Carbon fiber reinforced polymer (CFRP) composite materials are used in aerospace structures due to its high strength-to-weight ratio. The presence of internal damage reduces the service life of CFRP structures and requires non-destructive evaluation (NDE) methods that inspect parts and materials without affecting their future usefulness. Ultrasonic testing is among the NDE methods used in CFRP structures. Guided ultrasonic waves possess long propagation range and are better suited for surface and subsurface flaws detection. In addition, these waves can interact with cracks causing them to open and create electrical resistance changes in the material which allows for enhancement of other NDE methods such as Electrical Resistance Tomography (ERT). However, the propagation of Lamb waves in CFRP laminates is complicated due to their inherent anisotropy. To effectively use an NDE method using guided waves in CFRP composites, it is necessary to understand the existing physical interaction of propagating waves in the presence of material discontinuities. The governing equation describing the physics of wave propagation in multilayered anisotropic media must be solved numerically. Wave propagation in multilayered anisotropic media requires high-order, accurate and scalable methods that can also adapt to complex geometries. Discontinuous Galerkin Spectral Element Methods (DGSEM) are high-order accurate and parallelizable methods used for problems with complex geometries as in geophysics. This research has focused on the computational modeling of wave propagation problems using a DGSEM method in layered orthotropic material, as seen in a CFRP laminates. The spectral convergence of the method provides efficient modeling for wave propagation in anisotropic media. The solution considering material discontinuities can also be used to model internal damage such as delamination. The coupling of this DGSEM solution to the electrostatics problem solver previously implemented will allow computationally efficient simulation of the forward problem for ultrasonic guided wave actuated enhanced Electrical Resistance Tomography (ERT).

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Discontinuous Galerkin Spectral Element Methods for Wave Propagation in Carbon Fiber Reinforced Polymer Composites

Governing equation in conservation law form

\[ \frac{\partial q}{\partial t} + \nabla \cdot \mathbf{f} = 0 \]

General problem of two half-spaces and incident harmonic wave

Incident Wave with angle \( \theta \)

Example of wave velocity magnitude

Normalized Amplitude

Numerical error with respect to analytical solution

Polynomial order \( N \)