of the propagating Lamb waves with the damage. The new DIs used at the best reconstruction frequency are shown to have excellent sensitivity to damage, ensure a low threshold for the undamaged case, and reflect the true severity of the damage. The sizing and localization of the damage are illustrated experimentally using the proposed baseline-free method. The effects of various parameters such as the adhesive layer between the transducers and the host plate, the tone burst count of the excitation signal, the plate thickness, and the piezoelectric transducer thickness on the time reversibility of Lamb waves in metallic plates are studied. The results show several trends that are contrary to general expectations, e.g. the quality of the reconstruction of the input signal after the TRP may increase with the increase in the adhesive layer thickness at certain frequency ranges, and narrower band of the signal does not necessarily enhance the time reversibility at all frequencies. An analytical solution for the excitation, sensing and time-reversal of Lamb waves in the undamaged actuator-structure-sensor system is also developed to provide a theoretical estimate of its best reconstruction frequency for the design of SHM systems based on the TRP.

# Biography

Prof. Santosh Kapuria received his B.E. degree in Civil Engineering from Jadavpur University, Kolkata, in 1989, and M.E. in Structural Engineering from Indian Institute of Science, Bangalore, in 1991, securing first rank in the Department of Civil Engineering in both the institutes. He obtained his Ph.D. degree in Applied Mechanics from Indian Institute Technology Delhi in 1997. He worked in Engineers India Limited (EIL), a premier engineering consultancy organization of Asia, during 1991-2011, where he gained a rich and distinguished experience in advanced engineering and industrial R&D. Since September 2002, he has been with the faculty of the Department of Applied Mechanics, Indian Institute of Technology Delhi, where he became a full Professor in December 2006 and received the Higher Academic Grade in 2013. He has been a Humboldt Research Fellow at Technische Universität Darmstadt, Germany during 2005-2006, and a Fulbright Senior Research Fellow in Stanford University, USA during 2009-2010. He is currently the Director of CSIR-Structural Engineering Research Centre, Chennai.

Prof. Kapuria's research interests are mechanics of smart (multifunctional) structures, mechanics of composite, sandwich and functionally graded material structures, computational structural mechanics, active vibration control, structural health monitoring, and biomechanics. He has published over 115 papers in top quality international journals. He is a Fellow of the Indian National Academy of Engineering (INAE), the Indian National Science Academy (INSA), Indian Academy of Sciences, Bangalore, and the National Academy of Sciences, India (NASI). He has delivered several keynote and invited lectures in national and international conferences and universities abroad.