# Modelling of Lamb wave propagation in composites using a fifth-order plate theory

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Composite materials show complex wave propagation behavior because of their inherent anisotropy and heterogeneity. The conduct of waves in composites strongly depends on the laminate layup, propagation direction, frequency and surface loads. The exact solution of the spectrum of propagation modes can be derived based on 3D elasticity, but, unfortunately, requires complex and demanding root searching algorithms. Alternatively, numerical approaches can be employed, however they tend to be unstable at certain angles and frequencies, and are computationally also expensive for multilayered structures. Approximate models using third order plate theory have also been proposed, but then again, these approximate models can only provide the dispersion characteristics of the low-order Lamb modes. In this study, an analytical solution for the dispersive behavior of Lamb waves in multilayered composite plates is proposed by using a 5th order shear deformation theory (5SDT). In general, such advanced high-order plate theory is computationally more expensive compared to lower order theories, but the problem can be reduced by rearranging matrices in the form of polynomial eigenvalue solution. As a result, the proposed 5th order approach allows to compute the dispersion curves of multilayered composites in less than a second (on a standard laptop). Further, by using the 5th order theory, the accuracy as well as the number of quantifiable lamb wave modes increases significantly. Combining the plate theory approximation with an equivalent single layer modelling, 9 symmetric and 9 anti-symmetric Lamb modes can be calculated over a wide frequency range. The performance of the developed 5th order procedure will be compared for different cases to both the hybrid matrix approach and the 3D elasticity based method. The results show that the newly suggested 5th order plate theory method provides a good agreement with the hybrid matrix method, and that it is more robust than 3D elasticity based methods. The strong advantage over the other approaches is that the computational time of the novel procedure is severely reduced, i.e. calculations are quasi real-time.