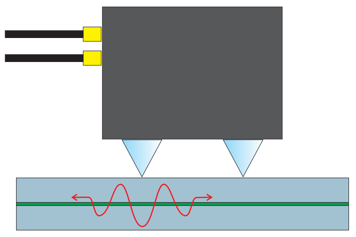
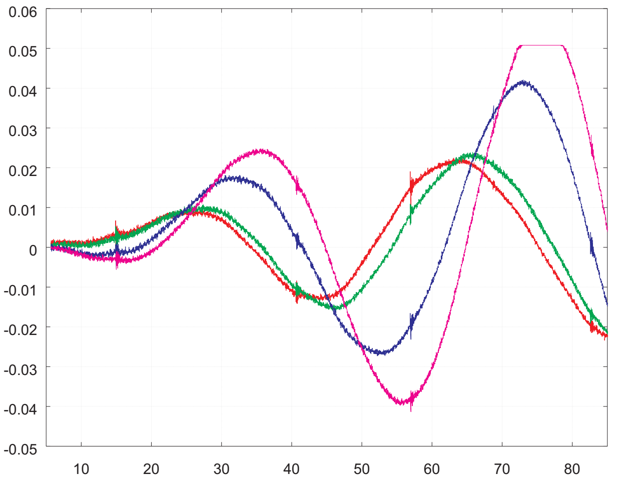
Centre for Imaging Research and Advanced Materials Characterization

Adhesive Bond Characterization

Feasibility Study: Lamb Waves



Lamb waves are the particular modes of vibration which propagate along plate-like geometries. These wave modes are highly dispersive, with velocities quite dependent on their frequency and the thickness of the plate, as well as the visco-elastic properties of the material. These properties make them excellent tools for probing adhesively bonded joints.

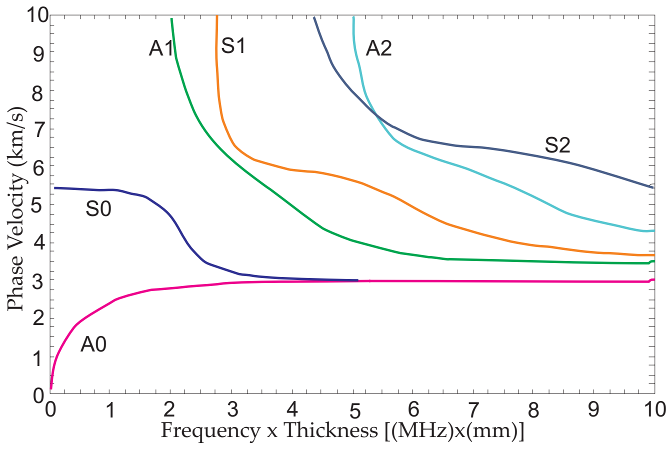


(Left) Typical signals received by Lamb wave device at 25 kHz, showing time of flight shifts due to slight changes in thickness. Time of flight was taken as the position of the first peak.

Physical Principles

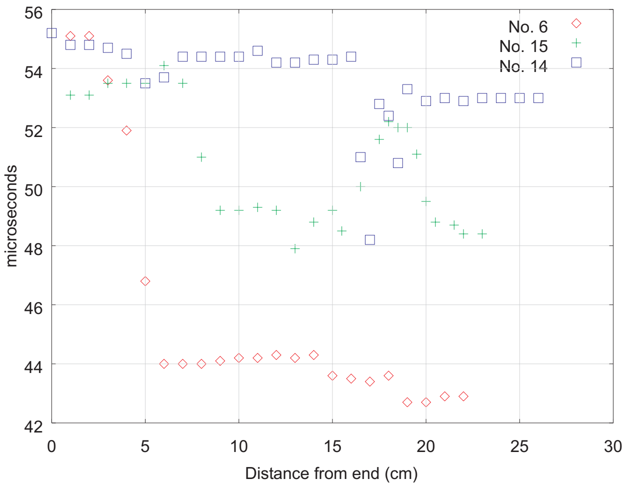
Lamb waves provide a fundamentally different approach from the pulse-echo or resonance methods. This is because the physical nature of Lamb waves is different from the longitudinal bulk waves used by the other approaches. The main changes are that Lamb waves propagate down the plate instead of through it, and employ much lower frequencies. This means using a separate transmitter and receiver is necessary, but it also means greater flexibility in terms of transducer technology. Lamb waves are also highly dispersive, meaning that different frequencies travel at different phase velocities (see below). The greatest advantage of this fact can be taken by using the A0 mode below 0.25 Mhz x mm, where the wavelength is small and the velocity is very sensitive to variations in thickness. The results displayed here were taken using a commercial contact transducer at a frequency of 25 kHz, generating an A0 wave with wavelength of 15 mm.

Spatial resolution for Lamb wave techniques depends a lot on the source-receiver distance and is significantly less , in principle, than one might get from bulk waves.

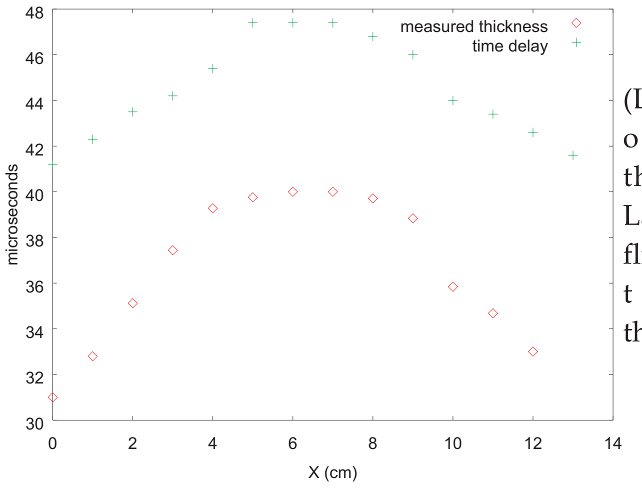


(Left) Dispersion curves for Lamb modes (in aluminum). Most of our work has been done at the far left end of the diagram, with the A0 mode.

Results



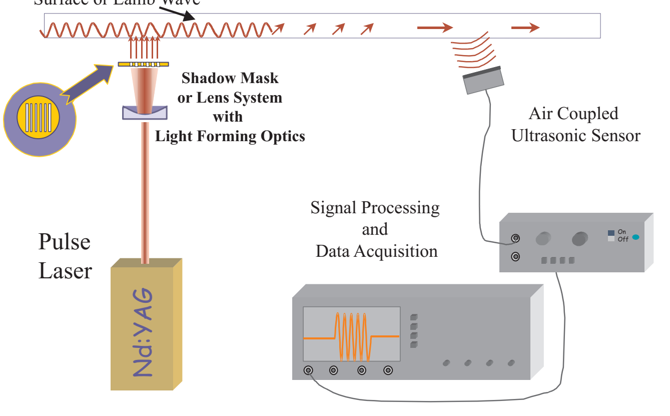
(Right) Time of flight changes along three different samples - good adhesive (No. 6), uncured adhesive with void (No. 15) and uncured, unstuck adhesive (No. 14). Between the good and lack of ahesive regions, we see a change of more than 20%. This is close to an order of magnitude increase in sensitivity over bulk wave methods.



(Left) Demonstration of sensitivity to thickness variation. Lamb wave time of flight is compared to the measured thickness.

Future Development

- Explore ways of increasing resolution
- Develop a clear theoretical model for Lamb propagation in such multi-layered structures
- Explore remote generation and reception technologies
- Develop a scanning and imaging technique



(Right) Alternate means of generating and receiving Lamb waves include non-contact methods such as laser and air coupled ultrasound.