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Efficient analysis of variable stiffness composite plates

Matthew P. O'Donnell and Paul M. Weaver

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A novel method for the rapid analysis of variable stiffness plate-like structures, using a Ritz based approach, is presented. Our approach offers significant computational efficiency improvements over established implementations of the semi-analytical framework. The improvement in the speed of analysis is achieved by reducing the number of numerical integrations that must be performed to solve the resulting system equations. By exploiting a Legendre polynomial (LP) basis, algebraic recursion relations allow many of the integrals encountered to be reformulated in "triple-product" form, with known analytical solutions. These analytical solutions are conveniently represented by a subset of the Wigner $(3j)$ coefficients.

The satisfaction of boundary conditions is achieved by modifying the general LP basis, via a LP pre multiplication function, thus ensuring all basis vectors are admissible. Through the use of Kronecker multiplication the formulation utilised for one dimensional systems can be applied to two-dimensional systems. It is demonstrated that any modification to the LP basis vectors or required differentiation can be accomplished via matrix multiplication. Using such an approach many of the the integrals encountered are thus reformulated into a common "triple-product" form. The resulting system demonstrates that significant computational advantages over direct numerical integration are expected. Development of the formulation is presented together with indicative performance studies where an order of magnitude speed increase, compared with adaptive Simpson's quadrature, is observed.

Where the variation in stiffness is described exactly by a LP basis the solution is exact - within the bounds of expected computational precision. Owing to the significant computational efficiencies high-order expansions of the stiffness variation can be used, capturing typical stiffness profiles. It is noted that in some instances, as the integration and differentiation of the basis functions is performed via matrix multiplication and "triple-product" integration, some difficulties observed with higher order expansions using direct integration approaches may be mitigated.

In the completed work we will include the following:

- Details of the "triple-product" formulation.
- Comparison of integration techniques.
- Formulation for variable stiffness beams.
- Comparison with direct integration techniques.
- Formulation for variable stiffness plates.
- Comparison with direct integration techniques.
- A discussion of how the approach could be applied to other systems.