Radial position independent directivity for laser generated ultrasonic shear waves in thermoelastic regime

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The shear waves generated by pulsed laser in the non-destructive thermoelastic regime, are commonly used for defect detection. The shear wave propagates inside the material with a strong angular-dependency, termed directivity. An accurate, consistent measure of shear directivity at all radial position is required to design inspections and maximise the signal-to-noise ratio (SNR). However, head waves, which travel on the free surface with longitudinal velocity and inside the material with shear velocity, interfere with the shear wave in certain regions. Due to the head wave having a different ray path, wavefront, and attenuation from the shear wave [1], the measured shear directivity varies with the radial distance from the source. This makes it challenging to extract the true shear wave directivity from finite element (FE) simulations without using very large spatial domains. A method is proposed to avoid this problem by removing the contribution from the head wave. This work uses FE simulations to show that a wavefield dominated by the head wave can be obtained by running a second simulation, which takes the displacements of the original simulation (simulating the physics of the laser ultrasonic wave generation mechanism) as boundary conditions, with damped initial pulses. This wavefield is subtracted from the original wavefield, leaving pure shear waves. This method is first benchmarked with the analytical shear wave directivity for a force dipole on the free surface of a homogeneous, isotropic half space [2]. The subtraction removes head wave interference in the region 30˚-51.6˚, and the Rayleigh wave near surface, as shown in Figure 1a. The directivity from 25˚-30˚ is difficult to fully reconcile with the analytical solution. This is because in FE simulations, the force dipole must be implemented as opposing point forces applied to adjacent nodes, which hence have a finite (as opposed to infinitesimal) separation. This method is then applied to an anisotropic material similar to that found, for example, in austenitic welds [3], to obtain a shear directivity independent of radial positions, as shown in Figure 1b, for which there is no analytical solution.

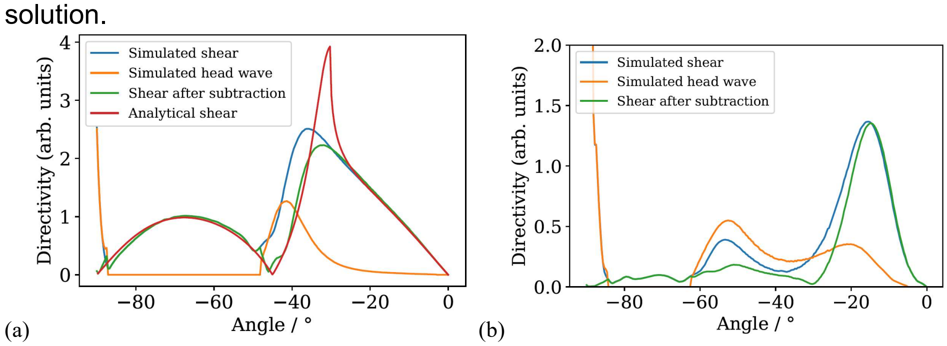

Figure 1: subtraction of head wave from shear wave directivity in (a) an isotropic material, fitted with analytical solution, and (b) a transversely isotropic material.

References:

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